U.S. Army
Corps of Engineers

New England District
Concord, Massachusetts

U.S. Environmental
Protection Agency

New England Region
Boston, Massachusetts

RESPONSIVENESS SUMMARY TO THE PEER REVIEW OF THE MODELING FRAMEWORK DESIGN AND QUALITY ASSURANCE PROJECT PLAN

Modeling Study of PCB Contamination in the Housatonic River

DCN: GE-053102-ABAQ

June 2002

Environmental Remediation Contract
General Electric (GE)/Housatonic River Project
Pittsfield, Massachusetts

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DCN: GE-053102-ABAQ

June 2002

Prepared by

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LIST OF ACRONYMS

ADCP	Acoustic Doppler Current Profiler
CMS	Corrective Measures Study
DOC	dissolved organic carbon
EFDC	Environmental Fluid Dynamics Code
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FS	Feasibility Study
GE	General Electric Company
HEC	Hydrologic Engineering Center
HSPF	Hydrological Simulation Program-Fortran
MFD	Modeling Framework Design
NWS	National Weather Service
OC	organic carbon
PCBs	polychlorinated biphenyls
PES	Particle Entrainment Simulator
POM	Particulate Organic Matter
PRPs	Potentially Responsible Parties
PSA	Primary Study Area
R&D	Research and Development
WESTON	Roy F. Weston, Inc.
TSS	total suspended solids
WDNR	Wisconsin Department of Natural Resources
WERF	Water Environment Research Foundation
WES	Waterways Experiment Station

INTRODUCTION

This document presents the response from the Environmental Protection Agency (EPA) to the comments and questions raised by the independent Peer Reviewers following their review of the Modeling Framework Design document (MFD) for the Modeling Study of PCB Contamination in the Housatonic River. This document, referred to herein as the Responsiveness Summary, has been prepared as part of EPA's obligations under Paragraph 22.h and Appendix J of the comprehensive agreement relating to the cleanup of the General Electric (GE) Pittsfield, Massachusetts facility, certain off-site properties, and the Housatonic River (referred to as the "Consent Decree"). The Consent Decree was entered on October 27, 2000, by the United States District Court of Massachusetts - Western Division, located in Springfield, MA.

Under the terms of the Consent Decree, EPA is required to develop, calibrate, and validate a model of the fate, transport, and bioaccumulation of polychlorinated biphenyls (PCBs) in the area referred to as the " Rest of the River," defined as the area downstream from the confluence of the East and West Branches of the Housatonic River in Pittsfield, MA. The model will be used by General Electric (GE) to quantify and compare the amount of time that it will take for PCBs in the environment in that portion of the river to achieve acceptable risk-based concentrations under potential remedial scenarios, including natural recovery. The Consent Decree requires that independent Peer Reviewers review three documents that describe the modeling process. The first of these documents, the MFD, was issued by EPA in October 2000. The remaining two documents are the Model Calibration and Validation Reports.

On April 25–26, 2001, the Modeling Peer Reviewers met at a public forum in Lenox, MA, to review and discuss the MFD within the framework of the charge given to them. The Peer Reviewers subsequently submitted final written comments to EPA's Managing Contractor (Marasco Newton Group, Ltd) for the Peer Review. This document is EPA's formal response to the final written Peer Review comments.

APPROACH AND ORGANIZATION OF THIS DOCUMENT

As stipulated in Appendix J to the Consent Decree, Peer Reviewers were discouraged from discussing their individual comments with each other outside of the public Peer Review Meeting that provided for full public discussion; therefore, the comments were prepared independently by each reviewer. As observed during the Peer Review itself, many of the reviewers noted some of the same issues with the MFD and therefore submitted similar written comments on these issues. Conversely, as might be expected, at times Peer Reviewers had differing views on issues; this is also reflected in the written comments. In addition, because the final written comments followed broad guidelines established by the Peer Review Managing Contractor to mirror the technical questions presented in Section 22.h of the Consent Decree and the Peer Review charge, the format of the observations made in Peer Reviewers' responses frequently did not facilitate the extraction of discrete individual questions or comments that could be answered in the Responsiveness Summary.

As a result of these considerations, EPA organized the Responsiveness Summary in a way that responds to the questions or comments advanced by each reviewer by grouping the comments into topics, thus avoiding unnecessary repetition, and reducing the length and providing clarity in EPA's Responsiveness Summary.

Following a careful review of the Peer Reviewers' comments by EPA staff and consultants for the Housatonic River modeling effort, 25 major themes in the comments were identified. The Peer Reviewers' questions and comments were assigned to one or more of these categories. Questions that could not be readily categorized were listed under a 26th category, titled "Miscellaneous." Some of the Peer Reviewers' comments were quite comprehensive and were therefore assigned to as many as four topics, while others were easily addressed under a single topic. The full text of each Peer Reviewer's comments, annotated to indicate how each comment was categorized, is presented in Appendix A of this document. A table indicating the reviewer, and the page and line number of the comment or question (from Appendix A) is included in the beginning of each section. This page-and-line numbering system applies only to the review comments as reproduced in Appendix A of this document; due to document formatting, the page/line references may vary from other sources of the exact same comments. In each section of the Responsiveness Summary, the table showing the Peer Reviewers' comments is followed by EPA's response to the issues within that topic.

Prior to the Peer Review Meeting on April 25 and 26, 2001, EPA responded to a series of questions that were submitted to EPA by the Peer Reviewers after their preliminary review of the Housatonic River Modeling Framework Design document and related materials. Appendix B presents EPA's response to these initial questions and is reproduced as it was submitted to the Peer Reviewers on April 12, 2001. Because these questions and responses predate the Peer Review Meeting and the Peer Reviewers' final comments on the MFD and QAAP, some of the material and the responses may no longer be applicable, and many of the issues raised in these questions were further clarified at the meeting and are further discussed in this Responsiveness Summary. In the time since these responses were prepared, additional data have been collected and evaluated, and various aspects of the modeling approach have been modified.

RELATIONSHIP OF THE RESPONSIVENESS SUMMARY TO THE MODELING FRAMEWORK DESIGN DOCUMENT

To better document and integrate the changes to the proposed modeling study beyond the scope of the Responsiveness Summary, EPA will issue a final MFD that will provide additional technical information relevant to the responses provided here. The MFD will contain a crosswalk, i.e., a matrix that will identify where in the MFD changes have been made to specifically address comments from the Peer Reviewers.

MODELING STUDY PHILOSOPHY

EPA and the modeling team would like to take this opportunity, following the review of the Peer Review comments, to reiterate that we acknowledge that the modeling study for the Housatonic River is, as recognized by the Peer Reviewers, a very ambitious undertaking. Modeling a river with the characteristics of the Housatonic to achieve the objectives of the modeling study has not been attempted before to the team's knowledge. Therefore, EPA believes it is necessary to clearly describe the path that is being followed in a manner that allows outside parties to follow the rationale used in making decisions on the modeling study. It may seem to experts in the field that some points that EPA addresses in the documents are intuitively obvious, yet EPA's goal in developing these documents is not only to provide information to the scientific community, but to the public as well.

To reiterate, EPA's modeling philosophy is to first consider all processes known to affect PCBs in a river system such as the Housatonic, and using an iterative approach, evaluate and document each process with regard to the relative importance of the process in achieving the modeling objectives of the study at the Housatonic, while adhering to the tenets of modeling such as achieving mass balance and the goals of model calibration and validation. It must be recognized, however, that the state of the art of modeling may not exist in a tested and peer-reviewed forum for some of the processes deemed important at this site, and in fact may not exist at all, requiring the application of new or untested approaches to simulating or otherwise accounting for the influences of these processes. EPA believes not only that such a modeling effort is necessary for the Housatonic River, but also that through an approach that includes careful development and application of the techniques applied, the modeling study can succeed even though some aspects of the study have not been conducted before.

Within this challenge lies the requirement not to make the model overly complex, imposing unreasonable computational constraints or difficulty in parameterization. Likewise, the modeling approach cannot be overly simplified to the extent that modeling objectives cannot be met or that an acceptable simulation of the Housatonic River cannot be obtained. The optimal situation is to establish what constitutes "acceptability" under the present circumstances of a regulatory application versus research. It should be noted that the EPA modeling team has also applied the scientific method in taking an iterative approach to collect and evaluate data, test hypotheses, and review adequacy of model formulations. This approach is further reflected in the fact that the conceptual model evolved between the development of the MFD and the actual Peer Review, and has continued to advance since that time as noted in many of the responses provided in this Responsiveness Summary. EPA will continue to implement this iterative process as new information becomes available, with attention to the modeling study schedule, budget, and regulatory framework.

In conclusion, while EPA agreed with many of the comments provided, EPA did not agree with some of the comments provided by the Peer Reviewers; these are documented in the responses.

EPA appreciates the effort from the Peer Reviewers in providing their insights, which have improved the modeling process, and looks forward to the future modeling Peer Reviews as an opportunity to better inform EPA's process going forward.

1. PEER REVIEW PROCESS—PR

1.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Adams	2	15-21
Endicott	2	10-21
Garcia	2	22-26

1.2 BACKGROUND

Appendix J of the Consent Decree provides a framework for the Peer Review process for the Rest of River. The process described in the Consent Decree limits the interaction between the Peer Reviewers and EPA to responses to factual questions and/or clarifications. The public, including GE, is provided an opportunity at the Peer Review session to present oral comments to the panel. The Consent Decree requires that EPA develop the modeling framework and calibrate and validate the model(s), and that the products from the three steps of the process, as described in the introduction to this Responsiveness Summary, be subject to Peer Review. The Consent Decree also requires that following the Peer Review of the validation of EPA's model, the model be given to GE to use in evaluating various remedial alternatives. GE is responsible for preparing the Corrective Measures Study, which is the report of the analysis of the remedial alternatives.

1.3 SUMMARY OF ISSUES

The Peer Reviewers expressed the following concerns regarding the Peer Review Process:

- The constraints of the Consent Decree make the Peer Review more difficult, particularly the lack of opportunity for open dialogue between the Peer Reviewers and the modeling teams.

- The existence of two separate modeling teams (EPA and GE) working independently complicates the process.

1.4 EPA'S RESPONSE TO COMMENTS REGARDING THE PEER REVIEW PROCESS

1.4.1 Limited Opportunity for Dialogue Between the Peer Reviewers and Modeling Teams

In response to comments expressed by the Peer Reviewers, EPA and GE agreed on modifications to Appendix J. Three substantive modifications are as follows:

- First, to expand the time frame in which the Peer Review is to be conducted to 13 weeks from 75 days (10½ weeks) to allow more flexibility for review by the Peer Reviewers and for EPA's response to Peer Reviewer questions.
- Second, to provide an opportunity during Week 10 to conduct a 1-day Presentation Session for the Peer Reviewers in the Pittsfield area. At the meeting, EPA's modeling team will make a presentation on its document and the responses that were provided to the written questions from the Peer Reviewers, and provide additional clarifications, as necessary. During this session, Peer Reviewers' questions will not be limited to factual questions. GE's role during this session will be to assist EPA in answering questions and to respond to the Peer Reviewers' questions regarding GE information.
- Third, to allow for more direct responses by EPA's modeling team to questions by the Peer Reviewers.

It is EPA's view that independent discussion between Peer Reviewers outside the Peer Review session forum is not in the best interest of the project. Were such discussions to take place, many of the details of the Peer Reviewers' concerns would be unavailable to the general public. Appendix J has been modified to require that a conference call take place 1 week prior to the Peer Review for the Managing Contractor to clarify logistical and process-related issues for the Peer Reviewers prior to the review session.

1.4.2 Two Separate Modeling Teams (EPA and GE) Working Independently

The Consent Decree requires that EPA and GE both establish modeling work groups. EPA understands that the existence of two separate modeling teams may seem less than desirable to the Peer Reviewers. However, it should be recognized that the parties may have differing viewpoints on the problems being addressed by the modeling effort. Since the beginning of the modeling study, much information and many ideas have been exchanged between the two teams regarding each party's modeling approaches and data collection activities. In fact, cooperative data collection activities have taken place since the April 2001 Peer Review.

1.5 REFERENCES

United States of America, State of Connecticut, and Commonwealth of Massachusetts, Plaintiffs, vs. General Electric Company, Defendant. Civil Action Nos. 99-30225, 99-30226, and 99-30227-MAP (Consolidated). October 1999. *Consent Decree*.

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2. MODEL SELECTION—MS

2.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Adams	5	4-7
	5	26-27
Bohlen	10	10-26
Endicott	2	22-32
	2	33-44
	3	1-19
	3	21-34
Garcia	9	8-14
Lick	6	10-22
List	3	8-20
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	4	25-31
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	6	9-17
	6	22-32
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	7	35-45
	8	1-3
	8	37-44
	9	2-8
	9	31-39
Shanahan	3	27-34
	5	34-42
	6	1-4
	8	7-37
	9	19-28
	11	41
	12	1-12
	13	23-40
	15	40
	16	1-7
	16	25-30
	17	1-3
	17	10-17

2.2 BACKGROUND

The selection of a modeling framework for the Housatonic River Project was guided by the modeling study objectives:

1. How long will it take for PCB-contaminated sediments to be sequestered by the deposition of clean sediments?

2. How long will it take for PCB levels in target fish tissue to be reduced to levels that no longer pose a risk to either human health or the environment?

3. How do rare storm events contribute to the redistribution of sequestered PCB-laden sediments back into the water column, the surficial sediment bed, and the biota of the river?

The Housatonic River Primary Study Area (PSA) is complex, with a broad floodplain and highly meandering, free-flowing river transitioning into the impounded backwaters of Woods Pond. Under flood conditions, solids and associated PCBs have been exported from the river channel to the 10-year floodplain, resulting in varying levels of PCB contamination in much of the floodplain. Potential remediation scenarios that will be evaluated with the model may include the removal and/or capping of contaminated sediments from the river channel and contaminated soil from the floodplain, as well as natural attenuation. The pathways of water, solids, and PCBs between the river channel and the floodplain are one of the important considerations in the design of the model framework.

2.3 SUMMARY OF ISSUES

The Peer Reviewers expressed concern that the selection of HSPF, EFDC, and AQUATOX as components of the model framework was not supported by the conceptual model nor was there sufficient documentation presented in the MFD of a formal model selection process. Many reviewers thought that EFDC and AQUATOX were overly complex to address the regulatory decision-making objectives of the study. The reviewers recommended that simpler models for hydrodynamics and PCB bioaccumulation be considered for the study. The reviewers noted that, in relation to the model selection process, the MFD was deficient in the following areas:

- **Conceptual model/simple box models:** Reviewers questioned the adequacy of the analysis of available data, and proposed the development of conceptual and simple "box models."

- **Literature review of models available to address key processes.** Reviewers recommended the identification of processes important for modeling PCB transport, fate, and bioaccumulation as well as the elimination of minor processes; a literature review of models available to address key processes; and documentation of a formal process used to consider candidate models for final model selection.

2.4 EPA'S RESPONSE TO COMMENTS REGARDING MODEL SELECTION

2.4.1 Conceptual Model/Simple Box Models

EPA will use data collected during the 1998 to 2001 field programs to perform an analysis of the relative magnitude of solids and PCB loads in the river during base flow/low flow periods and storm event/flood conditions. Water balances, solids, and PCB mass balances will be estimated for the two flow regimes using data collected near the upstream boundary (Pomeroy Avenue), a midpoint location within the PSA (New Lenox Road), the downstream boundary (Woods Pond Footbridge), and external sources contributed by the Pittsfield WWTP and tributaries. The flow regimes that will be considered are base flow and high flow.

Using time-averaged estimates of fluxes for each hydraulic domain, simple box model budget calculations will be performed to compare the sum of the estimated flux contributions of the various sources and sinks to the observed loads of solids and PCBs. Sources of solids and sorbed PCBs into the water column include external loads from upstream, resuspension from the river sediment bed, erosion of the river bank, and erosion from the floodplain. Sources of dissolved PCBs include external loads from upstream, and diffusion and advection from porewater across the sediment-water interface. Losses of solids and PCBs out of the water column include deposition to the river and Woods Pond sediment beds, deposition onto the floodplain, and outflow over the Woods Pond Dam.

The box model calculations are expected to provide further definition of the relative significance of the various sources and sinks of solids and PCBs for the river and Woods Pond/backwaters under base flow and high flow. The results of the box model analysis will also be used to revisit the space and time scales (see also Section 20) and to further justify inclusion or exclusion of various processes in the model framework.

2.4.2 Literature Review of Models Available To Address Key Processes

The models selected for inclusion in the framework can attempt to represent only the most significant mechanisms and processes that influence the pathways and fate of PCBs. The refined conceptual model and simple box model developed for the final MFD will be used to further identify those processes and interactions determined to be most important for PCB fate, transport, and bioaccumulation. Numerous models have been developed with varying degrees of complexity ranging from simple screening models to complex numerical models that include at differing levels many physical and biogeochemical processes and interactions. The final MFD will present a more comprehensive and detailed discussion of the model selection process. The review of available models relevant to the Housatonic River study will be organized by the following model categories:

- Watershed runoff
- Hydrodynamics
- Sediment transport
- PCB transport and fate
- PCB food web bioaccumulation.

For each model category, the review will be guided by the revised conceptual model and the following:

- Identification of key physical and biogeochemical processes/interactions
- Spatial and temporal scales relevant to PCB fate and bioaccumulation
- Literature review of models available for key processes/interactions
- Knowledge or data gaps for key process/interaction
- Documentation of criteria for model selection
- Identification of candidate models
- Evaluation of candidate models
- Justification for rejection/selection of candidate models.

The following criteria will be used to document the evaluation of candidate models:

- Level of scientific understanding/knowledge of process/interaction
- Level of model complexity (simple screening, intermediate, complex)
- Spatial dimensionality (1D/2D/3D)
- Temporal scale/resolution
- Inclusion of appropriate state variables and external forcing functions
- Data requirements for (a) site characterization and (b) model vs. data performance
- Availability of site-specific data from the Housatonic River
- Record of successful model calibration/validation
- Record of model application for regulatory decision-making
- Computational burden/computer hardware requirements
- Level of expertise/effort required to use the model
- Availability of pre- and post-processing tools to aid model input/output
- Degree of linkage with other models
- Applicability of model for Housatonic River meanders/floodplain interactions
- Availability (public domain/proprietary) of model software and source code

- Availability of documentation manuals/technical support
- Access to sponsor/developer/source of model.

In addition to information derived from the modeling team's network of professional colleagues, sources that will be used to identify candidate models include literature recommendations provided by the Peer Reviewers and reviews of water quality models reported in HydroQual et al. (2001), Tetra Tech (2000), McCutcheon (1989), Martin and McCutcheon (1999), Thoms et al. (1995), ASCE (1996), EPA (1997), and Deliman et al. (1999). The formal review of available models will also consider numerical models of hydrodynamics and sediment transport developed for meandering rivers, bank erosion, and floodplain interactions. These models are described in Carling and Petts (1992), Hickin (1995), Ikeda and Parker (1989), Anderson and Bates (2001), and Hey et al. (1982). Specific book chapters and journal articles relevant to models of meandering rivers, sediment transport, bank erosion and floodplain interactions that will be included in this effort are listed in the bibliography below. Other appropriate information will be included if identified during this effort.

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3. MODEL DOMAIN—MD

3.1 COMMENT SUMMARY

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3.2 BACKGROUND

The Housatonic River Supplemental Investigation was designed to evaluate impacts from PCBs disposed of at the General Electric (GE) facility in Pittsfield, MA, in portions of the river and floodplain that are not subject to the ongoing removal actions by GE and EPA. Under the Consent Decree executed between the Agencies and GE, contaminated river sediment and bank soil between the facility and the confluence of the East and West Branches of the Housatonic River (the confluence) are being removed in two Removal Actions: the first removal action being performed by GE addresses the first half mile of the river adjacent to and downstream of the facility; the second removal action covers the next 1 ½ miles and is being performed by EPA, with costs being shared by GE. In addition, contaminated floodplain soil and groundwater contributions to the river are also being addressed by GE in separate actions under the Consent Decree.

The portion of the river that is the subject of the Supplemental Investigation begins immediately downstream of the removal actions, at the confluence of the East and West Branches of the Housatonic River, and extends into Connecticut. The majority of the PCB contamination historically has been observed in the first 10.7 miles (17 km) from the confluence to the Woods Pond Dam, the first impoundment downstream from the facility.

This section addresses concerns expressed by the Panel Reviewers related to the selection of the Model Domain. Model Domain issues are also addressed in Section 7 (Additional Data Collection Activities).

3.3 SUMMARY OF ISSUES

The Peer Reviewers expressed the following concerns related to the model domain:

- The model domain should be extended upstream in the area of the proposed/ongoing remediation to evaluate the remediation activities.
- The model domain should be extended downstream below Woods Pond.
- Monitoring should continue during the remediation activities.

3.4 EPA'S RESPONSE TO CONCERNS RELATED TO THE MODEL DOMAIN

3.4.1 Extension of the Model Domain Upstream in the Areas of Remediation

EPA believes that it is necessary and appropriate for the upstream boundary of the model domain to remain fixed at the confluence of the East and West Branches of the Housatonic River for the following reasons. First, the Supplemental Investigation was designed to gather data prior to the start of the removal actions in the river (to avoid any possible impact from the actions on the data being collected), for the modeling study and risk assessments. Accurate information specific to the point and nonpoint source loadings of PCBs and solids to the river reaches upstream of the confluence is not available. During the development of the initial conceptual model, EPA requested that GE provide some estimate of the inputs to the upstream reaches, GE's response was that they were unable to provide any estimate. Without such information, these loadings cannot be parameterized for the model. An attempt to model these loads would result in unbounded estimates and a great deal of uncertainty. The solution implemented when collecting the data to support the modeling study was to represent the integrated loadings from the upstream reaches in a straightforward approach as a simple flux of solids and PCBs at the upstream boundary.

Second, EPA notes that the project schedule precludes extending the model domain upstream to include the reaches subject to removal actions, and the evaluation of the ongoing Removal

Actions as part of the Modeling Study. The 1 ½-Mile Removal Action is currently scheduled for completion at the earliest in FY 2007, and a decision on remediation for the Rest of River is currently scheduled to be proposed in FY 2005, and finalized after public comment in FY 2006. Delaying the modeling study to include an evaluation of the effects of the removal actions on PCB loadings would significantly delay the decision on the Rest of River. If the modeling study were delayed, EPA's decision on the Rest of River would be delayed by at least 4 years (from 2005 to 2009 at the earliest), given the necessity to collect additional data to describe the new baseline conditions, the subsequent completion of model calibration peer review and validation peer review, the development of the Corrective Measures Study, and the completion of the EPA decision-making process.

Third, data will be collected in the upstream reaches as part of other actions. As noted above, the 2 miles of river immediately above the confluence are being addressed in two separate removal actions under the Consent Decree. These actions have work plans that define the performance standards that are separate from the evaluation being performed for the Rest of River, which is defined in the Consent Decree explicitly as the area downstream from the confluence. Monitoring data are being collected and will be used to evaluate these actions independent from the Rest of River activities. However, EPA will consider any available information obtained during these removal actions to inform decision-making for the Rest of River at the time EPA develops the Statement of Basis, which will include EPA's proposed actions for the Rest of River.

Further discussion related this topic is provided in Section 25, Remediation.

3.4.2 Extension of the Model Domain Downstream from Woods Pond

EPA believes that it is reasonable to establish the downstream boundary for the modeling study at the Woods Pond Dam. This allows the modeling study to focus on the reaches where the majority of PCBs are currently located in the river and floodplain, as indicated by data collected historically by GE and by EPA during the Supplemental Investigation. Characterizing and modeling these reaches alone represents a significant undertaking, as recognized by the Peer Reviewers.

It is EPA's understanding that GE has constructed a model with a domain that extends into Connecticut. Output from EPA's modeling analysis can be compared to output from the GE model for the PSA, to inform decisions for reaches farther downstream in the river, if warranted.

3.4.3 Continuation of the Monitoring Activities During the Remediation of the Upper Reaches

The Peer Reviewers recommended that data collection continue through the ongoing remediation. EPA agrees with this recommendation; however, this monitoring is outside the scope of the Rest of River Supplemental Investigation. EPA notes that remediation monitoring is a component of the work plans for both the ½-Mile and 1 ½-Mile Removal Actions, and that GE has continued to perform monthly surface water monitoring at selected locations. The monitoring plans have been adjusted to respond more directly to the comments of the Peer Reviewers. These programs are discussed further in Section 7 (Additional Data Collection Activities).

3.5 REFERENCES

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United States of America, State of Connecticut and Commonwealth of Massachusetts, Plaintiffs, vs. General Electric Company, Defendant, Civil Action Nos. 99-30225, 99-30226, and 99-30227-MAP (Consolidated)**.** October 1999. *Consent Decree.*

4. CONCEPTUAL MODEL/PROCESS PRIORITIZATION –CMP

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4.2 BACKGROUND

In building an effective model of PCB transport, fate, and bioaccumulation for the Housatonic River, it is important to include the key processes that drive PCB fate and bioaccumulation, and to predict the impact of alternative remediation scenarios on the fate and bioaccumulation of PCBs. The inclusion of unnecessary processes adds computational burden and diverts resources from the core of the modeling study without adding information that would further the understanding of PCB fate and bioaccumulation and of the impacts of remedial alternatives.

Prior to developing the actual numerical models, a preliminary conceptual model was constructed to provide the modeling team with insight on the relative significance of the processes and interactions that influence PCB fate and bioaccumulation in the Housatonic River. The conceptual model was developed in three steps. The first step was a qualitative synthesis of the various physical and biogeochemical processes that are related to PCB dynamics in the river. This synthesis of information drew on the experience of the modeling team as well as published literature to provide a descriptive characterization of the cause-effect interactions related to PCB fate and bioaccumulation. The second step of the conceptual model development was a compilation of the available site-specific data to evaluate key spatial and temporal dependencies of solids, PCBs, and other relevant properties in the water column, sediment bed, and biota. The third step was a site-specific description and quantification of the various processes and interactions.

The original MFD presented a synthesis of the many physical and biogeochemical processes and interactions possibly related to PCB fate and bioaccumulation. The MFD also presented a compilation of data available at the time, demonstrating the spatial and temporal variation of solids and PCBs in the water column, sediment bed, and biota of the Housatonic River. When the original MFD was prepared, complete datasets were not yet available for analysis; therefore, quantification and evaluation of the processes identified as potentially important for PCB fate and bioaccumulation could not be presented in many cases. Using the best available data at the time and published literature, each process determined to be relevant for the model framework was identified. Of the 68 processes identified in the conceptual model, 42 were determined to be important enough to be included in the modeling effort, 9 were identified for exclusion from the framework as unimportant, and 17 processes were identified for further analysis and evaluation. As stated in the MFD, the conceptual model is viewed as a dynamic and iterative process that is being revisited, now that more data are available and model testing is under way. It is expected that further refinement of the conceptual model will provide additional focus for the modeling study.

4.3 SUMMARY OF ISSUES

The Peer Reviewers provided comments on the conceptual model from varying perspectives. Some reviewers noted that whereas the conceptual model identified the appropriate processes that may be relevant to the Housatonic River system, the detailed assessment of each process identified in the conceptual model was not comprehensive enough. A number of the reviewers requested that the conceptual model present a quantitative assessment of the relative importance of each of the processes for the mass balance calculations. A reviewer commented that the inclusion of so many processes results in too many user-specified model parameters, and that a "closely reasoned discussion of the relative importance of the processes" should be presented. Another reviewer stated that since almost all of the significant processes have been included in the conceptual model, the numerical models will be overly complex.

The Peer Reviewers commented that the MFD presented an inadequate discussion of the following:

- Elimination of the upstream sources of PCBs.

- Sequestering of PCB-contaminated sediments.
- Dynamics of bars and terraces.
- Floodplain as a sink or source of PCBs.
- Out-of-bank flows and interaction with the floodplain.
- Bedload versus suspended load transport.
- Effects of severe storms.
- Surficial sediment mixing and thickness of active layer.
- River meanders and bank erosion.
- Representation of PCB fate and transport as "abiotic" and "biotic" components.
- Food web predator/prey linkages and feeding descriptions at the base of the food web.

The Peer Reviewers also expressed concern that the level of data supporting some of the processes was limited, and recommended that simple box models or "back of the envelope" calculations be performed to confirm which processes either were important or were of negligible significance.

Several of the reviewers' comments related to Section 4 (Conceptual Model/Process Prioritization) have also been responded to in other sections of this Responsiveness Summary, specifically Section 8 (Floodplain/Channel Interactions), Section 19 (Grid Scheme/Spatial Scale), Section 9 (Floodplain Vegetation), Section 2 (Model Selection), and Section 18 (Model Linkages).

4.4 EPA'S RESPONSE TO COMMENTS REGARDING CONCEPTUAL MODEL/ PROCESS PRIORITIZATION

EPA agrees with the Peer Reviewers that a more detailed presentation and evaluation of the transport and fate processes, including estimates of their relative importance to the mass balance of PCB, would improve the MFD. Now that the Peer Review has occurred, the modeling team better understands the topics of interest to the Peer Reviewers and will revise the conceptual model to address these concerns. The revised conceptual model to be presented in the final MFD will include further analysis of the data to prioritize the importance of the processes based on simple box model estimates and other evaluation techniques. Each process will be described in greater detail, and additional data will be presented and evaluated to support the conclusions. The final MFD will also present the initial selections of theoretical formulations, including the adjustable model calibration parameters, to clarify the plans for how the key processes and interactions will be numerically represented in the models. The final decision on these numerical representations will be presented in the model calibration report.

Additional data collection necessary for further evaluation of the selected processes is currently underway, including but not limited to, the following: bedload transport, supplemental surface water sampling, pore water sampling, bank erosion analysis, supplemental storm sampling, and an updated report on the meandering of the river. These data collection activities are described in more detail in Section 7 (Additional Data Collection Activities).

4.4.1 Elimination of Upstream Sources of PCBs

Once the models are calibrated and validated, they will be used to establish baseline conditions and to evaluate the long-term effectiveness of a number of alternative scenarios for remediation of PCB-contaminated sediment in the river and in the floodplain. In the process of establishing baseline conditions, the upstream boundary loadings of PCBs can be defined by changing the initial conditions of PCB levels in the water column and the sediment bed to represent upstream removal of contaminated sediments. These loadings can be established using data collected by both GE and EPA during and upon completion of these removal actions. Under the terms of the Consent Decree, it is the responsibility of GE, not EPA, to simulate the baseline conditions and to perform the evaluation of the effectiveness of possible remedial scenarios in the Rest of River. Section 25 (Remediation) of this Responsiveness Summary presents additional discussion of this topic.

4.4.2 Sequestering of PCBs

Based on a review and analysis of sediment data, there is little evidence of widespread sequestering of PCBs in the study area within the sediments. This interpretation was based upon the observation that the highest concentrations of PCBs detected in sediment and soil samples were most frequently in the surficial (0 to 6 inch [0 to 15 cm]) samples. Additional core-by-core analysis is being performed at each location with data available from multiple depths.

The Peer Reviewers expressed concern over the thickness of the 6-inch sample intervals. The panel noted that the thickness of the sediment sample might "mask" any sequestering that might be occurring on a finer scale and that the modeling team's interpretation was not adequately supported by the available data.

The sampling interval used for the majority of the sediment and soil samples collected by EPA was selected to provide results that could be used to fulfill a variety of data quality objectives including site characterization, modeling, human health risk assessment, and ecological risk assessment. Furthermore, most of the historical samples collected by GE (60% or more) were based on 6-inch sediment layer intervals.

Additional "deep" river cores have been collected, and the lithology logged and samples collected for PCB analysis from selected depths and lithologies. This information will be presented in the final MFD. A "fine" surficial layer was rarely observed when collecting the sediment cores, yet dramatic layering was observed on a coarser scale.

Sequestering does not appear to be occurring across most of the study area. Further statistical analysis on a location-by-location basis is being performed to determine where total PCB concentrations appear to either increase, or decrease, with depth in the sediment bed; this analysis will be presented in the final MFD.

4.4.3 Physical Processes

A more complete discussion of the potentially significant physical processes will be presented in the revised conceptual model in the final MFD. In particular, emphasis will be placed on the role of stream bank erosion, the dynamics of bars and terraces, river meandering, out-of-bank flows, and the interactions of the floodplain with the river (specifically whether or not the floodplains provide a pathway as a source or a sink for PCBs), bedload transport, the effects of storms (including, if possible, data from a storm larger than those previously sampled).

4.4.4 Active Layer

The thickness and spatial variability of the active layer are being further evaluated. Initial observations from the deep cores discussed above suggest that the active layer may in some areas extend to depths that exceed 6 inches.

The results of this evaluation will be presented in the final MFD. Further discussion of the issues related to the active layer is provided in Section 12 (Active Layer).

4.4.5 River Meanders and Bank Erosion

Based on a review of extensive historical information, large-scale, rapid meandering of the river within the Primary Study Area appears to be limited as a process of concern from a modeling perspective. Observations from aerial photographs taken since 1944 and a review of historical topographic maps dating to the late 1800s, indicate that the current river course and meander patterns have changed very little during the past 100 years. The course of the free-flowing river in Reach 5a and portions of Reach 5b is tightly controlled by moderately steep-sloped sidewalls. Backwaters and slower velocities created by the impoundment from Woods Pond Dam minimize the likelihood of major future changes to the river shoreline in Reach 5c. EPA is conducting a detailed survey of meanders and bank erosion in the river. This evaluation will enable the modeling team to further assess the importance of these processes on historical, and future, changes in the location of the river bank. The findings of the river meander investigation will be presented in the final MFD.

4.4.6 Representation of PCB Fate and Transport as "Abiotic" and "Biotic" Components

In the MFD, EPA proposed to perform transport and fate simulations of abiotic PCBs in EFDC and as the "biotic" form in AQUATOX. The Peer Reviewers expressed concerns that the proposed linkage of inorganic/organic and biotic/abiotic solids between EFDC and AQUATOX would most likely fail to maintain a mass balance. The reviewers believed that this approach would introduce uncertainty and confusion into the interpretation of model results.

In response to the Peer Reviewers' concerns and as discussed in more detail in Section 17 (Bioaccumulation Model/AQUATOX), EPA has concluded that it is preferable to perform the transport and fate simulation of PCBs only with EFDC. The use of a single model will avoid the introduction of the artificial split of PCBs as chemical sorbed to "abiotic" solids and chemical sorbed to "biotic" organic matter. Mass loadings for three sediment grain size classes may be provided to EFDC by HSPF or will be determined empirically from available data. The organic carbon fraction of each grain size class will be defined as input to EFDC based on site-specific field data for PCB partitioning calculations. POC produced internally in Woods Pond may be specified as a forcing function in EFDC.

4.4.7 Food Web Predator/Prey Linkages

EPA agrees with the Peer Reviewers that it is neither practical nor technically advantageous to attempt to quantify PCB concentrations within every distinct taxon in the system. At some point, the implied precision of modeling numerous biological compartments is overwhelmed by the uncertainty introduced by the complexity of such a model.

Accordingly, the conceptual model for the food web will group organisms deemed to be similar with respect to feeding habits and PCB uptake processes. Individual species will be selected to represent each of these biological compartments. An iterative approach will be used to identify the number of compartments required to describe the aquatic community in the Housatonic River.

The conceptual model for the aquatic community divides fish into one of three main categories – predatory (piscivorous) fish, forage fish, and benthic fish. These distinctions are made based on feeding preferences, which determine dietary PCB exposures. Bioaccumulation modeling efforts at other sites have shown that division of fish species on the basis of their primary feeding pathway is justified, given: (1) the importance of dietary uptake in terms of PCB bioaccumulation, (2) the potential disequilibrium between sediment and water column concentrations of PCBs and associated microfauna, and (3) the demonstration of increasing biomagnification in piscivorous fish. For benthic invertebrates, the conceptual model will also make distinctions between biological compartments based on differences in exposure pathways (i.e., water-column organisms versus sediment infauna). Further subdivision of the invertebrate component of the model will be determined during calibration.

5. CONCEPTUAL MODEL/EVALUATION OF SITE DATA–CMD

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5.2 BACKGROUND

A global list of processes considered in the development of the conceptual model was presented in the MFD. In developing the conceptual model, EPA identified those processes that were initially determined to be important to the modeling effort. Certain processes were retained for further consideration in the model framework, pending the completion of additional data collection efforts. The analysis will be iterative, and further evaluation of the data is underway. In response to the Peer Reviewers comments, a revised conceptual model will be presented in the final MFD, rather than in the Model Calibration Report as originally proposed.

This section addresses the issues raised by the Peer Reviewers related to the data analysis and to evaluate the significance of the processes. Additional responses to the Peer Reviewers' concerns regarding the Conceptual Model and the Evaluation of Site Data are included in Section 8 (Floodplain/Channel Interaction), Section 9 (Floodplain Vegetation), Section 11 (Rare Flood Events), Section 12 (Active Layer), Section 13 (Sedflume), and Section 20 (Time Scale/Step Interactions).

5.3 SUMMARY OF ISSUES

The Peer Reviewers expressed the following concerns related to the conceptual model:

- The Peer Reviewers commented that there was insufficient analysis of the available data presented in the conceptual model. A few of the reviewers suggested that simplified "box models," one-dimensional models, and "back-of-the-envelope" type of calculations be used to evaluate the available data and determine which processes are important or of negligible importance.

The Peer Reviewers also provided comments on the need for the additional evaluation of site data in the following areas:

- Mass balance of PCB quantities and fluxes through the system.
- Absence of hypothesis-based field sampling.
- Role of meandering.
- Evaluation of sequestering of PCBs and explanation of sampling intervals.
- Analysis of high flow events and PCBs in the floodplain.
- Role of bed load versus suspended load.
- Evaluation of radionuclide data and estimated sedimentation rates.
- Evaluation of spatial variability of PCBs in sediment.
- Sediment-water mass exchange coefficients.
- Relative importance of in-bank versus out-of-bank flow.
- Absence of Sedflume data
- Development of rating curves.
- PCB data normalized on an organic carbon (OC) basis.
- Use of long-term historical data.

5.4 EPA'S RESPONSE TO COMMENTS REGARDING CONCEPTUAL MODEL/EVALUATION OF SITE DATA

5.4.1 Revision of Conceptual Model

A revised conceptual model is being developed to address many of the concerns expressed by the Peer Reviewers. To maintain consistency with the MFD, the revised conceptual model will retain much of its current structure for the descriptive synthesis of the observed physical characteristics of the system and the various processes and interactions. The revised conceptual model will, however, place an increased emphasis on the evaluation and presentation of the available site-specific data used to identify the processes of significance, including the documentation of spatial and vertical patterns and temporal trends. In addition, processes will be revisited and assessed using available data to determine whether that process should be included in the model. "Proofs," or "back-of-the-envelope" calculations, as necessary, will be developed and presented in the revised conceptual model to justify those determinations. Additional discussion of this approach is presented in response to Section 20 (Time Scale/Step Interactions).

5.4.2 Mass Balance of PCB Quantities and Fluxes Through the System

Using data collected at the confluence of the East and West Branches of the Housatonic (the upstream boundary), at Woods Pond (the downstream boundary), and the external sources (loads contributed by the Pittsfield WWTP and key tributaries), water balances, solids and PCB mass balances will be estimated for base flow and high flow. A simple flux analysis of flow, solids, and PCBs is being developed at three locations (Pomeroy Avenue, New Lenox Road, and Woods Pond) along the river. The results of these analyses will be presented in the final MFD.

5.4.3 Absence of Hypothesis-Based Field Sampling

Data collection efforts by EPA were conducted in an iterative manner to test hypotheses used in the development of the conceptual model. The sampling was performed in accordance with the *Supplemental Investigation Work Plan for the Lower Housatonic River* (WESTON, 2000). The initial conceptual model evaluated the nature and extent of PCB contamination at the GE facility and hypothesized what the likely transport mechanisms would be from the GE facility downstream to Woods Pond and beyond. The hypothesis that high flow events transported and deposited PCB-contaminated sediments onto the floodplain, and that areas of scouring and deposition in the river may be occurring, led to the collection of numerous samples in the river and in the floodplain to gain a better understanding assessment of the distribution of PCBs.

Subsequent to mapping of the topography and wetland habitats, additional sampling was conducted to evaluate variability between wetland habitats. The presence of bank scours and point or aggrading bars suggested that areas of the river may act as a source or sink for sediments contaminated with PCBs. Hence a sampling program that specifically addressed these areas was undertaken. Other sampling efforts supported the requirements of the Human Health and Ecological Risk Assessments.

The conceptual model presented in the MFD confirmed many of the hypotheses and related processes that EPA initially identified as the most relevant and important. The evaluation of the data also indicated that other processes may be important, which in turn led to the collection of additional data. For example, the data collected in 1998-2001 indicated that bedload transport may be a significant process in the river. Accordingly, EPA is conducting additional sampling to obtain measurements of both bedload and suspended load. One bedload sampling event was completed prior to issuing the Responsiveness Summary. This event will be described in the final MFD.

5.4.4 River Meandering

As noted in Section 4 (Conceptual Model/Process Prioritization), the modeling team is completing an evaluation of the meandering history of the Housatonic River based upon historical aerial photographs and topographic maps, as well as detailed field observations. The results of the river meander study will be included in the final MFD.

5.4.5 Sequestering of PCB-Contaminated Sediments and Resolution of Depth Sampling of Sediments and Soils

Reviewers questioned why sediment and soil samples were collected in 6-inch (15-cm) depth intervals, rather than finer intervals. EPA agrees that finer resolution may have been useful in some limited cases, but the majority of sediment and soil samples for EPA were collected at 6-inch intervals to address the multiple objectives of the project while maintaining cost control. Samples had to provide useful data to fulfill not only the modeling objectives, but also the objectives of the Human Health and Ecological Risk Assessments. The 6-inch sampling interval was also consistent with samples collected historically by GE.

Sequestering of PCBs in sediments and sample resolution is further discussed in Section 4 (Conceptual Model/Process Prioritization).

5.4.6 Floodplain and Channel Interactions

The role of the floodplains will be discussed in greater detail in the final MFD. It is EPA's belief, based upon the available data, that the distal floodplain, in general, serves as a sink for PCBs. During high flow events, the proximal floodplain (the floodway) may serve as either a sink or a source for PCBs, depending on the existing flow velocities. The final MFD will present further definition of the distal floodplain compared to the proximal floodplain with an analysis of the role of each component of the floodplain in the system. More detail on issues related to the floodplain is provided in Section 8 (Floodplain/Channel Interactions), Section 9 (Floodplain Vegetation), and Section 11 (Rare Flood Events).

5.4.7 Bedload and Suspended Load Data

As indicated above and in Section 7 (Additional Data Collection), a bedload study is being conducted to provide the data necessary to characterize bedload movement and its relative importance as a process for the sediment transport model. Additional storm and surface water data collection is planned to increase the available time-series data for characterization of the suspended load.

5.4.8 Radionuclide Data and Sedimentation Rates

EPA agrees that the available radionuclide data can be further evaluated against other data collected for this project to develop a better understanding of depositional processes. Initial evaluation suggests that the active nature of the sediment bed upstream of Woods Pond may complicate the interpretation of these data. Further evaluation is currently ongoing, in conjunction with the expanded evaluation of the active layer, and will be presented in the final MFD.

5.4.9 Analysis of Spatial Variability of PCBs in Sediments

The analysis of the spatial distribution of PCBs presented in the conceptual model was intended to provide a general understanding of how PCBs are distributed across the diverse geomorphic terrains within the Primary Study Area (PSA). The sampling program not only included systematic sampling at regular intervals (three samples across the channel at 1,500-foot (460-meter) intervals along the length of the river in the PSA), but also included discrete sampling of distinct floodplain and river features (i.e., bars and terraces, oxbows, etc.). EPA believes that adequate samples have been collected from across the study area to characterize spatial variability.

Further evaluation of spatial variability of the data will be presented as part of the updated conceptual model in the final MFD.

5.4.10 Mass Flux Coefficients for Sediment-Water Exchange

Subsequent to the MFD, a study was conducted to better understand the partitioning behavior of PCBs in Housatonic River sediments and surface water. The mass flux from the sediment bed to overlying water will be adjusted during calibration to match the data collected in this study. These data will be presented in the final MFD.

5.4.11 Storm Data and Out-of-Bank Flows

EPA agrees that data from a storm larger than those previously sampled would be a significant addition to the modeling study. Sampling of a 10-year storm or other significant out-of-bank event will be conducted, if one occurs during the course of this study. See the discussion in Section 11 (Rare Flood Events) for more detail on this topic.

5.4.12 Sedflume Data in Floodplain

EPA believes that Sedflume data for floodplain soils are not necessary. A discussion of the issues related to the lack of Sedflume measurements for floodplain sediments is presented in Section 13 (Sedflume).

5.4.13 Rating Curves Upstream of Model Domain and Sediment Load Rating Curves

There is one rating curve station measuring flow, stage height, total suspended solids (TSS), and PCBs located upstream of the hydrodynamic, sediment transport, and PCB fate model domain at Pomeroy Avenue. There are also other stations located in the main river channel from which flow, stage height, TSS, and PCB data have been collected to construct additional rating curves. The rating curves will be presented in the final MFD.

5.4.14 PCB Data Analysis on OC-Normalized Basis/Deposition Regime

The conceptual model presented in the MFD included discussion of organic carbon-normalized PCB concentrations. A more detailed evaluation of the sediment and PCB data within the main river channel aggregated by depositional regime, including the examination of OC-normalized PCB distribution, is currently being conducted. This assessment will be presented in the final MFD.

5.4.15 Use of Long-Term Data

The project database includes all known historical data, all of which have been evaluated for data quality and usability for the modeling study. A temporal analysis of the PCB data will be presented in the final MFD.

5.5 REFERENCES

WESTON (Roy F. Weston, Inc.). 2000. *Supplemental Investigation Work Plan for the Lower Housatonic River*. Vol. I - Text and Figures and Vol. II - Appendices. Prepared for U. S. Army Corps of Engineers, New England District, Concord, MA.

6. ADEQUACY OF DATA—AD

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6.2 BACKGROUND

The Housatonic River modeling study is supported by a large, diverse, and carefully documented data set that has been used to refine the conceptual model of the key processes that determine the fate of PCBs in the Housatonic River. Over the last 3 years, EPA has collected and analyzed thousands of individual samples of soil, sediment, water, and biota to characterize the physical conditions and chemical contamination in the river. Most samples were analyzed for total PCBs, and a large number of samples were also analyzed for a wide variety of additional constituents, including PCB congeners, dioxins/furans, and Appendix IX constituents (40 CFR 264). Many samples were also analyzed for important ancillary parameters such as total organic carbon and grain-size distribution.

EPA has completed or is conducting supplemental studies as described in Section 7 (Additional Data Collection Activities), to provide insight and to support model calibration of such important processes as sediment resuspension, PCB partitioning, and bedload transport.

Data collected by GE and other parties over the last two decades have also been incorporated into the project database. EPA has obtained and evaluated these data to assess their usability for the modeling study and risk assessments.

The MFD presented a conceptual model of the river and floodplain, and a preliminary identification of the key processes that determine the fate and transport of PCBs and other constituents in the river, based on the data available at the time it was written. The final MFD will provide further evaluation of significant processes and a revised conceptual model based on the expanded database.

This section addresses the concerns raised by the Peer Reviewers regarding the adequacy of the data to support the development and implementation of the Housatonic River transport, fate, and bioaccumulation modeling study. Discussions related to the adequacy of data are also presented in Section 7 (Additional Data Collection Activities), Section 14 (PCB Fate), and Section 19 (Grid Scheme/Spatial Scale).

6.3 SUMMARY OF ISSUES

The Peer Reviewers' comments on the adequacy of data available to support development and implementation of the Housatonic River transport, fate, and bioaccumulation modeling study included concerns regarding:

- Spatial resolution of data in relation to the grid size(s) selected for the model.
- Availability of historical bathymetric data.
- Adequacy of site-specific data on PCB partitioning (pore water collection techniques).

- Data quality.
- Adequacy of particle size, density, erosion rates on horizontal scale.
- Spatial/temporal TOC/POC/TSS data.
- Validation of trophic pathways.
- Spatial/temporal plankton and benthos data.
- Mixed layer.

6.4 EPA'S RESPONSE TO COMMENTS REGARDING THE ADEQUACY OF DATA

6.4.1 Spatial Resolution of Data

The Peer Reviewers questioned whether the spatial resolution of the data is adequate to support the proposed model grid scheme(s). EPA believes that adequate data are available to support any reasonable grid scheme for the Housatonic River Modeling Study. A model provides a tool for mathematically representing physical and biogeochemical processes. The scale over which processes are assumed to be essentially homogeneous, or within which variability is not a factor, defines the spatial scale of resolution for a model.

Determination of the model grid is based on the resolution necessary to accurately simulate the fundamental fate and transport processes. It is not necessary to obtain site-specific data for state variables for every grid cell, nor is it possible except for a grid at a scale that is too coarse for proper representation of the processes in a river such as the Housatonic. Modeling studies are rarely supported by data for each element of the model grid and must therefore employ some procedure to populate the model grid based on the available data.

Variability in PCB concentrations in the Housatonic River sediment and floodplain data was evaluated. In general, spatial/temporal variability in the floodplain is small in comparison to the main channel sediments. Data from transects were collected specifically to investigate cross-channel variability in sediment. These data and data from numerous other co-located samples in the river clearly indicate that PCBs, TOC, and grain-size distribution, as well as other parameters, are highly variable in this system, particularly at more upstream main channel locations where localized hydraulic regimes create small-scale features that can vary on the scale of feet or even inches. These data indicate clearly that considerable localized variability (in both space and time) exists on scales that are too fine to be sampled directly. Characterization of this variability will be presented in the final MFD.

In the Housatonic River modeling study, the available data in the floodplain will be used to develop a spatially weighted surface at 3-m resolution using inverse distance weighting. Because the model grid likely to be implemented in the floodplain will be larger than the 3-m resolution resulting from the spatial weighting, values will be assigned to model grids as the average of the corresponding spatial weighting grid elements.

Analysis of sediment data from the main channel of the river indicates that considerable spatial and temporal variability exists on a scale much smaller than the scales of interest for the model, requiring that a different approach than that implemented in the floodplain be used to establish initial conditions. In these areas, EPA is investigating alternate approaches such as developing frequency distributions from the data for discrete sections of the river. Under this approach, model cells in these sections would be populated probabilistically from the frequency distribution using Monte Carlo techniques. EPA believes that this probabilistic, or some similar, approach may be a more realistic representation of the state of knowledge of conditions in the river channel sediments at any point in space and time than the deterministic approach, and that the existing data density is sufficient to support this approach.

6.4.2 Bathymetric Data Availability

The Peer Reviewers questioned the availability of bathymetric data, both historical and current, for the river channel and Woods Pond. Since the PCB contamination of the Housatonic River system was identified approximately 30 years ago, a variety of studies have been conducted by GE, EPA, and other interested parties. To the extent possible, these historical sources of data (approximately 100 different studies) have been evaluated for potential use in the modeling effort. These studies did not include historical bathymetric data for the river channel of Woods Pond, nor did they include any dredging records. EPA collected extensive cross-sectional data (over 250 cross-sections) on bed elevations in the river channel and performed a bathymetric survey of Woods Pond to support the modeling study. These data were summarized in the MFD, and provided in EPA's April 2001 responses to the Peer Reviewers' questions.

6.4.3 PCB Partition Coefficients

One reviewer questioned whether adequate data exist for properly describing the site-specific partitioning of PCBs. EPA recognizes that PCB partitioning is technically complex, and that an understanding of partitioning behavior is important for accurate modeling of PCB fate and transport in a river system such as the Housatonic. PCB partitioning varies according to the chlorination level of the individual PCB congener in question. In general, a more highly chlorinated congener has a higher K_{ow}; consequently, the sediment/water partition coefficient (K_d) and the organic carbon/water partition coefficient (K_{oc}) are higher, indicating that comparatively more of the congener is associated with the particulate rather than the dissolved fraction. Over the range of PCB congeners of concern in the Housatonic River, the differences in these partition coefficients can be a few orders of magnitude.

Modeling PCB fate and transport requires a choice between the use of a single partition coefficient to represent more complex behavior or the use of multiple coefficients representing individual PCB congeners, the latter of which is computationally possible for only the most simple models. This issue has been recognized for some time. Thomann et al. (1991), for example, represented PCB homologs in developing a model of fate and bioaccumulation of PCBs in the Hudson estuary.

A number of approaches are available to accommodate a range of K_ds in the modeling effort. A common approach is to model level-of-chlorination homolog groups as a compromise between total PCB and individual congeners. A more direct approach is to use empirically derived site-specific K_ds for total PCB as a reasonable integrator of what is happening in the system. This latter approach is proposed for the Housatonic River modeling and is discussed in greater detail in Section 14 (PCB Fate).

At the time the MFD was prepared in October 2000, a limited amount of data was available to evaluate the site-specific apparent K_ds in the PSA, particularly in sediments. The Peer Reviewers expressed a concern regarding the quality of this data due to differing extraction techniques. EPA agrees that the data set has limited value for calculating PCB partitioning coefficients throughout the PSA. A supplemental pore water study, described in Section 7 (Additional Data Collection Activities), generated the data used for calculation of PCB partitioning coefficients, rendering the Peer Review concerns moot. The results from the pore water study and the determination of partitioning coefficient(s) to be used in the modeling effort will be presented and discussed in the final MFD.

6.4.4 Data Quality

One reviewer, while noting that the data inventories suggested that an adequate quantity of data exists, questioned whether the quality of the data is adequate. The data supporting the Housatonic River modeling study were collected in accordance with established Standard Operating Procedures and Protocols presented in the Field Sampling Plan (WESTON, 2001a), preparation of which was guided by a detailed Supplemental Investigation Work Plan (WESTON, 2000). All data have been subjected to formal and informal Quality Assurance and Quality Control review procedures, including formal Good Laboratory Practice validation when appropriate as specified in the project QAPP (WESTON, 2001b). Automated routine and non-routine reviews of data are conducted regularly by the project Quality Assurance Team and the principal investigators. The database is also shared with GE, who use the data and identify discrepancies for investigation and correction.

The discrepancies cited by the reviewer that led to a comment concerning data quality resulted from differences regarding the timing and interpretation of data, rather than an issue of quality of the data, per se. EPA agrees that such issues require further investigation and clarification, but should not be interpreted to reflect on the quality of the data used in the modeling study.

6.4.5 Adequacy of Particle Size, Density, Erosion Rates on Horizontal Scale

The Peer Reviewers questioned whether sufficient data on sediment characteristics and erosion rates were available to support the modeling study. Approximately 2,000 sediment grain size samples have been collected from the main channel of the PSA, a distance of approximately 10.7 miles (17 kilometers). This density of data on sediment characteristics is considerably greater than is typically available for studies of this type, and EPA believes that these data are adequate for establishing initial conditions for the model.

Data on erosion rates, developed from the Sedflume study, are based on 24 cores generating data on 165 separate sediment "samples" and are therefore these data are less dense than the grain size data. However, the cores were collected from areas of the river specifically selected to represent the full range of ambient sediment types. As discussed in the description of the two alternative methods for use of Sedflume data in the EFDC model in Section 13 (Sedflume), Method 1 would match the erosion rate data obtained from the Sedflume for this comprehensive range of sediment types to the grid cells with sediments of corresponding grain size and bulk density characteristics in the river. Alternatively, Method 2 would use the range of erosion rate data to develop functional relationships between grain size, bulk density, and erosion rate and would use these relationships to mechanistically derive erosion rates for grid cells using the assigned sediment characteristics. EPA believes that the extent of the sediment data, in combination with the comprehensive Sedflume data, are sufficient to support either approach.

6.4.6 Spatial/Temporal TOC/POC/TSS Data

One reviewer questioned the data available to support some of the equations linking these parameters from EFDC to AQUATOX. Because EPA has decided to replace AQUATOX with a simpler bioaccumulation model that does not require similar linkages, the specific question regarding these equations is no longer applicable. However, the question of available TOC/POC/TSS data remains valid. EPA has implemented a supplemental surface water sampling program to address this issue and has also incorporated data collected by GE into the project database for use in the modeling study.

6.4.7 Validation of Trophic Pathways

A Peer Reviewer commented that data should be collected to validate the trophic pathways in the food web model. Although EPA agrees that an understanding of predator/prey relationships is necessary for implementation of a bioaccumulation model, EPA does not believe that site-specific gut analyses are necessary.

The bioaccumulation model is based on modeling of trophic levels rather than individual species, and, to the extent that data for individual species are used in the model, they are intended to serve only as surrogate values to be applied equally to groups of species based on trophic type. Accordingly, proper application of the model is not dependent on validation of specific trophic pathways but rather requires only that the species in the Housatonic River be correctly assigned to the appropriate trophic type.

As part of the Housatonic River Ecological Characterization (Woodlot Associates, 2001), available life history information has been assembled and reviewed for species in the PSA that will be simulated in the bioaccumulation model. This information, in combination with other literature information on life histories of similar species, and applicable studies in other watersheds, will be evaluated through a weight-of-evidence approach to assign these PSA species to the correct trophic type.

6.4.8 Spatial/Temporal Plankton and Benthos Data

One reviewer commented on the lack of spatial and temporal data on plankton and benthos. Although EPA agrees that the available data may have been inadequate for the calibration and validation of AQUATOX, ongoing analysis of the sensitivity of candidate bioaccumulation models indicates that, for the Housatonic system, the models will not be greatly sensitive to seasonal changes in planktonic and benthic populations. EPA believes, therefore, that the current data on these communities, which do reflect spatial (though not temporal) variability, will be sufficient to support the bioaccumulation model at a level that is commensurate with its sensitivity to these parameters.

6.4.9 Mixed Layer

A reviewer questioned the adequacy of data on the mixed layer. The issue of the mixed or active layer is discussed in Section 12 (Active Layer). In response to the Peer Reviewers' comments, EPA conducted a deep core study encompassing 26 cores collected at 13 locations in the river. An analysis of these data, in combination with data from other study components, which are now believed adequate to determine the role of the mixed layer with sufficient accuracy for use in the model, will be presented in the final MFD.

6.5 REFERENCES

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Woodlot Alternatives, Inc. 2001. *Ecological Characterization of the Housatonic River (Revised Preliminary Draft)*. Prepared for U.S. Environmental Protection Agency. DCN GE-042501-AAJX.

7. ADDITIONAL DATA COLLECTION ACTIVITIES – DC

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7.2 BACKGROUND

The concerns expressed by the Peer Reviewers were of two types: the need for additional data and the need for further analysis of data. The additional data collection efforts undertaken by EPA as part of the modeling effort are described in this and other sections. Further analysis of data is described in other sections of this Responsiveness Summary:

- Role of the floodplain (e.g., source/sink) (Section 8 – Floodplain/Channel Interactions)
- Critical erosion velocities and density profiles (Section 13 – Sedflume)
- Sediment settling speeds (Section 6 – Adequacy of Data)
- Additional Sedflume data (including sediment densities) and their use in the model (Section 13 – Sedflume)
- Radionuclide measurements (for sedimentation rates and evaluation of sediment mixing zones) (Section 5 - Conceptual Model/Evaluation of Site Data)
- Sediment rating curves (extrapolated to out-of-bank conditions) (Section 5 - Conceptual Model/Evaluation of Site Data).
- Flow and TSS monitoring at a tributary (Section 2 - Model Selection, and Section 15 - HSPF).
- Lower food web PCB concentrations (Section 17 - Bioaccumulation Model/ AQUATOX).
- Diet (predator/prey relationships and benthic/pelagic pathways) (Section 17 - Bioaccumulation Model/AQUATOX).

- Additional datasets that may not have been considered (Section 5 – Conceptual Model/Evaluation of Site Data, and Section 26 – Miscellaneous)

7.3 ISSUES

Concerns identified by the Peer Reviewers that will require additional data collection include:

- Surface water transport - organic carbon (POC)/DOC) and TSS relationships, PCB partition coefficients, and POC/DOC uncertainties.
- Pore water - PCB partition coefficients, relationship with organic carbon.
- Vertical extent of PCB contamination.
- Monitoring of remediation.
- Major storm event.
- Settling velocities.
- River processes - sediment bedload, suspended load, and river meandering.

7.4 EPA'S RESPONSE TO COMMENTS RELATED TO ADDITIONAL DATA COLLECTION ACTIVITES

EPA agrees that additional data would be useful to support the modeling effort. Accordingly, supplemental sampling programs that address the concerns identified by the Peer Reviewers have been planned and/or implemented, as described below.

7.4.1 Supplemental Surface Water Study

A supplemental surface water study is planned to measure the total, particulate, and dissolved phases of PCBs and organic carbon (OC) in surface water in the Primary Study Area (PSA). Other parameters, including total suspended solids (TSS) and chlorophyll-a, will be measured. These data will be used to parameterize the empirical state variables. These data will augment those previously collected in the EPA monthly baseline and storm sampling programs, GE's water monitoring program, and data being collected in other sampling programs described in this section.

Samples will be collected at the following locations along the Housatonic River:

- **Pomeroy Avenue Bridge**—This station, located on the East Branch immediately upstream of the PSA, was sampled during the monthly surface water baseline study and the storm water sampling program, and represents an upstream boundary condition.

- **West Branch (of the Housatonic River)**—This station, approximately 60 meters upstream from the confluence of the East and West Branch, was sampled during the monthly surface water baseline study and the storm water program, and represents an upstream boundary condition.

- **New Lenox Road Bridge**—This station, approximately in the middle of the PSA and the downstream boundary of the Test Reach, was sampled during the monthly surface water baseline study and the storm water program.

- **Woods Ponds Footbridge**—This station, representing the downstream boundary of the PSA, was sampled during the storm water program. It is approximately 300 meters upstream of the Woods Pond Dam, which is the lower boundary of the PSA. The Woods Pond Dam was sampled during the monthly surface water baseline study.

Three sampling events are planned for high (>200 cfs as measured at the USGS Coltsville gage), medium (100 cfs), and low (50 cfs) flows. In addition, a single sampling event at the Pomeroy Avenue location will be conducted to test the protocol and analytical procedures. A high-volume, pressure filtration apparatus will be used during sample processing to minimize the effects from potential PCB adsorption onto the filters and processing apparatus.

Data collected in this study will be used to address the relationship of organic carbon (POC/DOC) and TSS, PCB partitioning in the water column, and loadings of TSS and PCBs as a function of flow. Current drought conditions may delay completion of this study; available data will be presented in the final MFD.

7.4.2 Supplemental Pore Water Study

A supplemental pore water study was conducted to measure PCBs and organic carbon in pore water and bulk sediment at 50 locations within the PSA. The data will be used to assess PCB partition coefficients and their relationship to organic carbon in various sediment types throughout the PSA.

Sediment within the study area ranges from fine, organic silt/clay in Woods Pond to coarse sand in the upper reaches. Pore water was extracted using the centrifugation-filtration approach. This approach was selected over an ultra-centrifugation technique without filtration to minimize variability due to operator processing and consistency of the separation of the pore water. This technique, however, did not result in adequate pore water separation for extremely sandy sediments. An alternative "spin-out" technique was necessary to separate the pore water prior to the filtration step. In this technique, the wet sandy sediment was placed into a centrifuge vessel with holes in the bottom, lined with a stainless steel screen. A stainless steel receiving vessel was placed below the sample vessel to collect the pore water centrifuged from the sandy sediment at relatively low speeds (200 – 700 rpm).

The results of this study will be presented in the final MFD.

7.4.3 Deep River Cores

Paired deep cores were at collected 13 locations (total of 26 cores) in the main river channel in the PSA to assist in defining the vertical extent of PCB contamination and in understanding the geomorphology of the river sediments and sediment stability. This work was a component of the Supplemental Modeling Investigation but had not yet been conducted at the time of the Peer Review. Routine sampling in the river was typically conducted at depths of less than 3 feet (0.9 meters) and rarely encountered sediments in which PCBs were not detected.

The deep cores collected during this study were located in pairs, placed on opposite sides of the thalweg, to depths of up to 13 feet (3.9 meters). The lithology of each core was logged and videotaped. Sediment samples were collected from the top 6 inches (15 cm) of each core. Additional samples were collected from 6-inch intervals from particular lithologic layers (e.g., clay, peat, sand, gravel) deeper in the core. Samples were analyzed for total PCBs, organic carbon, and grain size. A bulk density measurement was obtained for each lithological layer where possible. The remainder of the cores were archived for further interpretation and analysis. The results of this study will be presented in the final MFD.

7.4.4 Remediation Monitoring

GE is conducting ongoing monitoring as part of the sediment removal being performed in the first 1/2 mile of the East Branch. The current monitoring program includes a biweekly measurement of TSS and total and dissolved PCBs at a location above the remediation (upstream of the Newell Street Bridge), and downstream of the remediation (downstream of the Lyman Street Bridge). EPA will conduct a similar program when performing the removal in the 1 ½ mile.

In response to concerns raised by the Peer Reviewers, GE has agreed to continue monthly monitoring of total PCBs, TSS, POC, and chlorophyll-a in the PSA, and has relocated its historical Hubbard Avenue location to Pomeroy Avenue to provide a continuity of record at the upstream boundary of the PSA.

7.4.5 Major Storm Event Sampling

To address concerns raised by the Peer Reviewers, EPA will sample a major storm event, weather permitting, before the conclusion of EPA's investigation. The objective of the program is to characterize extreme out-of-bank flow conditions in the Housatonic River. These data would supplement data from the 1999 storm sampling program. The sampling locations include West Branch and Pomeroy Avenue (upstream boundary of the PSA), Woods Pond (downstream boundary), the Electric Power Research Institute (EPRI) location (upstream boundary of the Test Reach) and New Lenox Road (downstream boundary of the Test Reach).

Samples will be collected for analysis of total PCBs, total organic carbon, and TSS; measurements will be obtained of the stream velocities and the stage heights (for calculation of the flows), as allowed by safety considerations due to river conditions. Sediment bedload will also be measured at the Pomeroy, EPRI, and New Lenox locations.

Data generated by the sampling will allow an assessment of suspended PCB and TSS loads as a function of flow during an extreme event. In addition, the data will allow the extension of the rating curves at the various PSA locations. To date, no qualifying storm event has occurred; therefore, EPA will not be able to report the results of the additional sampling in the final MFD.

7.4.6 Settling Velocities

One of the reviewers requested that data be collected on site-specific settling velocities for the cohesive sediments. EPA agrees that such data could be of value; however, initial upper and lower bound values for settling velocities obtained from the literature will result in reasonable values for specifying deposition processes in EFDC.

7.4.7 Supplemental Modeling Data

The following additional data are being collected to support model development:

- Sediment bedload will be measured as a function of flow during up to four high flow events (three in addition to the extreme event) at the Pomeroy Avenue location, and upstream and downstream Test Reach boundaries (EPRI and New Lenox Road, respectively).
- Water column samples will be collected at the same locations as the sediment bedload samples and will be analyzed for TSS, TOC, and total PCBs.
- Pressure transducers have been installed to allow a continuous record of stage heights (and thus flows as the rating curves are developed) at five locations.
- Additional Acoustic Doppler Current Profiler (ADCP) studies in the vicinity of the Test Reach, Woods Pond, and selected other locations have been conducted to characterize river velocities.
- Toe pins were installed at five major river bends and are being measured after storm events to evaluate bank erosion and slumping. Selected cross-sections are being re-surveyed after selected flow events, to evaluate bank and sediment bed erosion and deposition.
- A study of river meandering (discussed in Section 8, Floodplain/Channel Interactions), is being performed to evaluate the importance of this process.

Collectively, these data will contribute to the understanding of sediment bedload, impacts of high flow events, suspended load, and river meandering, and will be presented in the final MFD as available.

8. FLOODPLAIN/CHANNEL INTERACTIONS—FC

8.1 COMMENT SUMMARY

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	10	15-22
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8.2 BACKGROUND

The floodplain of the Housatonic River for the purposes of the EPA Modeling Study is defined by the 10-year flood elevation. The floodplain ranges in width from about 250 to 1,000 meters on the western side of the river channel and is topographically constrained to less than about 100 meters wide on the eastern side of the river. More than 60 vernal pools and numerous backwaters of the river have been identified within the floodplain. PCB-contaminated sediments are present in many of the vernal pools. Soil samples collected from within the floodplain indicate that PCBs are present throughout most of the floodplains in the Primary Study Area

(PSA), ranging from non-detect (about 0.5 mg/kg or lower) to greater than 900 mg/kg. PCB concentrations in floodplain soils are generally highest nearer the river and decrease laterally away from the river channel.

The processes and interactions of the floodplain and river will be incorporated in the modeling study to support the evaluation of remedial scenarios associated with contaminated river sediment and floodplain soils. The modeling effort will account for three different flow conditions: (1) in-bank flow; (2) moderate out-of-bank flow within the proximal floodplain; and (3) extreme out-of-bank flood flow onto the distal floodplain. The vegetation density in the floodplain will also be incorporated in the model framework as a spatially variable friction factor that attenuates surface water flow and sediment transport over the floodway.

A preliminary evaluation of the EPA data suggests that most of the PCB mass in the PSA is situated in the bed sediment of the river, riverbanks, and floodplains. Less than 1% of the total resident mass of PCBs is accounted for by sediment in the aggrading and point bars of the river. The Conceptual Model section of the MFD described the processes and terrains that affect the distribution of PCBs in the system. Some of the processes that relate to the interaction of the river with the proximal floodplain were still under investigation at the time of preparation of the MFD in October 2000. The final MFD will be revised to include the findings from these more recent investigations. Monitoring and sampling of surface waters in the PSA during a high-flow event is planned for the future.

This section presents EPA's response to comments related to Floodplain/Channel interactions. Further responses to issues related to the river channel and floodplain interactions of the Environmental Fluid Dynamics Code (EFDC) grid scheme are presented in Section 19 (Grid Scheme /Spatial Scale) of this Responsiveness Summary. The "experimental nature" of the proposed application of EFDC is addressed in Section 16 (EFDC).

8.3 SUMMARY OF ISSUES

The Peer Reviewers focused on the following issues related to floodplain/channel interactions:

- Adequacy of the Conceptual Model to describe the function of the floodplain environment as a source or depository of PCB-contaminated sediments.

- Representation of the transition from in-bank flow to out-of-bank flow conditions, and the accuracy of the representation of out-of-bank flow using the EFDC Model. The Peer Reviewers asked how the use of the dual grid scheme in the hydrodynamic model would influence predictions of the transport and fate of PCBs within the floodplain.

- Alternatives to the proposed two-dimensional application of EFDC. The Peer Reviewers suggested that simpler, one-dimensional models be considered as an alternative to the proposed two-dimensional application of EFDC. It was noted that the proposed coupling of a highly meandering river and floodplain has never been accomplished using EFDC or any other hydrodynamic model.

8.4 EPA'S RESPONSE TO COMMENTS REGARDING FLOODPLAIN/CHANNEL INTERACTIONS

8.4.1 Conceptual Model of Floodplain

EPA intends to expand the Conceptual Model section of the MFD to include a description of the fate and transport of PCBs in the floodplain. The modeling team agrees with the Peer Reviewers that the thick vegetative cover attenuates the velocity of flow across the floodplain and creates a depositional environment for sediments in the distal floodplain. Additionally, EPA agrees that PCBs suspended in the water column and adsorbed to these sediments or other particulates are also attenuated by the presence of vegetation. The effect of the floodplain vegetation is expected to vary by habitat type and by season. The modeling team preliminarily concludes that the entire floodplain acts as a depositional sink for PCBs sorbed to sediments, with only the proximal floodplain likely to serve as a source of PCBs during high flow conditions. Additional data collection and analyses are underway to refine the Conceptual Model and will be presented in the final MFD. The final MFD will include a more detailed evaluation of the extent of PCBs in the distal and proximal floodplain, estimates of bank erosion rates, a discussion of how EFDC will represent the transport of sediment in the distal floodplain, and an analysis of the historical changes in meanders of the river.

8.4.2 Use of the Hydrodynamic Model (EFDC) To Represent the Transition from In-Bank Flow to Out-of-Bank Flow Conditions

Additional work has been performed since the MFD that addresses the concerns expressed by the Peer Reviewers with respect to the ability of EFDC to represent the hydrodynamics and sediment transport between the river channel and floodplain during out-of-bank flow conditions. Specifically, the modeling team has developed and is testing different grid schemes conserving mass and momentum between the river and proximal floodplain. The final MFD will provide more detail on this approach, including the formulations and graphical representations demonstrating velocity vectors and the conservation of mass and momentum for the test reach. Two model test cases, using data presented in Lopez and Garcia (1998) and James et al. (2001), will be compared with results obtained from EFDC to test the hydrodynamic effects of vegetation and flow in the model during the transition from in-bank to out-of-bank flows in the revised MFD.

8.4.3 Alternatives to the Proposed Two-Dimensional Application of EFDC

It was suggested that EPA consider the use of separate one-dimensional models to represent the three distinct flow conditions of: (1) in-bank flow; (2) moderate out-of-bank flow within the proximal floodplain; and (3) extreme out-of-bank flood flow onto the distal floodplain. Panel members noted that a number of one-dimensional models have an extensive track record of successful applications for flood risk simulations of floodplain inundation. The modeling team is aware that one-dimensional hydrodynamic models, such as NOAA's NWS FLDWAV model (NOAA, 2000), have been successfully applied for numerous flood risk investigations, yet believes that this approach would not adequately represent the circumstances and processes for the Housatonic River.

Calibration of the type of one-dimensional model suggested by the Peer Reviewers requires that three sets of "composite" bottom friction coefficients be determined to reproduce observed stage heights for each of the three distinct flow conditions. The friction factors that are calibrated for each separate flow condition thus represent a set of cross-sectional coefficients that parameterizes the lateral variability of bottom friction for the very different bottom conditions of the river channel, river bank, and the different types of vegetation in the proximal floodplain and distal floodplain. If the only objective of a one-dimensional model is the simulation of stage height to map the extent of floodplain inundation at different elevations under the three sets of flow conditions, as it is for FEMA studies for example, then the use of a simplified one-dimensional hydrodynamic model is an appropriate choice.

A one-dimensional hydrodynamic model that is then interfaced with the sediment transport and PCB transport and fate models, however, will provide only the longitudinal distribution of sediments and PCBs for each of the three flow conditions along the length of the Housatonic River. For the in-bank flow condition, a longitudinal simulation is an appropriate simplification that averages out the small lateral and vertical gradients of sediment and PCBs across the channel relative to the much larger gradient along the length of the river channel. However, for the out-of-bank flow conditions, the one-dimensional model will provide only a single concentration of sediment and PCBs for each cross section of the river channel. Vertical dependence of PCBs would be simulated by the representation of multiple bed layers in the model. The results would provide only a laterally averaged concentration of sediments and PCBs along the length of the river. No quantitative information can be extracted from the one-dimensional model results to test the performance of the model against the observed distributions of PCBs at different locations along the river, which have been characterized by significant cross-sectional gradients.

The MFD proposed the use of one-dimensional models, such as GSTARS (Yang et al., 1998) and HEC-6, to assist in bounding parameter estimates and overall sediment behavior for in-bank flow conditions. EPA believes that further use of one-dimensional models of hydrodynamics and sediment transport to predict PCB distributions within the model domain would result in excessive spatial averaging, especially in a floodplain that is up to a 1,000 meters wide, with PCB concentrations ranging from non-detect to more than 900 mg/kg. More detailed discussion of EPA's review and evaluation of alternative one-, two-, and three-dimensional models of hydrodynamics and sediment transport will be presented in the final MFD.

8.5 REFERENCES

James, C. S., W. Liu, and W.R.C. Myers. 2001. "Conveyance of Meandering Channels with Marginal Vegetation." Water and Maritime Engineers, Proceedings of the Institution of Civil Engineers, 148(2): 97-106.

Lopez, F. and M. Garcia. 1998. "Open-Channel Flow Through Simulated Vegetation: Suspended Sediment Transport Modeling," *Water Resources Research*, 34(9): 2341-2352.

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Yang, C.T., T. Mark and S. Francisco. 1998. Generalized Stream Tube Model for Alluvial River Simulation, GSTARS Version 2.0. U.S. Bureau of Reclamation, Denver, CO.

9. FLOODPLAIN VEGETATION—FV

9.1 COMMENT SUMMARY

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Garcia	3	41-47
Shanahan	6	37-40
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9.2 BACKGROUND

The floodplain of most rivers is characterized by deposits of fine-grained sediments from recurring cycles of overbank flood-flow events. The rate of sediment deposition is highly variable, and depends upon the sediment load; the character of the sediments; the magnitude, frequency, and duration of the overbank flows; and the morphology of the floodplains. Vegetation in the floodplain is an important process in the Housatonic River Primary Study Area (PSA) because vegetation attenuates flow, which results in an increase in sediment deposition and decreases resuspension. The effects of floodplain vegetation on attenuating flow will be represented in the hydrodynamic model to adequately simulate solids deposition and the decrease in resuspension attributable to floodplain vegetation. EFDC will be calibrated to obtain good agreement with the simulated depth of flow over the floodplain and observed elevations during storm events.

9.3 SUMMARY OF ISSUES

The Peer Reviewers identified the following issues regarding the impact of floodplain vegetation on the fate and transport of PCBs in the Housatonic River:

- The role of vegetation in trapping sediments and associated pollutants needs to be discussed. The reviewers commented that this may be an important factor in sediment transport, and that simply increasing floodplain roughness coefficients in EFDC will not tell us much about the fate and transport of PCBs in woody areas commonly found in the floodplain.

- They further commented that some portion of the sediment deposited on the floodplain may remain mobile to be progressively washed from the surface of the floodplain by subsequent rainfall events, independent of river stage.

9.4 EPA'S RESPONSE TO COMMENTS REGARDING FLOODPLAIN VEGETATION

9.4.1 Role of Floodplain Vegetation and Bottom Roughness

EPA agrees that the effect of floodplain vegetation on sediment and PCB transport must be accounted for in the model simulations. Sediment transport in the vegetated floodplain is affected by the same parameters as open channel flow; namely, the sediment particle settling velocity and the hydraulic characteristics of the flow. Hydraulic conditions are significantly influenced by the presence of vegetation, which tends to reduce velocity, decrease momentum transfer to the bed, and modify the turbulent structure of the flow. These impacts decrease sediment transport capacity, increase deposition rates, and decrease resuspension of solids on the vegetated floodplains. The magnitude of the impact depends on a variety of factors, the most significant being the vegetation density and the height of the vegetation relative to the flow depth (Fischenich, 1996; Lopez and Garcia, 1998). Thus, the effect of the vegetation varies by season and wetland vegetative type so that various combinations of these factors will reduce the suspended sediment load to differing degrees. Vegetated floodplains have been shown to have "trap efficiencies" ranging from 40 to 90%, depending on the characteristics of the sediment, flow, vegetation, and floodplains (Thornton et al., 1997; Leeds et al., 2000).

These processes will be represented in EFDC by flow over the floodplain as a function of vegetation stem densities and diameters. These parameters will be adjusted to match hydraulics in the model (i.e., to match timing of flood peaks) to achieve calibration.

9.4.2 Floodplain Runoff of Solids and PCBs

The ability of overland flow to entrain sediments from the vegetated floodplain along the Housatonic is severely limited by the low slopes. The surface water flow does not generate the near-bed turbulence or shear stress necessary to erode the sediment particles except in areas of flow concentration in the proximal floodplain. Moreover, any sediments eroded from the floodplain are likely to be entrained by vegetation prior to delivery to the main channel. Thus, suspended sediment and PCB loadings from the floodplain to the river due to storm runoff is not considered to be a significant process and will not be directly included in the modeling framework. The potential for reintroduction of larger volumes of floodplain sediment to the channel because of channel avulsions or localized bank erosion is being evaluated as part of the study on meandering and bank erosion.

9.5 REFERENCES

Fischenich, J.C., 1996. *Velocity and Resistance in Densely Vegetated Floodways*. Ph.D. Dissertation, Colorado State University. University Press, Fort Collins, CO.

Leeds, R., L. Brown, M. Sulc, and L. VanLieshout. 2000. *Vegetative Filter Strips: Application, Installation and Maintenance*, Ohio State University Extension, Fact Sheet AEX-467-94.

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10. BANK SLUMPING/EROSION/MEANDERING—BSE

10.1 COMMENT SUMMARY

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Endicott	19	9-15
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10.2 BACKGROUND

Localized bank erosion, mass failure of banks, and bar formation occur on a small time scale on the Housatonic River. Over a time scale on the order of hundreds to thousands of years, large changes occur through channel meandering processes, oxbow cutoffs and channel avulsions, and larger bar/terrace formation.

The primary mechanism of bank loss on the Housatonic River is gradual erosion of the unvegetated bank toe, followed by translational, rotational, or cantilever failure of the middle and upper banks. Upper bank failures are generally discrete events that often capture large trees from the riparian corridor. This introduction of large woody debris into the stream channel plays a significant role in the channel evolution process on the Housatonic River. The large woody debris constricts the channel, generates local turbulence, and amplifies both the rate and magnitude of local bank erosion and sediment deposition.

Longer-term meandering, avulsion, and terrace formation processes on the Housatonic River result from external stresses (i.e., river discharge and sediment supply) acting upon the channel boundary. Variations in vegetative cover, sediment and soil stratigraphy and characteristics, and channel morphology cause smaller scale processes, including bank failure, erosion, and deposition to occur, and result in outward and downstream migration of bendways and concurrent point bar evolution. The external stresses and the channel boundary conditions change with time and vary spatially, thus making it difficult to formulate predictive equations for channel meandering.

EPA has divided the Primary Study Area (PSA) of the Housatonic River into four reaches: Reach 5a, the confluence to the wastewater treatment plant; Reach 5b, the wastewater treatment plant to Roaring Brook; Reach 5c, Roaring Brook to Woods Pond, and Reach 6, Woods Pond. EPA has characterized the primary processes affecting bank slumping and erosional meandering in each reach as follows:

- In Reach 5a, erosion and deposition are primarily controlled by large woody debris as discussed above. Erosion and deposition are largely unrelated to the channel planform, and the reach is very active. Approximately one-third of the banks are eroding/failing, approximately one-third are stable, and the remainder are depositional.
- Reach 5b is less active, and the processes are more consistent with channel morphology. The reach is primarily erosional, with some point bar formation.
- Reach 5c is very low gradient and has little active bank erosion. Sediment deposition is nearly uniform along the channel margins and consists of a thin layer of fine sediments.
- Reach 6 is a pond with little or no banks. No erosion occurs.

This section presents EPA's response to comments related to bank slumping, erosion, and meandering. EPA's findings regarding these processes in each reach will be presented in greater detail in the final MFD.

10.3 SUMMARY OF ISSUES

The Peer Reviewers offered comments regarding the impact of the meandering process and its relationship to PCB flux and distribution. These comments centered on the magnitude of the geomorphological changes within the modeling time scale. The cumulative impacts of channel scour and deposition, bank erosion, bank slumping/failure, and bar/terrace formation may influence the mass of PCBs that could become mobilized. The Peer Reviewers noted that these processes and the associated flux of PCBs into the river were not adequately described in the Conceptual Model. The major categories of the issues are summarized below:

- Do geomorphological data exist to determine the magnitude of the various processes within the time scale of the Housatonic River model framework? The reviewers believed that this information is needed in order to make determinations regarding whether a particular process should be included in the model.
- Process-based analyses should be conducted to estimate the magnitudes and impacts of the processes in question, especially if direct measurements are not available.
- If a specific process is deemed important, how will it be incorporated into the model and what are the implications to the model and the modeling process?

Some comments regarding the distal floodplain have also been addressed in Section 19.4.4 (Grid Scheme/Spatial Scale). The modeling team is evaluating the literature references provided by the reviewers and will consider the approaches presented in this literature in the development of the final modeling approach.

10.4 EPA'S RESPONSE TO COMMENTS REGARDING BANK SLUMPING, EROSION, AND MEANDERING

10.4.1 Data Availability

Assessments of historical aerial photography (including the over-flight conducted in 2000) and topographic surveys are being performed by EPA to estimate the sediment mass that has been added to the river from bank failures/erosion and channel meandering in the past 40 to 50 years. An assessment of near-term channel and bank processes is also underway. In 2000, toe pins were installed at five major bends in the Test Reach and are being monitored to measure bank erosion and accretion. In addition, numerous channel cross sections within the PSA are being resurveyed periodically to assess seasonal/storm event-induced changes in channel morphology.

EPA is conducting bank surveys along the river to monitor the frequency, size, and location of bank failures, as well as to characterize the mechanisms of failure. The main objectives of the study are to characterize and quantify the spatial and volumetric properties of erosion and deposition. Data being collected for each river reach include:

- The percent of bank eroding, percent accreting, and percent stable over a short time frame and following several flow events (1.5-year storm event).
- Modes of bank loss.
- The volume of bank erosion and accretion per area (or in a representative sample of eroding and accreting areas).
- Boundary conditions including vegetation, soil lenses, and sediment grain size for a sample of eroding banks.

The evaluation of all the historical channel data, as well as the toe pin, channel resurveys, and bank surveys, will be included in the final MFD.

10.4.2 Process Models

EPA is conducting analyses to determine the significance of the river meandering processes to estimate the mass of sediment and PCBs mobilized into the river. From the net change in bank position and estimates of bank heights (using both current and historical topography), sediments and PCB loads to the river will be determined. From this assessment, taken with other metrics such as the bank loadings, the significance and location of this process can be used to inform the modeling effort.

10.4.3 Modeling Framework

EPA acknowledges that it is important to understand the contribution of solids and PCBs resulting from past and future meanderings of the Housatonic River. Based on the preliminary investigations performed by EPA since October 2000, it is not necessary to explicitly represent channel width changes, bank slumping erosion processes, meandering, or other larger scale geomorphologic changes in the model framework. These processes are influenced by physical conditions (e.g., root density, unexposed clay layers, thin layer sediment strata in the overbanks, individual bank slopes), which are of a much smaller spatial scale than the Housatonic River modeling should simulate. The locations and specific mass loading of solids and PCBs are best described empirically.

Using the results from the analysis summarized above, these processes will be represented in EFDC by the removal of sediment (and associated PCBs) from the proximal floodplain cells and transferred to the adjacent channel cell as a mass loading term. The mass and timing of these transfers will be based on annual/seasonal bank erosion and failure rates developed from the existing data and ongoing investigations. Adequate data are not available (nor could they be collected) to parameterize the model to any greater level of detail within an acceptable range of uncertainty. Integrating these processes within each reach, as spatial and temporal forcing functions, will provide a level of resolution in the EFDC model appropriate for the modeling study objectives.

Bar formation on a spatial scale that is smaller than reasonable model grid cell dimensions will be treated as part of the overall bed erosion/deposition of the sediments. Bars that are larger than the grid cell dimensions will be subject to the initial sediment bed conditions and simulated channel hydraulics in that river segment. No other attempt will be made to explicitly model bar dynamics at the subgrid scale. Calculations based on the available data indicate that the PCB mass contained in the bars constitutes a small percentage of the overall mass of PCBs in the Housatonic River.

11. RARE FLOOD EVENTS—RF

11.1 COMMENT SUMMARY

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Garcia	4	13-23
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11.2 BACKGROUND

The widespread presence of PCBs in the soil of the Housatonic River floodplain without any identified point sources other than the GE facility upstream indicates that flood events are a factor in the transport of solids and associated PCBs from the river channel to the floodplain. Rare or extreme flood events may contribute significantly to the mass transport of PCBs from the river channel to the floodplain.

One of the objectives of the modeling study is to quantify the relative contribution of extreme storm events to the resuspension and redistribution of PCB-laden sediment within the study area. An additional objective is to evaluate the effectiveness of remedial scenarios that address contaminated floodplain soils and sediments in the river channel.

An explicit representation of the processes and interactions of the floodplain and river channel that influence the spatial distribution of flow, solids, and PCBs in the floodplain will be incorporated in the hydrodynamic, sediment transport, and PCB fate models to address these objectives.

The model must be able to account for three different flow conditions: (1) in-bank flow; (2) moderate out-of-bank flow within the proximal floodplain; and (3) extreme out-of-bank flood flow onto the distal floodplain. The degree to which rare flood events affect flow, solids, and contaminant transport is highly dependent on the specific conditions within a particular river system.

This section focuses on the representation of out-of-bank extreme flow onto the distal floodplain in the model framework. Additional responses to the Peer Reviewers' concerns regarding to the treatment of floodplain processes in the model framework are presented in the responses to Section 8 (Floodplain/Channel Interactions), Section 19 (Grid Scheme/Spatial Scale), Section 9 (Floodplain Vegetation), and Section 13 (Sedflume).

11.3 SUMMARY OF ISSUES

The concerns of the Peer Reviewers can be summarized as follows:

- The absence of data collected under extreme high flow conditions.
- The ability of the watershed and hydrodynamic models to accurately represent rare flood events.
- The ability of sediment transport and PCB fate models to accurately represent mass fluxes during rare flood events.

11.4 EPA'S RESPONSE TO COMMENTS RELATED TO RARE FLOOD EVENTS

11.4.1 Absence of Data Collected Under Extreme High Flow Conditions

EPA agrees that data that represent extreme flood conditions would be useful in calibrating the models. EPA collected data during a series of 10 storm events sampled during 1999 and presented the data in the MFD. During this period of sampling, abnormally dry conditions prevailed. The largest storm that was monitored had a return period of approximately 1.5 years. The team is confident that a reasonable calibration of the models can be obtained using the data that are available from the special studies, routine sampling, and the storm event monitoring program data sets, as well as aerial photography and limited hydrology data from two extreme storms. However, in response to the Peer Review comment, EPA intends to monitor a 10-year, or some other large magnitude, out-of-bank flood flow event, should such an event occur before completion of the modeling study. If such an extreme flow event does not occur, evaluation of the effects of a rare flood event on solids and PCB fluxes will then be based on an evaluation of the reasonableness of the results obtained from the simulations of sediment and PCB transport under such extreme conditions rather than on a comparison to observed data sets.

The evaluation of reasonable results will include a comparison of the simulated hydrology with the aerial photos of an extreme flood event that occurred during August 1990, and for a storm that occurred in June 2000, for which stage measurements and observations of out-of-bank water levels were collected. During the August 6 to 9, 1990 event, streamflow measured at Coltsville ranged from 200 to 4,080 cfs. During the June 2000 event, streamflow measured at Coltsville ranged from 120 to 2,642 cfs. This information will be used to test the ability of the hydrodynamic model to reproduce the spatial extent of penetration of flood flow onto the distal floodplain.

Based on the evaluation of the floodplain soil grain size distribution and vegetation, EPA does not believe that additional Sedflume data from the floodplain are necessary for calibration of the sediment transport model. Additional information relative to this conclusion is provided in Section 13 (Sedflume) and will be presented in the final MFD.

11.4.2 Ability of the Watershed and Hydrodynamic Models To Accurately Represent Rare Flood Events

EPA concurs with the Peer Reviewers that HSPF will accurately simulate rare flood events because HSPF has been designed to specifically represent watershed runoff driven by a series of storm events.

With respect to the hydrodynamic model (EFDC), the fundamental processes included in the model are applicable to the range of anticipated flow regimes. The resolution and accuracy of the elevations of the river channel bed and the floodplain as represented by the computational grid scheme will influence the extent to which the hydrodynamic model will provide an acceptable representation of extreme flood flow conditions. Digital terrain data obtained from the USGS topographic database have been supplemented with field surveys of floodplain and river channel topography to develop a digital terrain model that will provide input data for EFDC. Another factor in the ability of the hydrodynamic model to simulate flow-driven fluctuations of surface water elevations is the representation of the spatial variability of the bottom friction factor and the vegetation-related friction factor for the floodplain. A more detailed discussion of the computational grid and floodplain vegetation is presented in the responses to Section 19 (Grid Scheme/Spatial Scale) and Section 9 (Floodplain Vegetation).

In response to the concerns expressed by the Peer Reviewers related to the conservation of momentum between the proximal and distal floodplain in the proposed dual-grid scheme, EPA has modified the approach originally proposed in the MFD. The EFDC code has been revisited since the Peer Review Meeting, and alternatives have been identified. The final MFD will include an overview of these alternatives in a discussion of the computational grid schemes. To demonstrate the ability of the hydrodynamic model to represent the transition from in-bank flow to out-of-bank flow under extreme flood flow events, the modeling team is applying EFDC to a series of test cases derived from simulation data sets published by Lopez and Garcia (1998); James et al. (2001); Shiono and Muto (1998); Ervine et al. (2000); and Patra and Kar (2000). See discussion under Section 19 (Grid Scheme/Spatial Scale) for more details of the proposed test cases.

11.4.3 Ability of Sediment Transport and PCB Fate Models To Accurately Represent Mass Fluxes During Rare Flood Events

Although EPA concurs that large storm events contribute to sediment flux and solids redistribution in the Housatonic River, EPA believes it is premature to conclude that extreme flow events are the dominant factor that controls PCB fluxes in the Housatonic River. The modeling team is conducting a sediment and PCB flux analysis that will refine the conceptual model and evaluate the relative importance of base flow versus storm flow. In conjunction with this flux analysis, the modeling team will use one-dimensional models, such as EFDC-1D (Tetra Tech, 2001) and HEC-6 (USACE, 1991), to compare the results of one-dimensional simulations to the two-dimensional EFDC simulations of both water levels and solids transport in the floodplain. See the discussion in responses to Section 8 (Floodplain/Channel Interactions), Section 2 (Model Selection), and Section 19 (Grid Scheme/Spatial Scale). The methods used and the results of the flux analyses for solids and PCBs will be presented in the final MFD.

11.5 REFERENCES

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James, C. S., W. Liu, and W.R.C. Myers. 2001. "Conveyance of Meandering Channels with Marginal Vegetation," Water and Maritime Engineers, Proceedings of the Institution of Civil Engineers, 148(2): 97-106.

Lopez F. and M. Garcia. 1998. "Open-Channel Flow Through Simulated Vegetation: Suspended Sediment Transport Modeling," *Water Resources Research*, 34(9): 2341-2352.

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Shiono, K. and Y. Muto. 1998. "Complex Flow Mechanisms in Compound Meandering Channels with Overbank Flow." *J. Fluid Mechanics,* 376: 221-261.

Tetra Tech. 2001. EFDC-1D: A One-Dimensional Hydrodynamic and Sediment Transport Model for River and Stream Networks. Model Theory and User's Guide. Technical report prepared by Tetra Tech, Inc., Fairfax, VA, for U.S. Environmental Protection Agency, Office of Science & Technology, Washington, DC.

USACE (U.S. Army Corps of Engineers). 1991. HEC-6, Scour and Deposition in Rivers and Reservoirs, User's Manual. U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC), Davis, CA.

12. ACTIVE LAYER—AL

12.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Adams	8	31-32
Endicott	17	18-26

12.2 BACKGROUND

The active layer represents the integration of numerous processes, including bedload transport, bioturbation, turbulent flow from debris, and wind action, and controls the interactions of many sediment transport and sediment/water column fluxes during erosive events. EFDC simulates the active layer by altering the bulk density and layer thickness. In the initial response to questions from the Peer Reviewers, it was noted that an active layer depth of 6 inches (15 cm) would serve as the operational definition throughout the Primary Study Area (PSA).

12.3 SUMMARY OF ISSUES

The Peer Reviewers' comments and concerns regarding the active layer were as follows:

- Determination of bio-mixing coefficients
- Selection of a 6-inch mixing depth.

12.4 EPA'S RESPONSE TO COMMENTS REGARDING THE ACTIVE LAYER

In response to comments received from the Peer Reviewers regarding the establishment of a single 6-inch active layer throughout the PSA, EPA has conducted further review of site conditions and available site-specific data to provide better documentation of the depth and variability of the active layer in the PSA. This review includes:

- Development of a better working definition of the active layer. The definition presented in the final MFD will include a discussion of how the active layer is handled versus the subsurface layers in the model.

- Assessment of the deep cores collected in the river.

- Review of data that have direct or indirect bearing on the numerical value chosen for the active layer.

The results of this work will be presented and discussed in the final MFD. The final MFD will also include an expanded section on the use of the active layer in the model.

13. SEDFLUME—SF

13.1 COMMENT SUMMARY

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13.2 BACKGROUND

An accurate representation of resuspension processes for cohesive and non-cohesive sediment is needed for developing a PCB fate and transport model. Erosion rates and critical stresses that trigger resuspension of cohesive and non-cohesive sediment are key parameters in the sediment transport model. To reduce uncertainty for these parameters, site-specific data on sediment resuspension have been collected for the sediment transport model.

In summer 2000, the Waterways Experiment Station (WES) collected, and subsequently analyzed, 24 Sedflume cores (McNeil et al., 1996) and performed 18 Particle Entrainment Simulator (PES) (Tsai and Lick, 1986) tests on cohesive and non-cohesive sediments from the Housatonic River Primary Study Area (PSA) to support development of the sediment transport model. These data are reported in *Sediment Erosion Study for the Housatonic River, Massachusetts* (Gailani et al., 2000).

The Sedflume data provided direct estimates of gross erosion rate as a function of grain size and bulk density. Sedflume data can be used to drive a sediment transport model using either of the following two methods:

- **Method 1**— The gross erosion rate measured in the Sedflume is directly input into a properly formulated sediment transport submodel. The data collected from the most representative core for each sediment type and/or bed region are assigned to the computational grid cells of the sediment bed submodel based upon the assigned grain size of the sediment for that cell. This approach applies the observed erosion profile from a Sedflume core to a specific location, and is dependent on a sufficient number of cores collected to accurately represent the operationally defined sediment groups. Jones and Lick (2000) used this approach to obtain results for a sediment transport model developed for Lower Green Bay in Wisconsin.

- **Method 2**— Gross erosion rates, bulk densities, median grain sizes (d50's), and organic carbon contents obtained from the Sedflume study are used to develop functional formulations for critical shear stress (Jepsen et al., 1997a; 1997b; Jepsen et al., 1998). This approach requires that the functional formulations for erosion be valid over the range of site-specific conditions, and that the total number of samples (number of cores and number of depth intervals per core) is sufficient to statistically represent the bulk erosion properties for each operationally defined particle size class.

This section addresses concerns from the Peer Reviewers related to the use of Sedflume data in the model. The use and adequacy of Sedflume data is also addressed in Section 9 (Floodplain Vegetation) and Section 19 (Grid Scheme/Spatial Scale).

13.3 SUMMARY OF ISSUES

The Peer Reviewers had two main issues with respect to the Sedflume data:

- **Sufficiency of the data.** Although several reviewers felt the study would benefit from more data in the river channel, the focus of the comments about the sufficiency of data dealt more with the lack of Sedflume data for the floodplain. Since data were not collected from the floodplain, the concern of the Peer Reviewers was that there is insufficient information to describe the erosion properties of floodplain soils to support the development and calibration of the sediment transport model under out-of-bank flood flow conditions.

- **Use of the Sedflume data to assign input parameter values for the sediment transport model.** The results from the Sedflume tests are represented as a gross erosion rate as a function of the grain size and bulk density. Using these data, values of critical shear stress for erosion can be computed. The main concern cited by the Peer Reviewers is whether the Sedflume data will be used directly as depth-dependent gross erosion rates (Jones and Lick, 2000) (Method 1) or whether critical shear stresses derived as functional formulations from the Sedflume data will be input to the model (Method 2).

13.4 EPA'S RESPONSE TO COMMENTS REGARDING SEDFLUME DATA

13.4.1 Sufficiency of Data for the Floodplain Soils

Although several reviewers expressed a concern over lack of Sedflume data in the floodplain, EPA believes that Sedflume data for the floodplain are not necessary.

Given the same grain size distribution and bulk density, the main difference between the erosion characteristics of channel sediments and the floodplain soils is the armoring or surface protection mechanisms of the bed. With the floodplain soils, the primary protection from erosion, other than being out of the high shear stress areas, is the presence of vegetative cover. The vegetation on the Housatonic River floodplain ranges from grasses and shrubs to large trees, and varies seasonally. The importance of these factors in the erosional processes in the floodplain outweighs the soil erosion characteristics. An overview of the floodplain soil properties will be provided in the final MFD. In addition, Section 9 (Floodplain Vegetation) presents more information on this topic.

Generally, during a Sedflume test, the effect of vegetation is not measured because non-sediment debris is removed from the core as it is exposed (debris is treated as a "contaminant" for the Sedflume test), and the Sedflume coring device can not practically collect a sample from soils with even moderate vegetative cover because of interference of roots and woody debris. Sediment cores with short-cropped grass (<4 cm) are the only type of vegetated cores that it would be possible to recover for conducting a Sedflume test. In addition, were it possible characteristic cores, a multi-season effort and a large number of samples would be required to represent the range of soil and vegetation types and seasonal conditions that occur in the floodplain. Therefore, EPA believes that it is not possible to obtain representative data on floodplain soils using the Sedflume, and that Sedflume data in the floodplain are not critical to the success of this modeling effort. Use of the river channel Sedflume data, in conjunction with literature values and an appropriate consideration of floodplain vegetation, is expected to be sufficient to parameterize the model, particularly because it is generally agreed that the distal and, to a lesser extent, the proximal floodplains serve primarily as a depositional environment for solids.

13.4.2 Use of Sedflume Data

Twenty-four cores were collected from the Primary Study Area (PSA) and analyzed at approximately 2-cm intervals with the Sedflume device, resulting in over 165 samples. Locations were selected within the river channel, Woods Pond, and selected backwaters to represent a range of sediment grain sizes. Within EFDC, each sediment size class has assigned erosion parameters, which do not vary over space or time. Therefore, once the erosion parameters for a size class are determined, these values will apply to the appropriate size class for all computational grid cells in the model domain.

In the response to the Peer Reviewers questions in April 2001, EPA outlined the Method 2 approach to using Sedflume data in the sediment transport model. The proposed approach was to compute the critical shear stress for erosion as a function of bulk density and grain size, and then assign the erosion properties to each particle size class modeled. Because the sediment transport characteristics are associated with each particle size class, once the distribution of the size classes within the model domain is mapped, the spatial patterns of erosion can be estimated. The final MFD will clarify the approach by showing example calculations performed on the Test Reach.

EPA is considering the incorporation of the Sedflume results directly into a modified version of the EFDC model using the methodology developed by Jones and Lick (2000). The advantages and disadvantages of each of the two methods as well as EPA's approach for using Sedflume measurements for the Housatonic River study will be discussed in the final MFD.

13.5 REFERENCES

Gailani, J. Z., S. J. Smith, M. G. Channell, G. E. Banks, and D. B. Brister. September 2000. *Sediment Erosion Study for the Housatonic River, Massachusetts* (DRAFT). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Jepsen, R., J. Roberts, and W. Lick. 1997a. "Effects of Bulk Density on Sediment Erosion Rates." *Water, Air and Soil Pollution*, 99: 21-31.

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Jones, C. and W. Lick. 2000. "Effects of Bed Coarsening on Sediment Transport." *Proceedings, 6th International Estuarine and Coastal Modeling Conference.* New Orleans, LA. November 1999.

McNeil, J., C. Taylor, and W. Lick. 1996. "Measurements of the Erosion of Undisturbed Bottom Sediments with Depth." *Journal of Hydraulic Engineering,* 122(6): 316-324.

Tsai, C. H. and W. Lick. 1986. "A Portable Device for Measuring Sediment Resuspension." *J. Great Lakes Res.*, 12(4): 314-321.

14. PCB FATE—PCB

14.1 COMMENT SUMMARY

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14.2 BACKGROUND

The rate and mode of transformation or degradation of PCBs in the environment is generally referred to in this document as PCB fate. PCBs are a complex mixture of up to 209 congeners. Each congener has specific physical and chemical properties that affect the transport of that congener. The number of congeners, if dealt with separately, could overwhelm the computational capabilities of the model, as well as generating information that could be difficult to interpret. A challenge of the modeling effort is to achieve a reasonable representation of the fate of the PCBs present in the Housatonic River in a way that is sufficiently precise and yet not overwhelmingly complex.

14.3 SUMMARY OF ISSUES

The Peer Reviewers expressed the following concerns related to the fate of PCBs:

- The need to include a range of values in the model representing differing PCB congeners.
- Consideration of time-dependent fluxes of PCBs among the modeled compartments.
- Consideration of PCB dependence on organic matter sorption.
- Methods to model the flux of PCBs from bed sediment to the overlying water independent of erosion of the sediment bed.

14.4 EPA'S RESPONSE TO COMMENTS REGARDING PCB FATE

14.4.1 Modeling the Transport of Different Congeners

The Peer Reviewers noted the lack of multiple partition coefficients and other parameters covering the range of behavior of PCB congeners in the EFDC model. At this time, EPA believes that using single values characteristic of the PCBs observed in the system ("apparent" K_ds) is the most reasonable approach for representing PCB partitioning in EFDC. This judgment was made based on the following:

1. The results from the pore water study conducted in 2001 indicate that the congener-specific log apparent K_d (normalized to organic carbon) is closely correlated with the log K_{ow} for each of the PCB congeners examined in the study. The constancy of this relationship for each congener over a range of four orders of magnitude of the coefficients supports the use of a single apparent K_d for tPCBs to represent the combined net partitioning of the mixture of congeners present in the PSA.

2. The PCBs found in the Housatonic River system are primarily the more highly chlorinated congeners found in Aroclor 1260, which was used at the GE facility. The congeners constituting the bulk of the mass of PCBs span a narrower range of partition coefficients and other transport-controlling variables than that for all congeners. In addition, these more highly chlorinated congeners have higher partition coefficients so that dissolved-phase fluxes are less important than would be the case with less-chlorinated congeners.

3. Spatial and temporal variations in congener patterns are not observed in the data.

Therefore, a range of congeners will not be modeled in EFDC.

The bioaccumulation model will simulate representative congeners through the food web, accounting for congener-specific transfer characteristics. Because the congener compositions in exposure media are relatively constant, the distribution of congeners can be effectively estimated by modeling total PCBs in EFDC and then re-creating the congener distributions using the ratios observed in empirical data. This approach will be presented in more detail in the final MFD. In this manner, inputs to the bioaccumulation model can be estimated using a combination of EFDC modeling and empirical data.

14.4.2 Time-Dependent Sorption

As the Peer Reviewers noted, time-dependent sorption has been reported in the literature, and is characterized by differences in the rate of PCB uptake and loss, as well as decreases in the loss rates over time. However, the ability to predict the effects of time-dependent sorption in a manner useful to the modeling effort is limited. The time-dependent functions are specific both to the PCB congeners involved and the nature of the organic matrices acting as sorption sites. Given the limitations on the ability to parameterize this process in the model, EPA has chosen not to incorporate time-dependent sorption in the model at this time. However, as suggested, the modeling results will be reviewed to estimate the possible uncertainty associated with this process.

14.4.3 PCB Partitioning and Transport Modeling in the EFDC

Reviewers commented on the difficulty of accurately predicting the transport and fate of PCBs with EFDC, because the model does not include explicit partitioning of a toxicant to organic matter. There was also the potential for substantially different predictions to arise from modeling abiotic PCBs with EFDC and modeling biotic PCBs with AQUATOX. EPA has resolved this issue by incorporating organic carbon partitioning into EFDC. EPA will also use EFDC as the sole model for simulating PCB fate and transport. The results from EFDC as exposure time series of PCB concentrations in the water column and sediment bed will be interfaced with a simpler food chain bioaccumulation model.

EPA is evaluating whether the full three-phase partitioning is necessary for application to the Housatonic River modeling effort. Additional data collected since the Peer Review is being evaluated to determine the importance of this three-phase partitioning, and further discussion will be provided in the final MFD. The two-phase approach will be used if it can be determined that the DOC correlates with the POC, in which case an operational partition coefficient will be used to distribute the PCB between the settling (particulate) and non-settling (dissolved and DOC-associated) phases. Based on a preliminary review of the data, EPA believes that DOC need not be dynamically simulated in EFDC, but can be represented as a constant. Alternatively, equations will be applied that discriminate among these three PCB transport phases (e.g., EPA, 2000a, 2000b, 2000c).

The modeling team will not attempt to distinguish the difference in polarity within the organic carbon pools in the river. In general, dissolved organic material will be more polar than particulate organic matter. More subtle differences have been posited to exist between refractory and labile organic material. Older data and modeling efforts failed to distinguish between PCBs that were truly dissolved and those that were complexed with DOC. In contrast, recent PCB modeling efforts (Gobas, 1993; EPA, 2000a, 2000b, 2000c) have attempted to better define bioavailability, e.g., by extrapolating from operational concentrations to truly dissolved concentrations, using equations that explicitly incorporate the dissolved and particulate organic carbon concentrations. The increased mechanistic representation of these efforts must be balanced with the limited empirical data against which to test and calibrate the models.

The bioavailability of PCBs in the water column represents an important consideration for modeling biological fate. Bioavailability is greater for truly dissolved concentrations of PCBs relative to PCBs complexed with dissolved organic carbon (DOC). Association of PCBs with colloidal and dissolved organic carbon reduces bioavailability; such contaminants are unavailable for uptake by organisms (Stange and Swackhamer, 1994; Gilek et al., 1996). Therefore, the three-phase partitioning described above represents a potentially important component of the bioaccumulation model.

14.4.4 Net Flux of PCBs from the Pore Water

EPA agrees with the Peer Reviewers' comment that the transport of PCBs from the sediment is associated with the resuspension/erosion of PCB-laden sediment particles, as well as with the flux of PCBs from the pore water through a variety of processes including diffusion, groundwater convection, and bioturbation. Similar to time-dependent sorption, the contributions to the PCB flux from these individual processes are difficult to assess because they are not related to each other, are site specific, and vary in time and space. PCB flux results from the pore water study will be compared to the PCB data in the water column throughout the length of the PSA and collected during different seasons to confirm that the flux rates determined from the pore water study are of the correct magnitude in relation to the measured PCB concentrations in the water column.

14.5 REFERENCES

EPA (U.S. Environmental Protection Agency). 2000a. *AQUATOX for Windows: A Modular Fate and Effects Model for Aquatic Ecosystems – Volume 1: User's Manual*. EPA-823-R-00-006.

EPA (U.S. Environmental Protection Agency). 2000b. *AQUATOX for Windows: A Modular Fate and Effects Model for Aquatic Ecosystems – Volume 2: Technical Documentation*. EPA-823-R-00-007.

EPA (U.S. Environmental Protection Agency). 2000c. *AQUATOX for Windows: A Modular Fate and Effects Model for Aquatic Ecosystems – Volume 3: Model Validation Reports*. EPA-823-R-00-008.

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Gobas, F.A.P.C. 1993. "A Model for Predicting the Bioaccumulation of Hydrophobic Organic Chemicals in Aquatic Food Webs: Application to Lake Ontario." *Ecological Modeling*, 69:1-17.

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15. HSPF – H

15.1 COMMENT SUMMARY

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15.2 BACKGROUND

The model framework incorporates linked models to represent watershed runoff, hydrodynamics, sediment transport, PCB transport and fate, and PCB bioaccumulation. Using precipitation and other observed hydrologic and meteorological data, the watershed model incorporates information on land uses, soils properties, and basin topography to simulate surface runoff, streamflow, and pollutant loading in the network of tributaries and rivers defined for the drainage basin. HSPF is a lumped parameter watershed runoff model that has been used successfully for numerous watershed studies over the past 20 years, that was selected for the Housatonic River Rest of River Project to provide streamflow, temperature, and suspended solids data for the hydrodynamic, sediment transport, and PCB transport and fate models.

This section addresses comments raised regarding the use of the HSPF in the Housatonic River modeling effort. Refer to Section 25 (Remediation) on boundary conditions for post-remediation and evaluating remedial alternatives.

15.3 SUMMARY OF ISSUES

The major issues related to HSPF raised by the Peer Reviewers are as follows:

- Upstream boundary loading of PCBs and suspended sediments as input to EFDC for calibration, validation, post-remediation, and evaluation of alternative remedial scenario simulations.
- PCB washoff from areas along the Rest of River.
- The necessity of developing the in-stream river submodel of HSPF.
- Availability of data for HSPF calibration.

15.4 EPA'S RESPONSE TO COMMENTS REGARDING HSPF

15.4.1 Upstream Boundary Loading of PCBs and Suspended Solids

The reviewers questioned the methods of specifying the upstream boundary conditions as input to the hydrodynamic, sediment transport and PCB transport, and fate model (EFDC). Measurements recorded during the storm events monitored in 1999, along with other available surface water monitoring records, will be used to establish the upstream boundary loadings of suspended solids and PCBs for the calibration period (1999-2000). These data will be interpolated as necessary to provide input for EFDC. In addition, suspended solids will be simulated in HSPF for the calibration period and compared with the available surface water data. This comparison will facilitate the use of the predicted values to define boundary loadings for the validation period as described below.

For the majority of the validation period (1979-2000), a more limited set of flow and ambient PCB and TSS data is available. These data will be used to develop flow and constituent relationships. This will not be a simple regression equation or function because there is hysteresis in the relationship (i.e., the PCB and suspended sediment loading is not a single-valued function of discharge; it is different on the rising and falling limb of the hydrograph). These relationships will be used in HSPF simulations to provide inputs for flow and suspended solids for locations and time periods for which there are no data available.

Boundary conditions for post-remediation and the evaluation of remedial alternatives are addressed in Section 25 (Remediation).

15.4.2 PCB Washoff from Areas along Rest of River

EPA believes that the transport of solids and PCBs from the floodplain into the channel by precipitation and runoff is not a significant process that needs to be simulated in HSPF. HSPF will not be used to provide PCB loadings to EFDC at the upstream boundary, as described above. Within the Primary Study Area (PSA), PCB washoff from the proximal floodplain will be simulated by EFDC.

PCB loadings from tributaries below the upstream boundary of the PSA are negligible based upon sampling of soils and sediments in the watershed, past and current land use, and reported disposal practices, and are not represented in the modeling.

15.4.3 Use of In-Stream River Model of HSPF

Simulated flow generated by HSPF will serve as the basis upon which the remainder of the model framework is constructed. Data for calibration of the hydrologic and hydraulic model are available from USGS gages at Coltsville and Great Barrington, Massachusetts. The HSPF hydrologic model will be developed for the entire 282-square-mile drainage area that contributes flow to the Great Barrington gage, and will use these data. The in-stream hydraulic and water quality model of HSPF will also include the drainage area as far downstream as Great Barrington so that calibration of flow and suspended solids can be performed with the observed data at that gage.

EPA believes that it is necessary to use both HSPF and EFDC in modeling the river channel domain of the PSA. The coarse level of spatial resolution defined for the HSPF in-stream hydraulic and water quality reaches (ranging from 0.4 to 1.9 miles [0.6 to 3.1 km] in length) is not sufficient to represent detailed solids deposition, erosion and transport processes, and PCB transport and fate in the complex, meandering reaches of the Housatonic River. In contrast to the in-stream reach submodels available in HSPF, EFDC will provide considerably more advanced process descriptions of hydrodynamics and sediment transport (see Ziegler and Owen, 2001) applied to a much finer scale spatial resolution of the physical domain of the PSA.

15.4.4 Availability of Data for Calibration of HSPF

The Peer Reviewers agreed with EPA that HSPF has the longest history of application of any of the models selected for use in this study, and that established calibration procedures for HSPF are available from this long history of applications. Although the standard HSPF calibration procedures were described in the MFD, the Peer Reviewers requested additional details on calibration station locations and the availability of data. In response to this request, EPA will outline the methodology that will be used to define the functional relationships of flow, suspended solids, and PCBs as upstream boundary conditions and provide more information on the data and station locations being used for both the calibration and validation time periods in the final MFD.

15.5 REFERENCES

Ziegler, C.K. and C. Owen. 2001. "Improvements of Sediment Transport Dynamics in HSPF." Presented at American Water Resources Association Annual Spring Specialty Conference, April 30-May 2, San Antonio, Texas.

16. EFDC—E

16.1 COMMENT SUMMARY

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16.2 BACKGROUND

The Environmental Fluid Dynamics Code (EFDC), developed over the past decade by Hamrick (1992, 1996), has been selected by EPA as the public domain model that will be used to link state-of-the-art hydrodynamics and sediment transport with contaminant transport and fate for use nationwide. Of all the available public domain models, EFDC is unique in that a single source code has been developed to provide internally coupled submodels for hydrodynamics, sediment transport, and toxic chemical transport and fate. An inventory and evaluation of the available public domain models considered for selection as the hydrodynamic, sediment transport, and PCB transport and fate components of the Housatonic River model framework will be presented in the final MFD.

16.3 ISSUES

The Peer Reviewers' concerns related to the EFDC model algorithms, source code, and general input/output issues include:

- **Experimental/Research and Development (R&D) Application of EFDC.** Several Peer Reviewers commented that the proposed application of EFDC to a complex meandering river and floodplain system was an R&D study. The reviewers recommended that the approach be avoided because of rigid project time constraints.

- **1-D/2-D/3-D Application.** Some Peer Reviewers suggested that simpler, well-developed 1-D models such as those that have been routinely applied for riverine flood flow studies would be more appropriate than EFDC. Other reviewers agreed with the proposal in the MFD to apply EFDC as a 2-D model for the river channel, but disagreed that a 3-D representation in Woods Pond was necessary. A third concern was that accurate representation of flow fields during out-of-bank conditions at the floodplain and channel boundary would require a 3-D model. A related recommendation was to conduct tests to determine the appropriate dimensionality of the model application.

- **Algorithms and Code.** The Peer Reviewers posed a number of questions regarding the mathematical representation of certain processes and how they are incorporated in the model. These include:

  - Bedload transport
  - Sediment dynamics/transport
  - POM deposition/resuspension
  - Diffusion, bioturbation, and groundwater infiltration/percolation.

- **Representation of PCB Fate and Transport.** Most Peer Reviewers commented that it would be preferable to model PCB fate and transport in only one model, not in both EFDC and AQUATOX. One reviewer, however, felt that representing PCBs in both models provided a useful comparison as long as the two models had at least one PCB variable in common. There was a concern that the current representation of toxics in EFDC would provide an overly simplistic approach to PCB fate and transport.

16.4 EPA'S RESPONSE TO COMMENTS REGARDING EFDC

16.4.1 Experimental/Research and Development (R&D) Application of EFDC

EPA does not consider the proposed application of EFDC to the Housatonic River to be of an "experimental" or R&D nature. EPA acknowledges that EFDC (or any other similar public domain code) has not been applied to a highly meandering river system such as the Housatonic River. EFDC, however, has been applied to several freshwater and tidal rivers over the past few years, including the Blackstone River (RI), Christina River (DE), Schuykill River (PA), Yazoo River (MS), and the York River (VA). The EFDC hydrodynamic model has represented the transport processes in these river systems as well as the complexities of secondary flow and the related sediment transport processes of deposition and erosion observed in meandering rivers.

With respect to code enhancements to EFDC, necessary code modifications have been completed and third-party testing of the modifications has been performed. Simulations generated by the enhanced EFDC code have been successfully compared to laboratory-derived test cases including hydrodynamics and sediment transport in a 180-degree bend (Yen and Lee, 1995), and out-of-bank flow (Shiono and Muto, 1998). In addition, simulations produced by the enhanced model code are being compared with observed data from the Test Reach. The modeling team does not anticipate additional code modifications that would prevent meeting the schedule established for the project. The results of these test cases and Test Reach simulations will be provided in the final MFD.

16.4.2 1-D/2-D/3-D Applications

Based on the conceptual understanding of PCB dynamics in the Housatonic River system and the modeling objectives for the project, EPA remains convinced that the 2-D model specification discussed in the October 2000 MFD is the most desirable approach. Some Peer Reviewers suggested the use of much simpler, well-established 1-D models to replace the proposed 2-D application of EFDC. Reviewers also commented that a 2-D model could not represent three-dimensional flow fields accurately enough to be useful in simulating sediment transport and PCB transport and fate in the river and the floodplain, particularly between in-channel and out-of-bank conditions. EPA disagrees with the argument that a 2-D model cannot adequately represent the 3-D flow system of the Housatonic River, and further notes that an even simpler 1-D model is not a preferable alternative. Further discussion on the selection of the 2-D model domain, including a comparison with 1-D model outputs, will be included in the final MFD.

EPA agrees, however, with the Peer Reviewers that a 1-D model has a valid role in the modeling study. As discussed under Additional Supporting Analyses in the October 2000 MFD, 1-D models based on GSTARS and HEC-6 were proposed to provide bounding estimates and insight into overall sediment transport behavior. These analyses, as well as additional work using EFDC1D, have been largely completed.

Based on the results of these analyses and in consideration of the pronounced spatial gradients of PCBs observed from the river channel into the floodplain, EPA has decided that the use of a simpler 1-D model will not adequately represent the large spatial gradient of sediment-bound PCBs in the river channel and the floodplain. A comparison of 1-D, 2-D, and 3-D models and the rationale for the selection of the 2-D model will be presented and discussed further in the final MFD.

The Peer Reviewers expressed concerns specifically about the proposed 3-D representation of Woods Pond. This representation will remain under consideration as the team reviews the data and the pertinent literature and evaluates the preliminary model runs to confirm the desirability of a 3-D domain for Woods Pond. Because of concerns about the computational burden of the simulations with EFDC, the Woods Pond domain of the model will expand to 3-D only if required.

Following the approach used for the PCB model for Green Bay cited by the Peer Reviewers (Wang, et al. 1996) both 2-D and 3-D representations of hydrodynamics and sediment transport will be applied to the Test Reach. The 2-D and 3-D models will provide output that will be used to evaluate the differences, if any, in the simulated flows and fluxes of solids. The results of these tests will be used to guide the choice of either 2-D or 3-D spatial dimensionality for EFDC. The results and findings of the comparative 2-D and 3-D model simulations for the Test Reach will be presented in the final MFD.

16.4.3 Algorithms and Code

Bedload Transport—The Peer Reviewers questioned whether bedload samples would be collected and how bedload would be represented in EFDC. As described in Section 7, Additional Data Collection Activities, EPA has initiated a bedload sampling program to collect data at a variety of streamflows and locations. The bedload data will be used in establishing the upstream boundary condition (Pomeroy Avenue). The bedload will be added to the suspended load to provide the model with a total sediment loading for the Primary Study Area (PSA). Data collected at other locations within the PSA will be compared to model simulations during calibration.

Sediment Dynamics/Transport—The Peer Reviewers questioned how the sediment transport submodel of EFDC will be implemented and how the sediment transport model will be parameterized. EPA recognizes the Peer Reviewers' concern that the van Rijn method does not directly account for sediment mixtures, especially with respect to the sediment resuspension rate. As mentioned in EPA's previous response to questions from the Peer Reviewers (April 2001), the applicability of the van Rijn method is being tested with modifications to treat armoring (e.g., Karim and Holly, 1986). In addition, the Jones and Lick model (2000) is being incorporated into EFDC so that it can be investigated more thoroughly. The Garcia and Parker (1991) method for sediment mixtures is also being tested with EFDC using the relationships being developed from the Sedflume data of critical shear stress as a function of grain size. The final MFD will include a summary and comparison of these tests of alternative formulations and approaches along with the final methodology to be adopted for calibrating the sediment transport model.

Particulate Organic Matter (POM)—The Peer Reviewers observed that deposition and resuspension rates for phytoplankton differ from those for POM associated with fine-grained cohesive solids and questioned whether AQUATOX defined POM as a separate state variable from phytoplankton. Although this question as originally posed is no longer applicable because EPA has agreed to replace AQUATOX with a simpler bioaccumulation model, this question is still relevant to the treatment of phytoplankton and POM in EFDC.

Analysis of water column data from the Housatonic River indicates that phytoplankton is a constant percentage of the POM in the system at all locations and seasons, with the sole exception of Woods Pond in the summer. Therefore, dynamic simulation of phytoplankton is not necessary except possibly seasonally in Woods Pond. This latter issue is being further investigated and will be discussed in the final MFD.

Diffusion, Bioturbation, and Groundwater Infiltration/Percolation—The Peer Reviewers questioned whether diffusion, bioturbation, and groundwater infiltration/percolation are modeled as distinct processes or lumped into a single transport term. These processes are lumped within EFDC into a single mass flux term that will be used as a calibration parameter based on observed sediment pore water and water column PCB concentrations.

16.4.4 Representation of PCB Fate and Transport

EPA agrees with the recommendation of the Peer Reviewers that AQUATOX should not be used for PCB fate and bioaccumulation simulations for the Housatonic River. Therefore, the concerns about separately modeling the abiotic and biotic fate of PCBs, and the linkage of solids between EFDC and AQUATOX as proposed in the MFD, are no longer relevant. EFDC will be the only model used to simulate the transport and fate of PCBs within the modeling framework. Based on the recommendations of the Peer Reviewers, EFDC will provide organic carbon-normalized total PCB concentrations in the water column and sediment bed as exposure time series for input to a simpler PCB bioaccumulation model.

With respect to PCB fate and transport in EFDC, EPA acknowledges that the previous toxic chemical sub-model in EFDC required modification to meet the requirements of the Housatonic River study. Because AQUATOX will be replaced with a simpler model for PCB fate and bioaccumulation (see Section 17, Bioaccumulation Model/AQUATOX), EFDC was modified to allow for three-phase partitioning (DOC/POC/dissolved) for toxic contaminants, if necessary. However, based on an analysis of water column data, DOC concentrations are reasonably constant throughout the PSA, show no consistent spatial or temporal trends, do not vary in response to storm flows, and appear unrelated to other water quality parameters (i.e., TOC, POC, TSS, chlorophyll-a). Therefore, EPA believes that DOC need not be dynamically simulated in EFDC, and DOC will be represented as a constant. The bioaccumulation model, however, will implement three-phase partitioning. The EFDC appendix in the final MFD will be updated to reflect these changes to the kinetic formulations of the toxic chemical fate submodel.

The Peer Reviewers expressed concern that transport and fate of PCBs will be modeled in EFDC as a single state variable. As discussed in Section 14 (PCB Fate), site-specific data suggest that individual PCB congeners are present in a reasonably consistent ratio of congeners to total PCB throughout the model domain. EPA believes that the consistency of this relationship allows the modeling of total PCB in EFDC with the subsequent determination of individual congener concentrations for input into the bioaccumulation model. This approach will be further evaluated based upon additional analysis of the data and the modeling results and will be discussed further in the final MFD.

16.5 REFERENCES

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17. BIOACCUMULATION MODEL/AQUATOX - A

17.1 COMMENT SUMMARY

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17.2 BACKGROUND

EPA initially proposed the use of AQUATOX, an ecosystem-based bioaccumulation model, for use in the Housatonic River modeling effort. A consistent issue for the Peer Reviewers was the complexity of AQUATOX. The reviewers noted that AQUATOX was an inappropriate choice for the Housatonic River project for the following reasons: (a) excessive and unnecessary ecological complexity of processes and interactions; (b) over-parameterized; (c) insufficient site-specific data available for model calibration and validation; and (d) high level of uncertainty of model results. The reviewers recommended that the transport and fate of PCBs in the water column and sediment bed be simulated separately from AQUATOX and that either AQUATOX be used only as a simplified bioaccumulation model or an alternate bioaccumulation model be selected for the project.

In response to the Peer Reviewers' recommendations, EPA has selected a simpler model for use as the primary bioaccumulation model for the Housatonic River model framework. Many of the reviewers' comments were specific to AQUATOX and no longer apply to the new bioaccumulation model. Accordingly, detailed responses for these issues are not provided in this section unless they also have direct relevance to the new bioaccumulation model.

17.3 SUMMARY OF ISSUES

The Peer Reviewers' comments that continue to be relevant include:

- **Overall Model Complexity.** Several of the reviewers expressed concerns regarding the overall complexity of the AQUATOX model, noting that the model was over-specified, with too many parameters and excessive model uncertainty. A specific concern related to highly complex models is that flaws within the model could go undetected if calibration is unconstrained and involves too many parameters. It was also noted that AQUATOX was too detailed to discriminate between bioaccumulation attributable to water and to sediment pathways.

- **Model Process Inclusion/Exclusion.** The reviewers expressed the concern that too many biological fate processes have been screened in at this stage in the conceptual model, and that implementing a model with so many processes will lead to problems for interpretation and calibration. Several reviewers recommended that a stronger indication of the relative importance of each major model process be provided.

- **Uncertainties in Parameterization.** Several comments dealt with model parameterization and associated uncertainties. Although many of the issues raised were of a generic or global nature, referring to the inherent complexity of the AQUATOX model, some comments were more focused and dealt with parameterization/kinetic formulations:

  – The need for the ecosystem modeling capability provided by AQUATOX was questioned, since predictions of time variations in biomass and populations are difficult to cross-check using limited empirical data.

  – The importance of verifying constant congener distributions was noted. This is important because EFDC will model total PCB concentrations, and estimates of composition will be made to provide input to the new bioaccumulation model.

  – Several issues related to uncertainties in the fish bioaccumulation model were noted, including parameterization of fish feeding preferences, and chemical uptake efficiencies in fish.

  – The need for a robust uncertainty analysis was identified, particularly for highly complex model formulations.

- **Calibration and Validation.** A reviewer made reference to the bioaccumulation model calibration process, noting that it will not be possible to define all parameters *a priori*, and that use of "little model calibration" may not be a realistic assumption. Concern was also expressed that calibration and validation of bioaccumulation predictions appear to depend primarily upon predictions of PCB concentrations at the top of the food chain.

- **Detailed AQUATOX Kinetics.** The utility of sorption kinetics in the AQUATOX model was questioned, suggesting that equilibrium partitioning (or simple variant) would be preferable.

- **Modeling Biotic vs. Abiotic PCBs.** The reviewers expressed concerns that modeling PCBs as "abiotic" PCBs in EFDC and "biotic" PCBs in AQUATOX could produce conflicting results and was inappropriate.

Finally, the reviewers raised a number of specific questions regarding AQUATOX model description, elimination rates, and coefficients. With the exception of the more broadly applicable questions noted above, these questions are not addressed in this responsiveness summary since AQUATOX is no longer being applied as the primary bioaccumulation model.

17.4 EPA'S RESPONSE TO COMMENTS REGARDING THE BIOACCUMULATION MODEL

17.4.1 Overall Bioaccumulation Model Complexity

EPA has addressed the Peer Reviewers' concerns regarding the high degree of complexity of AQUATOX by agreeing to replace the AQUATOX model with a simpler bioaccumulation model. A review of candidate bioaccumulation models is being performed, and the model that is selected after testing will be presented and discussed fully in the final MFD. AQUATOX will be retained in a simplified form during model testing as a means of cross-checking the results of the new model. This approach is consistent with the Reviewers' suggestion to consider other models with a higher degree of complexity if and when the simpler models do not work.

The new bioaccumulation model will be a more simplified representation of the ecosystem and of the biological processes of PCB bioaccumulation and biomagnification. Primary consideration will be given to time-dependent, bioenergetics-based bioaccumulation models that have the ability to simulate sediment and water-borne PCB uptake as separate (i.e., decoupled) processes with a proven track record.

17.4.2 Model Process Inclusion/Exclusion

By selecting a simpler bioaccumulation model, EPA has addressed a number of concerns raised by the Peer Reviewers with respect to specific processes. To further address concerns related to identification, screening, and prioritization of biological processes, EPA has revisited the global list of processes identified in the MFD. Concerns related to process screening are being addressed in the following ways:

- By changing to a simpler model, the key biological fate processes that are known to drive PCB bioaccumulation will be more clearly identified. More complex processes, which may or may not be important or relevant to the Housatonic River application, can still be assessed following preliminary calibration of the model.
- Re-evaluating the global list of processes presented in the MFD to provide a stronger indication of the relative importance of each process will help to discriminate between essential and optional model processes. This ranking will be used to identify an appropriate starting point (i.e., base level of complexity) for initial modeling

efforts. A model will be chosen that incorporates only the bioaccumulation processes that are essential to representing the biological fate of PCBs.

In response to the Peer Reviewers' comments, EPA will provide a reassessment of the identified model processes and a summary of the importance of each process will be presented in the final MFD.

17.4.3 Uncertainties in Parameterization

Many of the Peer Reviewers' comments regarding the inherent complexity of the AQUATOX model have been addressed by substituting a simpler bioaccumulation model. These issues are not addressed here, but will form a large part of the discussion regarding the change in bioaccumulation modeling approach in the final MFD. Remaining issues related to model uncertainty and model parameterization are responded to below:

- **Ecosystem Modeling.** The new bioaccumulation modeling approach will be more consistent with an engineering-based approach to bioaccumulation (i.e., modeling at the level of individual organisms, without population dynamics or ecosystem modeling). This change is consistent with the recommendations of the Peer Reviewers.

- **Verifying Congener Distributions.** EPA agrees that this is an important step, and the final MFD will present an analysis of congener distributions in sediment, invertebrates, and fish. The results of this analysis will be used to derive the relationship between total PCBs and individual congeners. This relationship will be applied to the total PCB concentrations simulated by EFDC along with other criteria (e.g., toxicity), to provide congener-specific parameterization to the bioaccumulation model.

- **Predator/Prey Relationships in Fish Bioaccumulation Model.** A combination of life-history data from literature, knowledge of site-specific prey availability (e.g., from biomass study), gut contents data from appropriate indicator watersheds, and professional judgment will be used to establish plausible ranges of dietary preferences. This approach is fairly robust since it uses a weight-of-evidence approach in the establishment of preferences.

- **Partition Coefficients for Biota.** The proposed use of non-equilibrium partition coefficients for invertebrates and fish was questioned. For invertebrates, the new bioaccumulation model will begin with a base model that incorporates steady-state kinetics and progresses to time-dependent dynamics only if warranted. It should be noted that "steady-state" models do not equate with "equilibrium" models. For fish, a time-dependent model will be adopted to represent age-dependent accumulation in fish.

- **Respiration Rates.** The selection of respiration rates to be used in the bioaccumulation model was questioned. Species-specific respiration rates will be used, to the extent possible, in the new bioaccumulation model parameterization.

17.4.4 Calibration and Validation

The reviewers expressed concern that proposed calibration and validation of bioaccumulation predictions appear to depend primarily upon predictions of PCB concentrations at the top of the food chain. The calibration and validation process that was proposed assumes predictions at all trophic levels to be important. To the extent possible, the bioaccumulation model output will be compared against site-specific data such as benthic invertebrate tissue PCB burdens and phytoplankton PCB concentrations. Furthermore, predicted concentrations in not only sentinel fish species such as largemouth bass, but also lower-trophic level fish species, will be assessed. Comparison of forage fish and benthic fish bioaccumulation patterns may assist in determining sediment versus water column contaminant exposure and trophic accumulation pathways.

17.4.5 Modeling Biotic vs. Abiotic PCBs

The fate and transport portion of the AQUATOX model will no longer be applied to the Housatonic River system; the physical fate and transport processes for PCBs will instead be represented within EFDC, thus eliminating overlap and confusion within the modeling framework. This change addresses the comments made by several reviewers that AQUATOX should be used to represent bioaccumulation processes only.

18. MODEL LINKAGES—L

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18.2 BACKGROUND

A single model that incorporates all of the physical, biological, and chemical processes that determine the distribution of PCBs in the Housatonic River is not available. Therefore, individual models were selected for the following components of the model framework:

- Watershed contributions
- Hydrodynamics
- Sediment transport
- PCB transport and fate
- PCB bioaccumulation.

HSPF was chosen as the watershed model to provide upstream boundary and tributary streamflow and external loads of solids. EFDC was chosen to represent hydrodynamics, sediment transport, and PCB transport and fate processes. EPA originally proposed the use of AQUATOX to simulate the bioaccumulation of PCBs in fish and other key species as well as solids, organic matter, carbon, oxygen, and nutrient cycles in a food web-based aquatic ecosystem. Based on the comments provided by the Peer Reviewers, a simpler food chain model will be selected as an alternative model to AQUATOX to simulate PCB bioaccumulation. EFDC will be used to simulate the transport and fate of PCBs to provide time series of PCBs for exposure calculations in the water column and sediment bed in the food chain bioaccumulation model.

This section presents EPA's response to comments related to model linkages. A more detailed review of the candidate models considered for the Housatonic River model framework will be presented in the final MFD.

18.3 SUMMARY OF ISSUES

The linkage of data between the components of the model framework was identified from the beginning of the study as critical to ensuring mass balance.

The Peer Reviewers identified three key issues related to the model linkage of HSPF, EFDC, and AQUATOX:

- **Complexity of EFDC/AQUATOX linkage**. The reviewers commented that the linkage between EFDC and AQUATOX was unnecessarily complex. The reviewers recommended that EFDC alone be used for the simulation of the transport and fate of PCBs without differentiating abiotic and biotic forms of PCBs. The distributions of dissolved and sorbed PCBs simulated by EFDC in the water column and sediment bed would then be linked as exposure time series for use in the simpler food chain bioaccumulation model.

- **Empirical transformations and mass balance between models**. The reviewers commented that HSPF, EFDC, and AQUATOX are inconsistent in the state variables used to represent inorganic solids, and dissolved and particulate organic matter. The inconsistency between the models thus requires parameterization of empirical relationships to transform state variables between HSPF, EFDC, and AQUATOX. The empirical relationships are based on the availability of field data and as such are characterized by the inherent uncertainty of the spatial and temporal transformations. The uncertainty in the empirical relationships will thus contribute substantially to the uncertainty of the overall model framework. The reviewers questioned whether the study database is sufficiently robust to support the specification of the empirical transformations. The reviewers also questioned whether the linkages outlined in the MFD will maintain a mass balance of inorganic solids and dissolved and particulate organic matter in the transformation of state variables between HSPF, EFDC, and AQUATOX.

- **Solids linkage between EFDC and AQUATOX**. The reviewers commented that the procedure proposed for the linkage of deposition and resuspension of solids simulated in EFDC to AQUATOX needs to be clarified. In addition to the advective flux, the representation of mass transport of solids also requires specification of the dispersive flux of materials. Since dispersive processes simulated at the fine grid scale of EFDC will be aggregated to the larger grid scale of AQUATOX, one reviewer noted that artificial, or numerical, dispersion resulting from aggregation to the larger reaches needs to be considered in designing the linkage between EFDC and AQUATOX.

18.4 EPA'S RESPONSE TO COMMENTS RELATED TO MODEL LINKAGES

18.4.1 Complexity of EFDC/AQUATOX Linkage

In response to comments from the Peer Reviewers, EPA has abandoned the use of separate models for simulation of abiotic PCBs (EFDC) and biotic PCBs (AQUATOX as proposed in the MFD). EFDC will be used for simulation of hydrodynamics, sediment transport, and transport and fate of PCBs for input to the bioaccumulation model.

In the revised approach, external loading of three size classes of suspended solids (<63 microns, 63-250 microns, and >250 microns) can be provided to EFDC as watershed runoff of streamflow and solids class concentrations by HSPF, or as a functional relationship derived from the site-specific data. The measurement of total suspended solids (TSS) in the Primary Study Area (PSA) includes a mix of inorganic and organic materials derived from external loading and internal biological production of living and non-living detrital organic matter. Because the partitioning of PCBs is assumed to be dependent on the organic carbon content of particles, it is important to be able to determine the organic carbon fraction of the different classes of solids represented in the sediment transport and PCB fate models. PCBs also associate with dissolved (and colloidal) organic carbon (DOC). The fate of PCBs thus includes three phases: (1) dissolved, (2) particulate, and (3) DOC-complexed. The conceptual model to be presented in the final MFD will use a simple analysis to evaluate the relative contributions and the significance of internally produced organic matter (POM and POC). Seasonal differences will be addressed in the simple analysis. The findings of the conceptual model will be used to define the level of detail required for the sediment transport and PCB fate model that will be incorporated in EFDC.

18.4.2 PCB Bioaccumulation

EPA will use a simpler bioaccumulation model than AQUATOX for the Housatonic River study. EFDC will be used to provide spatially aggregated time series of carbon-normalized PCB concentrations for the food chain exposure calculations in the water column and sediment bed.

The coarse spatial scale of the computational segments of the simpler bioaccumulation model will be identical to the boundaries of the reaches originally proposed for AQUATOX. The total PCBs simulated in EFDC will be split into homologs or congeners for the bioaccumulation model based on observed distributions of homologs and congeners in site-specific data, with consideration of factors such as media and location, as appropriate.

18.4.3 Empirical Transformations and Mass Balance

To address the concerns regarding mass balance identified by the Peer Reviewers, EPA will abandon the model linkage detailed for solids from EFDC to AQUATOX. HSPF will be used to provide flow, water temperature, and potentially solids to EFDC, as described in the MFD. Rather than simulate the runoff of total PCBs, rating curves will be developed to specify the loads of total PCBs contributed by the upstream boundary.

18.4.4 Solids Linkage

Because EPA is no longer proposing the use of AQUATOX and because simpler bioaccumulation models do not require explicit input of solids, the linkage of solids from EFDC to the bioaccumulation model is no longer an issue.

19. GRID SCHEME/SPATIAL SCALE—GS

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19.2 BACKGROUND

Contaminant transport and fate models require the implementation of a grid scheme that is appropriate for the processes and data supporting those processes to be modeled, yet does not impose a computational burden. Conversely, excessively coarse spatial resolution in the model grid can result in a significant loss of information due to the averaging of both state and process variables. Many factors, such as channel depth and floodplain topography, and the PCB concentrations, sediment properties, and other characteristics, must be considered in choosing the spatial resolution of the computational grid of the hydrodynamic, sediment transport, and PCB fate and bioaccumulation models of the Housatonic River.

19.3 SUMMARY OF ISSUES

The Peer Reviewers raised issues regarding the model grid schemes and spatial scales. The main issues were as follows:

- **Data availability to support a grid scheme for EFDC.** Concerns were raised that there were insufficient field measurements to support a finely discretized system.
- **Floodplain/channel interactions.** The representation of the interaction between the channel and floodplain, especially the coupling of the channel and proximal floodplain with the distal floodplain, was a concern. The modeling team had proposed an EFDC grid scheme that was computationally feasible and conserved momentum within the channel and between the channel and the proximal floodplain cells, although it did not conserve momentum between the proximal and distal floodplain.
- **Grid scheme complexity.** The complexity of the proposed grid scheme, the resulting computational burden, and its impact on the analysis of uncertainty were questioned.

19.4 EPA'S RESPONSE TO COMMENTS REGARDING GRID SCHEME /SPATIAL SCALE

19.4.1 Data Availability To Support Grid Scheme

EPA believes that sufficient and appropriate data are available to discretize the physical domain for the floodplains, Woods Pond, and the main channel, both longitudinally and laterally. Within Reach 5 alone, there are more than 6,200 PCB sample results and more than 3,500 samples for which grain size distribution, TOC, and other parameters that are less spatially variable throughout the Primary Study Area (PSA) are available. In the absence of data, the common practice when developing a model is the assignment of the initial conditions and other model properties using interpolation of the observed data to assign a value for each grid cell. For the Housatonic Modeling Study, a large amount of data is available to support the implementation of virtually any grid scheme that would be computationally feasible. It is EPA's opinion, therefore, that sufficient information to calibrate, validate and, ultimately, apply the linked HSPF/EFDC/ bioaccumulation model to the issue of contaminant and sediment transport in the Housatonic River PSA has been collected.

With respect to comments on data developed from the Sedflume erosion and deposition processes, EFDC uses a single set of properties for a given grain size. The Sedflume data will be used to develop the erosion properties as a function of grain size. Deposition properties will be initialized using literature values.

Testing has been performed to compare several alternative scales of in-channel grid schemes using EFDC. The selection of the final EFDC grid will represent a balance between the spatial scales for the controlling processes in the Housatonic River and computational burden. The results of the test cases and this analysis will be presented in the final MFD.

19.4.2 Floodplain/Channel Interactions

To develop a practical grid, EPA continues to investigate alternative grid schemes. It is critical to conserve mass everywhere and to conserve momentum in the higher velocity areas (i.e., the channel and proximal floodplain cells that comprise the floodway). EPA believes that conservation of momentum is less critical in the backwater areas and distal floodplains where velocities, and thus momentum, are small, and have minimal impact on PCB transport.

For out-of-bank events, testing of the grid schemes will use flow systems presented in several journal articles (Shiono and Muto, 1998; Ervine et al., 2000; Patra and Kar, 2000) as the first step in the testing. The second phase of the testing will include applying the grid schemes to the Test Reach. During the testing, a range of flows will be used to determine the effect of various grid schemes on coupling the flow regimes between the channel and the proximal floodplain and the channel/proximal floodplain with the distal floodplain and on sediment transport.

Shiono and Muto have used the ratio (Dr) of floodplain depth to main channel depth as a primary descriptor of the overbank flow regime:

$$Dr = \frac{(H - h)}{H}$$

Where:

H = the main channel depth
h = the bankfull depth

Using this ratio will help in describing and comparing modeling results. For flows where Dr <0.2, the main channel geometry has a pronounced effect on the floodway velocity patterns, but once Dr >0.25, the channel has minimal impact on floodway velocity patterns. The grid testing will include a range of values of Dr to evaluate the channel/floodplain interactions. Grid-wide conservation of momentum is being explored in the testing of alternative grid schemes. The results of this testing will be presented in the final MFD.

19.4.3 Complexity of Grid Scheme

EPA agrees that it is desirable to develop a grid scheme that is as simple and yet as representative as possible. Qualitative testing of the hydrodynamic and sediment transport under different grid schemes will be accomplished during the test reach modeling. Selection of the final grid scheme and resolution will be the product of balancing the following factors:

- Channel Erosion/Deposition Patterns
- Flow Velocities
- Floodplain/Channel Interactions
- Data Density
- Computational Burden
- Post Processing/Result Presentation

19.4.4 Importance of Distal Floodplain and Impacts on Grid Schemes

A goal of the modeling effort is to reasonably predict the future PCB concentrations in the river channel and floodplain so that human and ecological exposures can be evaluated under the various remedial alternatives, including natural attenuation. The term "distal floodplain" refers to the area that is inundated during high-flow events but is generally outside of the floodway (i.e., high-velocity areas). Proper treatment of the distal floodplain is significant in the modeling effort to provide flood storage and sediment and PCB deposition.

The horizontal and vertical discretization of the distal floodplain domain is required to address these issues within the computational model framework. For example, the application of a 1-D model, that cross-sectionally averages PCBs in the sediments, could not address these issues.

Dual or nested grid schemes where the channel and the floodplain, especially the distal floodplain, have different cell dimensions were tested. A simple 5-meter Cartesian grid of the area within the 10-year floodplain results in a model that has 235,778 active horizontal cells, which is clearly computationally untenable. In contrast, a nested grid scheme with small cells in the channel and larger cells in the floodplain will produce a much smaller number of cells. However, momentum will not be conserved between the distal and proximal floodplains in a nested grid scheme. EPA is investigating the impact of the loss of momentum in a nested grid approach when applied to the Housatonic River.

The final grid scheme will be included and discussed in the final MFD.

19.5 REFERENCES

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Patra, K.C. and S.K. Kar. 2000. "Flow Interaction of Meandering River with Floodplains." *J. Hydraulic Engineering*, 126(8):593-604.

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20. TIME SCALE/TIME STEP INTERACTIONS—TS

20.1 COMMENT SUMMARY

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20.2 BACKGROUND

The Housatonic River modeling study seeks to account for the wide range of temporal and spatial scales over which the different physical transport and biogeochemical processes of importance operate.

Objectives of the modeling approach that are relevant to the choice of the temporal and spatial scales of the model framework include the following:

- How long will it take for PCB-contaminated sediments to be sequestered by the deposition of clean sediments?
- How long will it take for PCB levels in target fish tissue to be reduced to levels that no longer pose a risk to either human health or the environment?
- What is the potential effect of extreme storm events contributing to the redistribution of sequestered PCB-laden sediments back into the water column, the surficial bed sediments, and the biota?

This section presents EPA's responses to comments regarding time scale/time step interactions. The final MFD will identify the spatial scales and temporal scales of the various processes that are included in the model framework.

20.3 SUMMARY OF ISSUES

The concerns raised by the Peer Reviewers regarding time scale and time step interactions are as follows:

- The issue of rainfall disaggregation as input to HSPF is critical. Will procedures for combining local data collected at daily intervals with more distant hourly data be validated by measurements of short-term river flow and TSS data?
- Adequacy of Daily Aggregation. AQUATOX will be run with a daily time step, but loads will be aggregated. Because storms are important for transport, it is not clear whether daily aggregation will be adequate.
- There is a need to determine the spatial and temporal scales being addressed by the modeling effort, as these scales can be quite different, depending on the processes being modeled. Some events will occur over short-time frames, but impact large spatial areas, such as over-bank flooding and subsequent deposition in the floodplains versus bank erosion and failures that can occur over short time frames and small spatial areas.

20.4 EPA'S RESPONSE TO COMMENTS REGARDING TIME SCALE/TIME STEP INTERACTIONS

20.4.1 Integration and Validation of Data Collected over Different Time Intervals

An analysis of the relative magnitude of solids and PCB loads contributed during various flow regimes will be performed based on the results of monitoring programs conducted from 1999 to 2000. These data will be used to develop a flux analysis throughout the Primary Study Area (PSA), as well as for comparison of daily and hourly data collected for input to HSPF.

20.4.2 Adequacy of Daily Aggregation

One reviewer noted concern that since storms are important for transport, it is not clear whether daily aggregation will be adequate in relation to AQUATOX. Because AQUATOX is being replaced by a simpler bioaccumulation model, daily aggregation is no longer an issue. The model now being proposed is not sensitive to small-scale or transient events that occur on the order of hours to days. The scale of events that the model is sensitive to is on the order of weeks to months.

20.4.3 Determination of Spatial and Temporal Scales

Spatial and temporal scales that are appropriate for each process included in the modeling approach will be developed for use in the each of component models (HSPF, EFDC, and Bioaccumulation). The approaches for developing the scales that will be used in each component model are described below:

Hydrological Simulation Program-Fortran (HSPF) Model—To represent the increased solids and PCB fluxes that are observed under a high-flow regime, the watershed, hydrodynamic, and sediment transport models will be run using a high-frequency time scale of 1 hour or less. HSPF will generate time series of stream flow and solids concentration at 1-hour intervals to specify loads from the upstream boundary and tributaries as inputs for the hydrodynamic and sediment transport model. These calculations will be based on precipitation data and other meteorological records that are either available at 1-hour intervals or interpolated from daily intervals to 1-hour resolution as input data. Boundary conditions for PCBs will be generated at the same 1-hour interval using rating curves for PCB versus stream flows (generated by HSPF) developed for the upstream boundary and for each tributary to the Housatonic River. The 1-hour interval for the resolution of the output of HSPF stream flow and pollutant loads of solids, organic matter, and nutrients is a typical time interval used for watershed model simulations.

Environmental Fluid Dynamics Code (EFDC) Model—Time series of stream flow and solids, generated by HSPF, will be input to EFDC as external boundary conditions using a minimum of a 1-hour resolution interval. Rapid changes in flow, solids, and PCB loads resulting from transient storm events will thus be represented as input to EFDC. A time step on the order of seconds will be needed for numerical integration of the hydrodynamic and sediment transport model to accommodate the grid scale resolution and the numerical requirements for stability of the computational schemes used in EFDC.

EFDC is being modified to use an adaptive time step scheme to improve the computational efficiency of the code. During periods of little or no change in stream flow, longer time steps will be allowed rather than the shorter time step that is needed to numerically integrate rapidly changing flow conditions of a storm event. Regardless of the time step used for the hydrodynamic simulation in EFDC, boundary inflow time series generated by HSPF for input to

EFDC are linearly interpolated in EFDC to compute the upstream boundary loads as a continuous function of time during the simulation.

The time series results of EFDC will be written out at a user-defined time interval for post-processing of the results for input to the bioaccumulation model. Since HSPF will provide input time series of flow and solids loads to EFDC with a time interval of 1-hour resolution, the use of the same 1-hour interval appears to be appropriate for recording the output results from EFDC to retain the temporal representation of the rapidly changing conditions of storms and flood events. The time series results generated by EFDC with 1-hour resolution will be time averaged to provide a lower frequency time series for input to the bioaccumulation model. Longer time averaging periods will be used to differentiate relatively stable flow conditions from transient flow conditions to increase computational efficiency.

Bioaccumulation Model—Time series of stream flow, solids, and PCBs generated by EFDC over the fine grid scale of the hydrodynamic model will be aggregated spatially and numerically integrated (averaged) in time for linkage to the PCB bioaccumulation model. The simulation results obtained for multiple EFDC grid cells will be mapped onto a much coarser spatial scale to link the output results of EFDC as spatially aggregated input data for the larger computational segments of the bioaccumulation model. To accurately link the transient peaks in flow, solids, and PCB fluxes simulated by EFDC during storm events with the bioaccumulation model, numerical integration of the time series generated by EFDC will follow an adaptive time interval scheme for averaging the simulation results.

During base-flow periods in stream flow, high-frequency, 1-hour time series generated by EFDC will be averaged as a lower-frequency data set by numerical integration over 24-hour periods. During storm events with rapidly changing flow conditions, however, the high frequency 1-hour time series generated by EFDC will be averaged over a shorter 4- to 8-hour period to properly capture the transient pattern of the onset and decline of a peak flow event over a time scale of a few days that would otherwise not be accurately represented with a 24-hour, time-averaged output from EFDC. The bioaccumulation model will be modified, if necessary, so that an adaptive, or variable, time step can be imposed over the entire simulation period to differentiate periods of rapidly changing flow conditions from periods characterized by stable flow.

Consistent with the principles derived from time series sampling theory where observations are recorded at twice the maximum frequency to be resolved (i.e., Nyquist frequency) to avoid biasing of the information (Walsh, 1988), the bioaccumulation model time step should be set at least equal to one-half of the resolution of the input time series. For slowly changing conditions where the results of EFDC are integrated over 24-hour intervals, the time step (Dt) for the bioaccumulation model will be assigned as follows:

$$Dt\ (\text{Stable Flow}) = ½ *[24\ \text{hrs}] = [12]/24\ \text{hrs} = 0.5\ \text{days}$$

For storm event conditions when EFDC results are integrated over a finer resolution of approximately 4- to 8-hour periods, the time step for the bioaccumulation model will be assigned within the range shown below:

$$Dt\ (\text{Transient Flow}) = ½ * [4\ \text{to}\ 8\ \text{hrs}] = [2\ \text{to}\ 4]/24\ \text{hrs} = 0.083\ \text{to}\ 0.167\ \text{days}$$

20.5 REFERENCES

Walsh, John J. 1988. *On the Nature of Continental Shelves*. Academic Press, San Diego, CA, pp. 156-158.

21. CALIBRATION – C

21.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Adams	2	32-35
	8	21-25
Lick	2	26-32
Endicott	3	21-34

21.2 BACKGROUND

One of the most important components of a modeling study is the calibration of the model(s) to accurately reproduce site-specific conditions. Selection of a time period for calibration is determined by the availability of data obtained over a range of hydrologic conditions in the system.

To minimize the degrees of freedom used to calibrate the model, it is desirable to parameterize the model using as many site-specific data and field measurements as possible. The remaining values established for calibration parameters are, of necessity, based on data reported in the literature. During calibration, model parameters and kinetic coefficients are systematically adjusted within ranges observed from site-specific data and/or reported in the literature, until an acceptable degree of comparison is achieved between observed data and the simulation results.

21.3 SUMMARY OF ISSUES

The Peer Reviewers identified the following concerns:

- The process of model-data comparison is, by necessity, iterative and does not necessarily proceed in a sequential or linear manner. It may, therefore, be difficult for the peer review process to strictly conform to the prescribed sequence of evaluating the modeling framework document, the calibration report, and, finally, the validation report.

- A portion of the years assigned for the validation period should be devoted to calibration instead, to allow calibration tests of natural recovery processes.

- For decisionmakers to have confidence in the model for use in making remedial decisions, the determination of model parameters by calibration should be kept to a minimum.
- Contingency plans need to be incorporated into the study plan to identify alternate approaches that could be used to achieve calibration of the model.

21.4 EPA'S RESPONSE TO COMMENTS REGARDING CALIBRATION

21.4.1 Iterative Process of Model Data Comparison

EPA agrees that the iterative process of model development may, at times, be inconsistent with the linear process of the Peer Review as delineated in the Consent Decree.

The Housatonic River modeling study includes the following broad components: project database, conceptual model, model framework, site-specific/literature-derived model parameters, and adjustable (calibration)/fixed model parameters. In conducting the modeling study, feedback between these components is necessary. For example, preliminary calibration runs may result in revisiting the data and revising the conceptual model and model framework. Each significant iteration performed in building the components of the model framework may require some changes and accompanying explanation/documentation. There is sufficient flexibility in the existing Peer Review process to incorporate any such changes. For example, EPA has chosen to revise and reissue the MFD in response to comments received during the Peer Review.

21.4.2 Years Identified for Model Calibration and Natural Recovery

The Peer Reviewers identified the need for a decadal-scale, long-term simulation period to properly address the credibility of the model in representing natural recovery processes. From the 1930s through the late 1970s when PCBs were discharged into the river, the water column, sediment bed, floodplain, and biota became contaminated with PCBs. Since sampling began in the late 1970s, concentrations of PCBs in sediments, soils, and biota in the Housatonic River do not appear to have decreased. Therefore, EPA believes there is no available data set for the Primary Study Area (PSA) for any time period to test the ability of the model to simulate natural recovery, as suggested by the Peer Reviewers.

The 1999 to 2000 calibration period was selected because this period coincides with the most recent, detailed data set collected by EPA, including the data obtained under storm event conditions. In selecting this 1-year period, which was characterized by a fairly wide range of flow conditions, the strategy is to first perform preliminary calibrations of the hydrodynamic, sediment transport, and PCB fate models under the higher flow (out-of-bank) storm event conditions. Next, the model calibration process will focus on the base flow conditions. Finally, because data were not collected for an event greater than 1.5 years during the calibration period, EPA will compare the model simulations to observations for two large storm events that occurred outside the calibration period (see Section 11, Rare Flood Events).

EPA believes that the advantages of using the high quality/intensity data set for model calibration outweigh the fact that the period is too short to see evidence of natural recovery, which has not been observed over the entire period of record in the PSA, and that a properly calibrated model will reliably represent conditions on a decadal scale. The 20-year period identified for model validation (1979-2000) is sufficient to demonstrate the ability of the model to simulate processes occurring on decadal time scales (see Section 22, Validation).

21.4.3 Selection of Adjustable Parameters for Model Calibration

In the MFD and in the supplemental documents provided to the Peer Reviewers for the April 2001 meeting, EPA provided a complete list of the data that are available for use during the modeling study. Additional pore water, surface water, and bedload data are being collected. EPA agrees that the adjustment of model parameters during calibration should be minimized. Site-specific field measurements (i.e., grain size distributions), experimental data (i.e., Sedflume), and literature values can be used to establish reasonable bounds within which model calibration can justifiably be achieved. A listing of the key parameters that will be adjusted during calibration for each component of the model framework (watershed runoff, hydrodynamic, sediment transport, PCB fate, and PCB bioaccumulation models) will be presented in the final MFD.

21.4.4 Contingency Plans

Based on the history of the use of HSPF in similar applications for riverine systems, no difficulties of application to the Housatonic River are expected. Further, based on EPA's familiarity with the EFDC code and work performed by the modeling team to date, the necessary code modifications are attainable and are not of a level of complexity that constitutes research. Recognizing the Peer Reviewers' concerns regarding AQUATOX, however, EPA has chosen to replace AQUATOX with a simpler and more established bioaccumulation model.

EPA believes that sufficient time has been incorporated into the schedule to complete appropriate code modifications, third-party testing of modifications, calibration, and validation. If necessary, the schedule will be modified to allow time to meet the calibration and validation objectives.

It is important to recognize that the purpose of the model is to evaluate the relative effectiveness of remedial alternatives. EPA believes that following calibration and validation, the model will serve as a useful tool for the purposes of discriminating between the outcomes of remedial alternatives, even if model predictions are not correct in an absolute sense; therefore, a separate contingency plan is not necessary.

22. VALIDATION—V

22.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Endicott	3	21-34
	15	32-44
	16	1-14
	19	22-26

22.2 BACKGROUND

Confirmation of the ability of the model framework to represent the interactions of hydrodynamic and sediment transport processes on PCB transport, fate, and bioaccumulation in the Housatonic River must be demonstrated prior to using the model to evaluate remedial scenarios. Validation of the model framework is achieved by testing the ability of the model to reproduce observed distributions of solids and PCBs for a different, and typically longer, timeframe than that used for model calibration.

As noted in the MFD, model validation is in reality an extension of the calibration process. The proposed approach consists of using a part of the available record for calibration and then using the entire record for validation. The validation process consists of various comparisons between recorded and simulated values. As noted in the previous section (Section 21, Calibration), the process of validation is iterative and may require additional calibration of the model.

22.3 SUMMARY OF ISSUES

The Peer Reviewers identified two issues related to model validation:

- The MFD did not include adequate descriptions of how the long-term hindcast and long-term forecast simulations would be constructed for model validation.
- Contingency plans need to be incorporated in the modeling strategy.

22.4 EPA'S RESPONSE TO COMMENTS REGARDING VALIDATION

22.4.1 Long-Term Validation and Forecasts

The concern expressed by a Peer Reviewer was that the strategy for hindcast and forecast simulations was not adequately described in the MFD. EPA's strategy for model validation (hindcast) is to perform the initial validation of the model against independent data sets collected from 1979 to 1990. Assuming satisfactory validation of the model to the 1979 to 1990 data set, the robustness of the model will be demonstrated by extending the validation period through 1990 to 2000, which will encompass the entire period of record. It is expected that the continuous 20-year simulation will provide a sufficient period of time to demonstrate the ability of the model to reproduce site conditions based upon validation efforts conducted as part of previous modeling studies on the Fox and Hudson rivers. Model performance, as indicated by the results from these simulations, will also be compared to the model calibration output as a further indication of the predictive capability for model forecasts.

Initial conditions for PCBs, TSS, TOC, and grain size will be based on the available historical measurements ca. 1979-1980 in water, sediment, floodplain soil, and biota as applicable. These data are available at both the upstream and downstream boundaries of the model domain. These data will be evaluated with respect to the current understanding of the Housatonic River; the more limited data from this period may need to be bounded or further interpreted for use in establishing initial conditions. EPA recognizes that the availability of historical data has limited the success of model validation in other river modeling efforts (Gailani et al., 1996), and, after examination of the data set available for the Housatonic River, believes that adequate, but not extensive, data are available to perform the validation.

The definition of the boundary conditions of the PSA, which integrate the upstream loads into a single boundary concentration, is expected to simplify the process of achieving both successful model calibration and validation. Establishment of model boundaries with regard to the conceptual model for the site has been demonstrated to benefit model validation in previous studies (Velleux et al., 1995). Upstream boundary conditions of streamflow and solids loads will be provided to EFDC by HSPF after both models are calibrated, based on runoff simulations driven by land uses, drainage basin topography, and historical records of precipitation and other meteorological properties.

Flow records are available at two USGS gauging stations, which form the boundary conditions for the hydrology model for an extended period of record. This extended period of record will be of use in developing constructed hydrographs for long-term future simulations, an approach that has been demonstrated to provide reasonable and satisfactory results (Velleux et al., 1995).

Additional examination of PCB data since the Peer Review has confirmed that PCB data from this historical period of record are comparable to recently collected data, and that no systematic biases exist. Therefore no adjustments such as those performed in the Hudson River Modeling Study are necessary.

Initial conditions for defining the bathymetry of the river and Woods Pond are problematic since depth surveys were not conducted during the early years of PCB investigations in the Housatonic River. Best estimates of the bottom depths of Woods Pond ca. 1979-1980 will be determined using the contemporary bathymetric survey performed by EPA during 1999 adjusted by estimates of sediment deposition rates determined using Cs-137 profiles obtained from dated sediment cores. The PCB and grain size data in the sediment cores obtained from Woods Pond will also be used to interpret the success of the validation simulations as an integration of the simulation over the entire model domain.

Because the model simulations will need to predict future conditions to achieve the modeling study objectives, upstream boundary conditions must also be determined for future time periods. A number of approaches exist for establishing these boundary conditions. One approach could be based on simply extrapolating the actual sequence of historical hydrologic records to provide a long-term data set for a forecast simulation. An alternate approach could be based on using a random sequence of normal, dry, and wet years to represent the statistics of the observed hydrologic record that would include the occurrences of extreme drought and flood conditions. The external upstream boundary loading of PCBs will depend on assumptions related to a specific remedial alternative.

It is expected that the model parameters determined during model calibration, and confirmed during model validation, will remain unchanged for the remedial scenarios.

Details of the assumptions and methodologies to be used in compiling the input data sets for model validation simulation for the 1979 to 2000 period will be presented in the final MFD.

22.4.2 Contingency Plans

As noted by the Peer Reviewers, there is always the possibility that the long-term simulation for model validation may fail to match the observed database. This process would require revisiting the model framework, parameters, data, and the conceptual model to understand why the simulation did not produce reasonable results. EPA is not proposing additional contingency plans at this point in the modeling study.

22.5 REFERENCES

Gailani, J.Z., W. Lick, K. Ziegler, and D. Endicott. 1996. "Development and Calibration of a Fine-Grained Sediment Transport Model for the Buffalo River." *J. Great Lakes Res.,* 22(3):765-778.

Velleux, M., D. Endicott, J. Steuer, S. Jaegar, and D. Patterson. 1995. "Long-Term Simulation of PCB Export From the Fox River to Green Bay." *J. Great Lakes Res.,* 21(3):359-372.

23. MODEL SENSITIVITY (S)

23.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Adams	2	37-43
	3	1-3
	3	5-8
Endicott	5	32-45
	6	1-2
Garcia	5	42-45
	6	1-11
Lick	8	34-35

23.2 BACKGROUND

A sensitivity analysis provides information on the effect of systematic changes to a single adjustable model parameter on the outcome of the state variable responses of the model (Reckhow and Chapra, 1983). A sensitivity analysis will be performed during the calibration of each model to determine the key parameters that have the greatest influence on model predictions and which will be evaluated in the uncertainty analysis.

23.3 SUMMARY OF ISSUES

The Peer Reviewers' comments on Model Sensitivity are as follows:

- The Peer Reviewers noted the importance of systematic evaluations of parameters of sensitivity for each model.
- It was recommended that sensitivity analyses be performed to identify the model parameters that could affect model predictions.
- Concern was expressed that the computational burden of EFDC was such that it would not be feasible to perform analyses of the sensitivity of the hydrodynamic, sediment transport, and PCB fate models.

- The reviewers recommended the selection of a simpler model framework with a reduced computational burden so that a thorough analysis of sensitivity would be feasible.

23.4 EPA'S RESPONSE TO COMMENTS RELATED TO MODEL SENSITIVITY

EPA agrees with the Peer Reviewers that performing a sensitivity analysis is an important component of the modeling exercise. In a sensitivity analysis, several key model parameters are identified, an accepted range of parameter values is compiled, and the value of each parameter is systematically changed to determine the response of the model to changes in each parameter. This technique is referred to as "parameter perturbation." The effect of systematically changing each single adjustable parameter on the state variables and endpoints of the model results is then evaluated against a reference, or base run, to identify which adjustable parameters cause the greatest change in the model results. The outcome of the sensitivity analysis can provide guidance in determining which parameters have the greatest effect on the model predictions and hence require the most careful consideration for model calibration.

In the final MFD, the key calibration parameters for each model will be identified on the basis of the literature and experience of the modeling team. A preliminary list of the key calibration parameters for each model was presented in the Modeling QAPP (Beach et al., 2000).

The approach to evaluating sensitivity will be implemented during the model calibration process and documented in the calibration report. It is EPA's opinion that the computational complexity of the selected models should not prevent the implementation of a sensitivity analysis.

23.5 REFERENCES

Beach, R.B., J.S. Clough, P.M. Craig, A.S. Donigian, R.A. McGrath, R.A. Park, A. Stoddard, S.C. Svirsky, and C.M. Wallen. 2000. *Quality Assurance Project Plan: Modeling Study of PCB Contamination in the Housatonic River.* Prepared for U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. Prepared by Roy F. Weston, Inc., West Chester, PA. DCN GE-100500-AADY.

Reckhow, K.H. and S.C. Chapra. 1983. *Engineering Approaches for Lake Management, Volume 1: Data Analysis and Empirical Modeling.* Butterworth Publishers, an Ann Arbor Science Book, Woburn, MA.

24. UNCERTAINTY ANALYSIS—U

24.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Endicott	5	32-45
	6	1-2
	13	31-41
Garcia	5	42-45
	6	1-11
Shanahan	3	27-34
	4	6-12
	7	38-41
	8	1-3
	8	7-37
	9	12-18
	9	19-28
	12	34-41
	13	1
	13	2-8
	15	23-34
	17	24-32

24.2 BACKGROUND

The modeling efforts described in the MFD will be used to evaluate the extent to which remedial alternatives affect (1) PCB concentrations as a function of time and depth in the river bed sediments, riverbank, and floodplain; and (2) PCB concentrations as a function of time in target biota. The model predictions, as with any environmental model, will be characterized by an inherent degree of uncertainty. For the purposes of this uncertainty analysis, the term "uncertainty" will be defined as including those sources of uncertainty that are known and can be measured, those that are known and cannot be measured, and those that remain unknown. For the first categories of sources, an analysis will be conducted to evaluate the magnitude and bias with respect to model predictions.

This section presents EPA's response to comments regarding Uncertainty Analyses. The uncertainty analysis will address those parameters of most concern identified in the Sensitivity Analysis, as discussed in Section 23 (Model Sensitivity).

24.3 SUMMARY OF ISSUES

The Peer Reviewers raised the following issues with respect to the uncertainty analysis of the proposed models:

- **Computational burden of EFDC.** A concern was expressed about the computational demands associated with the EFDC model, and the possible impact on an uncertainty analysis. The use of a simpler (one-dimensional) hydrodynamic model to allow completion of a rigorous uncertainty analysis was proposed.

- **Additional data requirements**. It was suggested that more data be collected and the conceptual model of the distal floodplain be refined before EFDC is selected for use. Sampling of the next 10-year storm event was recommended to refine the Conceptual Model.

- **Methods used for uncertainty analysis**. A concern was expressed regarding the use of a model calibrated with data collected over a short-term for predicting long-term PCB fate and transport. It was suggested that generating synthetic time series for a range of model input parameters and boundary conditions should be done, with the goal of generating model outputs of statistical significance. It was noted that there is considerable uncertainty in the use of EFDC to forecast high-flow events and system response decades into the future. The reviewers proposed that model uncertainty be addressed by a combination of Monte Carlo analysis, Bayesian Monte Carlo analysis, and alternative bounding calibrations.

- **Identification of factors that affect uncertainty**. Processes that affect predictions of PCB concentrations in sediment, water and fish, that have the most significant (known) uncertainties associated with them were identified by the reviewers.

- **AQUATOX complexity**. The Peer Reviewers noted that the AQUATOX code was too complex for this application and as a result the uncertainties could not be estimated.

24.4 EPA'S RESPONSE TO COMMENTS REGARDING UNCERTAINTY

24.4.1 Computational Burden of EFDC

EPA agrees that an understanding of the uncertainty of model predictions is essential. However, as noted in the MFD and in EPA's April 12, 2001 written response to the Peer Reviewers' comments on the MFD prior to the Peer Review Meeting on April 25 – 26, 2001, a formal uncertainty analysis using the detailed, 2-dimensional model for the entire modeling domain is not possible because of the computational requirements of the EFDC code. This would be the case with the application of any hydrodynamic model that represents processes mechanistically over an entire modeling domain in a simulation spanning decades.

In response to this issue, EPA proposes a stepwise approach to the uncertainty analysis for EFDC. First, uncertainty associated with site data will be examined using data on precision and accuracy of measurements obtained from extensive quality assurance evaluations conducted during the course of the sample collection and analysis, as discussed in the Supplemental Investigation Work Plan (WESTON, 2000) and accompanying Quality Assurance Project Plan (WESTON, 2001).

Second, during the calibration process, comparisons will be made between model projections and site data. These comparisons will be used to quantify residual parameter-specific uncertainty in the calibrated model.

Finally, the information from the preceding steps will be used to develop a targeted formal approach to evaluating uncertainty in EFDC. At this time EPA believes this approach will involve using a simplified EFDC code and/or performing the uncertainty analysis on a smaller segment of the model domain. The details of this approach will be presented in the Calibration Report.

A broader discussion of the need for a 2-dimensional model and the limitations associated with a 1-dimensional representation is provided under Section 16 (EFDC Algorithms, Source Code and General Input/Output Issues).

24.4.2 Additional Data Requirements

EPA agrees that the collection of additional data for use in over-bank flow simulations, as well as other information and data, would be useful to better define uncertainty. Sampling during a large storm event is planned. Additional data collection activities, such as the storm sampling, as well as bedload sampling, meander and bank erosion evaluations, and additional coring in the river channel, are described under Section 7 (Additional Data Collection Activities).

24.4.3 Methods Proposed for Uncertainty Analysis

To develop an understanding of the uncertainties associated with model predictions, a simplified application of the linked models will be constructed. The simplified model application will include the most important processes relevant to the evaluation of remedial alternatives, at a more macroscopic level than the detailed application. The simplified model application is expected to have no more than 30 time-varying parameters and will permit the use of modern uncertainty analysis techniques. The simplified model application will be used to assess the reliability of the output produced by the more detailed model. For the purpose of conducting uncertainty and sensitivity analyses, developing a simplified model is preferable to developing synthetic time-series for a range of model input parameters and boundary conditions.

24.4.4 Key Parameters for Uncertainty Analysis

EPA recognizes that many of the most important factors in predicting PCBs in a given medium over time contribute to uncertainty in model predictions. Examples of such factors include:

- Spatial pattern of PCB concentrations.
- PCB loadings.
- Suspended solids loadings.
- Resuspension and deposition fluxes.
- Sediment bed mixing and diffusion.
- Loss of PCBs to the floodplain during floods.

The analysis described above will consider these sources of uncertainty using statistical descriptions (e.g., bounded probability distributions). For the variables that have been studied empirically, specific parameterized probability distributions could be used. For variables that are not well understood, it may be necessary to construct empirical or estimated distribution functions by regression or other estimation procedure based on limited sample sizes. In some cases, variables may be developed based only on rough estimates of the first one or two moments and/or the theoretical range of the variable.

24.4.5 AQUATOX Complexity

EPA agrees with Peer Reviewers that the complexities represented in AQUATOX may not be necessary for the Housatonic River application and will replace AQUATOX with a simpler bioaccumulation model. Other more simplified bioaccumulation models have been evaluated for use on the project. The evaluation and selection of another model is further discussed in Section 17 (Bioaccumulation Model/AQUATOX). Although there are uncertainties in bioaccumulation modeling (as in all modeling), EPA does not believe that these uncertainties are a barrier to effective implementation of the new model, particularly given the simpler model formulation.

For the new model, tests of the sensitivity of model outputs to the individual model parameters will be conducted throughout the bioaccumulation modeling task. Additional detail will be provided regarding the overall degree of confidence for those parameters to which the model is most sensitive. For those parameters determined to be the most sensitive, a formal uncertainty analysis will be conducted. Where possible, a weight-of-evidence approach will be used to develop parameter estimates, in order to minimize uncertainty.

24.5 REFERENCES

WESTON (Roy F. Weston, Inc.). 2000. *Supplemental Investigation Work Plan for the Lower Housatonic River*. Vol. I - Text and Figures and Vol. II - Appendices. Prepared for U. S. Army Corps of Engineers, New England District, Concord, MA.

WESTON (Roy F. Weston, Inc.). 2001. *Quality Assurance Project Plan*. Environmental Remediation Contract, GE/Housatonic River Project. Volumes I, II, IIA, and IV. Prepared for U.S. Army Corps of Engineers. DCN GE-021601-AAHM.

25. REMEDIATION-R

25.1 COMMENT SUMMARY

Reviewer Name	Page	Line Number(s)
Adams	4	27-28
Bohlen	5	40-44
	6	25-32
Endicott	22	8-10
Garcia	3	35-37
Lick	9	8-17
	9	28-34
	11	6-8
Shanahan	7	26-37
	11	10-17

25.2 BACKGROUND

A major objective of the MFD is to propose a modeling study that can accurately predict concentrations of PCBs in biota in the future under different remedial scenarios. Although EPA has the responsibility for generating and performing Peer Review on the Model Framework, and the Calibration and Validation Reports, GE is responsible for using the model to evaluate the remedial alternatives.

25.3 SUMMARY OF ISSUES

The Peer Reviewers expressed the following concerns regarding remediation:

- Contaminant flux and the relative contribution of the sources are not addressed in the MFD.
- Further assessment should be performed of the ongoing remediation efforts by GE and planned by EPA that will affect source characteristics. Remediation efforts

represent an experiment in progress that should be used to document system response to a reduction in contaminant flux.

- Further discussion on the representation of the remedial alternatives (including dredging and in situ remediation [natural or engineered]), and representation of model forcing functions during simulation of the remedial scenarios, should be provided.

- Extensive measurements of flow, TSS, and PCB concentrations within the remediation region are needed as a check on the modeling. Conditions at the confluence will be affected by the remediation and the models reparameterized to reflect these changed conditions.

25.4 EPA'S RESPONSE TO COMMENTS REGARDING REMEDIATION

The MFD presents EPA's approach to constructing the modeling framework. It is not appropriate for EPA to speculate on precisely what GE will do when parameterizing the model in the future when simulating the possible remedial alternatives. EPA's modeling team has had a number of discussions with the GE team on the possible approaches for modeling the remedial alternatives, and the responses below reflect those discussions. EPA believes the MFD provided a reasonable framework for a modeling study that has the capability of modeling possible remedial alternatives. The MFD did not address the application of the model to *specific* remedial alternatives because of the reason noted above (i.e., the lack of precise information about how GE will parameterize the model in the future).

25.4.1 Contaminant Flux and Relative Contribution of the Sources

EPA agrees with the Peer Reviewers that developing an understanding of the PCB/solids fluxes into and within the Primary Study Area (PSA) is important in the development of the conceptual model and the subsequent interpretation of model output. The flux analysis described in Section 20 (Time Scale/Time Step Interactions) and Section 2 (Model Selection) will address the contaminant flux and relative contribution of solids/PCBs across the upstream boundary conditions at the confluence into the PSA and within the PSA domain. The flux analysis will be included in the final MFD.

Characterization of the potential sources of PCBs in the upstream reaches differs greatly from characterization of PCB sources in the PSA. The conceptual model developed for the modeling study based upon data collected at the site identifies only three sources of PCBs to the PSA, those entering across the upstream boundary condition as a function of dissolved and particulate suspended load and bedload, those within the sediment bed and floodplain soil in the PSA, and atmospheric loadings. The historical and current sources in the upstream reaches are more numerous and are being addressed through other actions under the Consent Decree. Therefore, it is not necessary to perform an additional evaluation of relative contributions of contaminants from sources upstream to the East Branch as part of the modeling study.

25.4.2 Effects of the Ongoing Remediation Efforts by GE and Planned by EPA on Source Characteristics

Monitoring data are being collected and will continue to be collected as part of the ongoing remediation efforts. EPA shares the Peer Reviewers' interest in evaluating the effects of remediation on source characteristics, and EPA's project team will share these evaluations between team members as they become available to better inform all decision-making.

25.4.3 Representation of Remedial Alternatives, Including Dredging and In Situ Remediation (Natural or Engineered), and Representation of Model Forcing Functions in the Models During Simulation of Remedial Scenarios

As stated previously, it is GE's responsibility to model remedial alternatives and to parameterize the model forcing functions when doing so. Realistically at this time there are only three alternatives recognized for addressing most PCB-contaminated sediment—dredging, capping, and/or some combination of the two, or monitored natural attenuation. If unacceptable risks are identified that require remediation, these alternatives or some combination of them will be considered.

Engineered and/or natural in situ remediation is not a likely approach for this site. A significant body of research has been performed by GE's Research and Development Group in relation to the Housatonic River (Van Dort et al., 1997; Bedard et al., 1997; Deweerd et al., 1999). This research suggests that the overall degradation of PCBs was relatively limited. Thus in situ remediation (biodegradation) has limited promise at the scale necessary for consideration as a remedial alternative at this site.

EPA's modeling team has discussed these issues with GE and believes that there are reasonable approaches to representing the remedial scenarios and model forcing functions when modeling remedial scenarios. These approaches were summarized in the information GE provided in the April 2001 response to the Peer Reviewers' questions (see Appendix B, pp. 37-38).

25.4.4 Extensive Measurements of Flow, TSS, and PCB Concentrations Within the Remediation Region as a Check on the Modeling

Flow, TSS, and PCB measurements are being collected by GE as part of the ½-mile removal, and are proposed by EPA for the 1 ½-mile removal. In response to the concerns expressed by the Peer Reviewers, GE has agreed to continue to collect these data at Pomeroy Avenue, New Lenox Road, and Woods Pond Dam as remediation efforts continue. EPA expects that the data available at the time the modeling of remedial scenarios is performed will be used to inform the parameterization of the boundary condition fluxes and as a reality check on model predictions.

25.5 REFERENCES

Bedard, Donna L., Heidi M. Van Dort, Ralph J. May, and Lynn A. Smullen. 1997. "Enrichment of Microorganisms That Sequentially meta, para-Dechlorinate the Residue of Aroclor 1260 in Housatonic River Sediment." *Environmental Science & Technology* 31(11): 3308-3313.

Deweerd, Kim A. and Donna L. Bedard. 1999. "Use of Halogenated Benzoates and Other Halogenated Aromatic Compounds to Stimulate the Microbial Dechlorination of PCBs." *Environmental Science & Technology* 33(12): 2057-2063.

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Van Dort, Heidi M., Lynn A. Smullen, Ralph J. May and Donna L. Bedard. 1997. "Priming Microbial meta-Dechlorination of Polychlorinated Biphenyls That Have Persisted in Housatonic River Sediments for Decades." *Environmental Science & Technology* 31(11): 3300-3307.

26. MISCELLANEOUS – MISC

26.1 BACKGROUND

Some of the Peer Reviewers' comments could not be easily categorized under the issues described in Sections 2 through 25 in this Responsiveness Summary. These comments are addressed individually, rather than by topic, below.

26.2 EPA'S RESPONSE TO MISCELLANEOUS COMMENTS

Comment: The effort to assemble, modify as necessary, interface, then calibrate and validate three sophisticated models to an acceptable level of accuracy, could be very time consuming, especially since the models have never been used together in such an application. Thus a major concern is whether acceptable results can be obtained in a reasonable time. Given the time that will be required to complete the upstream (0.5 and 1.5 mile) remediation activities, perhaps the modelers could be given more time to develop the model(s) which will be used for potential remediation in the PSA.

EPA Response: EPA agrees that the current modeling schedule is ambitious, but believes that a workable numerical model of the PSA can be developed in the time proposed. The validation of the model(s) and their delivery to GE is one of the milestones that initiates GE's Corrective Measures Study (CMS), as specified in Attachment B to GE's Reissued RCRA Permit. The ½-Mile and 1 ½-Mile Removal Actions will not be completed for several years, and EPA believes that it is not in the best interest of the public to further delay the commencement of the CMS.

Comment: Everyone has their own guidelines for developing/evaluating models, but one I like was generating by an ASCE task committee I served on some years ago. The paper which was generated by that committee (Ditmars et al., 1987) includes six steps in model performance evaluation which might be helpful to the modeling team. These steps include:

1. Identification of problem
2. Relationship of model to problem
3. Solution scheme examination
4. Model response studies
5. Model calibration
6. Validation studies

EPA Response: EPA will review the Ditmars et al. article for potential application to the current modeling effort. The type and sequence of activities listed above is generally consistent with the proposed activities for the development of the model as outlined in various sections, particularly Section 5, of the MFD.

Comment: I would like to see more information on near-bottom sediment conditions; e.g., the role that any bottom fluff layer may play in sediment-water exchange.

EPA Response: The presence, behavior, and role in sediment/contaminant transport of so-called fluff or boundary layers is not well understood. In the ocean and in deep lakes, high suspended solid nepheloid layers are well documented, but their presence in lotic systems is less common. In the Housatonic River, observations suggest that while such layers do exist in certain areas under certain conditions, they are not common in the coarse sediments present in much of the PSA. There are no data on the spatial and temporal distribution of such layers, and the collection of such information would constitute a research program. Even less well understood, and likely more important, is the role of any such layers in mediating sediment-water exchange of PCBs and/or other contaminants.

Comment: Initial bathymetry (1980) will be developed using current bathymetry and subtracting sediment deposition inferred from Be-7, Pb-210, Cs-137, etc. Then when the model is run forward, the same deposited sediments will be added, presumably yielding current conditions. While this should provide a good history of recent morphology, it is not predictive of future changes. It is unfortunate that there are not any independent estimates of historical bathymetry.

EPA Response: EPA agrees that it would be very useful to have historical bathymetry to perform an assessment of the ability of the model to reproduce historical and current conditions of sediment deposition in the model calibration and validation runs. However, the data do not exist; therefore, historical deposition rates will be estimated using radioisotope data. The ability of the model to simulate the estimated historical rates demonstrates that the fundamental processes controlling sediment erosion, transport, and deposition have been accurately captured by the model. Although it is true that the ability to reproduce past events accurately does not conclusively demonstrate an ability to simulate future events with equivalent accuracy, the acceptance of such a demonstration is inherent in the modeling process for all models and all parameters. All future conditions are inherently uncertain, a fact that is the fundamental reason for modeling.

Comment: The pertinence of the issue of proper model structure is demonstrated in a recent review of the models developed to assess PCB contamination in the Fox River in Wisconsin (Tracy and Keane, 2000). A physically-based (as opposed to empirical) model of the Fox River was developed by the Wisconsin Department of Natural Resources (WDNR), calibrated to field data for PCBs and suspended solids, and apparently used as the basis for a draft Superfund Feasibility Study (FS) of alternative strategies to remediate the river. Alternative cleanup strategies range from no action to dredging and contained disposal of contaminated sediments at an estimated cost of $720 million (WDNR, 1999). Subsequent to the publication of the models and draft FS, the WDNR model has been examined in detail by consultants to the industries identified as Potentially Responsible Parties (PRPs). The consultants identified a serious structural flaw in the model. Numerical dispersion arising from the representation of PCB transport in the sediments produces a large artificial flux of PCBs from deep sediment layers to the sediment surface in the WDNR model. As the result of this and other differences in the models, the WDNR model predicts that 70% more PCBs will be discharged from the Fox River than does an alternative model developed by the PRPs' consultants. WDNR has corrected its model, but has not yet reported the effect on the model predictions. There appears to be no consensus among the various parties on a best model or best modeling approach and, as indicated by Dr. Lick during the Peer Review Workshop, estimates of bed erosion between the parties differ by two orders of magnitude. The specific flaw identified in the WDNR Fox River model is known to the modelers working on the Housatonic River and will not be repeated. Moreover, the Housatonic River modelers also know the recommendations of the Fox River Peer Reviewers, although the study is cited only in the EPA Response to Peer Reviewers Questions and not in the MFD or QAPP. Regardless of the specific flaw in the WDNR model and its correction, the Fox River example reveals a fundamental failing in the application of these highly complex models: the models are over-parameterized such that even an intrinsically flawed model can be "calibrated" to field data. I suspect that with the number of parameters included in the AQUATOX model, it could be satisfactorily calibrated to any time-series data set, including the Dow Jones Industrial Average.

Beck's review of model uncertainty leaves me pessimistic—he states, for example, that, "Over parameterization seems both intrinsic and an intractable problem" (Beck and Halfon, 1991). He also makes clear that a "physics-based mechanistic" approach is hardly a panacea (Beck, 1987). It is noteworthy that he cites the predecessor model of AQUATOX as an example of the misguided physics-based approach. In essence, Beck argues that these models cannot be tested by the scientific method because they cannot be shown to be false. There are too few field data to disprove the many subordinate hypotheses and parameters embedded in these complex models. Thus, one cannot test hypotheses as is incumbent with the scientific method. Despite this overall pessimism, Beck (1987) does provide some optimistic observations. In particular, he distinguishes simulation of hydrology (and by implication, hydrodynamics) from simulation of water quality. He cites the longer and more intensive study of hydrologic processes compared to the more ephemeral attention to water quality (which has shifted attention over the years from BOD/DO, to eutrophication, to acid precipitation, and now to toxic chemicals). As a result of more intensive historical examination, the hydrological and hydrodynamic processes are better understood, more certainly parameterized, and better identified. In the context of the Housatonic River modeling framework, the HSPF and hydrodynamic portion of the EFDC fall within this class of more certain models. The comparatively empirical AQUATOX and sediment transport portion of EFDC are within the less certain category.

Another seemingly pessimistic aspect of Beck's analysis is the fact that his focus is primarily on eutrophication modeling, which is only a subset of the modeling exercise proposed here and thus less complex. However, as Beck (1987, Figure 15) illustrates, the eutrophication problem has some intrinsic difficulties that may not be shared by the PCB problem. Specifically, the prediction of eutrophication involves the translation of relatively steady meteorological and nutrient loading forcing functions into episodic algal blooms—an abrupt transient response that bears little resemblance to the character of the forcing functions. The PCB problem can be idealized as a relatively better behaved problem: namely the exponential depletion and burial of mass over decadal time scales. Indeed, with this conceptual model, I wonder if a calibrated exponential decay coefficient for PCB loss could be as reliable a predictor as the modeling effort proposed here. A flaw in the exponential conceptual model is, of course, the potentially great influence of unusually high flow events. However, the predictive ability of the proposed modeling framework for high flow events is perhaps the single greatest uncertainty in the model.

The focus of this question is on theoretical rigor when many of the equations for hydrologic processes in HSPF, sediment resuspension, settling, and transport in EFDC, and biotic interaction in AQUATOX are empirical rather than theoretical. Indeed, one could argue that the only consistently theoretically rigorous aspect of the models is the hydrodynamic model in EFDC.

EPA Response: The reviewer is correct that the specific flaw in the WDNR Fox River model is well known to the Housatonic River modeling team and will not be repeated. With regard to the larger question of over-parameterization of the model(s) to be used in the Housatonic River, the modeling team is similarly aware of the problems associated with over-parameterization and the ability to demonstrate (apparent) calibration of such a model even if highly flawed, particularly when reasonable and possible ranges for state and process variables are imperfectly known. The discussion provided in the MFD outlines the intent of the modeling team to pursue a modeling framework that will avoid the dangers of over-parameterization. This objective, along with specific comments received from the Peer Reviewers, has prompted the modeling team to replace the AQUATOX model with a simpler bioaccumulation model, as discussed in Section 17.

Comment: As far as specific data issues, I am concerned by the project team's failure to consider important data available from Massachusetts sources. The following potentially valuable data were not considered and apparently were unknown to the modeling team:

Data Source	Data Type
Massachusetts Department of Environmental Protection	Past water-quality assessments in 1997-1998, 1992, 1985, 1976-1978, 1974, 1968-1969 that variously included water-quality sampling, wastewater discharge surveys, biota sampling, sediment sampling, and probably time-of-travel and other hydrodynamic field studies.

Data Source	Data Type
Mass GIS	Geographic information system coverages of soil types, land use, wetlands, surficial geology, topography, aerial photography, and other geographical features.
Federal Emergency Management Agency	Hydrologic and hydraulic studies conducted under the Flood Insurance Program and possibly high-water mark surveys after flood events

These data are likely to assist in the formulation of food-web relations, construction and calibration of the hydrodynamic and hydrologic models, and construction and calibration of the phytoplankton component of the water-quality model. I am concerned that the failure to search for and incorporate these important past data could betray a false confidence in the proposed modeling framework: in other words, that the modelers could have concluded that their models are so good and so fundamentally sound, that they do not need to exert every effort to locate the best available data.

EPA Response: EPA appreciates these references to additional data that may be useful in calibrating and validating the model(s). These sources will be consulted and used in the modeling effort as appropriate.

Comment: The QAPP does not appear to include procedures specifically to check model input data. Section 11 appears to touch on this, but should also specify that all input data time series be plotted for visual inspection and cross-checking.

EPA Response: As discussed in Section 11 of the Modeling QAPP, the data will be reviewed and evaluated by the modeling team members as well as by the project Quality Assurance Team. These reviews will include time series plots, as well as other standard techniques for visual inspection and cross-checking. The Modeling QAPP was not intended to provide an exhaustive description of all forms of data review and evaluation that might be undertaken as part of this effort; these procedures are established in the Project QAPP (WESTON, 2001).

Comment: The EPA Response to Peer Reviewers Questions indicates that the new sediment bed representation in AQUATOX was tested against the IPX V 2.74 model. It, and all other newly created code, should be also validated against analytical solutions for which there are known solutions.

EPA Response: EPA agrees with the comment that, where possible, code formulation should be verified against analytical solutions. This is being performed, and these comparisons will be presented in the final MFD.

Comment: EPA states (response, page 14): "Since this class of hydrodynamic models are based on first-principle physics, the hydrodynamic regime of both small and large water bodies can be simulated accurately as long as proper boundary conditions are imposed ...."

This is not correct. EFDC is not a first principle model. It is a model that uses the time-averaged Navier-Stokes equations with a turbulence closure model that requires empirically defined coefficients. If it were a first principle model it would solve the Navier-Stokes equations in a direct numerical simulation. This is a common misrepresentation by turbulent flow modelers, that they are using first principles, when in fact they are not. The fact is that these turbulence models have not yet been able to describe properly even the simplest hydrodynamic flow over an extended range of Reynolds number, e.g., determination of the drag coefficient for turbulent flow past a sphere. Nevertheless, the models have gained some measure of acceptance because they appear to be capable of reproducing the gross features of some large-scale flows. In other cases they have failed completely (e.g., Santa Barbara Channel). The failures seldom ever get published.

EPA Response: The reviewer is correct that EFDC is not a first-principle model; that statement will be removed from the final MFD.

Comment: The models would seem adequate to discriminate between water related and sediment-bound sources of PCBs. However, sediment itself could have an impact on habitat regardless of whether or not it's laden with PCB (Huang, X., and Garcia, M., "Pollution of Gravel Spawning Grounds by Deposition of Suspended Sediment," Journal of Environmental Engineering, vol. 126, No. 10, October, 2000).

EPA Response: The reviewer is correct that the physical effects of sediment deposition can impact habitat and resident populations, particularly populations of relatively sessile benthic organisms that are unable to cope with rapid burial. Exactly such an impact was seen during the Mussel Exposure Study initiated as part of the Housatonic Project but terminated due, in part, to unacceptable mortality resulting from burial of some of the mussel cages in sediment deposited during a storm.

Such sediment deposition, however, is a natural event and is conceptually similar to impacts due to an unusually dry summer, ice scour in an unusually severe winter, or any number of other impacts that are wholly unrelated to the GE Pittsfield facility and contaminants, particularly PCBs, in the river. Although such events may impact biota populations, at least in the short term, they do not directly affect the levels of contaminants in the biota. The objective of the modeling effort is to determine future levels of PCBs in biota within the PSA for various remedial alternatives simulated on decadal scales.

Comment: Some much-needed clarity would be gained by changing some of the nomenclature used in the MFD and QAPP. The best examples I can identify are:

Historical PCB sources-replace with "in-place PCBs"
Partition coefficients-Use of Kp, when you mean Koc, is a pain.
(Greater consistency would improve the document.)

EPA Response: The general comment and particular examples are noted, and the final MFD will be reviewed carefully to improve consistency in the use of technical terms.

REFERENCES

Ditmars, J.D., E.E. Adams, K.W. Bedford, and Dennis E. Ford. 1987. "Performance Evaluation of Surface Water Transport and Dispersion Models." *J. Hydraulic Engineering* 113(8):961-980.

Tracy, J.C. and C. M. Keane (editors). 2000. *A Review of Models Predicting the Fate and Export of PCBs in the Lower Fox River Below DePere Dam*. A report of the Lower Fox River Fate and Transport of PCBs Peer Review Panel. American Geological Institute, Alexandria, VA.

WESTON (Roy F. Weston, Inc.). 2001. *Quality Assurance Project Plan*. Environmental Remediation Contract, GE/Housatonic River Project. Volumes I, II, IIA, and IV. Prepared for U.S. Army Corps of Engineers. DCN GE-021601-AAHM.

APPENDIX A

COMMENTS OF PEER REVIEWERS SHOWING CLASSIFICATION OF COMMENTS

Peer Reviewers for Housatonic River Model

E. Eric Adams, Ph.D.
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E John List, Ph.D.
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President
HydroAnalysis, Inc.
Acton, Massachusetts

Codes Used in Classifying Major Issues To Be Addressed in MFD Responsiveness Summary

An @ sign marks the start of a comment that is marked at the end by one or more of the following codes:

1. Peer Review Process – **PR**
2. Model Selection – **MS**
3. Model Domain – **MD**
4. Conceptual Model/Process Prioritization – **CMP**
5. Conceptual Model/Evaluation of Site Data – **CMD**
6. Adequacy of Data – **AD**
7. Additional Data Collection Activities– **DC**
8. Floodplain/Channel Interactions – **FC**
9. Floodplain Vegetation – **FV**
10. Bank Slumping/Erosion/Meandering – **BSE**
11. Rare Flood Events – **RF**
12. Active Layer – **AL**
13. Sedflume – **SF**
14. PCB Fate – **PCB**
15. HSPF – **H**
16. EFDC – **E**
17. Bioaccumulation Model/AQUATOX – **A**
18. Model Linkages – **L**
19. Grid Scheme/Spatial Scale – **GS**
20. Time Scale/Step Interactions – **TS**
21. Calibration – **C**
22. Validation – **V**
23. Model Sensitivity – **S**
24. Uncertainty Analysis– **U**
25. Remediation – **R**
26. Miscellaneous - **MISC**

APPENDIX A.1

COMMENTS OF E. ERIC ADAMS

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

E. Eric Adams
Massachusetts Institute of Technology
May 29, 2001

RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

- @The effort to assemble, modify as necessary, interface, then calibrate and validate three sophisticated models to an acceptable level of accuracy, could be very time consuming, especially since the models have never been used together in such an application. Thus a major concern is whether acceptable results can be obtained in a reasonable time. Given the time that will be required to complete the upstream (0.5 and 1.5 mile) remediation activities, perhaps the modelers could be given more time to develop the model(s) which will be used for potential remediation in the PSA. **MISC**

- @The task is made harder by constraints imposed by the consent decree and the fact that there are two modeling teams (EPA and GE) working essentially independently. If the peer review panel could interact more directly with the modeling team(s) and with their consultants, the task would be easier. It seems strange to think that GE will be handed the EPA model suite and then asked to use it. So much of modeling has to do with the "feel" for the model. I would find this quite awkward. Wouldn't it be easier for them to participate more directly in the model development? **PR**

- @The model framework, as presented, seems too complicated. I would prefer if the developers started with a conceptual model, then progressed to more sophisticated models as needed. The conceptual model could nominally include all of the potentially important processes, but just not with complete spatial and temporal resolution. This way it would be easier to see which processes were really important and which could be eliminated or approximated more simply. There is a nice discussion of conceptual modeling, at the beginning of Chapter 3 of the MFD, but it appears that the modelers are starting big and planning to pare down. Perhaps they will end up at the same place. **CMP**

- @Regardless of whether ones builds up or pares down, each iteration requires some model-data comparison (hence, calibration) to assess model adequacy. As such, it may be difficult for the peer review process to conform strictly to the prescribed sequence of model framework design, calibration, then validation. **C**

- @Perhaps most importantly, the model framework needs to consider the particular application, and the sensitivity of model processes/parameters to that application. This point is made in the statement of model objectives, but it seems to be lost in the detailed framework design. My sense is that it is easier for a model(s) to reliably compare the environmental benefits of various mitigation options, than it is to predict absolute contaminant concentrations a decade into the future. That is, model predictions of relative benefits may be less sensitive to some highly uncertain processes/parameters because these processes/parameters are common to several applications and hence errors in the way they are represented may cancel. By looking at applications from the beginning, a lot of extra work may potentially be avoided. **S**

- @The process of model development involves sensitivity. The charge to the peer review panel asks whether or not this or that process/parameter is "adequate". The answer, in part, depends on model sensitivity (in the context of the proposed applications). We won't be able to fully answer these questions until we see more model-data comparisons. **S**

- @Everyone has their own guidelines for developing/evaluating models, but one I like was generating by an ASCE task committee I served on some years ago. The paper which was generated by that committee (Ditmars, et al., 1987[1]) includes six steps in model performance evaluation which might be helpful to the modeling team. These steps include: **MISC**

    1. Identification of problem
    2. Relationship of model to problem
    3. Solution scheme examination
    4. Model response studies
    5. Model calibration
    6. Validation studies

- Despite these somewhat negative general comments, there is a lot of strength behind this project. The suite of chosen models is quite sophisticated and each model has been successfully applied in a number of previous cases (though unfortunately none quite like the present). Furthermore, the modeling team and their consultants appear experienced, they have diligently addressed a broad array of questions, and they have assembled and/or are planning to collect a lot of field data.

- As such, I remain cautiously optimistic and look forward to viewing model results.

[1] Ditmars, J. D., E. E. Adams, K. W. Bedford and Dennis E. Ford, 1987, "Performance evaluation of surface water transport and dispersion models", J. Hydraulic Engineering, 113(8):961-980.

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. Modeling Framework and Data Needs

1. ***Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?***

- @Many of the PCBs are in floodplain areas on the fringe of the various sub-watersheds. It is not clear to me whether these PCBs are more likely to enter the river by erosion from an occasional flood, a process handled by EFDC, or by wash-off from more frequent rainfall and snow melt, processes originally assigned to HSPF, but now apparently to be neglected. **FC**

- @I would like to see more information on the mass exchange coefficients (or functions) describing sediment-water exchange. **CMD**

- @I would like to see more information on near-bottom sediment conditions; e.g., the role that any bottom fluff layer may play in sediment-water exchange. **MISC**

- @Several papers have been written describing the extent of possible in situ remediation, either natural or engineered. It is not clear how this is to be modeled. **R**

2. Based upon the technical judgment of the Peer Review Panel:

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?***

Watershed/HSPF:

- HSPF certainly appears adequate for modeling routine flow and TSS.

- @I originally had questions regarding the ability of HSPF to model PCB wash off. This is because HSPF is a lumped parameter model not well-suited to simulating wash-off of contaminants concentrated in a relatively narrow (fringe) area of each sub-watershed. Now, however, that has been removed from the scope (though it is not clear that the process is not important). **HSPF**

- @As noted in the response to my question 11 (Question 113), spatially resolved models such as MIKE-SHE do exist, and could be used to compute PCB runoff from the fringe areas of the watershed. I have not used this particular model, and am not advocating it, per se, but hydrologists in our department are using it on comparable types of applications. **MS**

River/EFDC:

- @For typical flows (within banks) modeling is relatively simple, since there is no communication between banks and floodplains. One could go with either curvilinear coordinates or Cartesian. My hunch is that curvilinear is better, but perhaps Cartesian is safer. (Here it would be nice to be able to sit down with QEA and John Hamrick to more fully discuss advantages, disadvantages, pitfalls, etc.) In either case, the resolution can be quite small (order of 5 elements per width), momentum and mass should be conserved and the model should be sufficiently efficient so that multiple runs can be made. **GS**

- @EFDC is a generalized 3-D hydrodynamic/transport code, and not a river model *per se*. Along with some of the other panel members, I am concerned about the lack of previous applications to predict erosion and transport in complex channels and the possible need to engage in code enhancements in the middle of a tight schedule. This sounds like interesting research that might not bear fruit in a timely fashion. **E**

- @In view of this uncertainty, other simpler models should be explored. GSTARS was mentioned. **MS**

- @Several PCB congeners or homologs, spanning a range of appropriate partition coefficients, should be included in the EFDC simulations. As emphasized during the review meeting, the degree of hydrophobicity could substantially affect chemical residence time. **PCB**

- @Initial bathymetry (1980) will be developed using current bathymetry and subtracting sediment deposition inferred from Be-7, Pb-210, Cs-137, etc. Then when the model is run forward, the same deposited sediments will be added, presumably yielding current conditions. While this should provide a good history of recent morphology, it is not predictive of future changes. It is unfortunate that there are not any independent estimates of historical bathymetry. **MISC**

Bioaccumulation/AQUATOX:

- @I am not very familiar with AQUATOX, but based on the panel discussion and Park et al.

(1999), the model may be more complicated than necessary. AQUATOX includes ecosystem modeling that doesn't seem necessary, when only bioaccumulation is required. Indeed, if one assumes that the ecosystem won't change, the relative impact of various mitigation options should simply depend on the relative water column and sediment concentrations. **A**

Interfacing:

- @HSPF includes a relatively simple river model. As long as EFDC is going to be used to transport PCBs in the river, it is not clear why it is necessary to develop/calibrate the river section of HSPF. Conversely, as a first cut, it seems possible that the river section of HSPF could be augmented to handle the transport tasks asked of EFDC. **H**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

- @The proposed coupling between river and floodplain is complicated and does not conserve momentum. **FC**

- @It seems like the river is the more important part. This is where most organism exposure takes place and is the only region that AQUATOX simulates. The floodplain is not involved during normal flows and during high flow serves principally as a sink. The high flow erodes the channel bottom and banks, depositing sediment and PCBs on the floodplain (like a snow blower). **FC**

c. ***Are the models adequate for describing the impacts of rare flood events?***

- @Rare flood events are difficult to simulate, because they require coupling between the floodplains and the river. It is not clear that the proposed approach will work. But I am not sure it is that important to fully simulate rare events. Based on data presented at the review meeting, during high flow, flow rate and concentration may each be about ten times higher than under average conditions, making water column transport about 100 times higher. And if high flows occur about one percent of the time, then the time-averaged water column mass transport under high and average conditions are about equal. But our concern is with bioaccumulation, which is proportional to time-integrated concentration (both sediment and water column) and not transport. The contribution of extreme events would be only 10 percent for water column and 1 percent for sediment (assuming no change in sediment concentration). Hence bioaccumulation should result much more from exposure at average, rather than extreme, flows. **RF**

- @Floods erode channel bottoms and banks resulting in particle-sorbed PCBs being transported downstream and sequestered in Woods Pond. Dissolved-phase PCBs liberated during this process will simply be washed downstream. Hence high flows are helpful for removing PCBs from the basin and errors in their representation are thus conservative. Since we are not able to predict extreme events in other than a statistical sense, anyway, I would think their role could be simulated with simple erosion/deposition assumptions, rather than a complex coupling of models with nested grids, etc. **RF**

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

3.Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

- @I would like to see the model domain extended further upstream. I realize, as the modeling team reiterated in their response to my question 4 (Question 106), that the present focus is the region between the confluence and Woods Pond. However, the ongoing/proposed remediation in the upper two miles above the PSA would provide a good basis for model/data comparison. Can the models predict the (presumably substantial) decrease in PCB loading arriving at the confluence following remediation? This will likely be a much bigger perturbation (hence more valuable test of model skill) than the changes that have occurred in the approximately 20 year period used for calibration/validation. It would also parallel one of the potential mitigation options that could be chosen for the PSA. **MD**

- @Similarly, while the generally lower PCB concentrations downstream of Woods Pond imply that this region is less important from a human and ecological health standpoint, valuable data have been collected, and it would be nice to see if the model can predict them. Demonstrated skill in properly predicting these downstream concentrations can be used to assert confidence in model predictions upstream of Woods Pond, including conditions after mitigation when PCBs loadings in that region will also be smaller. **MD**

- @From my experience, the issue of rainfall disaggregation (as input to HSPF) is critical, but the modelers recognize this, and have identified procedures for combining local data collected at daily intervals with more distant hourly data. Hopefully their procedures will be validated by measurements of short-term river flow and TSS data. **TS**

- @AQUATOX will be run with a daily time step. The response to my question 23 (Question 125) clarifies that the computational time step can be subdivided (based on an adaptive time-stepping algorithm), but the loads will be aggregated. Since storms are important for transport, it is not clear if daily aggregation will be adequate. **TS/L**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

- Combine answer with 6.

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

- @One objective of the study is to assess natural recovery. The two-year calibration period is useful to assess model skill in simulating processes, but too short to see much natural recovery, as the team concedes in their answer to my question 3 (Question 105) I wonder if a larger portion of the 20-year study period should be devoted to calibration rather than validation, or if additional data (GE or earlier EPA) should be used? **C ?**

- @It is unfortunate that there are not good data available for establishing initial bathymetry. The plan to use bathymetry and subtract sediment deposition inferred from Be-7, Pb-210, Cs-137 seems reasonable under the circumstances, but it is not predictive. **DA**

- @Bioturbation is mentioned in several places, but I have not found reference to calculated bio-mixing coefficients. **AL**

- @The current data collection program should be extended through the terms of the upstream remediation (0.5 and 1.5 mile) activities. **MD**

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

IV. Concluding Comments

APPENDIX A.2

COMMENTS OF W. FRANK BOHLEN

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

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RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

This is an ambitious project. The EPA in collaboration with GE seeks to develop and apply a predictive numerical model of PCB fate and transport in the Housatonic River. Initially this model will focus on the river reach extending for a distance of approximately 11 miles south from the confluence of the east and west branches of the Housatonic to Woods Pond (defined as the Primary Study Area (PSA)). This area, beginning just to the south of the GE manufacturing facility in Pittsfield, Massachusetts, is known to contain significant concentrations of PCBs in sediments resident within the main stem channel of the river as well as in the bordering banks and floodplain. The model is intended to assist in the development and assessment of a variety of remedial alternatives both active and passive.

The range of processes affecting the transport, fate, and biotic impact of PCBs in a river system includes a multiplicity of physical, chemical and biological factors. To accommodate this complexity the proposed model will consist of three principal sub-models; HSPF to define watershed hydrological characteristics and the resulting streamflows and selected contaminant fluxes, EFDC a hydrodynamic/sediment transport model and AQUATOX a PCB fate and bioaccumulation model. The sub-models are intended to function collaboratively and to form a relatively coherent whole with capabilities in excess of a simple summation of individual contributions.

@The linking of three discrete numerical models to form a coherent unit is a complex undertaking and requires in-depth understanding of the site-specific factors affecting PCB fate and transport in the PSA both to design and implement the model and to constrain governing parameters. In the absence of such understanding it is difficult to justify the complexity of a multi unit model approach. The MFD begins, as it should, with a discussion of the conceptual model forming the basis for the proposed approach. This discussion includes consideration of selected historical data as well project specific data gathered over the past few years by EPA. In outline the development of the conceptual model appears reasonably comprehensive. Examination of the details however, indicates that the conceptual model exercise is seriously deficient with many key elements remaining to be established. Weaknesses resulting from this deficiency adversely affect all components of the MFD and call into question the need for the proposed complex modeling scheme.

The inadequacies in the details of site assessment affecting the conceptual model development appear to be primarily the result of limited data analysis and the absence of hypothesis based field sampling. With few exceptions, the majority of the sampling activities place primary emphasis on detailing the spatial distributions of PCBs, sediments, and a variety of the geomorphological characteristics of the River and adjoining watershed. There are few studies dealing with system dynamics and as a result the discussion presented of the relative importance of a variety of factors including stream meandering, the floodplain as a source or sink, bed-load transport, and implications with respect to the long term sequestering of PCBs is largely conjectural. This leaves entirely too many model parameters to be user specified and will ultimately limit the utility of the model as a predictive tool.

To correct this situation and to develop a basis sufficient to justify the complexity of the proposed modeling approach the Modeling Team must present a more closely reasoned conceptual model supplemented by additional field work, as necessary. Using the extensive spatial data in combination with indications from GE regarding the annual input of PCBs to the Housatonic, the development of this model might begin with a mass balance discussion (or box model) of the amount(s) of PCB resident in the study area and probable fluxes to and through the system. Several bits of information presented to the Peer Review Panel suggest that the system is quite "leaky" and that introduced PCBs move downstream rapidly. EPA comments regarding the absence of sequestering appear to support this view. What are the implications of this response ? One might be that effective elimination of the Pittsfield source would reduce the downstream flux to near zero since all remaining reservoirs represent deep burial in equilibrium with a wide range of flow conditions. This hypothesis seemingly is in the process of being tested and needs little model support. Alternatively, one might posit that elimination of the primary source would only slow downstream flux due to the inherent instability of the multiple reservoirs. Here again is an hypothesis to be tested by field sampling following completion of the ongoing source control projects. These data may show transport time scales short compared to remedial implementation times. (i.e. before remediation/cleanup can be implemented all PCBs will have left the PSA). It's only if we believe that the variety of repositories of PCB in the study area represent continuing long-term sources that detailed modeling is justified. A mass balance review would assist in the development of a reasoned justification for the proposed model approach.

Following initial justification, the MFD should clearly present an evaluation of each of the primary factors affecting PCB fate and transport. Begin with a discussion of source(s) and the form of the contaminant (NAPL, solute, particle bound, airborne, etc.) and implications re modeling. Continue with a presentation of the transport system and the importance of all relevant factors including suspended vs. bedload, the role of the sediment column as a source/sink, biotic mediation, and the effect of storms. How will transport be affected by meandering ? How will meandering be modeled? This may be rendered un-necessary since the mass balance discussion might indicate PCB transport time scales short compared to meandering times. Move next to the matter of floodplain dynamics and present a process based discussion of the role of this area in the transport system. Much of what is included in the MFD with respect to the floodplain is inferential and lacks specificity. Throughout include discussion of the role of each of these components as a factor controlling the flux of PCB to and up the food chain. Conclude with a summary statement describing the system that is to be represented numerically. Such a reasoned presentation would greatly increase confidence that the proposed model complexity is justified and that the resulting product will ultimately prove to be a valuable adjunct to remedial efforts. **CMP/CMD/DC**

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. ***Modeling Framework and Data Needs***

1. ***Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?***

@The MFD includes consideration (or at least mention) of all significant processes affecting PCB fate and transport in the Housatonic River. The evaluation of the relative importance of these processes is, however, not well done. As a result, the component models include entirely too many user specified parameters. The modeling team should present a closely reasoned discussion of the relative importance of the variety of processes governing PCB fate and transport in the Housatonic River. **CMP**

@With regard to process description, the MFD provides an adequate description of the factors affecting river hydrodynamics and the combination of HSPF and EFDC appear able to accurately simulate a wide range of conditions ranging from daily average to the extreme storm event. While care must be exercised in the development of the spatial segmentation particularly with respect to floodplain areas to insure numerical stability and mass continuity I am more concerned with the physical basis for the selected scheme. e.g. What spatial resolution is required to accommodate the observed variations in sediment type and/or geomorphological form (i.e. bars, shallows, meanders). This aspect is not discussed in the MFD and it is not clear that the required field data exist to answer the question. e.g. Review provides no indication that a number of transects have been subjected to high density spatial sampling in order to permit quantitative specification of the relevant spatial scales. If such data exist a short summary should be provided in the MFD. **GS/AD**

@Moving next to the issue of sediment transport, the MFD discusses most of the processes affecting erosion, transport and deposition and presents some amount of supporting data. The subsequent development of a conceptual model of the sediment transport regime would benefit from high frequency time series observations of suspended material and bed load fluxes and finer spatial sampling scales over the vertical. It is not clear, for example why all analyses of PCB distributions began with a composite sample of the upper six (6) inches of the sediment column. Are there data to indicate that sampling at 1in increments (or some such) shows an essentially uniform vertical distribution ? Are these data supported by the radionuclide data ? The combination would have some interesting implications relative to transport. **CMD**

@The higher resolution time series (sampling rates of N samples/day for bedload and N samples/hour for suspended load) observations of both bed load and suspended load in combination with the radionuclide data detailing long term sedimentation rates at several locations throughout the PSA would permit quantitative definition of the structure and form of the sediment water interface, critical erosion velocities, the extent of sediment recycling, and the overall trapping efficiency of this region of the River. All represent information essential to accurate modeling of sediment fluxes. There is no indication that such data presently exist. The available time series data set is sparse and provides limited temporal resolution. The use of SEDFLUME to define critical erosion velocities provides little information on the small scale processes affecting the immediate sediment water interface and no information on the flux and recycling of high water content suspended materials resident along the interface. These latter materials can transport significant quantities of recently introduced PCBs and measurably affect the storage of the contaminants within the underlying water column. Lacking an accurate specification of the role of these materials the modeler is often forced to introduce a “transport parameter” artificially driving PCBs from the sediment column to the overlying water in quantities sufficient to satisfy mass balance requirements. The resulting construct often represents a poor substitute for reality, is open to easy criticism, and typically complicates the development of acceptable long term remedial methods. **DC**

@Beyond the details of the sediment transport process, the geomorphological implications are not adequately discussed in the MFD. In particular it is not at all clear just how the model plans to treat the matter of channel meandering, bank erosion, and the dynamics of the River’s bars, terraces, and benches. PCBs are observed in these latter areas with introduction apparently the result of both natural transport during high water events and man associated placement of fill. Given the complexity of some of these components a “black box” approach maybe the best that can be expected. Alternatively, some relatively simple site-specific observations may provide indication that some few or all of these components can be neglected. Of these three for example, it may be that only bar and terrace dynamics need be considered since the transport time scales affecting meandering or bank erosion are long compared to those characterizing the majority of the PCB transport. **CMP/CMD/BSE**

@The modeling of sediment transport to and through the PSA is intended to directly complement evaluations of PCB flux and definition of the longterm potential of the area as a contaminant reservoir and continuing source to adjoining and downstream regions of the Housatonic River. Central to the specification of PCB flux is the definition of the source(s) presently supplying the contaminant burden crossing the upstream boundary of the PSA. The

MFD provides relatively little information on source flux and contaminant form (dissolved, particulate, aerosol, NAPL) and no discussion of manner in which the ongoing mitigation efforts by GE and those planned in the near future by EPA will affect source characteristics. **R**

2. Based upon the technical judgment of the Peer Review Panel:

3.

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?***

@The approach outlined in the MFD appears sufficient to accurately define streamflows and the associated suspended material flux crossing the upstream boundary of the model. The MFD provides no indication of just how the bedload flux is to be incorporated. One might suspect that it will be defined using measurements of bedload obtained at a variety of streamflows. These measurements are yet to be obtained. **DC/EFDC**

@Although not specifically defined in the MFD it is my understanding that the PCB flux crossing the upstream boundary will not be a modeled parameter but rather will be specified using EPA field data obtained over the past few years. The adequacy of this approach must be carefully demonstrated. In addition a clear indication of just how this specification is to be handled following completion of the ongoing source remediation efforts in Pittsfield. As stated on a number of occasions, the remedial efforts represent an experiment in progress and full advantage should be taken of the opportunity to document system response to a reduction in contaminant flux. **R/AD**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

@Nowhere is the transport system affecting floodplain PCB concentrations discussed making it difficult to evaluate model adequacy. In particular, the role of vegetation, with the possible exception of frictional effects, is ignored. It would appear that the floodplain is to be treated simply as a sediment deposit with entrained PCBs. Displacement is fundamentally a sediment transport process and is to be simulated using some estimated critical erosion characteristics with boundary shear stress specified in EFDC. Floods bring additional particulate load and/or serve to scour resident materials. Although this may be true to some extent there is no doubt that vegetation plays an significant role in the process and may in fact represent the dominant governing factor. The MFD provides no indication that this possibility has been considered. e.g Consider the following; is it possible that the floodplain sedimentary deposit is essentially in equilibrium with a wide range of flows including those occurring during floods and that the majority of the contaminant exchange process is governed by resident flora ? During floods PCB laden sediments are carried over the floodplain and are trapped within the understory and as a surface coating on leaves, stems, and fronds. Some fraction of these PCBs are incorporated into the sediment column but the majority remain mobile to be progressively washed from the surface of the floodplain by subsequent rainfall events - independent of river stage. Even some portion of the contaminants bound within the sediment column are taken up by plants and leave as a fraction of the detrital load in the fall and winter. Sediment transport plays a minor, secondary, role in the overall transport process serving only as the initial source. **FC/FV**

Such a view has profound implications relative to modeling and ultimately remediation and seemingly warrants discussion.

c. ***Are the models adequate for describing the impacts of rare flood events?***

@Given the weakness of the process discussion in the MFD this remains to be seen. Fundamentally the models appear adequate to numerically simulate the impacts of the rare flood event. But their ability to do so accurately is uniquely dependent on the algorithms used to detail impacts (cause and effect relationships) and the data available for calibration and verification. At the moment the combination appears best able to establish the effects of floods on system hydrodynamics -stage, velocity and boundary shear - at least within the main stem of the River. I'm less confident of model ability to simulate sediment transport process leading to an accurate specification of mass flux. HSPF should provide a reasonably accurate indication of the boundary flux of suspended materials during a high flow event. Here the issue may be only one of data adequacy for verification. **RF @**The ability to model bed-load transport across the boundary and within and through the PSA however, remains an open question which the MFD indicates is "under investigation". **DC** @Similarly, the MFD recognizes the importance of meandering but provides no indication of just how this process is to be treated (p.3-40). **BSE**

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

This is a subject outside of my area of expertise.

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

@The proposed models are able to accommodate a range of spatial and temporal scales sufficient to accurately simulate PCB fate and transport and system response to a variety of remedial options. I would like to see a more detailed justification for the spatial scales selected for segmentation as well as the longstream extent of the model. I'm willing to exclude the Pittsfield area from the model domain if there is clear indication that the effects of the ongoing remediation is being carefully monitored and that the results will be incorporated in the definition of source and the specification of the functional relationship between streamflow and PCB concentrations used to establish the upstream boundary conditions. As for the downstream boundary it seems advisable to extend the model domain in the interest of efficiency and recognition of future needs. If there are administrative reason why this is impractical and one only considers model function, Woods Pond and the bounding dam represent acceptable boundaries supported by a relatively long-term data set. **MD**

@As for the scale of the individual model element or grid, The MFD fails to provide a process based discussion of the criteria used in the selection/specification of grid size. As discussed above, this might include analysis of the spatial distributions of sediment/PCB along and across selected cross-sectional transects. I was unable to extract this information from the data plots and suspect that it is not available. In the absence of such detailing it is impossible to evaluate the adequacy of the specified spatial scales.**GS/AD**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

The theoretical rigor of the algorithms used in each of the component models is adequate and sufficiently flexible to accommodate a wide range of processes.

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

@As discussed above, the modeling exercise would immediately benefit from the addition of time series observations detailing the response of the sediment transport system at a number of locations throughout the PSA and under a range of streamflows. These data in combination with the radionuclide analyses of longterm deposition rates would permit quantitative evaluation of the structure and form of the sediment water interface as well as definition of critical erosion conditions. This combination would significantly improve the quality of the sediment transport model and the accuracy of the associated PCB fluxes. **CMD/DC**

@In addition to the time series observations, the model effort would benefit from more detailed analysis of the spatial patterns of the sediment/PCB distributions. The majority of the available data appear to have been obtained on a fixed grid (e.g. three stations spanning the channel) and not intended to detail spatial variability. Absent these data it's impossible to evaluate the adequacy of the proposed model segmentation. **CMD**

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

See Above

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

Overall these reports are reasonably well written and clear. Given the complexity of the issue and the number of authors involved this represents a major accomplishment. All responsible are to be complimented.

IV. Concluding Comments

@As stated previously this is an ambitious effort. The EPA and its Modeling Team have made an impressive start. There is real promise that their efforts to establish a basis sufficient to permit quantitative evaluations of the factors governing PCB fate and transport in the Housatonic River and to design an optimum remedial plan can succeed. Success however, requires careful development of a logical model framework and the continuing acquisition of supporting data. The required framework would increase in complexity as our understanding of processes governing PCB fate and transport in the PSA increases. There is some indication that this fact has been lost sight of in the development of the MFD and that the proposed multi-component model is un-necessarily complex, on the one hand, while neglecting fundamental processes on the other. The absence of a clear indication of a "walk before running" philosophy leads to the suspicion that the emphasis here is on the modeling exercise rather than on the adequacy and accuracy of the model output. This impression is best corrected by a careful process based discussion of the PCB transport and fate in the Housatonic using all available data and an honest critical evaluation of knowns and unknowns. My review suggests that such a presentation would result in the proposal of a far simpler modeling scheme. Alternatively, this evaluation would lead to additional process driven field sampling to test a variety of carefully structured hypotheses .
CMP/CMD/MS/DC

APPENDIX A.3

COMMENTS OF DOUGLAS ENDICOTT

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

Douglas Endicott
Great Lakes Environmental Center
May 24, 2001

RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

INTRODUCTION

@The modeling study of PCBs in the Housatonic River is a substantial undertaking, and this is reflected in the Modeling Framework Design (MFD) report and the associated Quality Assurance Project Plan (QAPP). These documents address a complex problem, in terms of the modeling objectives, and in some ways succeed in developing a defensible modeling approach. Complexities of the site and of the aquatic and terrestrial ecosystem, along with numerous uncertainties, data limitations, and other constraints, makes the Housatonic River PCB contamination as difficult a problem as I have seen. It has required substantial effort for the Peer Review Panel to absorb and understand all of the elements of the MFD. The opportunities for dialog with the EPA modeling team have been too limited to be productive. A more open dialogue amongst the peer reviewers, and between the panel and the modeling team, would have greatly facilitated this process. I encourage EPA and GE to revise the process prior to subsequent iterations of peer review. **PR**

@I perceive the value of peer review at this stage of the project (conceptual design) to be fairly limited. There are two reasons for this. First, you hire a modeler, not a model. By that I mean the choice of model and modeling approach depends upon who is doing the work. We have all invested years of effort developing expertise in at most a handful of models, gaining skill in their use through site-specific applications. The choice of models and modeling approaches that comprise the MFD are essentially complete once the modeling team is selected, and this bridge has been crossed. There has appeared to be little flexibility on the part of EPA or their modeling team to consider alternatives to the 3-model construct defined by the MFD. I hope that is not the case, because the Panel has attempted to advance constructive comments and suggestions, with the objective of improving the scientific defensibility and likelihood of success of the modeling exercise. **MS**

@Secondly, it can be difficult to judge the success of modeling based upon prior review. The success of modeling is judged in terms of predictions, not formulations. At best, we can compare the overall MFD and it's elements to models and modeling approaches which have succeeded or failed in the past. However, it is possible that alternative models and approaches may perform as well (or better). I have struggled with this issue through much of the MFD, particularly with aspects of the MFD considered "avante garde" by the standards of most water quality modelers. These include:

- the incorporation of the food web bioaccumulation simulation within an ecosystem model,
- kinetic models of PCB partitioning to detrital (sediment) and planktonic organic carbon,

- parallel models for abiotic and biotic PCB transport and fate processes, and
- the direct use of SEDFLUME experimental data to parameterize sediment resuspension properties.

Much of the Panel's deliberation at the Public Meeting focused on the seemingly excessive complexity of these and other aspects of the MFD. In general, we concluded that adopting complex or avante garde approaches to modeling required specific justification or rationalization, and that this generally had not been provided by the MFD. The defense of the avante garde is made by the modeling team:

> New applications and linkages of existing models are not necessarily undesirable. Development of a successful modeling framework for a challenging problem such as the evaluation of baseline conditions and alternative PCB remediation strategies for the Housatonic River has the potential to significantly advance the body of knowledge for contaminant transport and fate modeling in riverine systems.[1]

By itself, this is not an adequate justification for the complexity of the modeling framework. **MS**

@There are risks which accompany innovation; most obviously, the risk of failure. Prior success may be the best indicator of a favorable outcome. This conservative philosophy is one basis of the engineering discipline. Many of the comments submitted by Quantitative Environmental Analysis (QEA) on November 30, 2000 critical of the MFD are a reflection of this conservatism. A second risk is that if too much effort is devoted to making a new application succeed, some other more fundamental task may be overlooked or shortchanged, possibly jeopardizing the project. A project such as this one, where the timelines and schedule appear to be carved in stone, is the wrong place to get creative. The tolerance for risk is much higher in the research and development environment than it is in the regulatory arena. Since the stated objectives of this project fall entirely within the latter, it is necessary to consider the "What if this doesn't work?" contingency in the event of failure. I have concluded that constructive criticism of the avante garde approach can best take the form of suggesting what additional data collection, analytical and modeling efforts are appropriate as contingencies. Contingency plans need to be built into the MFD. **MS/C/V**

@EPA and Marasco Newton both emphasized the importance of prioritizing recommendations in our final written comments. I believe the Panel's most important recommendation, is to continue a monitoring program during and after remediation in the upstream river reaches. This should include monitoring flow, TSS/POC/DOC, and dissolved and particulate PCBs on a regular basis, at 3-5 locations in the Study Area including the confluence, bridges, and Wood's Pond dam. To this should be added annual sampling of target fish species, for determination of

[1] *EPA Response to Peer Review Panelist Questions on the Housatonic River Modeling Framework Design* (April 12, 2001).

trends in lipid and PCB body burdens. **DC**

SUMMARY OF CHARGE

The following are comments in response to the Peer Review Panel's "Summary of Charge", which otherwise do not seem to fit in response to the Peer Review Questions which follow:

- ***Are the available data sufficient for development of models of the hydrodynamics, sediment transport and the chemistry, fate and transport, and bioaccumulation of PCBs in the Housatonic River?***

@The project data described in the MFD are insufficient for calibration and verification of several significant processes. Data are lacking for:

Tributary boundary conditions
Bed load of sediment and PCBs
Erosion Rates (including aggrading bars/terraces and banks)
PCB partitioning
Lower food web PCB concentrations
Diet (predator/prey relationships) **DC**

- ***Are the processes in the final models calibrated/validated to the extent necessary for prediction of future conditions?***

@Accuracy of both event and long-term simulations may be difficult to demonstrate due to lack of necessary validation data ("big event" sampling, and data quality and comparability issues involved with measuring long-term contaminant decline).Without such data, significant model processes will not be adequately constrained by calibration to ensure reliability of forecast predictions. **DC**

- ***How sensitive are the models to uncertainties in the descriptions of the relevant processes?***

@All models are sensitive to uncertainty! They are most sensitive to unexpected/unknown uncertainties, which unfortunately cannot be estimated. In terms of PCBs predicted in water and sediment, the most significant (known) uncertainties are associated with the following processes:

Loadings (PCBs and suspended sediments)
Initial conditions for sediment PCB concentrations
Resuspension and deposition fluxes (especially at high shear stresses)
Sediment bed mixing and diffusion
Partition coefficients
Net loss of PCBs during overbank flood conditions

For PCB concentrations predicted in fish, additional uncertainties include:

Plankton and benthos biaccumulation relationships (i.e., BAF and BSAF predictions)

Fish prey, dietary contaminant assimilation relative to food, and elimination rates
Sediment feeding selectivity and invertebrate uptake and elimination rates **U/S**

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. ***Modeling Framework and Data Needs***

1. Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?

@In general, the MFD does identify the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River. The process descriptions are also generally adequate; as mentioned, some of the process models are excessively complex. Weaknesses in the process descriptions are noted for the following:

- Erosion of river bank solids and PCBs (apparently this cannot be described?)
- Deposition or other losses for PCBs transported onto the flood plain,
- Partitioning of PCB transport and fate into "abiotic" and "biotic" processes,
- Food web predator/prey linkages and feeding descriptions at the base of the food web,
- Surficial sediment mixing,
- Chemical transport and fate descriptions in EFDC, and
- Some alternatives are offered to the organism-level bioaccumulation formulations and parameterization used in AQUATOX**,**
- Detrital carbon sorption kinetics (i.e., desorption kinetics) model used in AQUATOX.

I would suggest discarding "Non-partitioning of PCBs" and wind-driven transport processes from conceptual model. **CMP/CMD**

AQUATOX ecosystem model

@The "classical" or conventional approach to modeling chemical bioaccumulation in food chains and food webs (as defined by Weinenger, et al.,1983; Nordstrom, 1976; Connolly and Thomann, 1984; Thomann, 1989; Gobas, 1993), is based on a mass balance applied at the whole-organism level. Mass balance equations for representatives of each trophic level are coupled in a prescribed manner by the specification of predator-prey relationships. These can be simple or complex, including such factors as change in diet with age, season, and/or location. It can be demonstrated, either by observation or via sensitivity analysis, that bioaccumulation of highly-hydrophobic chemicals is very sensitive to predator-prey relationships. This is especially true for organisms consuming a diet including both benthic and pelagic food items, because of the large gradient in hydrophobic chemical exposure observed between water and sediment.

The accuracy and certainty of the predator-prey specification is constrained by the data available to describe organism diet, typically gut content analyses. This approach of specifying predator-prey relationships can be criticized for (at least) the following:

- Gut content data reflect the predator-prey relationship at a particular time and place. Depending on the circumstances, this data may be extremely variable. Collecting this data is labor-intensive and logistically difficult; therefore, even in the best case, there is usually not enough gut content data to adequately define the predator-prey relationship in a continuous manner. Although other analytical methods (nitrogen isotope ratios, for example) may overcome some of the discontinuity problem, the general problem of uncertainty in this specification of predator-prey relationships remains.

- Gut content data reflect the predator-prey relationship at the time of sampling, and have no predictive (forecasting) power other than assuming that tomorrow will be like today. We know this not to be true, therefore bioaccumulation forecasts made with specified predator-prey relationships will be inherently uncertain.

Several food web models have been developed which couple the bioaccumulation process with ecosystem simulation of predator-prey dynamics. AQUATOX, BASS, and the MCM are examples of this type of coupled ecosystem/bioaccumulation model. The ecosystem model is used to simulate the density and/or biomass of food web organisms. The density of different organisms serves to modify the specified prey preference of predators according to abundance. The goal of this approach is to develop food web models which overcome both of the limitations identified above, (namely) the use of insufficient, discontinuous measurements to specify predator-prey relationships, and the lack of forecasting ability. Unfortunately, there are a number of problems with this approach as well:

- A great deal of site-specific data are required to properly constrain an ecosystem simulation, much more than will exist for an aquatic ecosystem unless great resources are brought to bear;
- Many fish, especially top predators, may have specific prey preferences and are essentially insensitive to prey abundance;
- Unless confirmed by gut contents data (the need for which was supposed to be avoided), ecosystem simulation of predator-prey relationships may be no more

(and possibly less) accurate than use of gut contents data to directly specify predator-prey relationships;

- Especially worrisome is the possibility that an unconstrained ecosystem simulation could shift the modeled predator-prey relationship towards an unrealistic feeding scenario, for example a planktivorous fish feeding on detritus or benthos due to the relative abundance of biomass. An error of this sort apparently occurred in the AQUATOX application to PCBs in Lake Ontario (Park, August 1999), when parameterization error caused amphipod biomass to drop below the minimum level for feeding by smelt. This error in the ecosystem simulation had an effect on PCB bioaccumulation which cascaded up through the trophic levels.
- I am aware of no research to demonstrate that bioaccumulation predictions made by ecosystem-based food web models are more accurate and/or reliable than specified food web models;
- The forecasting ability of ecosystem-based food web models depends upon whether the forcing functions (climate, nutrient and energy fluxes, fisheries management, invasive species, ...) can be anticipated. Since this is not likely, the best that can be done is to use the ecosystem model for bounding analysis, something that can probably be done directly using life history data for the food web organisms of interest.

QEA has commented that AQUATOX ecosystem dynamics (biomass change with time) will be unconstrained by data. They argue it is better to specify diet based upon site data and literature, and deal with uncertainty in the diet specifications. The Peer Review Panel lacks an ecological modeler. I know I am not, so I really cannot evaluate whether the planned collection of biomass data will adequately constrain the simulation of ecosystem dynamics in AQUATOX. AQUATOX calibration/validation (QAPP 4.7) does include biomass as a calibration goal.

If population densities of trophic levels modeled in the AQUATOX food web cannot be confirmed by available biomass data, trophic linkages based upon both abundance and prey preferences will be unconstrained in the absence of site-specific diet studies. The ecosystem dynamics incorporated in AQUATOX are otherwise irrelevant for the Housatonic River application. The uncertainty in bioaccumulation predictions (including pelagic vs. benthic contaminant accumulation routes) may be large (to an unknown extent), especially over annual and longer time scales. It is crucial for bioaccumulation modeling that the trophic linkages be realistic during simulation; an ecosystem modeling approach doesn't appear to guarantee this. The model must do better than "produce realistic ecosystem dynamics based on general principles", it must do the best job possible to describe the predator-prey relationships in the ecosystem. The conventional engineering modeling approach appears to be simpler and less uncertain.

To sum this up, there may be little to gain by using the ecosystem-based modeling approach in the Housatonic River. For this application, it adds unnecessary complexity to an already difficult modeling problem. It also specifies the collection of biomass data which is otherwise irrelevant to the problem at hand. These aspects are distractions from the stated modeling objectives. Ecosystem model simulation has no direct utility in the context of the modeling objectives; it is only relevant in terms of establishing trophic (predator/prey) relationships. My recommendation is that the ecosystem dynamics simulated by AQUATOX be constrained or disabled so that predator-prey interactions in the food web remain consistent with data from other similar ecosystems, the literature, and applicable site-specific gut content studies, and that data should be collected to validate the trophic pathways in the food web model. **A/DC**

AQUATOX Model Description

@I am quite familiar with AQUATOX and the contaminant-specific research it incorporates, yet I found the model description in the MFD baffling at times. Examples:

- AQUATOX mass balance equations account for contaminant transfer associated with deposition and erosion, but apparently not pore water diffusion nor groundwater infiltration. Is this correct? These may be significant processes for sediment-water contaminant exchange under low flow conditions.
- Does AQUATOX not account for accumulation of DOC in sediment pore water as a result of detrital carbon decomposition? This differs from several other diagenesis models I have reviewed, where detrital carbon undergoes transformation to DOC as well as CO_2.
- Are inorganic solids (D1, D2 and D3) treated as state variables in AQUATOX? Do they adsorb PCBs? Is this based on assuming an organic carbon content?
- I am not sure why AQUATOX calculates non-equlibrium partition coefficients for invertebrates (eqn. 53) and fish (eqn. 54). Is this done to address slow biphasic chemical elimination? Otherwise, it seems to make AQUATOX inconsistent with other bioaccumulation models for invertebrates (Morrison, Landrum) and fish (Gobas, Thomann). Why not calculate equilibrium partition coefficients from organism lipid content?
- Doesn't AQUATOX use a better calculation of respiration rate (species-specific bioenergetic) than the allometric cited from Thomann?

I recommend that this section of the MFD (Appendix D) as well as the QAPP be revised, to make it easier to understand how AQUATOX is being applied in the Housatonic River. **A**

@Other Comments and Recommendations for AQUATOX

- A whole literature exists of correlations for K_{oc} (KOM in equations 49 and 50). For the sake of consistency, it would be worth considering results from studies where K_{oc} was determined simultaneously for both particulate and dissolved organic carbon phases, such as Eadie et al. (Chemosphere, 1990).

- Elimination rates (equation 82): There has been much good elimination rate data published for PCBs and other HOCs. Data from Sijm and van der Linde (1995), de Boer et al. (1994), and Sijm et al. (1992) should be added to the training set for this regression.

- Regarding the use of Swackhamer et al.'s kinetic model for phytoplankton bioaccumulation, it would be worthwhile to update AQUATOX to reflect the use of organic carbon as the sorbing matrix instead of lipid (Skoglund and Swackhamer, ES&T, 1999). Also, the exposure time and growth rate parameters in that model should be coupled to the relevant variables in AQUATOX. Of course, the phytoplankton BAF predictions must themselves be validated to data.

- Heather Morrison's steady-state model should be considered for modeling invertebrates; it appears to do about the best job in matching the BAFs and BSAFs observed for PCB congeners. **A**

AQUATOX Sorption Kinetics

@AQUATOX incorporates a kinetic model for sediment partitioning, as opposed to the equilibrium partitioning model used in most contaminant transport and fate models. The limitations of the equilibrium partitioning assumption for modeling hydrophobic organic chemicals have been discussed extensively in the literature, and have been demonstrated via model simulations (Lick et al., 1997; Song et al., 1977), yet the assumption remains popular for a number of reasons. First, it greatly simplifies and speeds the solution of the mass continuity equations in the model. Second, it requires only the measurement of "standard" water quality measurements for parameterization. And third, no generally-accepted kinetic model has emerged from 20 years of process experimentation and modeling. The kinetic model used in AQUATOX is Karickhoff's reversible 2-compartment model. This model considers desorption as occurring simultaneously from slow and rapid sorbent sites, each characterized by first-order kinetics. Whether this approach is any better than equilibrium partitioning (or simple modifications to equilibrium partitioning; for example, QEA's Hudson River model) is debatable, and should be tested in the model. As noted by Wu and Gschwend (1986 and 1988), desorption rate constants are NOT constant over the duration of the desorption process, a complexity arising from the distribution of particle sizes in suspended solids, as well as from non-uniform sorbate concentrations (Gong and DePinto, 1988). Currently, most process modelers seem to prefer distributed parameter or heterogeneous radial diffusion models. Incorporation of such kinetic models is well beyond the capabilities of AQUATOX, as it requires high spatial and temporal resolution, treatment of sediment hysteresis, and solution of stiff partial differential equations.

There also appears to be an error in Equation 66, the estimate of desorption rate k_2. Using a K_p value appropriate for hexachlorobiphenyl, I get a desorption rate of 10^{-5}/d. This contrasts with desorption rates of 0.1/d (Song et al., 1997) and 0.05/d (Lick et al., 1997). Maybe Equation 66 estimates desorption rates in units of seconds^{-1}? Otherwise the difference is too great to reconcile. **A/PCB**

EFDC Model Description

@Process representation for PCB transport/fate in EFDC are overly-simplistic, both in relation to "state of the art" and the partitioning representations in AQUATOX. Simple EFDC process representations seems inappropriate, for example lumped first-order loss rates and the lack of 3-phase partitioning. **E/PCB**

<u>Modeling Framework: EFDC (Abiotic) vs. AQUATOX (Biotic) Components</u>

@Separation of biotic and abiotic components of PCB transport and fate is a potentially significant weakness. This separation is artificial, and appears to be motivated by the selection of models that (without modification) are not truly appropriate for this application. There is no such thing as biotic and abiotic PCBs, per se. This creeps into the description of EFDC, for example:

> EFDC will model abiotic components and AQUATOX will model both biotic and abiotic components.
>
> This code modification (to EFDC) will allow, for example, the capability to define seasonal and spatial differences in the organic carbon fraction of each solids class to account for winter-summer differences in phytoplantkon that are included as a component of field measurements of grain size distributions, TSS and POC. Specific modeling of volatilization and microbial degradation in EFDC is not envisioned other than as lumped first-order rates.

This separation is not as clean a separation of processes as, for example, transport/fate vs. bioaccumulation, which has been successfully applied in PCB models for the Hudson River and Green Bay/Fox River. Using separate programs to model abiotic and biotic transport and fate processes is untested; success of this approach has not been demonstrated.

I think there are a number of alternatives to the PCB transport and fate model that should be considered by the modeling team. These include:

- Modeling all PCB transport/fate in EDFC, which would appear to require only the incorporation of a 3-phase organic carbon equilibrium partitioning model.
- Choose an alternative model which can simulate both biotic and abiotic processes;

Likewise, there are viable alternatives for modeling PCB bioaccumulation:

- Model only PCB bioaccumulation in AQUATOX (the only "biotic" PCB transport and fate processes unique to AQUATOX are sorption kinetics and accumulation by periphyton and macrophytes, neither of which have been demonstrated to be of significance in the Housatonic River application)
- Choose an alternative food web bioaccumulation model more consistent with this engineering application.

I expect that the effort necessary to develop an alternative modeling framework (based, for example, on EFDC and AQUATOX) would probably be less than that proposed for handling the complex linkages that are required by the framework described in the MFD. **A/E/PCB**

Model Framework Linkages

@The model linkages between solids and organic carbon sorbent state variables, are a potential weakness of the modeling framework design, and potentially a significant source of error. While these linkages do solve the problem of incompatible state variable definitions between models, there are a number of problems which are not adequately addressed in the MFD:

- Several of the linkages may not conserve mass
- Several of the linkages are based on empirical relationships, which may be only weakly predictive

The key requirement for the model linkage is the necessity to maintain a careful mass balance of flow and constituent loads between HSPF, EFDC and AQUATOX.

State variable linkages for solids/sorbents between models are complex procedures (models, in effect): grain size vs. organic/inorganic particle states, BOD vs. POC, etc. "Linked" state variables (example: organic carbon sorbents) must be calibrated/confirmed like other predicted state variables. The intricacy of several of these linkages may lead to a great deal of effort and potential for errors. Is the empirical approach for establishing linkages good enough to use in a quantitative modeling framework? Seems like this has not been addressed, yet it may be significant in overall uncertainty of modeling. Such linkages have apparently been applied in the past in conjunction with HSPF; hopefully, this would provide some basis for discussion in the MFD. **L**

@A related concern is how deposition and resuspension velocities are aggregated in both space and time (QAPP 4.9.3.6). In particular, it is not clear how the aggregation scheme will handle erosion and deposition occurring within the same averaging period and/or aggregated segment. Will the individual (gross) deposition and resuspension velocities be averaged separately for transfer to AQUATOX, or will net particle velocity (deposition - resuspension) be averaged/transferred? This detail of the aggregation and linkage schemes must be properly designed to ensure that the correct interaction of sediment and suspended solids in AQUATOX. **L**

Data linkages from EFDC to AQUATOX

@The QAPP goes through the state variable linkages in some detail, which is good. However, some further clarification is necessary:

- Equations 4-3 and 4-4: How good are the spatially- and temporally-dependent estimates of TOC:TSS? Don't you really want the POC:TSS ratios? **AD**
- @Equation 4-3: Shouldn't the TOC:TSS ratios be different for each PIM size class? **AD**
-
- @PIM export/import: From this I assume that AQUATOX must partition PCBs onto PIM? I could not confirm this from the documentation. How are these partition coefficients determined, since by definition these particles have no organic carbon content? **A/PCB**
- @POM deposition/resuspension: Cohesive solids deposition and resuspension velocities are applicable to the POM associated with fine-grained cohesive solids; they would not for phytoplankton (unless river phyto are much smaller than diatoms). Is POM a state variable independent of phytoplankton? Again, this is something I could not confirm in the AQUATOX documentation **A/E**

@While the description of EFDM-AQUATOX linkages in the QAPP(4.9.3) refers to erosion and deposition fluxes, in fact it is vertical particle velocities which are linked (?). **L**

<u>Data linkages from HSPF to AQUATOX</u>

Similarly, there is need for clarification in the QAPP regarding these linkages:

- @Equations 4-8 and 4-9: Is there an error in these equations (what happened to BOD)?

From the mingling of model state variables and data I cannot tell, but I suspect these linkages do not conserve mass. If so, doesn't this violate an objective of the MFD? Regardless, POC and DOC boundary conditions must be calibrated and validated as predicted states. **L**

<u>Model Uncertainty Analyses</u>

@There is some discussion of uncertainty analysis in the AQUATOX description. To be useful in the context of the linked modeling framework, however, such analyses must consider all aspects of the transport, fate, and bioaccumulation simulation, including uncertainty in external forcing functions and state variable linkages. Model uncertainty should be addressed by a combination of:

- Monte Carlo analysis; preliminary, similar to sensitivity analysis (AQUATOX description makes use of too few realizations to be quantitative)
- Bayesian Monte Carlo; informative parameter distributions based on calibration (may be computationally intensive for dynamic simulations)
- Alternative bounding calibrations (although this approach can be abused by subjective application) **U**

2. Based upon the technical judgment of the Peer Review Panel:

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?***

@Complete and accurate loadings of solids, organic carbon, and especially PCBs is probably the most critical factor in the success of the mass balance models. HSPF is not suitable (unless confirmed) for prediction of upstream PCB loadings. The modeling team apparently agrees, and has chosen to use PCB loading estimates based upon conventional regression models instead. This is the most suitable and accepted method for representing contaminant loadings, assuming that the necessary flow-weighted sampling has been conducted. This, of course, should be reflected in revision of the MFD. **H**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

@It is unclear whether the proposed linkage will correctly predict the net transport of PCBs from the river to the flood plain. In their presentation, QEA showed results of mass balance analyses suggesting that the magnitude of this interaction could be estimated based on PCB concentrations measured in the river during floods. Such estimates would at least constrain the PCB transport interactions between the floodplains and the river. **FC/CMD**

c. ***Are the models adequate for describing the impacts of rare flood events?***

@Other models, based on the same tau-epsilon resuspension relationships, have been demonstrated to accurately describe sediment transport impacts of flood events (excluding bank slumping, overbank flow, and small-scale bed features). However, model adequacy must be demonstrated in each system due to great variability. I am not sure that the magnitude of the flow events sampled in 1999 is large enough for such demonstration; data is available for one 2-5 year flood. Obviously, data for a larger event would be valuable, and such monitoring should be considered if possible. **RF/DC**

@It is not clear how the resuspension data provided in the Gailani et al. (September 2000) report will be used to generate the spatially-distributed resuspension properties required to model the sediment bed of the river and pond. The report points out that considerable variation of sediment bulk properties and erosion rates were observed above Woods Pond, and that further effort would be required to develop a sediment mapping of these properties and test them with a sediment transport model. This recommendation should be pursued, in order to develop a complete data set for resuspension properties. How well this is done may determine the success or failure of the sediment transport simulation. **SF**

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

@The question is poorly posed. Food web bioaccumulation models can simulate PCB accumulation via sediment and water exposure routes, given appropriate information regarding diet. See comments regarding AQUATOX food web simulation under Question 1. **A**

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

Spatial Resolution of Models

@The spatial segmentation of the water column in AQUATOX appears reasonable, but the same segmentation applied to the surficial sediment bed may be too coarse. Cursory examination of the sediment PCB distribution maps, indicates that concentrations deviate in a systematic manner between mid-channel and near-shore regimes, longitudinally within subreaches, and with depth and location within Woods Pond. This suggests that additional sediment segmentation may be warranted. The relationship between erosion and deposition regimes as predicted by sediment transport model, and the AQUATOX sediment segmentation should also be considered. If not, then AQUATOX may erroneously associate low (or high) PCB concentrations with sediments being resuspended from a particular EFDM sediment segment. **MD/GS**

@MFD does not adequately consider how long-term hindcast and forecast predictions will be constructed, although these issues are critical to the outcome (Gailani et al., 1996; Velleux and Endicott, 1996). Usually modelers don't think about this until model calibration/verification is complete; it is generally too late then!

Another issue to consider is the methodology for long-term validation:

> Following calibration of the models using data from 1991-2000, the models will then be validated by assigning initial conditions based on data sets collected during 1979-1980. Model validation will be based on a long-term simulation beginning in 1979 and ending in 1990. The long-term

> simulation from 1979-1990 is intended to provide validation of the models with an independent data set. Continuation of the validation period of the simulation through 1991-2000 then provides an additional rigorous test of the predictive capability of the models using a continuous simulation against data available within a 20-year period. If the models can successfully reproduce the observed data sets over a 20-year period, then the credibility of the model for projecting the potential impacts of alternative remedial action scenarios >50 year decadal time scales will be greatly enhanced.

A reasonable approach. One question about this: What is the contingency plan in the event that the long-term hindcast fails to validate the models? How and where will corrective action take place? **V**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

@There are various possible process representations for PCB transport and fate, which vary in terms of complexity and theoretical rigor. However, most models have adopted representations which are consistent with conventional principles: organic carbon-based equilibrium partitioning in both particulate and dissolved phases, two-film resistance volatization using temperature-dependent Henry's constants, a well-mixed surficial sediment layer, reductive dehalogenation of specific congeners above a saturation concentration, and molecular diffusion from pore water. As previously noted, assumptions of equilibrium partitioning when applied to PCB desorption from resuspended sediments is a potentially significant weakness of most models.

Models of PCB transport and fate, and underlying theory, are not sufficiently robust that parameter values determined a priori can account for all of the site-specific variability that is observed in critical model parameters. This is not a weakness of the models specifically, rather an acknowledgment that all transport and fate models are imperfect representations of chemical behavior in an extremely complex system.

In terms of PCB transport and fate, the issues of resolution and processes in questions 3 and 4 can best be addressed by taking advantage of the redundancy offered by EFDM and AQUATOX. It seems likely that EFDC and AQUATOX predictions of water and sediment concentrations will diverge. This will result from differences in spatial/temporal resolution, and from differences in the transport/fate processes (and their formulation) included in each simulation. Since these models are using different process descriptions, applied at different resolutions, to model the same PCB mass balance, a comparison of their predictions offers an objective test. Do the predictions agree? Why or why not? Which model performs better? It is extremely important to understand both the magnitude of divergence in predictions and their underlying causes. The same PCB state variable needs to be run in both models, however, something the MFD fails to define:

> Since only selected congeners will be simulated, AQUATOX will not simulate total PCBs and the results generated by AQUATOX will not be compared to field observations of total PCBs.

I think it is very important that both EFDC and AQUATOX model at least one consistent PCB state variable. Also, note the importance of verifying constant congener distribution; if distribution varies, chemical parameters for total PCB will not be constant. **PCB/A/E**

Sediment Mixing and Diffusion Processes

@In all reviews of sediment mixing processes I have seen, bioturbation is primarily attributed to the activities of benthic invertebrates. Benthic feeding by fish is mentioned by several authors as a possible mixing mechanism, but the extent and intensity of this factor over time is highly uncertain. Attempting to relate sediment mixing to observed carp feeding is tenuous at best. In fact I suspect that the cause of bioturbation really doesn't matter, as in any case the process is parameterized in the models as the depth of the surficial mixed layer, "background" resuspension, and lumped pore water diffusion. Some additional consideration should be given to the 15 cm mixed depth: what is the rationale for this value? Can it be independently confirmed? **AL**

@On the other hand, there appear to be inconsistencies in the MFD and the model documentation, regarding how molecular diffusion, bioturbation, and groundwater infiltration/percolation are represented in the transport/fate models. Are these modeled as distinct processes, or are they limped into a single transport term? **E**

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

I believe that the modeling team is well aware of the data required for model calibration and verification. My only comment specific to this question, is that the description of AQUATOX somewhat trivializes the importance of site-specific calibration.

Calibration and Verification of AQUATOX

@Considerable effort is required to calibrate partitioning, particle transport, and especially bioaccumulation processes in a PCB transport and fate model. The parameterization and empirical relationships used to estimate parameter values, as presented in the AQUATOX documentation, should be viewed as prior estimates which are then updated through the calibration process. “Little calibration will be necessary for ecosystem variables in AQUATOX” conflicts with my own experience. Models of PCB transport and fate, and underlying theory, are not sufficiently robust that parameter vaulues determined *a priori* can account for all of the site-specific variability that is observed in critical model parameters. This is not a weakness of AQUATOX specifically, rather an acknowlegement that all transport and fate models are imperfect representations of chemical behavior in an extremely complex system. Statements that little calibration will be necessary in either Woods Pond or upstream river reaches seem unlikely. River systems impacted by in-place pollutants are challenging at the least, as demonstrated by efforts to model PCB dynamics in the upper Hudson River and the Fox River.

AQUATOX makes use of a variety of chemical parameter correlations based upon the octanol-water partition coefficient (equations 49-54, 69-70, 72, 75, 78, 82). These correlations are commonly used to generalize laboratory or field observations of hydrophobic organic chemical parameters, usually under specific controlled or site-specific conditions. As such, they are an acceptable means of generating initial (prior) estimates of chemical parameters for transport, fate and bioaccumulation models. However, adjustment of these estimates is usually necessary as part of the model calibration process; if the data available for validation is suitably constraining, adjustment is almost inevitable. It is not clear from the model description whether AQUATOX allows ready calibration of these parameters, or whether such calibration is anticipated by the modeling team.

I am also somewhat concerned that calibration and validation of bioaccumulation predictions in AQUATOX depend primarily upon predictions of PCB concentrations at the top of the food chain:

> The final confirmation will be in the ability to simulate the observed PCB concentrations in the key fish species.
>
> The test of the validity of this approach will be how effects from the lower food web are integrated into the predicted fish concentrations, for which there is a substantial data set.

This may leave important aspects of the bioaccumulation predictions at lower trophic levels untested and unconstrained, including those which resolve sediment versus water column contaminant exposure and tropic accumulation pathways. I would prefer that calibration and validation consider predictions at all trophic levels to be important, as this would better constrain the model. **A/PCB**

@Data should be collected to validate the trophic pathways in the food web model. This was not done because:

Labor-intensive gut analyses and studies of depth of disturbance over seasons was clearly beyond the scope of this site investigation.

I tend to question this, given the extent of soil and sediment sampling performed for this study. **AD**

Sediment PCB Data Analysis and Use in Models

@What is most striking to me about the maps of PCB distribution in soil and sediment, are the high concentrations (and presumably mass) of PCBs in the river banks. Given what I presume to be this enormous inventory of PCBs in direct proximity to the river, I wonder whether bank erosion might not represent a worse-case scenario for PCB transport and exposure. As I understand it, erosion and slumping of the river bank cannot be resolved or represented in the sediment transport model? Some consideration should be given to how such an event could be simulated. **BSE**

@Aggregation of sediment PCB data should be based on :

- organic carbon normalization;
- deposition regime of sampling location;
- as well as river mile and grain size factors, which were discussed.**CMD**

@The methodology for determining initial conditions for PCB sediment concentrations in 1979, for the hindcast verification, should be discussed. The first sediment PCB measurements were made in 1979-80. Are these data comparable to current measurements, in terms of sampling resolution and analytical methods? If not, won't bias in specification of initial conditions for the hindcast be a problem for long-term validation? **V**

PCB Partitioning

@Use of Kp, when you mean Koc, is a pain. Greater consistency would improve the document. The prevalent usage of PCB data normalized to dry weight in sediment is inconsistent with the models, which are representing partitioning to organic carbon/matter.

Inconsistencies in the partitioning data presented in the MFD strongly suggest that additional data be collected to support calibration of PCB partition coefficients in water (including seasonality & range of POC values) and sediment. The modeling team should also look at the range of partition coefficients obtained using a 3-phase (dissolved/POC/DOC) partitioning calculation, to see whether such a model is capable of simulating the range of observed partition coefficients.

The following are two tables with some selected values for PCB partition coefficients in sediment and water. These could be greatly expanded, if desired. The point is that by comparing the range of these values to partition coefficients measured in the Housatonic River, some judgements can be made regarding their quality and representativeness.

PCB partition coefficients measured in sediment

literature source	log K_d	log K_{poc}	log K_{doc}
Di Toro et al. (ES&T, 1985)	5.1	6.6 (cites range of field data as 4.2 - 6)	
Hunchak-Kariouk et al. (ES&T, 1997)		4.6	4.7 - 5.6
Brownawell and Farrington (Geochimica..., 1986)	3 - 4.4		
Velleux and Endicott (JGLR, 1994)		6.35	5.35
QEA (Hudson River, 1999)		5.6 (reversibly sorbed PCBs)	

PCB partition coefficients measured in water column

literature source	log K_d	log K_{poc}	log K_{doc}
Eadie et al. (Chemosphere, 1990)		5.8	3.9
Velleux and Endicott (JGLR, 1994)		6.35	4.35
QEA (Hudson River, 1999)		5.6 - 6.3	

Regarding the low values of sediment Kp, I intended to look at the range of partition coefficients obtained using a 3-phase (dissolved/POC/DOC) partitioning calculation, but then I ran out of time. **PCB/DC**

@The issue of whether phase separation of sediment samples has been done by filtration or centrifugation remains. The response to Peer Review comments says:

Most of the samples were centrifuged to collect the pore water, a procedure recognized as leaving organic material in the suspended phase.

However, this conflicts with the memos provided from Rich DiNitto, which indicate that filtration predominated. **AD**

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

@The available data, and data collection planned by EPA, are generally consistent with the information required to develop the PCB transport, fate, and bioaccumulation models. There is not an abundance of data for PCBs in the water column or biota, however, and there appear to be some problems with the quality of dissolved PCB measurements. Several other specific weaknesses are evident:

- Data to support empirical state variable linkages - The model linkages for solids and organic carbon states depend upon many observations from which correlations must be constructed. From what I have seen (scatter plots of all TSS and TOC data), the data may not be available to support this approach.
- Loading data
- Partition coefficients
- Diet data to define trophic interactions and benthic/pelagic pathways
- Spatial and seasonal variability of PCB concentrations in plankton and benthos
- Sediment mixed layer thickness **AD/DC**

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

@Some much-needed clarity would be gained by changing some of the nomenclature used in the MFD and QAPP. The best examples I can identify are:

Historical PCB sources- replace with "in-place PCBs"
Partition coefficients- Use of Kp, when you mean Koc, is a pain.
(Greater consistency would improve the document.) **MISC**

@EMFD should make better use of long-term data when developing the conceptual model and identifying important processes. For example, use the GE YOY fish PCB data and 1979-80 sediment PCB data to show changes in PCB concentrations over time. Analysis of long-term data is helpful to determine whether PCB dynamics are controlled by internal (sediment inventory) vs. external (loadings, events) factors. This exclusion from the MFD is unfortunate. **CMD**

Aquatic Biological Conceptual Model description is good; quite complete treatment for lower trophic levels.

@Lack of specification of model grid and process selection/representation are weaknesses of the MFD. **CMP/GS**

@The MFD does not address how HSPF will predict past PCB loadings for long-term confirmation (hindcast) simulations, nor does it address how remedial action in the Rest-of-River study area will be represented in the different models. **H/R**

@QAPP: Tandem application of AQUATOX and EFDM is not presented in QAPP Section 4.8. Specific comparisons (QAPP, 4.7.1) are not defined: what spatial and temporal resolution; how will data be aggregated? What is the objective of this comparison? **MD/L**

IV. Concluding Comments

Clarification of transcript exchange with Dr. Lick regarding Question 4 (i.e., rigor):

When I commented that there was little "rigor" in the equilibrium partitioning calculation for PCBs and other hydrophobic organic chemicals (HOCs), I was referring to the analogy that is made between n-octanol, organic carbon, and lipid phases. Although it can be argued and is, in fact, often observed that chemical partitioning from water into octanol approximates the partitioning of that chemical into organic carbon and lipid, by definition an approximation is not "rigorous". So when a model is filled with estimates of equilibrium partitioning (to sediment, plankton, fish, etc.) that are based on correlations to the octanol-water partition coefficient, these estimates are not rigorous either. According to Thomann et al. (1992):

> Partitioning of organic chemicals into aquatic organisms is governed *to first order* by the lipid pool of the organism.

and:

> The tendency for organic chemicals to partition into lipid and organic carbon pools is *broadly represented* by the octanol/water partition coefficient ... *to first approximation*, the preference for chemicals to partition to octanol, lipid, and organic carbon is considered identical.

The analogy between octanol, organic carbon, and lipid is an extremely powerful approximation for models of HOC transpor, fate, and bioaccumulation. Claims as to it's rigor are questionable, however.

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APPENDIX A.4

COMMENTS OF MARCELO H. GARCIA

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

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June 12, 2001

RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

The proposed Modeling Framework Design (MFD) is a very well prepared document that provides a very good foundation for a major undertaking: Modeling of PCB Contamination in the Housatonic River.

The intent of this response is to point out some of the potential problems that the reviewer has found mainly with some of the modeling approaches proposed in the MFD. At the same time, many references are provided in the response so that the modeling team should be able to enhance the capabilities of the hydrodynamic and sediment transport models to be used for the Housatonic River.

The problem at hand is very complex and the project goals are very ambitious. However, this is a great opportunity to learn about the dynamics of contaminated sediments. Thus the imperative need to use the best tools available and to develop those that are needed but do not currently exist.

@On a more personal note, this reviewer feels that the evaluation of the MFD would have been facilitated if the members of the review panel had been able to communicate directly with the modeling teams. The possibility of discussing different issues directly with the modelers would have been very beneficial in many ways, in particular, the expertise provided by the review panel would have been used to its fullest extent. **PR**

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. ***Modeling Framework and Data Needs***

1. ***Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?***

@The modeling framework proposed by EPA does include most of the significant processes that need to be accounted for in order to model PCB transport and fate in the Housatonic River. However, several processes such as floodplain sedimentation, erosion, transport, and deposition of sediment mixtures, streambank erosion, lateral stream migration and associated morphological changes, and flow through vegetated channels are not well formulated under the current framework and lack the level of understanding needed in an effort of this magnitude. At this stage, the proposed modeling framework is adequate to model PCB transport and fate, but provides only a reasonable starting point and should not be considered as the most accurate way for predicting the dynamics of PCBs in the Housatonic River. **CMP**

2. Based upon the technical judgment of the Peer Review Panel:

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?***

The modeling approaches proposed to represent external forcing functions and boundary conditions, are well suited. @Perhaps less clear is the issue of how far upstream should the modeling start. There would be some very clear advantages if the modeling were extended further upstream, in particular for the evaluation of future remediation activities. **MD/R**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

@Not in their present stage. The dynamics of sediments in floodplains is very poorly understood, in particular the role of vegetation on trapping sediments and associated pollutants. Simply increasing roughness coefficients will not tell much about the fate and transport of PCB in woody areas commonly found in the floodplain of the Housatonic River. A useful reference on this topic is Lopez F. and Garcia, M., "Open-Channel Flow Through Simulated Vegetation: Suspended Sediment Transport Modeling," Water Resources Research, vol. 34, No9, p. 2341-2352, 1998. **FV**

@Most numerical problems are encountered in the transition from inbank to overbank flow conditions. A good set of experiments to test the numerical model, including also vegetation effects, can be found in the following reference: James, C.S., et al., "Conveyance of meandering channels with marginal vegetation," Water and Maritime Eng., Proc. of the Institution of Civil Engineers, 97-106, vol. 148, issue 2, June 2001. An excellent set of data to test the hydrodynamic model can also be found in: Shiono, K., and Muto, Y., "Complex flow mechanisms in compound meandering channels with overbank flow," Journal of Fluid Mechanics, vol. 376, pp. 221-261, 1998. **FC**

c. ***Are the models adequate for describing the impacts of rare flood events?***

@The hydrodynamic model might be capable of predicting flood routing through the Housatonic River. However, sediment resuspension and transport during floods can be substantially different from normal flow conditions. The hydrologic record indicates that sediment transport in the Housatonic River is mainly driven by storm events. The proposed models do not account for the lag effects and adaptation lengths commonly observed for suspended sediment transport by unsteady flows. A useful reference is Admiraal, D. et al., "Entrainment Response of Bed Sediment to Time-Varying Flows," Water Resources Research, vol. 36, No1, p. 335-348, 2000.

During large floods, water levels could be determined first with a 1-D model such as the one commonly used by the National Weather Service, and this information could then be used to test the overall predictive capabilities of a 2-D model. **RF**

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

@The models would seem adequate to discriminate between water related and sediment-bound sources of PCBs. However, sediment itself could have an impact on habitat regardless of whether or not its laden with PCB (Huang, X., and Garcia, M., "Pollution of Gravel Spawning Grounds by Deposition of Suspended Sediment," Journal of Environmental Engineering, vol. 126, No. 10, October, 2000). **MISC**

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

@The challenge for this modeling effort is that time and space scales are quite different depending on what process is to be modeled. For example, most streambank erosion takes place during and right after floods associated with storm events. So the time scale here can extend from a couple of hours to a few days, depending on the duration of the hydrologic event responsible for the flood. While overbank flows will take place during a flood as well, sediment deposition and accumulation on the floodplain will take place over time scales that are much longer, on the order of several years. Thus the need to determine very clearly what are the spatial (i.e. local erosion or watershed-scale erosion) and temporal scales (i.e. sediment transport event or natural recovery) being addressed by the modeling effort. This issue is not clearly addressed in the proposed modeling framework. **GS/BSE/TS**

@Of particular relevance will be the numerical grid size and type (e.g. curvilinear, rectangular) used to model the main channel and the flood plain of the Housatonic River. For flows up to bankfull, I would be in favor of using EFDC with curvilinear coordinates. EFDC seems capable of reproducing secondary flows induced by stream meandering, and would also give a good approximation of near bank flow velocities to compute fluvial erosion. Momentum transfer by secondary flows to the banks plays a major role on streambank erosion. For overbank flow conditions, the use of a rectangular grid throughout the river channel and floodplain would be a wise approach. I would strongly recommend against the use of the computational grid proposed in page 54 of the EPA Response to Peer Review Panelist Questions (April 12, 2001). The challenge still remains for the modeling of moderate floods, when the flow of water through the floodplain is not very different from that in the main channel. **GS/FC**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

@It is adequate but far from complete. The references provided above could shed some light for the development of more sound algorithms. I am particularly worried about the fact that sediment transport algorithms developed for bedload and suspended transport of uniform-size sediments (e.g. Van Rijn) are being considered to model sediment transport and fate in a river system with a broad range of sizes such as the Housatonic. Two useful references about existing formulations that could be used for modeling purposes are: Garcia, M.H., "Modeling Sediment Entrainment into Suspension, Transport and Deposition in Rivers," Chapt. 15, in Model Validation: Perspectives in Hydrological Science, Edited by M.G. Anderson and P.D. Bates, John Wiley & Sons, Ltd., 2001. For a compendium of different approaches see also: Garcia, M.H., "Sedimentation and Erosion Hydraulics" Chapter 6 in Hydraulic Design Handbook, Edited by Larry W. Mays, McGraw-Hill, 113 pages, 1999. **E**

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

@The data already available should be useful for the calibration of the models. However, I am concerned about the use of models calibrated with short-term observations to predict long-term transport and fate of PCBs in the Housatonic River. However in the absence of more data, there are not many options to pursue other than to try to generate synthetic time series for a range of model input parameters and boundary conditions, with the goal of generating model outputs of statistical significance. Such exercise could be done by performing Monte Carlo simulations that would hopefully shed some light on the behavior of the reach of the Housatonic River being modeled, thus facilitating any future predictions of PCBs transport and fate. This undertaking should be done very carefully while being aware of the models limitations and shortcomings. Uncertainties and risks associated with model predictions should be clearly stated by the modeling team. There are tools available in the literature to help with this (e.g. Lopez and Garcia, "Risk of Sediment Erosion and Suspension in Turbulent Flows," Journal of Hydraulic Engineering, vol. 127, No3, March, 2001). The Quality Assurance Project Plan (QAPP) seems to have several provisions in place to ensure that the uncertainties associated with the modeling predictions as well as the data are clearly noted. **U/S**

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

@The available data seems adequate for the development of a model for predictive purposes. One concern is the lack of any information about streambank erosion data and how this will be modeled without such data (i.e. erodibility properties of streambanks). Aerial photographs taken several years apart could be analyzed to determine streambank erosion rates and the location of potential meander cut-offs. A meandering stream model developed for Illinois streams in the 1990's has shown that sediment resulting from bank erosion can be a major source of pollution to streams (Garcia et al., "Mathematical Modeling of Meandering Streams in Illinois: a tool from stream management and engineering," Civil Engineering Studies, Hydraulic Engineering Series No43, UILU-ENG-94-2012, University of Illinois, November 1996). **BSE**

@It would be particularly useful to find out if there are bathymetric data for Woods Pond as well as dredging records. This information could in turn be used to assess a mean annual sediment load for the Housatonic River upstream of Woods Pond. These data could then be used to assess if the hydrodynamic and sediment transport models can predict sediment loads, before using them to predict PCB transport and fate. **AD**

@Another data analysis that would be useful, is the development of sediment load rating curves for the Housatonic River. These curves could be very helpful to corroborate the predictions made by the hydrodynamic and sediment transport models, and could also be used to set boundary conditions. **CMD**

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

The MFD is not very specific about streambank erosion and this is a very important component for the modeling of PCBs transport and fate in the Housatonic. In what follows, some comments and guidelines are provided so that if desired the MFD could be improved.

@Processes of bank retreat and advance may occur together or separately at different locations and times along the same reach of the Housatonic River. Modeled rates of bank advance and retreat on both banks at a single section determine the rate of width adjustment.

Fluvially controlled processes of bank retreat are essentially twofold. Fluvial shear erosion of bank materials results in progressive incremental bank retreat. Additionally, increases in bank height due to near-bank bed degradations or increases in bank steepness due to fluvial erosion of the lower bank may act alone or together to decrease the stability of the bank with respect to mass failure. Bank collapse may lead to rapid, episodic retreat of the bankline. Depending on the constraints of the bank material properties and the geometry of the bank profile, banks may fail by any one of several possible mechanisms (Thorne 1982), including planar- [e.g., Lohnes and Handy (1968)], rotational- [e.g., Bishop (1955)], and cantilever- [e.g. Thorne and Tovey (1981)] type failures. A separate analysis would be required for analysis of bank stability with respect to each type of failure.

Nonfluvially controlled mechanisms of bank retreat include the effects of wave wash, trampling and grazing by livestock, as well as piping- and sapping-type failures [e.g., Hagerty (1991a,b) and Ullrich et al. (1986)] associated with stratified banks and adverse groundwater conditions.

For models of noncohesive bank erosion, hydraulic shear erosion of the banks is commonly simulated through application of the sediment transport model in the nearbank zone. Comparatively little is known about the mechanics of cohesive bank fluvial entrainment. Excess shear stress formulations are difficult to apply as the value of shear stress required to entrain the bank particles varies widely and is influenced by diverse processes (Grissinger 1982). For example, processes such as frost heave or dessication, which result in weakening of the intact material, may exert a more dominant control on observed rates of fluvial erosion than the intensity of the near-bank flow (Lawler 1986).

It is important to include a method in the MFD to predict the hydraulic shear erosion of cohesive bank materials in width adjustment modeling because erosion directly influences the rate of retreat of the banks and it also steepens the bank profiles and promotes retreat due to mass bank instability. These could contribute large amounts of contaminated sediments to the river. Approaches that exclude analysis of fluvial erosion of bank materials are, therefore, somewhat limited. Widening models that attempt to account for fluvial erosion of cohesive bank materials utilize empirically based methods, such as that of Arulanandan et al. (1980), which was reviewed extensively by Osman and Thorne (1988). Borah and Dashputre (1994) and Darby and Thorne (1996b) have, however, suggested that these methods are subject to some serious shortcomings. **BSE**

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IV. Concluding Comments

The MFD and QAPP for the Modeling Study of PCB contamination in the Housatonic River are both very well prepared documents. In particular, the MFD has a substantial amount of detail about the way numerical models will be used and the field data available to test and validate model predictions.

@Perhaps a more efficient way of preparing the MFD, would have been to determine first all the processes relevant to better understand the dynamics of PCBs in the Housatonic River, followed by a literature review to explore what models would be more suitable to accomplish the objectives of the project. This second intermediate step would have provided a better idea of the strengths and limitations of the different models available in the literature and would have pointed out gaps in knowledge (e.g. streambank erosion, floodplain sedimentation) that could eventually make any modeling predictions useless for the goals of the project. **CMP/MS**

Without doubt, there will be many challenges facing the modelers when they start the calibration and validation process. However, by maintaining a fluid dialogue with the review panel it should be possible to achieve the goals of the project.

APPENDIX A.5

COMMENTS OF WILBERT LICK

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

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May 17, 2001

RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

A quantitative model of the transport, fate and bioaccumulation of PCBs in the Housatonic River will be developed by EPA. This model and its predictions will be used by EPA, together with other information, in making decisions regarding potential remediation actions for river sediments and associated floodplain soils for a portion of the Housatonic River. This portion is from the confluence of the east and west branches of the Housatonic down to and including Woods Pond (hereafter called the model test section).

As is usual with models of this type, there will be a large number of parameters in the model that can not be determined a priori but will be determined by calibration or “fine tuning” of the model, i.e., by comparing computational results from the model with observed data and then varying parameters until the calculations and observations agree. In this way, the model (and all similar models) will be “successful” in that the results of model calculations eventually will compare favorably with observed data.

Unfortunately, models can be made to fit limited observational data in a number of ways, with a wide range of processes, and a wide range of parameters that govern these processes. Although a good comparison of calculated and observed data is necessary, it is not sufficient for remediation purposes.

@For scientists and users to have confidence in the model, especially sufficient confidence to make remediation decisions that require large amounts of money, time, and inconvenience to those on the river, it is necessary to have confidence in the submodels, i.e., to be sure they are describing the major processes accurately. As much as possible, the determination of parameters by calibration should be kept to a minimum. Parameters should be determined a priori on the basis of laboratory experiments or field tests. It is only in this way that confidence in the modeling results sufficient for remedial action will be developed. **C**

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. ***<u>Modeling Framework and Data Needs</u>***

1. ***Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?***

@The modeling framework described in the report includes three models: HSPF, EFDC, and Aquatox. Each of these models is very general and their descriptions include almost all conceivable processes that affect the hydrodynamics, sediment transport, and PCB transport, fate, and bioaccumulation in the Housatonic. Even if some processes have not been previously included in the models, the report indicates that additional processes will be considered, investigated, and possibly included at some future time.

However, including every possible process in a model does not make a good model; only the most significant processes should be included. Overly complex models are difficult to interpret and evaluate; too many parameters make calibration difficult and/or inaccurate. What is missing in the report is preliminary estimates of the significance (especially relative significance) of different processes. Once this is done, the most significant processes can be retained while processes with negligible influence can be ignored. This can usually be done without use of a complex model; simplified descriptions of the processes and estimates of the essential parameters are needed.

Although almost all significant processes are included in the models, the details of how these processes will be treated are missing. This is unfortunate, since "<u>The devil is in the details</u>". It is easy to say, for example, that cohesive sediments, bed load, suspended load, and bioturbation will be included in the model, but how are you going to do this? The details are missing and, I suspect, have not been considered thoroughly.

In a summary response to Question #1: (a) Almost all significant processes have been included in the model; (b) In fact, more processes than necessary have at least potentially been included and hence the model is overly complex; and (c) Detailed descriptions in the report of the process models are insufficient and inadequate. Some positive suggestions on how to improve this are given below. **CMP/CMD**

2. Based upon the technical judgment of the Peer Review Panel:

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?***

@HSPF seems to be suitable for predicting flows, solids, and probably PCB loadings before GE's remediation. It is not obvious that it is suitable after remediation without additional measurements and calibration because of changes in the 2-mile reach above the confluence. **R**

@There is insufficient information on initial sediment properties such as particle size, density, and erosion rates as a function of horizontal distribution. **AD**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

@At the meeting, it was mentioned that momentum was not conserved between the river and floodplain. This may be justified, but some estimates need to be given. Better yet, momentum should be conserved. **FC**

@Despite comments to the contrary, the coupling between EFDC and Aquatox seems to be overly complex, especially at the river-floodplain boundary. EFDC should be used to predict sediment and PCB transport throughout the river-floodplain system, while Aquatox (if necessary) should be used as a food chain model only.

Aquatox is an ecosystem model and presumably will predict changes with time of biomass and populations of species and in trophic levels as well as PCB transport and fate, both abiotic and biotic.

Abiotic transport and fate should be left to EFDC. Model linkages are too complex otherwise. Although Aquatox may be an excellent ecosystem model, predicting the time variation of species in the Housatonic River (with little or no supporting data) is difficult and potentially misleading. A much simpler food chain model should be sufficient. **A/E**

c. ***Are the models adequate for describing the impacts of rare flood events?***

@Rare flood events are probably the dominant cause of sediment and PCB transport and fate in the Housatonic. This is indicated by the distributions of sediments and PCBs in the river, large deposits on the floodplain, and large historical flows, which are larger by factors of 20 to 40 than average flows. Because of this, transport and fate during these big events must be described properly. **RF**

@In the report, the description of the models is inadequate to determine whether they can describe the impacts of rare flood events. There is no emphasis in the report on modeling big events or any details on how it will be done. This is unfortunate. **RF**

@In order to model big events accurately, fundamental information on sediment erosion rates as a function of sediment depth and shear stress is needed. The reasons for this are that (a) erosion rates change by orders of magnitude with depth and (b) there is a very nonlinear relation between erosion rates and shear stresses (which increase by large amounts during big events). Hypothesizing some functional forms for erosion and deposition and then obtaining the appropriate parameters by calibration is not sufficient (Tracy and Keane, 2000; appendix by Lick). Large errors can result from this procedure. Sedflume data is essential for determining erosion rates, and this data must then be properly incorporated into the transport model (see below). **SF/DC**

d. Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

@Various grids (both curvilinear and rectangular) with different spatial scales have been suggested. My comments here are primarily for the spatial grid of EFDC and the description of hydrodynamics, sediment transport, and PCB transport and fate in the river and its floodplain. Because of the very convoluted path of the Housatonic, a curvilinear grid is probably not the best choice because of singularities and small elements in the grid. A rectangular grid throughout (with coupled grids of different sizes) is probably the best choice.

Recent advances in sediment transport modeling along with the capability of obtaining erosion rate data from Sedflume have demonstrated that accurate and predictive modeling of sediment transport is possible. However, to take advantage of these improved models, a grid fine enough to distinguish and delineate features within the river (such as changing bathymetry and changing sediment types) is necessary. A grid on the order of 5 m within the river including banks and regions close to the river is necessary. This is where the action is!

Farther away from the river on the floodplain, a 20 or 40 m grid is probably sufficient. This assumes that the floodplain is primarily depositional and will not erode significantly even in large floods. Some estimates of the validity of this hypothesis are necessary by a combination of estimates of water velocities, shear stresses, and erosion rates during flooding.

I do not agree with GE's statement that they will use a 20 m grid in the river area. If this size grid is used, significant features and variations in the river will be obscured by averaging and, as GE acknowledged, more parameterization will be needed. As models become coarser and less realistic with more parameterization necessary, confidence in the model and its predictions decrease rapidly. The model can always be calibrated and hence "successful" but with a loss of confidence in the model.

This is not necessary and should be avoided. **GS**

@The above implies that a two-dimensional (vertically integrated), time-dependent model of the transport and fate of sediments and PCBs will be used. A one-dimensional, time-dependent model is insufficient based on extensive previous analyses by EPA, GE, and others (including myself). A three-dimensional, time-dependent model consumes much more development and computational time and is probably no more accurate in practice than a two-dimensional, time-dependent model (with a correction for quasi-equilibrium distribution of sediments in the vertical). This latter model is also much more computationally efficient. This has been shown in numerous cases. Even for the pond, a two-dimensional model is sufficiently accurate to predict sediment and PCB transport. As an example, see Wang et al (1996) where results of sediment transport calculations in Green Bay are compared for (a) a constant density, three-dimensional flow, (b) a vertically stratified, three-dimensional flow, and (c) a vertically integrated, two-dimensional flow. For all practical purposes, the results of the three cases are identical. This would be true for PCB transport also. **MS/E**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

@As stated above, the description in the report of the basic processes affecting sediment and PCB transport and fate is insufficient. Various suggestions to improve the modeling of sediment and PCB transport and fate are as follows.

It is assumed that any description of sediment transport will be based on Sedflume data, i.e., erosion rates as a function of shear stress and depth in the sediments, not just a critical shear stress as seems to be implied in the report.

With this assumption, additional Sedflume data beyond that already reported needs to be collected. This is especially necessary, (i) in river regions where sediment properties are changing rapidly, (ii) on the floodplains, and (iii) on the river banks.

As far as Sedflume data is concerned, it is desirable when collecting data to obtain erosion rate data near the original sediment water surface as accurately as possible, with a resolution of as little as 1 mm. The reason for this is that this is the region where resuspension/deposition occurs during low to moderate flows, and hence is also the region, which most influences any calibration/validation that is done. Accurate measurements of density variations with depth are also necessary for accuracy. This can be obtained by a density profiler using ^{137}Cs as a source and measuring the absorption of that radiation (Gotthard, 1998).

In general, for a valid sediment transport and fate model, the following needs to be included: (i) Sedflume data, (ii) multiple sediment size classes, (iii) inclusion and unified treatment of bed load and suspended load, and (iv) the effect of bed load on erosion rates, i.e., bed coarsening. For medium sediments, bed load is mostly important because it modifies surficial sediments by armoring and hence decreases erosion rates. For coarser sediments, bed load is an important transport process.

These processes and parameters have been recently included in sediment transport calculations and have been shown to be significant (Jones and Lick, 2001). This type of sediment dynamics, or equivalent, needs to be included in EFDC. **SF/DC/E**

With these improvements, an accurate and predictive description of sediment transport and fate in the river can be made. The extension to the floodplains (although never done previously) is probably also valid (with Sedflume data for the floodplains). @Bank erosion is more difficult. Little work has been done on this problem, but some reasonable estimates based on observations and simple theories can probably be made.

As far as formation or cut-offs of ox-bows during big events, I don't believe this has ever been modeled in detail, but I don't see why it can't. In big events, these ox-bows are probably underwater. The standard hydrodynamics and sediment dynamics models should be able to predict variations in bathymetry and topography under these circumstances. Since it's never been done before, it would take some effort, but it would be nice to try. **BSE**

@Settling speeds of sedimentary particles are modified by flocculation. The sizes of flocs and their settling speeds are functions of sediment concentration and fluid shear (Burban et al., 1989, 1990; Lick et al., 1993). If anything is to be done about settling speeds besides parameterization, settling speeds of flocs should be measured in the laboratory as functions of these quantities and the resulting parameters then introduced into the model. Measuring settling speeds of flocs as they are in the river, as indicated in the report, is insufficient since conditions and hence sizes and settling speeds of flocs change as a function of suspended sediment concentration and fluid shear, especially during big events during which measurements have not been made in the field. **DC**

@In order to accurately model PCB transport and fate, an average partition coefficient is not sufficient. Partition coefficients, K_p's, for PCBs vary widely, often from 10^2 to 10^6 or even more (see refs). A legitimate average over quantities that vary by orders of magnitude is hard to define. The value of K_p makes a difference in partitioning but also in transport. PCBs with low K_p's will generally be mostly dissolved in the overlying water and hence be transported out of the Housatonic test section in hours or days. PCBs with high K_p's will be absorbed to sediments in the overlying water and move with them as they are deposited, later resuspended and deposited, etc., or may be more or less permanently deposited on the bed and covered by other sediments. The transport out of the system, if it occurs at all, is much slower than the transport of water or PCBs with low K_p's.

This process is difficult to average. Worse, an average K_p from short-term observations and calibration will be much different from an average K_p needed to describe partitioning and transport over long time.

Time-dependent sorption of PCBs should also be included in the model since it has been shown to have a major effect (Chroneer et al., 1996). Differences of 2 to 5 have been demonstrated. Rates are known or can be estimated for PCBs with different K_p's, (e.g., Lick and Rapaka, 1996; Jepsen and Lick, 1999). However, because (i) K_p's for PCBs are sometimes not well known, (ii) sorption rates may also not be well known, and (iii) minimal modeling of this type has been done, maybe the inclusion of time-dependent sorption is too ambitious at this point.

However, the effects of time-dependent sorption should at least be estimated so that a better idea of the accuracy of the predictions can be made. **PCB**

@The major cause of PCB flux between sediments and overlying water is sediment resuspension and deposition and the subsequent absorption/desorption. However, other processes such as diffusion, bioturbation, pore-water convection (all modified by sorption) may be significant under certain circumstances, or may even be dominant under low flow conditions. Although each one of these processes has been investigated and modeled, the relative significance of each one of these processes is generally not known and the overall contaminant flux due to all of these processes has never been modeled. **CMP/PCB**

@Because of these difficulties, the contaminant flux (except for resuspension/deposition) must be modeled by use of a bulk mass transfer coefficient acting over some length scale. These are both empirical parameters to be determined by calibration and should be labeled as such. There should be no pretense that somehow these processes are being modeled from basic principles. **PCB**

@For extra credit, estimates of the effects of these different processes on the contaminant flux should be made, again to ascertain the accuracy and predictability of the model. **CMP/S**

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

[See 6]

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

Remediation of region above confluence.

@The two-mile region of the Housatonic above the confluence is being remediated by GE. This will continue for approximately the next two years. As this happens, conditions at the confluence (the upstream boundary condition for the region presently being modeled) will change. PCB concentrations should decline, although temporary increases are possible. Sediment concentrations may also change. These changes will certainly modify conditions throughout the model test section.

This is an ideal situation to test the model in order to understand effects of boundary conditions on conditions in the test section, and also to build confidence in the predictive capability of the model. **R**

@I strongly recommend (a) measurements of flow, TSS (concentration and size distribution), and PCB concentrations at the confluence, at the outflow from Woods Pond, and in the test section during the remediation period. Flow and TSS measurements are cheap and should be done at least daily, preferably several times a day. PCB concentrations (preferably by congener or at least for PCBs with similar K_p's) are more expensive; as many PCB measurements should be done as the budget allows.

Modeling of the test section should then be done based on this data. **DC**

@A further question is the modeling of the remediation region above the confluence. It seems to me that this is quite difficult since the processes and consequences of GE's remediation are quite complex and difficult to measure. However, this modeling might be useful as a means to understand the remediation actions. If the modeling is done, extensive measurements of flow, TSS, and PCB concentrations within the remediation region would be needed; conditions at the confluence would serve as a check on the modeling and would be another reason for making measurements at the confluence. **R**

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

IV. Concluding Comments

@The EPA models seem to be overly complex. They include almost all conceivable processes, but do not justify the inclusion of most of them. **CMP**

@HSPF is valid for predicting boundary conditions of flow, sediment, and PCBs as long as background conditions do not change. Any remediation would require re-parameterization of HSPF, or better yet, measurements of flow, sediment, and PCBs at boundaries. **DC/R**

@EFDC is a valid transport model. The details of how it will include sediment transport and PCB transport and partitioning are weak or absent. However, much improved sediment dynamics models have been recently developed, are available, and should be included in EFDC. **E/PCB**

@Aquatox is overly complex and should be replaced by a simpler food chain model. Besides being overly complex, Aquatox will create difficulties with linkages and differences in representations of PCBs with EFDC. **A**

APPENDIX A.6

COMMENTS OF E JOHN LIST

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

E. John List
Flow Science Incorporated
May 22, 2001

RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

It is the opinion of this reviewer that, as presently defined, this extremely ambitious project has a very small likelihood of success. There are a significant number of fundamental impediments (discussed in more detail below) to the successful implementation of the models that are proposed to be used, and these impediments must be overcome before any information useful to remediation decision-making can be developed. The modeling proposed goes far beyond current state-of-the-art and, furthermore, it is not at all clear that the scope of the problem to which the model is to be applied has been sufficiently analyzed at the outset. Each of these issues is discussed in more detail before proceeding to specific responses requested by EPA.

As this reviewer understands the problem, the modeling effort proposed is to test the impact of specific proposed remediation decisions against a baseline "no action" condition. The "no action" baseline condition itself encompasses several possible hypotheses regarding the outcome of the remedial activity that is currently underway in the upper reaches of the east branch of the Housatonic River. In this "no action" baseline analysis it is proposed that a 50-70 year simulation be performed to describe the sediment and PCB transport within the broad river valley (encompassing both the meandering river channel and the proximal and distal flood plains). These simulations are expected to include the range of hydrologic conditions that could be expected to occur over this time span. The outcome of this hydrologic-hydrodynamic modeling is to be employed in an additional model to determine the biological impact of the remediation scenarios.

@The key factor in the analysis of the system is its innate complexity, which includes the meandering river channel, the interactions between the river and associated wetlands, banks and floodplains, and the extreme variability in the rates of erosion that have been associated with the river bed and channel sediment heterogeneity. Overlaying this great complexity is the apparent fact that almost half of the PCB currently in place in the river valley sediments appears to be resident in sediments (and at some points deep into the sediment) that are located out of the currently existing river channel. This fact alone is prima facie evidence that out-of-bank flows will be a key factor in the future fate of the extant PCB in the sediments. It also serves to underline the emphasis that needs be placed on the possible future migration of these out-of-channel sediments. **FC/CMP**

@The recent historical record (1944 on) indicates that channel reformation, either through ongoing bank erosion, or through extreme flood events, has lead to 6-10 significant modifications in the river channel geometry. This is evident in the plan form maps of the river valley, which appear to indicate substantial wetlands adjacent to and associated with the river. It is not clear if the formation of these wetlands is a result of ongoing river rechannelization by bank erosion or prior major flood events, or both. **BSE/CMP**

@Thus it is clear that out-of-bank flows and the associated sediment transport are going to be a significant factor in predicting the fate of a substantial fraction of the existing PCBs, especially given the fact that field data show that even frequent annual high flow conditions can lead to sediment transport rates that increase by as much as two orders of magnitude over normal river flows. **CMD/CMP**

@The basic problem is that there is no known numerical model that is capable of predicting flood plain and bank erosion in a quantitative and verified way. Another major problem is associated with the high degree of meandering that occurs in the Housatonic River. Out-of-channel flood events in highly sinuous rivers usually lead to a complete realignment of the flow vectors once the river is significantly out of its banks. This means that the hydrodynamic model has to be capable of both tracking the flow within the meandering river when in-bank flow occurs, while at the same time retaining the ability to realign flow directions when the river occupies a significant fraction of the flood plain. In so far as is known, no single two-dimensional model has ever accomplished this successfully for the flow field, let alone also include the associated sediment transport. It is possible that a three-dimensional model could be successfully used over a limited section of the river, but application of such a 3-D model to the entire river reach is probably not computationally feasible, and in any case would still be subject to the sediment data limitations discussed below. **E/MS**

@It is likely that a useful model could be developed that was restricted to in-bank flow. It is also highly likely that modeling of the significant over bank flows could also be successfully completed. However, it would require a different model in each case. In fact, one-dimensional models are widely used for these purposes. Specific examples include HEC-2 (Corps of Engineers), NWS Flood Wave, Fischer Delta Model (Hugo B. Fischer, Inc.), DWRDSM2 (Calif. Dept. of Water Resources), and there are probably many others. These one-dimensional models are widely used and have been calibrated and verified to exacting standards for both flow rates and water surface elevations, which is a necessary first step in sediment transport analysis. (For a discussion of some available models see the publication "River Hydraulics", American Society of Civil Engineers, 1996). What is missing from the MFD is any meaningful discussion as to why these models were not considered, or even used, before the project decision was made to proceed with a fully two-dimensional model in an extremely complex and hitherto unproven application. **MS/CMP**

@It appears that in-bank flow occurs probably most of the time and is probably responsible for perhaps half of the total annual transport of material within the river. However, as the data analysis presented by GE indicated, the eight major flow events analyzed for 1999 each can carry as much as two orders of magnitude more sediment over a one day period as would normally occur. Furthermore, at this point no one even seems to know what sediment load a 10-year or 20-year flood event would carry, or the lateral extent of the river migration during such an event. The likelihood of such an event occurring within the 50-70 year simulation period must be seriously entertained. **CMD**

Perhaps most perplexing of all about this project is the fact that the data that have been collected regarding river flow rates and associated sediment and PCB fluxes, do not yet seem to have been analyzed in any comprehensive detail. A careful analysis of these data would indicate the relative sinks and sources of sediment and PCB within the river, and also provide an indication of the relative importance of in-bank versus out-of-bank flows. A detailed analysis of these data would also provide the rates of erosion and the rates of deposition along the river, and how these rates were related to the rising and falling hydrographs. It would also provide estimates of the current fluxes of PCB under a variety of flow conditions. This information would be of consummate value in providing the type of cross-sectionally averaged data that could be used to calibrate a one-dimensional model of the system. It would seem highly appropriate to complete this analysis even before launching into a modeling exercise. This reviewer has some difficulty in understanding why this has not been done, or if it has been, why it is not discussed. **CMD**

@The model that is proposed will attempt to describe the rates of erosion and deposition on a 20-meter grid plan. As the field and laboratory data collected by the Corps of Engineers would strongly suggest, predicting the rates of erosion on a grid this small cannot avoid the substantial error that is associated with the heterogeneity of the sediments. It is implausible to think that the riverbed sediments can be characterized on a grid scale this small, so that attempting to model the fate of the sediment on such a scale appears quite inappropriate. In any case, the model output is to be aggregated to such an extent that the output will be used in AQUATOX on a grid scale that is about 250 times as large. The mismatch between the two spatial scales of the sediment transport model and the ecological model makes little sense, especially since the critical data necessary to predict erosion rates cannot be practicably known on the small scale proposed for the EFDC modeling. **GS**

@However, it does appear that reasonable data are available to analyze the laterally averaged rates and extent of erosion and PCB transport that occurs for distinct and identifiable reaches of the river. It therefore would appear to make much more sense to use these data to calibrate a transport model that is based upon a one-dimensional representation of the river system. Furthermore, the one-dimensional model need not be uniformly valid over all ranges of flow. The use of two or more models separately calibrated to in-bank and out-of-bank flows would be quite appropriate. **MS/GS**

@In summary, the approach that EPA is proposing is, in the opinion of this reviewer, inappropriate with little chance of success. Alternative approaches that can usefully employ the (seemingly as yet unanalyzed) data collected to date would appear to be far more fruitful and should have been attempted prior to launching into a modeling exercise that has so many unresolved issues. If indeed the one-dimensional approach discussed above proved fruitless (which seems very unlikely) at least there would be a strong indication of the key factors to address in a more comprehensive modeling exercise. EPA has made a fine job of categorizing every and all possible phenomena that could enter into the problem. However, there is no evident effort to order, or scale on a basic level, the relative importance of the processes that enter into the transport and fate of the PCB in the river valley. This is a crucial first step that could be easily accomplished with the data that are available. **CMP/CMD/MS**

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. ***Modeling Framework and Data Needs***

1. ***Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?***

@The modeling framework used by EPA is believed to be inappropriate. Unquestionably all of the processes that could affect the fate and transport of PCB in the Housatonic River appear to be well catalogued. However, what is missing is any experience or data analysis to suggest that the processes are captured correctly, or to the proper scale. As noted above, a careful interpretation of the existing data would help resolve this primary deficiency. In some cases there is an attempt to be too all encompassing, which is exemplified by the use of the two-dimensional EFDC model when the likelihood of obtaining sufficient sediment data at the grid scale to characterize either the soil heterogeneity, or the erosion/deposition data needed for calibration, is extremely remote. **CMD/GS**

2. Based upon the technical judgment of the Peer Review Panel:

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?***

@Representation of the hydraulic forcing functions via the HPSF modeling is appropriate, whether the sediment and PCB loads will be adequately represented is another question altogether and this may take some careful analysis. What would be desirable is to establish a sediment rating curve for the section of river above the modeling reach. There are some data available to do this but it is not clear that there are sufficient data for the high level out-of-bank flows that are going to impact the PCB transport in a significant way. Extrapolation of the rating curve to these high flow conditions could be done by reference to data records for streams of a similar nature. **CMD/DC** @Similarly, there is a vast literature on the partitioning of PCBs between sediments, water and fish and it seems unlikely that this river has sufficiently unique features that these data bases from elsewhere cannot be used to supplement the data available from the prior field work on this river. However, it seems that the use of an overall partition coefficient that does not recognize the fractional mass of chlorine atoms present may present some problem. **CMD/PCB**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

@As made clear in the discussion above, this reviewer believes that the model chosen to describe the water flow and sediment transport in the river is not appropriate. There is no prior experience with the application of a single model to such a sinuous and meandering river over a complete range of flow records that include out-of-bank flows. At transition from in-bank to out-of-bank flow the flow vector distribution becomes very three-dimensional and it is very unlikely that a two-dimensional depth-averaged model can properly capture this transition. There is no reason that bounding estimates of the normal in-bank flow and out-of-bank high flows cannot be well described by the application of two different one-dimensional models. **MS/FC/E**

c. ***Are the models adequate for describing the impacts of rare flood events?***

@Given the sinuous nature of the river and the large number of meanders it is likely that the river will have a complete change in flow pattern when it flows out-of-bank. It is not clear how often such flow transitions will occur and whether they really are so rare. Given the presence of the PCB on the flood plains it would appear that they are not so rare. The transition from in-bank to out-of-bank flow is therefore very dramatic in terms of the directional distribution of the flow vectors. Successfully describing such a process with a two-dimensional model is believed to be implausible and there are no known verified applications of a two-dimensional model in this context. It would seem more appropriate to use two separate and distinct one-dimensional models for each of these two distinct flow situations. As described in the general comments above, it is known that such models do work in these contexts and there are a large number of verified flow applications. **MS/FC/GS**

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

This reviewer is not totally competent to offer a substantive opinion with respect to this issue. However, it does appear that the primary issue may be the partition coefficient for the PCBs and the reviewer is not at all sure that the partition coefficients have been adequately described. It is known that there are very large differences in this coefficient between low chlorine and high chlorine PCBs. This issue does not seem to have been addressed in any detail. The measurements of the partition coefficient that have been made relate the coefficient to distance from the GE site, which may be a reflection of the partitioning with respect to chlorine weight.

Furthermore, the measurements of partition coefficient in the sediments were made on centrifuged sediment samples rather than core squeezed samples. Some investigators are of the opinion that centrifuging to obtain pore water samples does not give a true representation of the concentration of tracers within the movable pore water. Comparisons between squeezed and centrifuged samples for other halogenated hydrocarbons (e.g., DDE) have shown very significant differences in partition coefficient. **AD/DC**

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

@This issue has been addressed above at some length. To reiterate, it is believed that the spatial scaling intended for the EFDC modeling is congruent neither with the sediment data that are necessary to specify erosion, nor the flux data that will be used to calibrate and verify the model. In any case there is a substantial mismatch between the scales of application of the AQUATOX and EFDC models. As explained above, cross-sectionally averaged data, as would be used in a one-dimensional model may be quite adequate for a description of the efficacy of remediation processes. If it is not, then we need to understand why it is not before proceeding with a fine-scaled model that may only be accurate when the flow is in the basic river channel. **MS/GS**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

@The basic problem is not with the theoretical rigor of the equations, but with the context within which they are placed. For example, the description of resuspension and erosion of particles can be described quite adequately by using the empirical data developed by the SEDFLUME apparatus. The issue becomes how to use these data in the modeling when it is known from the sediment sampling in the river channel and flood plains that the sediments are extremely variable with respect to the rate of erosion. It is not possible to describe completely the surface and depth distribution of the sediment properties that control erosion at the fine scale necessary to apply a two-dimensional model with a 20-meter (or less) grid scale. However, from the sediment flux data that have been developed in the field it should be possible to give average sediment properties that can be used to describe in a general way the resuspension of river bed sediments and flood plain sediments. This is not unusual in fluid mechanics; sometimes less is more.

There are many examples of flow calculations that work extremely well in one-dimension and yet cannot be modeled with any accuracy in two or three dimensions (pipe flow is an obvious example). **MS/GS/SF**

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

@This reviewer is of the opinion that there are probably adequate data collected already for the calibration and verification of a one-dimensional fate and transport model. The data inventories suggest that at least there is the quantity of data necessary. However, it is not at all clear that the quality of the data is adequate. For example, the description of the May 19-21 storm event by GE and EPA showed some fairly substantial discrepancies in magnitude of sediment concentrations, and timing of flows. In addition, a quick review of the data provided by EPA in response to Question 85 shows some unusual and inconsistent behavior for the sediment concentrations in relationship to the flood hydrographs plotted at several locations. These data need a very careful analysis, interpretation, and appraisal, before they are used to calibrate and verify any modeling. It is not clear that this appraisal has yet been performed. **AD/CMD**

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

@See answer to the previous question. This question cannot be answered without some interpretation of the existing data. The inconsistencies that became apparent at the Peer Review meeting would seem to indicate that there could be some problems that need addressing. **DA**

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

@The EPA response to the questions posed by the Peer Review Committee was not always forthright. For example, on page 2, EPA states:

" Although the application of these three models in such a coupled framework has not been previously developed, particularly for a complex meandering river such as the Housatonic River with the associated flood plain, each of the individual models has a lengthy (~10-20 year) history of successful applications to a wide range of waterbody types and problem settings, including linkage with other models."

The fact is that the EFDC model has not ever been successfully applied to the major problem being faced here, where about 50 percent of the transport occurs while the river is within its channel boundaries (where the EFDC model has been previously used), and about 50 percent appears to occur in the infrequent periods when the river moves out of its sinuous boundary and onto a flood plain. There is no history of successful application of any one model in this circumstance and there is no good reason to believe that the two-dimensional EFDC model can be successfully applied in this context. **MS/E**

@EPA states (response, page 14): "Since this class of hydrodynamic models are based on first-principle physics, the hydrodynamic regime of both small and large water bodies can be simulated accurately as long as proper boundary conditions are imposed ...."

This is not correct. EFDC is not a first principle model. It is a model that uses the time-averaged Navier-Stokes equations with a turbulence closure model that requires empirically defined coefficients. If it were a first principle model it would solve the Navier-Stokes equations in a direct numerical simulation. This is a common misrepresentation by turbulent flow modelers, that they are using first principles, when in fact they are not. The fact is that these turbulence models have not yet been able to describe properly even the simplest hydrodynamic flow over an extended range of Reynolds number, e.g., determination of the drag coefficient for turbulent flow past a sphere. Nevertheless, the models have gained some measure of acceptance because they appear to be capable of reproducing the gross features of some large-scale flows. In other cases they have failed completely (e.g., Santa Barbara Channel). The failures seldom ever get published. **MISC**

IV. Concluding Comments

@Overall, the basic criticism of the modeling plan remains the fact that there are so many complex difficult modeling issues that remain unresolved and are yet to be addressed. As a consequence there is no clear indication that the project as currently planned will be at all successful. An initial application of a more conventional "bounding " analysis on the data already collected would more than likely be far more profitable, especially if this were coupled with the application of simpler proven models. If and when these simpler models do not work is the appropriate time to consider others with a higher degree of complexity. (See "The Neglected Art of Bounding Analysis", Environmental Science and Technology, page 162A, April 1, 2001). **MSA/CMD**

APPENDIX A.7

COMMENTS OF PETER SHANAHAN

MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

Peter Shanahan
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May 28, 2001

RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

This document provides my review of the proposed modeling study of contamination of the Housatonic River by polychlorinated biphenyls (PCBs). It is based on a review of the Modeling Framework Design (MFD) (Beach *et al*., 2000a), its accompanying Quality Assurance Project Plan (QAPP) (Beach *et al*., 2000b), and various supporting documentation and data provided by the U.S. Environmental Protection Agency (EPA). My views were further influenced by the Peer Review Workshop held April 25 and 26, 2001 in Lenox, Massachusetts.

CONCEPTUAL MODEL

@A major concern discussed at length during the Peer Review Workshop is the soundness of the conceptual model of the Housatonic River system developed by EPA. Chapter 3 of the MFD does not provide a succinct coherent summary of the conceptual model of the Housatonic River system. Rather, it provides a lengthy discussion of all phenomena that may be influential and the various data available to describe those phenomena. In this sense, it is more of a "data dump" than a conceptual model. There is little provided in the way of data analysis, calculations, simple "back-of-the-envelope" models, and dimensionless scaling analysis based on the data. What is particularly missing is a sense of priority: that is, of which processes are of paramount importance and must be captured in the model and which are secondary and can be omitted without compromising predictive ability. **CMP/CMD**

@The weakness of the conceptual model comes to the fore in making decisions regarding how to model the hydrodynamics and sediment transport of the floodplain. This is the subject that garnered the most attention from the Peer Review Panel during their April Workshop. It is important because of the significant computational difficulties it poses. The hydrodynamic interaction of the river channel with the distal floodplain is proposed by EPA to be handled in an approximate fashion using a dual-grid approach that does not conserve momentum. However, a fully rigorous two-dimensional model of the river channel and floodplain would carry a punishing and probably infeasible computational burden at least with the EFDC model. As it is, the approximate approach put forward by EPA is still so computationally intensive as to preclude systematic uncertainty analysis. **GS/FC**

@Lack of a clear conceptual model for the floodplain prevents making clear recommendations for an alternative hydrodynamic model. The conceptual model put forward in the MFD and supplementary responses to the peer review panel by EPA seems to be the following: Most PCB-contaminated sediments are found in the river channel and Woods Pond (accounting for 37% and 17%, respectively, of the mass of PCBs in the Primary Study Area (PSA)). An additional 17% of the PCB mass lies in the proximal floodplain. These fractions of the PCB mass, which amount to about 71% of the total in the PSA, lie in areas within or directly adjacent to the river channel that can modeling straightforwardly. The remaining 29% of the PCB mass lie in the distal floodplain. The distal floodplain is inundated only infrequently, by storms occurring less often than about once in every 5 years. When inundated, river flow over the floodplain is slowed by vegetation, with the result that sediment is deposited on the floodplain. **CMP/CMD** **@**However, as stated on page 3-49 of MFD, "Erosion of the floodplain can occur under extreme high flow events and from bank slumping."

The specific basis for this last statement regarding the effect of extreme high flow events is not stated in the MFD and is not apparent from the Workshop discussions and other materials provided by EPA. Sedflume erosion studies completed by Gailani *et al.* (2000) did not include floodplain samples, so the erosional properties of floodplain soils are not known in detail. The storm events monitored in detail during 1999 do not seem to include an event large enough to have inundated the distal floodplain, much less to have eroded it, so there are no observations of distal floodplain erosion. While it seems logical that erosion of floodplain soils might occur during large floods, the heavy vegetative cover would likely minimize the extent and degree of such erosion. Finally, even if some erosion were to occur, it is not a foregone conclusion that the mass of PCBs mobilized by such an event would be significant. After all, the entire distal floodplain area contains only 29% of the PCB mass, PCB concentrations in floodplain soils are less than in other areas according to Table 3-8 of the MFD, and the floodplains are a net depositional area. In the final analysis, there is not a clear conceptual model of the importance of the distal floodplain to the eventual recovery of the Housatonic River. **CMP/CMD/BSE**

@The import of understanding the distal floodplain as a source is great. Were the floodplain a wholly or predominantly one-way sink for PCBs, modeling could be greatly simplified. There would be no need to model the distal floodplain per se. Rather, it could be simply considered as a sink for PCBs from the river system. Remediation alternatives for floodplain deposits could be evaluated as a separate issue, based on risk assessment rather than modeling. **CMP/BSE** @The Housatonic River could then be considered as an essentially one-dimensional channel, without all of the complexities and computational burden engendered by the distal floodplain. A simpler hydrodynamic model, possibly a one-dimensional model, would suffice, enabling greater computational flexibility. With fewer computational demands, the modeling study could address other concerns raised by the peer review panel, specifically, the completion of uncertainty analyses that could place the model results in perspective, and the simulation of multiple fractions of PCBs rather than simply total PCBs. **CMP/MS/U/PCB**

@It is my recommendation that the role of the floodplain be better defined before the EPA commits to an overly complicated and computationally burdensome hydrodynamic model. **CMP** @Sedflume studies should be conducted on floodplain soils to understand the propensity of those soils to erode. **SF** @Simple calculations should be completed to estimate stream velocities and shear stresses in the floodplain during large storm events. With that information, estimates of the mass of PCBs released from the distal floodplain during large storm events should be developed and compared with mass estimates for existing channel deposits and stormflow suspended solids. That comparison will provide an indication of the significance of floodplain-derived PCBs and enable decisions as to the need for and approach to modeling the distal floodplain. Only then should the hydrodynamic modeling approach be committed. At present, in the absence of a coherent model of the role and importance of the distal floodplain, decisions as to hydrodynamic modeling are premature. **CMP/CMD**

MODEL COMPLEXITY

@Despite lip service to model parsimony in Section 3.1.1 of the MFD, the models proposed for this study appear to have been developed with the philosophy that the more detailed and complex the formulation, the better. I see intrinsic difficulties in this approach, although my aversion is more visceral than analytical. Fortunately, Bruce Beck has provided an analysis of the issue that is both philosophical and rigorous in two papers (Beck, 1987; Beck and Halfon, 1991). The problems he identifies can be generally described as an inability to develop a proper model structure, uncertainty in the model parameters, and poor predictive capability. **CMP/U**

@The pertinence of the issue of proper model structure is demonstrated in a recent review of the models developed to assess PCB contamination in the Fox River in Wisconsin (Tracy and Keane, 2000). A physically-based (as opposed to empirical) model of the Fox River was developed by the Wisconsin Department of Natural Resources (WDNR), calibrated to field data for PCBs and suspended solids, and apparently used as the basis for a draft Superfund feasibility study (FS) of alternative strategies to remediate the river. Alternative cleanup strategies range from no action to dredging and contained disposal of contaminated sediments at an estimated cost of $720 million (WDNR, 1999).

Subsequent to the publication of the models and draft FS, the WDNR model has been examined in detail by consultants to the industries identified as Potentially Responsible Parties (PRPs). The consultants identified a serious structural flaw in the model. Numerical dispersion arising from the representation of PCB transport in the sediments produces a large artificial flux of PCBs from deep sediment layers to the sediment surface in the WDNR model. As the result of this and other differences in the models, the WDNR model predicts that 70% more PCBs will be discharged from the Fox River than does an alternative model developed by the PRPs' consultants. WDNR has corrected its model, but has not yet reported the effect on the model predictions. There appears to be no consensus among the various parties on a best model or best modeling approach and, as indicated by Dr. Lick during the Peer Review Workshop, estimates of bed erosion between the parties differ by two orders of magnitude.

The specific flaw identified in the WDNR Fox River model is known to the modelers working on the Housatonic River and will not be repeated. Moreover, the Housatonic River modelers also know the recommendations of the Fox River Peer Review Panel, although the study is cited only in the EPA Response to Peer Review Panelist Questions and not in the MFD or QAPP. Regardless of the specific flaw in the WDNR model and its correction, the Fox River example reveals a fundamental failing in the application of these highly complex models: the models are over-parameterized such that even an intrinsically flawed model can be "calibrated" to field data. I suspect that with the number of parameters included in the AQUATOX model, it could be satisfactorily calibrated to any time-series data set, including the Dow Jones Industrial Average. **MISC/A**

@Beck's review of model uncertainty leaves me pessimistic—he states for example that "Overparameterization seems both intrinsic and an intractable problem" (Beck and Halfon, 1991). He also makes clear that a "physics-based mechanistic" approach is hardly a panacea (Beck, 1987). It is noteworthy that he cites the predecessor model of AQUATOX as an example of the misguided physics-based approach. In essence, Beck argues that these models cannot be tested by the scientific method because they cannot be shown to be false. There are too few field data to disprove the many subordinate hypotheses and parameters embedded in these complex models. Thus, one cannot test hypotheses as is incumbent with the scientific method. **MISC**

@Despite this overall pessimism, Beck (1987) does provide some optimistic observations. In particular, he distinguishes simulation of hydrology (and by implication, hydrodynamics) from simulation of water quality. He cites the longer and more intensive study of hydrologic processes compared to the more ephemeral attention to water quality (which has shifted attention over the years from BOD/DO, to eutrophication, to acid precipitation, and now to toxic chemicals). As a result of more intensive historical examination, the hydrological and hydrodynamic processes are better understood, more certainly parameterized, and better identified. In the context of the Housatonic River modeling framework, the HSPF and hydrodynamic portion of the EFDC fall within this class of more certain models. The comparatively empirical AQUATOX and sediment transport portion of EFDC are within the less certain category. **MISC**

@Another seemingly pessimistic aspect of Beck's analysis is the fact that his focus is primarily on eutrophication modeling, which is only a subset of the modeling exercise proposed here and thus less complex. However, as Beck (1987, Figure 15) illustrates, the eutrophication problem has some intrinsic difficulties that may not be shared by the PCB problem. Specifically, the prediction of eutrophication involves the translation of relatively steady meteorological and nutrient loading forcing functions into episodic algal blooms—an abrupt transient response that bears little resemblance to the character of the forcing functions. The PCB problem can be idealized as a relatively better behaved problem: namely the exponential depletion and burial of mass over decadal time scales. Indeed, with this conceptual model, I wonder if a calibrated exponential decay coefficient for PCB loss could be as reliable a predictor as the modeling effort proposed here. A flaw in the exponential conceptual model is, of course, the potentially great influence of unusually high flow events. However, the predictive ability of the proposed modeling framework for high flow events is perhaps the single greatest uncertainty in the model. **MISC**

@In the final analysis, AQUATOX appears to be overly complex for the task it was chosen to do: modeling the bioaccumulation of PCBs within the food chain. As explained by Mr. Endicott during the Peer Review Workshop, AQUATOX simulates the entire aquatic ecosystem. This incorporates and adds to the already complex eutrophication model about which Beck is so pessimistic in his analysis of model uncertainty. The alternative, as also explained by Mr. Endicott, is the simpler food-chain models that have already been used in other riverine PCB models. This alternative eliminates much of the duplication and potential conflict of modeling PCBs by two different approaches with EFDC and AQUATOX. The MFD, QAPP, and EPA Responses provide no evaluation of why the AQUATOX approach is superior to this more established alternative. One can in fact view this as a failure of the Quality Assurance process: the QAPP accepts the models chosen in the MFD as a given, but should in fact provide for quality assurance evaluation of the process by which particular modeling codes are chosen. **A/MS**

Overall, the considerable complexity, and possible "over-complexity," of the proposed models creates challenges for model calibration and necessitates an explicit evaluation of the confidence that can be placed in the model predictions. These topics are further discussed in the following.

MODEL CALIBRATION

Beck's analysis makes clear that a "good" calibration in and of itself does not guarantee that the model has been defined correctly or that its parameter values are reasonable. Moreover, simple statistical measures may be misleading as was demonstrated by the apparently successful calibration of the incorrect Fox River model.

@A partial remedy to the calibration issue is achieved in the Housatonic River MFD and QAPP by disaggregating certain process and calibrating those separately. For example, completion of an independent sediment erosion study (Gailani *et al*., 2000) provides some assurance that even if the entire modeling framework cannot be calibrated and verified, important sediment processes can be adequately represented. The more such "subcalibrations" can be completed, the more confidence can be ascribed to the overall model. This approach seems to be endorsed by the Fox River Peer Review Panel as well (Tracy and Keane, 2000). Thus, I would encourage close scrutiny of the models for subprocesses that can be isolated and tested. The evaluation of sediment erosion using Sedflume is a critical such analysis, but should be extended to distal floodplain soils as well as the in-channel samples analyzed by Gailani *et al.* (2000). **CMD/SF**

The following discusses the calibration for the individual model components: HSPF, EFDC, and AQUATOX.

HSPF. @Given its long history of use, and the fact that it has been tested and found successful in at least one post-audit (Hartigan, 1983), I have more confidence in the use of HSPF than of the other models. Nonetheless, I found the description of the HSPF calibration in Section 4.5 of the QAPP to be inadequate. The text is a litany of the parameters that will be adjusted, and the sequence in which they will be adjusted, but provides little information on the field data to which the data will be calibrated. It is obvious however that the available data will allow only gross calibration of the model based primarily on mainstem hydrologic stations. Data collected in 1999 are apparently the only tributary data available, although the MFD's description of the datasets is sparse. The Supplemental Investigation Workplan (Weston, 2000, Figure 5.3-1) shows a limited number of tributary stations. This data set will be used for calibration, apparently leaving no tributary dataset available for validation. Given the history of use of HSPF this seems acceptable although undesirable. **H**

EFDC. @The application of EFDC (or other hydrodynamic and sediment transport codes) to the Housatonic River is clearly a difficult undertaking. The hydrodynamic regime includes transitions between at least three general modes of flow:

- in-bank flow within the meandering river during most of the time;

- out-of-bank flow in the also meandering proximal flood plain during flood events of less-than-approximately-5-year recurrence intervals; and
- widespread flow within the relatively straight floodplain during large flood events (greater-than-approximately-5-year recurrence).

Further complexity affects the two flood-flow modes due to the extensive floodplain vegetation, which reduces flow velocities and enhances sediment deposition. As discussed above, data are insufficient to describe and understand the distal floodplain, and the conceptual model of the floodplain is incomplete. **FV/FC/CMP**

@Presuming the plan to use the EFDC model for hydrodynamics and sediment transport goes forward, the dataset for calibration of the EFDC model is insufficient to test a critical aspect of the model: its ability to accurately predict the effect of high-flow events. The potential impact of future high flow events is a matter of speculation at other riverine PCB contamination sites, but has nonetheless been held out as a rationale for expensive dredging remediation alternatives. Until a sufficiently extreme flow event presents itself and is thoroughly monitored, the predictive abilities of the Housatonic River model will remain in doubt. Completing Sedflume studies on the floodplain soils can reduce this uncertainty, but the EPA should retain the ability to thoroughly monitor a large storm event should one present itself. **DC/RF**

AQUATOX. @The AQUATOX model is a classic example of an overparameterized model. The QAPP lists numerous statistical and qualitative measures that will be used to assess the calibration of the AQUATOX model, but these will provide no assurance that the model calibration is unique or correct. There are simply too many parameters and too few data to calibrate the model in a completely satisfactory way. I see no escape from this dilemma other than that the model predictions must be qualified by explicit calculation of the model uncertainty so that decision makers can judge the confidence with which the model results can be used. **A**

UNCERTAIN PREDICTIVE ABILITY

@Prognostic simulations included within the model objectives include estimates of the effects of selected remedial actions, of natural recovery, and of extreme storm events. Remedial alternatives in the case of river sediments necessarily include dredging. Since opinions on dredging run the gamut from a remedial panacea that is practically pre-ordained to counterproductive folly that only spreads and worsens the contamination, it is important to foresee as a part of the modeling framework design how dredging will be evaluated with the model. The representation of dredging, though a critical factor in the eventual model-based decision-making, is absent from the MFD. I am pessimistic that a fair assessment of the effects of dredging will be accomplished without its prior explicit specification. How will sediment disruption and collateral release during dredging be modeled? Is this modeling framework adequate to address that question? I fear that if these questions are not answered upfront, the eventual model application will founder on disagreements over its application. **R**

@There is also the considerable uncertainty, alluded to earlier, in the use of the models to forecast behavior of the system at two extremes: the high-flow event, and the system response over decades. The short record available for calibration, and the absence of high-flow events from that record, are ominous for both of these capabilities. By definition, it is unlikely that a high-flow event will be observed during the data-collection period, and it is impractical to extend the observation period to decades. Thus, neither of these critical needs is likely to be addressed. This is not just an issue for model calibration but also of model identification. **DC/U** **@**Specifically, there is considerable uncertainty that the EFDC model can adequately represent the transition from in-bank flow within the meandering stream channel to overbank flow through the floodplain. **FC**

@How then, in the absence of adequate data, can the uncertainty in these extreme predictions be factored into decision-making? It seems that there is only one possibility, namely to include within the modeling exercise explicit tasks to estimate and report the uncertainty bounds on the model estimates. This task is given only token attention in the MFD, and even then indicated as an optional task that "may" be done. In the absence of explicit evaluation of uncertainty, the inevitable result is that described by Beck and Halfon (1991):

> *There must have been many occasions on which a large model, confronted with hopelessly inadequate data, has been accepted as an appropriate tool for prediction, and without any attempt at quantification of the error attaching to the predictions so obtained.*

In effect, without explicit evaluation of uncertainty, the model is implicitly portrayed as certain. For example, the tracing of a single solid predicted-results line on a graph, without error bounds, would represent an implicitly certain forecast. The risk is that unnecessary exposure to PCBs and unwarranted expenditures would result from the selection of a predicted outcome that does not in actual fact differ from an unselected alternative.

The MFD indicates that the complexity of the models, and particularly the EFDC code, precludes rigorous evaluation of uncertainty. In its place, sensitivity tests are proposed. I found the description of the approach to be inadequate however. It seems to me that it is at least as important to communicate to decision makers the level of uncertainty in the model predictions as it is to communicate the predictions. Thus, I believe more explicit and formalized procedures for the calculation and communication of uncertainty should be incorporated into the MFD.

Some of the other members of this panel have asked about a contingency plan in the event the models are found inadequate to meet the study objectives. While I do not share concerns about this issue per se, I have a closely related question, namely: With what confidence can the models be used to answer the questions posed by the study objectives? In essence, I assume the modelers can get an answer—my concern is the utility and reliability of that answer. That reliability can only be known to the decision makers if the modelers explicitly calculate the uncertainty and reliability of their model predictions. It is essential to add this task to the modeling study in my opinion. This also implies that it is essential to find a simplified alternative to the EFDC model to make an uncertainty analysis computationally feasible. **U/MS/E**

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. ***<u>Modeling Framework and Data Needs</u>***

1. ***Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?***

@The presumption of this question is that "accurate" models and process descriptions are possible. With processes of the complexity and uncertainty as those at issue, a focus on achieving accuracy is misplaced. Rather, it should be recognized that the models are necessarily inaccurate. The focus, therefore, should be on quantifying the uncertainty of the model predictions through as rigorous an uncertainty analysis as possible. Information on the uncertainty of the model predictions then needs to be provided to decision makers and the public along with the model predictions so that truly informed decisions can be made. **U**

@The computational burden of the EFDC model is clearly an impediment to achieving the goal of quantifying uncertainty. As indicated by EPA during the Peer Review Panel Workshop, the EFDC model requires too much computer time to be subject to a quantitative uncertainty analysis. Unless ways can be developed to remedy this defect, the inability to assess uncertainty makes EFDC an unsuitable tool for this study. Nonetheless, there may be ways to remedy the defect including developing a simplified version of the EFDC model specifically for uncertainty analysis or by completing a rigorous uncertainty analysis on a representative subreach of the model. In any case, as indicated in my General Overview above, I believe that any decision to use the EFDC code is premature until more data are collected and a coherent conceptual model of the distal floodplain is developed. **U/MS/FC/E**

Issues of uncertainty aside, the models need at least to attempt to include all significant processes with an appropriate degree of accuracy. I use the words "appropriate degree of accuracy" in conscious distinction from Question 1's phrase "sufficiently accurate." The term sufficiently accurate implies that insufficient accuracy is unacceptable, but excessive accuracy is irrelevant. In fact, greater "accuracy" in representing physical processes usually implies greater model complexity, more parameters, and a greater computational burden. These by-products of accuracy can be as detrimental to the overall success of the modeling program as insufficient accuracy, and are to be avoided as well.

@With this in mind, I am concerned that all of the models may suffer from some degree of "over-accuracy." I am least concerned in this regard with HSPF. Although complicated, HSPF has a long history of use and an experience base in choosing parameter values. The intended use of the HSPF model for the Housatonic River study seems to be in flux, although in a favorable direction. The MFD and numerous responses to the Panel's question clearly indicate that HSPF was intended to be used to generate PCB loadings. We learned at the Peer Review Panel Workshop that this was not the plan after all, and that PCB loadings would be generated by coupling HSPF flow predictions with PCB field data measurements. The exact nature of this procedure has apparently not yet been documented in writing or otherwise defined in detail and therefore has not been subject to this peer review. Nonetheless, the decision to not use HSPF to generate PCB loads eliminates the most uncertain and speculative aspect of the MFD's plan for HSPF. Thus, overall, the use of HSPF satisfies the goal of "accuracy." **HSPF**

@The EFDC model is a conundrum as far as process representation. The model includes a great many processes, but most are physically-based and reasonably well established. Thus, I am for the most part comfortable with the representation of individual processes and the relative absence of poorly defined coefficients. At a larger scale, however, the aggregation of so many processes in a fine-grid model has created an unfortunately large computational burden. As a result, in the net, the model is over-accurate to the point that the model's overall utility is diminished. **GS**

@The exception to my general characterization of the EFDC code is the proposed dual-grid scheme for representing channel-distal floodplain interaction. The proposed approach is essentially experimental and there is little basis to judge whether the accuracy of this process in the model is sufficient. The fact that momentum is not conserved between the channel and distal floodplain represents a significant compromise in theoretical accuracy, but the impact on practical accuracy (i.e., predictive ability) is uncertain. In the net, I view the application of EFDC to this complex river system to be experimental and the accuracy for this application to be at best uncertain. **GS/FC/E**

@The AQUATOX model is highly overparameterized, as discussed in my general overview. In this sense, I view it as "over-accurate." The effect of this is to diminish the confidence in the model parameterization and calibration. That said, I was assured in the Peer Review Workshop that the model runs efficiently enough to be used in formal uncertainty analysis. Completion of such an analysis would mitigate my concerns about the accuracy of this model. Nonetheless, as stated in my General Overview, I believe simpler models are preferable to AQUATOX. **A**

@The modeling framework also incorporates algorithms for linking the various model components. None of the models are consistent in their representation of the pertinent state variables, and translation is required to transfer information from HSPF to EFDC and from HSPF and EFDC to AQUATOX. This seems an intrinsically inaccurate undertaking that adds uncertainty to the model results. To the extent possible, the conversion algorithms should be individually tested and validated, the their contribution to model uncertainty quantified. Better still would be the use of other models in which conversion of state variables in unnecessary. **L**

2. Based upon the technical judgment of the Peer Review Panel:

a. ***Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing***

quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?

@Modeling approaches for forcing functions appear, for the most part, to be reasonable and appropriate at at least a conceptual level. At an operational level, some of the forcing functions for EFDC and AQUATOX are generated in HSPF and EFDC and must be converted as a part of the model linkage algorithms. The model linkages are not well defined in the MFD, but the presumption seems to be that empirical correlations can be used to define conversion formulas. As discussed under Question 1 above, this procedure is fraught with potential difficulties and needs to be avoided if possible, but thoroughly tested if unavoidable. **L**

@I am also concerned with respect to forcing functions is the representation of remediation. This affects both the upstream boundary condition and the simulation of future scenarios in the PSA. As far as the upstream boundary, we were told that boundary conditions might span the range of assuming upstream remediation to be 100% effective to 0% effective. Such uncertainties introduced at the upstream boundary could overshadow all of the model's predictions. Similar concerns affect the representation of remedial alternatives within the PSA, as discussed in my General Overview above. The Modeling Framework is incomplete until these very important model forcing functions are determined. **R, DC**

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

@This particular question is pertinent to only the EFDC model: neither HSPF nor AQUATOX address the floodplains. The application of EFDC (or other hydrodynamic and sediment transport codes) to the Housatonic River is clearly a difficult undertaking that is complicated by different modes of flow within the channel, in the proximal floodplain, and in the distal floodplain. As discussed in my General Overview, there does not seem to be a coherent conceptual model of the floodplain to enable decisions on how it should be modeled. **CMP**

@The proposed application of the EFDC model to this complicated flow regime is essentially experimental. The proposed solution for modeling is the creation of a dual-grid model: a curvilinear grid along the river channel and proximal floodplain, and a separate linked-grid for the distal flood plain. The linkage between the two grids is not described in detail in the MFD, its appendices, or the EPA's Responses to Peer Review Panelist Questions. The EPA's Responses indicate that the dual-grid scheme will not conserve momentum.

The uncertainty of the dual-grid approach is implicit in the EPA's indication that the linkage mechanism will be tested, although the character of that testing also is not defined in detail. It appears that this testing will be a comparison against a single-grid model rather than field data, which are lacking. With respect to field data, there do not appear to have been hydraulic measurements made within the floodplain against which to test the model of floodplain flow. Sediment erosion tests by Gailani *et al.* (2000) were also restricted to the river channel. Thus, the floodplain linkage algorithm appears to be uncertain and there do not appear to be field data to test it. **GS/E**

@As stated in my General Overview, I am not convinced there is a need to model the distal floodplain explicitly. Nonetheless, if one assumes that a model incorporating the distal floodplain is needed, it is incumbent to find an acceptable alternative to the proposed model. Unfortunately, although there seem to be problems with the dual-grid approach, there do not appear to be clearly superior alternatives. My sense is that a finite-element alternative, such as HSCTM2D, might present greater flexibility in structuring a grid that provides needed detail in the river channel and proximal floodplain, but lesser detail (and computational efficiency) for the distal floodplain. While the EPA's responses (pg. 14) indicate that HSCTM2D is considerably slower than EFDC, no details on the comparison are given and I wonder about the relevance of that comparison to the unusual Housatonic River configuration. I also am unable to shake my concern, which is possibly unfair, that alternatives to EFDC were not seriously considered, but that the model's availability and modeler's prior experience with the code preordained its selection. **MS**

In the final analysis, the answer to Question 2b is "I do not know." Changing this answer requires the type of conceptual model development described in my General Overview above.

c. ***Are the models adequate for describing the impacts of rare flood events?***

@The question is relevant to HSPF and particularly EFDC. It has limited relevance to AQUATOX given the longer time step and limited spatial domain (no overbank areas) of that model. With respect to HSPF, I see no fundamental limitation in HSPF to capturing rare flood events.

With EFDC, the complexity of the Housatonic River and the use of the approximate linked-grid approach raise doubts as to the ability of the model to capture rare flood events in the same way they raise doubts as to describing channel-floodplain interaction. The lack of intensive data collection during a truly high-flow event (i.e., with flow within the distal floodplain) impedes the modeler's ability to test the model's predictions for high-flow events. Moreover, a lack of Sedflume data from the floodplain areas means that there are few data to specify sediment-related parameters for the distal floodplains during high-flow events. **RF/SF/DC**

As with Question 2b, the answer to this question is "I do not know" in the absence of more data and a coherent conceptual model for the distal floodplains as discussed in the General Overview.

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

@This question is relevant primarily to AQUATOX. Given the many transformation pathways included in AQUATOX, the model is fundamentally able to discriminate between water-related and sediment-related sources of PCBs to biota. However, the accuracy of the predictions is a function of the parameter values chosen for use in the model. As discussed in my General Overview, there are too few data and too many parameters in AQUATOX to ensure reliable determination of parameter values. Thus, while the model algorithms may be adequate, the model predictions can be expected to be highly uncertain. Unless this uncertainty is quantified and communicated to decision makers, I would not consider the model application to be adequate. **A/U**

@The sediment transport predictions by EFDC also relate to this question. Setting aside the reservations expressed above concerning floodplain and large-flood predictions, the EFDC model should be adequate for predicting sediment movement in the river channel. Again, these predictions are subject to parameter uncertainty. In this case, the parameter uncertainty is compounded by the uncertainties in modeling channel-floodplain interaction and large flood events. Here again, unless uncertainty is quantified and communicated, I would not consider the model application to be adequate. **U**

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

As with some of the other questions above, the issue may not be: Are the scales adequate? (i.e., fine enough spatially or short enough temporally), but, Are they too small? Short time steps and fine spatial detail increase the computational burden and reduce the ability to assess model uncertainty.

For HSPF, the spatial scale (hydrologic subbasins) and time scale (hours) are logical and commonplace in hydrologic analysis.

@For the EFDC code, this particular question is premature inasmuch as the MFD and EPA responses give no explicit recommendation as to the grid size. The EPA's response to questions 52, 54, and 118 implies a channel grid size that is relatively small: $\Delta y \cong 25$ feet (three grids across the channel) and, very roughly, $\Delta x \cong 200$ feet. Small spatial elements create a double penalty in computational burden: they require the time step to be reduced for computational stability and also increase the number of computations needed to cover the spatial domain. Thus the selection of the EFDC spatial resolution is a critical decision. The longitudinal distance is not excessively small relative to field data density or the Cartesian grid size recommended by GE (20 meters = 66 feet). On the other hand, the lateral size appears to exceed the resolution of most of the field data and the EPA's responses indicate no intent to model gravel and point bar deposits within the channel. These considerations suggest that a single cross-sectional element may suffice, which would reduce the computational burden. A further improvement could be the alternative discussed at length by the peer review panel—a one-dimensional model. In either case, the modelers should investigate the sensitivity of the predictions to grid size and use as large a size as possible. Given that the eventual outcome of the model is prediction of decadal-scale recovery, loss of spatial detail in the hydrodynamic and sediment transport code should not compromise predictive ability so long as the overall flux of PCBs to and from the sediment is represented reasonably. **GS/AD/MS**

@For the AQUATOX code, presuming a simpler alternative is not substituted, the spatial scale and temporal scales are appropriately large. This reduces the computational burden, allowing uncertainty analysis, but still captures appropriate system dynamics on decadal scales. My one concern with respect to the spatial scales of the AQUATOX model is that for large-scale box models of this type, the dispersion coefficients determined from the hydrodynamic model results should be adjusted to account for the implicit dispersion in the large-box AQUATOX elements (see Shanahan and Harleman, 1984). The discussion in the MFD implies that it is simple and straightforward to aggregate flows and fluxes from EFDC for use in AQUATOX. There are in fact considerable subtleties in such aggregation including the introduction of artificial or erroneous fluxes. **A/L**

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

@The focus of this question is on theoretical rigor when many of the equations for hydrologic processes in HSPF, sediment resuspension, settling, and transport in EFDC, and biotic interaction in AQUATOX are empirical rather than theoretical. Indeed, one could argue that the only consistently theoretically rigorous aspect of the models is the hydrodynamic model in EFDC. **MISC** @Ironically, EPA plans to violate this uniquely rigorous computation in the dual-grid linkage between the stream channel and distal floodplain by failing to conserve momentum. EPA did not justify the necessity and/or benefit of this deviation from theory. Unless the computational savings are substantial, and the deviation can be demonstrated to be harmless, this approach should be avoided. **FC/GS**

@The EFDC code also deviates from theoretical rigor by lumping all PCBs into a single state variable and representing their highly disparate adsorptive and other properties with single, empirically determined values. Again, the computational burdens on EFDC appear to be influential in this question. It would seem far more defensible to divide total PCBs into coherent subgroups of similar character (for example, homologs). However, this would increase the already large computational burden of the EFDC code. It is unclear, however, the degree to which the contaminant transport portion of the model, which would need to be repeated for each contaminant subgroup, contributes to the computation as opposed to the hydrodynamic and sediment transport portions, which need be run only once. **PCB/E/A**

@Finally, it is unclear the degree to which the EFDC simulation of PCBs is even needed. The computation is to some extent duplicative but to another extent complementary with AQUATOX. In particular, the EFDC PCB simulation is proffered as a means to address the PCBs deposited in the distal floodplain. As discussed at length in my General Overview, the need to model explicitly the distal floodplain needs to be further evaluated through a coherent conceptual model. The alternative would be to model sediment fluxes alone with the hydrodynamic code, and use the predicted sediment fluxes as input to a separate PCB model (either AQUATOX or a simpler alternative). **PCB/A/E**

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

@The presumption of this question is that a comprehensive accounting of supporting data needs can be accomplished prior to data analysis and interpretation, conceptual model development, and even preliminary model development. In fact, data collection should go hand-in-hand with these other processes and be guided by them. For example, as discussed in my General Overview, there does not appear to have been an adequate attempt to analyze the data and understand the degree to which distal floodplains are a source of PCBs to the river system. The skeletal conceptual model outlined in my General Overview identifies a gap in understanding: we do not seem to know to what degree distal floodplains are a source of PCBs to the river and biotic system. Identification of this knowledge gap then leads to identifying such specific data needs as additional Sedflume studies specific to the distal floodplain and better characterization of flow dynamics during distal floodplain inundation.

With this general paradigm in mind, what needs to be done to answer Question 5 is to analyze the already available data with simple quantitative tools, develop preliminary conceptual models of important processes, and through those conceptual models, identify gaps in characterization and understanding. This process then leads logically to the identification of specific additional supporting data needs. **CMP/CMD/DC/SF**

@Although additional data analysis and conceptual model development is needed to identify data needs more completely, certain existing data needs can be identified. For HSPF, additional validation data sets would be valuable, but are probably not essential. The EPA may wish to consider a single tributary flow-gaging station with occasional TSS measures as supplementary data for HSPF validation. For EFDC, the lack of data to characterize a large storm event and floodplain inundation is an unfilled data gap. Although the occasion of this type of data is a vagary of nature, the EPA should allocate the resources to monitor such an event in detail if it occurs. As far as AQUATOX, as stated above, there are not enough data and probably never will be enough data to calibrate and validate a model of this complexity. Mr. Endicott identified selected data that would be valuable to collect. I concur with his recommendations, but in the final analysis, emphasis should be placed on developing and implementing a robust approach to uncertainty analysis for this component of the modeling framework. **DC/A/U**

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

@The answer to Question 6 is much the same as the answer to Question 5: it is impossible at this stage in the study to judge whether the available data are adequate. What seems clear based on the peer review panel workshop and my own thinking about this question, is that the process being conducted by EPA appears to be inadequate. The specific inadequacy is premature selection of sophisticated and complex modeling codes without a clear prior understanding of the system dynamics and simple quantitative analysis to identify the importance processes within that system. I emphasize again the importance of developing a coherent conceptual model as discussed in my General Overview. **CMP/CMD/MS**

@As far as specific data issues, I am concerned by the project team's failure to consider important data available from Massachusetts sources. The following potentially valuable data were not considered and apparently were unknown to the modeling team:

Data Source	Data type
Massachusetts Department of Environmental Protection	Past water-quality assessments in 1997-1998, 1992, 1985, 1976-1978, 1974, 1968-1969 that variously included water-quality sampling, wastewater discharge surveys, biota sampling, sediment sampling, and probably time-of-travel and other hydrodynamic field studies.
MassGIS	Geographic information system coverages of soil types, land use, wetlands, surficial geology, topography, aerial photography, and other geographical features.
Federal Emergency Management Agency	Hydrologic and hydraulic studies conducted under the Flood Insurance Program and possibly high-water mark surveys after flood events

These data are likely to assist in the formulation of food-web relations, construction and calibration of the hydrodynamic and hydrologic models, and construction and calibration of the phytoplankton component of the water-quality model. I am concerned that the failure to search for and incorporate these important past data could betray a false confidence in the proposed modeling framework: in other words, that the modelers could have concluded that their models are so good and so fundamentally sound, that they do not need to exert every effort to locate the best available data. **MISC/DC**

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

- @The QAAP does not appear to include procedures specifically to check model input data. Section 11 appears to touch on this, but should also specify that all input data time series be plotted for visual inspection and cross-checking. **MISC**
- @The QAPP does not include a discussion of the QA process governing code selection. The selection of particular codes should be appropriately documented by describing the alternative codes considered, the advantages and disadvantages of the alternatives, and finally how those factors were weighed in the final code selection. This should not be an after-the-fact apology for some predetermined codes: rather it should be an analytical and, if possible and appropriate, quantitative evaluation of the codes. Returning again to the

example of the hydrodynamic model: it should be possible to estimate the relative magnitude of different transport mechanisms and thereby educate the selection of a one-, two-, or three-dimensional modeling code. **MS**

- @The EPA Response to Peer Review Panelist Questions indicates that the new sediment bed representation in AQUATOX was tested against the IPX V 2.74 model. It, and all other newly created code, should be also validated against analytical solutions for which there are known solutions. **MISC**

IV. Concluding Comments

@In summary, I believe that the Modeling Framework Design for the Housatonic River is premature. Information presented and otherwise made available to the Peer Review Panel does not reveal that there is yet an adequate conceptual model of the Housatonic River system upon which to base the selection of modeling tools. While the HSPF model seems a logical and solid choice, the EFDC model is too burdensome computationally and the AQUATOX model too complex to ever be unequivocally calibrated. Misgivings over these choices are not assuaged by the information provided—a solid analysis of the data and river system does not appear to have been conducted to justify these choices. **CMP/MS**

@Before the EPA fully commits to the modeling framework it has chosen, a coherent conceptual model is needed. This is particularly critical for the distal floodplains. It is not apparent based on the information given whether and to what extent the distal floodplains can act as a source of PCBs to the river channel and aquatic ecosystem. Until this fundamental question is answered, informed decisions as to the necessary dimensionality and spatial structure of the hydrodynamic model cannot be made. **CMP/FC**

@The great complexity of the modeling framework necessarily implies considerable uncertainty in the calibration of the model parameters. This is particularly the case for the AQUATOX model. Although the complexity of AQUATOX seems excessive for this particular project, some level of complexity and uncertainty is unavoidable. **A** @ Accordingly, it is imperative that the modeling framework be modified to include formal uncertainty analysis. To simply provide decision makers model predictions without information on the uncertainty of those predictions would be a disservice that could result in needless squandering of remediation funds. Decision makers need to be provided with a good assessment of the reliability and uncertainty of the model predictions so that choices between remediation alternatives are fully informed. **U**

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APPENDIX B

EPA RESPONSE TO PEER REVIEW PANELIST QUESTIONS ON THE HOUSATONIC RIVER MODELING FRAMEWORK DESIGN APRIL 12, 2001

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

General Response to Comments

In order to develop quantitative evaluations of the effectiveness of remediation alternatives for PCB contamination in the Housatonic River, a mass balance model of PCB transport, fate and bioaccumulation is required. The deposition and resuspension characteristics of cohesive (fine-grained) and non-cohesive (coarse-grained) solids require a hydrodynamic model to determine the distribution of bottom shear stresses that control deposition, transport and erosion processes of solids particles in the sediment transport model. Because PCBs preferentially adsorb to solids, a sediment transport model coupled with the PCB fate model is needed to account for partitioning of PCBs into the dissolved and particulate phases. And since one of the principal goals of the modeling analysis is to evaluate PCB concentrations in biota, the ability to simulate bioaccumulation is also necessary.

As stated in the Executive Summary of the MFD, the proposed modeling study was designed to (1) represent the full range of relevant physical, chemical and biological processes of concern for PCB transport, fate and bioaccumulation in the Housatonic River, and (2) address a number of site-specific study objectives detailed in the charge to the Modeling Peer Review. The processes and objectives, in turn, dictated the choice of the types of models that could provide the data and information needed to meet the study objectives. The modeling study objectives are:

- Quantify future spatial and temporal distributions of PCBs (both dissolved and particulate forms) within the water column and bed sediment. (EFDC)
- Quantify the historical and relative contributions of various sources of PCBs on ambient water quality and bed sediment (HSPF and EFDC).
- Quantify the historical and relative contributions of various sources of PCBs to bioaccumulation in targeted species (AQUATOX).
- Estimate the time required for PCB-laden sediment to be effectively sequestered by the deposition of “clean” sediment (i.e., natural recovery) (EFDC).
- Estimate the time required for PCB concentrations in fish tissue to be reduced to levels that no longer pose either a human health or ecological risk based on various remediation and restoration scenarios, including allowing for natural recovery (AQUATOX).
- Quantify the relative risk(s) of extreme storm event(s) contributing to the resuspension of sequestered sediment and the re-distribution of PCB-laden sediment within the area of study (EFDC).

The study objectives clearly delineate the need for very different types of abiotic and biotic information about PCB transport and fate that would likely be based on different models, driven by very different time and space scales.

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

In considering alternative strategies for developing the modeling framework, the modeling team balanced the overall objectives with the technical credibility of the approach, as well as the practical aspects of computational feasibility. In addition to the key processes identified in the Conceptual Model of hydrodynamics, sediment transport, and PCB fate and bioaccumulation, an important factor considered in the evaluation of the technical credibility and the robustness of the model framework was the choice of using either external forcing functions (e.g., flow-concentration rating curves for a tributary) or internal dynamically coupled solutions (e.g., output from watershed-based hydrologic runoff model) to generate model input parameters. This choice determines, in part, the number of adjustable calibration parameters needed for the models.

Since it is impossible to build an environmental model based on a truly closed system, models need to be designed to minimize the data input via open boundaries. A model framework based on the use of dynamically coupled models, although requiring an intensive effort to develop, is expected to provide a very robust framework based on technically credible model formulations, which are driven by few open boundaries and a small number of adjustable parameters. An alternative modeling framework developed using external forcing functions, although much simpler to develop since many more degrees of freedom are available through a greater number of open boundaries and adjustable parameters, is expected to result in a less robust framework with less technical credibility. The substance of a modeling framework is, however, ultimately dictated by the selection of models that best represents the key processes identified in the Conceptual Model for the Housatonic River. The choice of such a modeling framework can then be used with confidence to prepare scientifically credible evaluations of baseline conditions and the impact of alternative remediation scenarios.

The modeling team has chosen to propose a modeling framework based on the internal coupling of the results of a watershed runoff model (HSPF), and a hydrodynamic and sediment transport model (EFDC), with a PCB fate and bioaccumulation model (AQUATOX). Although the application of these three models in such a coupled framework has not been previously developed, particularly for a complex meandering river such as the Housatonic River with the associated floodplain, each of the individual models has a lengthy (~10-20 year) history of successful applications to a wide range of waterbody types and problem settings, including linkage with other models.

Over the past few years HSPF has been coupled with EFDC to provide a number of TMDL assessments. In a model of nutrients, algae and dissolved oxygen for a TMDL assessment of the Yazoo River basin (Tetra Tech, 1999) for example, HSPF was used as the watershed model to provide flow and pollutant loads to EFDC for the hydrodynamic and water quality simulations. In an extensive risk assessment of 25 pesticides used on corn in all regions of the U.S., PRZM was used to provide daily loadings of pesticide runoff into farm ponds, which were then modeled by AQUATOX. New applications and linkages of existing models are not necessarily undesirable. Development of a successful modeling framework for a challenging problem such as the evaluation of baseline conditions and alternative PCB remediation strategies for the Housatonic River has the potential to significantly advance the body of knowledge for contaminant transport and fate modeling in riverine systems.

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

Overall Modeling Framework

General Response

As mentioned above, the modeling analysis is an ongoing process. Evaluation of existing data and new information continues to provide insights (e.g. the recent resurvey of the channel morphology) which refine the conceptual model and correspondingly, the modeling framework. The models selected and their domains proposed in the MFD reflected the team's best understanding of the issues associated with the mathematical representation of the important processes in the Housatonic River and the objectives of the model analysis. To date, no information or data evaluation has suggested that any circumstances exist which would alter the general approach proposed in the MFD. The opportunity to answer the Peer Reviewer's questions and provide an update to the process outlined in the MFD is welcomed, and should provide additional insight as to the thought-process regarding the topics of the reviewer's inquiries.

The models selected have undergone substantial review and scrutiny by many parties other than those associated with this modeling analysis, which demonstrates the utility and applicability of these models. The model updates/enhancements, linkages, and nature of this application have required that additional review and testing be undertaken for the modifications to AQUATOX and EFDC. While this is the first application of AQUATOX and EFDC to this type of river domain, the extent of the data available and the rigorous review process, including the input from the Peer Review Panel, provides just the type of project needed to make this approach successful. The modeling team continues to believe the approaches outlined in the MFD provide a solid process for achieving model parsimony and implementability, balanced with the modeling objectives.

103. The modeling effort is a major undertaking. Somewhat similar efforts have been made for other PCB-contaminated water bodies (Hudson River, New Bedford Harbor, Fox River, etc.), with varying degrees of success. How does the proposed effort on the Housatonic compare with other studies in terms of degree of difficulty and expected results. Based on such comparison, do the model developers feel confident that the proposed MFD will address the stated objectives in the proposed timeframe? (EA1)

Response: Please see General Response above.

Overall Modeling Framework

1. Is a three-dimensional hydrodynamic (and sediment transport) model necessary? A two-dimensional, time-dependent hydrodynamic and sediment transport model (with a correction for quasi-equilibrium distribution of sediments in the vertical) should be sufficiently accurate in the river. It is also much more computationally efficient. This has been shown in numerous cases. Even for the pond, a two-dimensional model is sufficiently accurate to predict sediment and PCB transport. As an example, see Wang et al (1996) where results of sediment transport calculations in Green Bay are compared for (a) a constant density, three-dimensional flow, (b) a vertically stratified, three-dimensional flow, and (c) a vertically integrated two-dimensional flow. For all practical purposes, the results of the three cases are identical. This would be true for PCB transport also. (WL2)

123. Although Woods Pond is thermally stratified at times, it is not clear that this stratification (and hence the use of a 3D model) is important for understanding PCB transport. Has consideration been given to the use of EFDC in only 2D, or the use of another (2D or 1D) model? (EA21)

Response: The MFD (p. 4-47) was unclear in describing whether the model was intended to be run in a two-dimensional or three-dimensional mode. As clarification, a two-dimensional model is planned for the PSA with the exception of Woods Pond. Preliminary reviews of temperature data from Woods Pond indicate that it is stratified during part of the year, therefore, a three-dimensional model is being considered for this area.

The primary purpose for proposing a 3D application in Woods Pond is not related to sediment and PCB transport, but to PCB fate and bioaccumulation, particularly with regard to anaerobic degradation of PCBs. AQUATOX will be run both with and without stratification to see if stratification makes a significant difference in the fate of PCBs; if it doesn't, then a two-dimensional model will be applied throughout the PSA.

2. The fundamental issue with all of the models presented in this report is that there is no examples of prior applications that were either successful or not. No examples of applications to simple flows or problems where the model has successfully reproduced field or laboratory data are offered. It is apparent that a lot of new things are to be done here and it is not at all clear that they will be successful. This reviewer would have a lot more confidence if he could see that the models have peer-reviewed publications that describe successful model applications. Instead there appear to be only enumerations of where the models have been applied and who has used them, without any comment as to the success or otherwise of the model in the application. It is surprising to learn that EFDC, for example, appears to have not been previously applied to a sinuous river flow before. Is this correct? (JL1-24)

Response: Within the Peer Review Panel questions, there are several questions suggesting that the proposed modeling framework includes too many new approaches. Conversely, there are several questions which suggest that other new approaches be developed which add capabilities

Overall Modeling Framework

that do not currently exist in the proposed models. In developing the modeling framework, an approach was taken which, upon definition of the demands that would be placed on the framework, strove to develop and apply the models in new ways, when a significant need existed, and in a manner that complemented previous code developments for the model(s). No models (or collection of models) were identified in the public domain that could have been used "off the shelf", all would have required some (usually significant) code enhancements. Also, no model(s) were identified that had been applied to a model analysis of the scope and complexity of the Housatonic River.

A list of peer-reviewed EFDC publications (See Appendix C) and a list of all previous EFDC applications (see Appendix G) and links to the EFDC websites (Appendix F) have been included in this response. Few 2D hydrodynamic sediment/toxic transport models have been applied to sinuous rivers similar to the Housatonic River, where one of the objectives is to evaluate floodplain deposition. HydroQual's and QEA's river applications have largely been for larger rivers, such as the Hudson and Tennessee, where the focus was within the main channel area.

The HSPF model was designed for application to this type of river system as well as other domains. A list of HSPF applications is provided in Appendix B.

With regard to AQUATOX, the model was also highly developed (75 file versions over 14 years), however some modifications to the model were still necessary to properly characterize the application to the challenges posed for the Housatonic River. The modifications to AQUATOX can be broken into three categories. First, individual model segments have been linked together, with the output from one segment being passed as loading to the next. Second, there is a new sediment bed representation added to the model to enable AQUATOX to represent toxicant fate within the sediment bed based upon the formulations developed and tested on the Fox River (IPX 2.74), described below. Third, the chemical representation has been expanded to model multiple chemicals simultaneously. [Beach, 2000] See Appendix A for further references to AQUATOX.

The linking of model segments, while a modification to the previous versions of AQUATOX, is not a controversial one. AQUATOX has always modeled the flow-through of water, material, and chemicals. Linking segments together is primarily the act of using the washout from an upstream segment as a loading for a lower segment. Water flows are available from the EFDC model, so that there are sufficient data to support the linkage of AQUATOX segments. Additionally, the linked segment representation has been thoroughly tested for mass balance and maintains toxicant mass within machine accuracy.

The modification to the sediment bed representation is based on the IPX V 2.74 model (Velleux et al., 2000), and the modifications have been tested for mass balance and for concordance with IPX results for a test case. More details about this model and the AQUATOX implementation of this model can be found in the response to Question 56.

Overall Modeling Framework

Finally, the model has been generalized to model as many as 20 chemicals simultaneously with linkage of chemicals subject to biotransformation. This is primarily a matter of utilizing the object-oriented code to replicate the chemical object in the code.

AQUATOX has been applied successfully in a relevant peer-reviewed validation with PCB congener data from Lake Ontario similar to modeling PCB bioaccumulation in the Housatonic River (EPA, 2000). Figures shown below are examples of this application to prediction of PCB congeners in Lake Ontario. The model "provided better fits to observed data for phytoplankton and mysids than those provided by the Gobas (1993) and Thomann (1989) models as implemented by Burkhard (1998), and equally acceptable results for smelt and lake trout when compared to the Gobas model." [EPA, 2000]

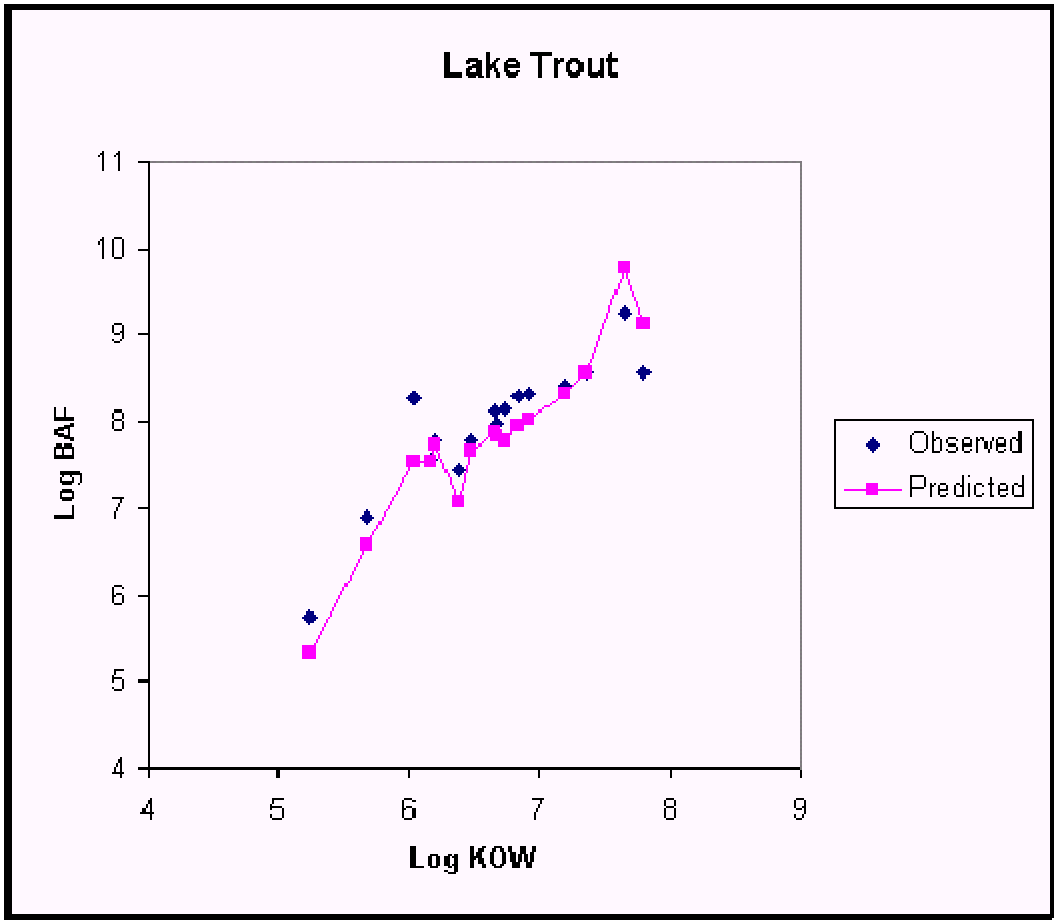
Another example relevant to the Housatonic River is an intensive series of applications conducted from 1998 to 1999 by Bart Koelmans, a Dutch bioaccumulation researcher and his student, Caroline Moermond, who performed a series of scenario studies with AQUATOX (Moermond and Koelmans, 1999). These scenario studies focused on the fate and effects of a PCB (PCB153), a PAH (benzo(a)pyrene and a pesticide (chlorpyrifos). The scenario studies were performed with the algae-dominated Lake IJsselmeer, the macrophyte-dominated Lake Wolderwijd and algae- and macrophyte-dominated model ecosystems with and without fish (Moermond and Koelmans, 1999). They continue to use AQUATOX in their ongoing research.

Furthermore, in a report, "Improvements in Applications of Models in Ecological Risk Assessment: Evaluation of Ecological-Effects Models," issued last fall and funded by the American Chemistry Council (previously the Chemical Manufacturers Association), the following statements were made concerning AQUATOX:

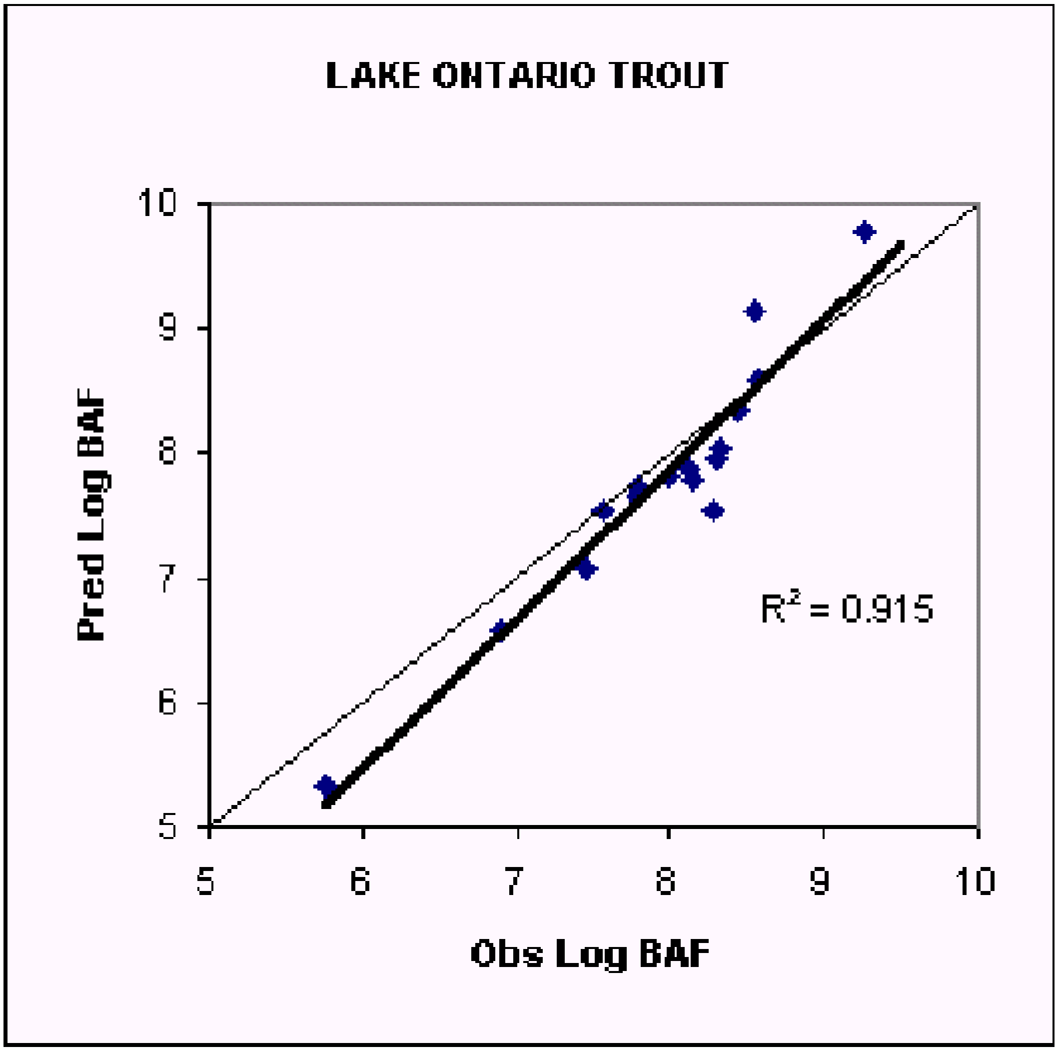
> "Realism—The model accounts for important biotic and abiotic interactions within and between several trophic levels and considers associated feedbacks." (p. 79)

Overall Modeling Framework

"On the basis of our evaluation of aquatic ecosystem models (Table 11), three models are recommended for more detailed evaluation and application in selected case studies. These models are AQUATOX, CASM, and IFEM." (p. 98)



<u>**Overall Modeling Framework**</u>



7. Pg. B-5 Recent HSPF Applications – Where are testimonials to its effectiveness and examples of its ability to predict hydrologic outcomes? (JL1-21)

112. Can the authors provide references on the ability of HSPF to accurately predict runoff, TSS and contaminant loads during extreme storm events? (EA10)

<u>Response:</u> Attached (in Appendix B) is a list of references of HSPF-related documents, including references for both model documentation and application. There have been literally hundreds of applications of HSPF in the U.S. and abroad since its initial release in 1980. It is currently in Release No. 12. EPA and USGS chose to jointly support and maintain HSPF. In addition, HSPF is the primary watershed model included in the EPA BASINS modeling system (Lahlou et al., 1998) and it has recently been incorporated into the U.S. Army Corps of Engineers Watershed Modeling System (WMS) (Deliman et al., 1999).

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

Overall Modeling Framework

Ongoing model refinements and enhancements to HSPF, including both model/algorithm and software/interface capabilities, have been supported by EPA, USGS, U.S. Army Corps of Engineers, South Florida Water Management District, and Minnesota Pollution Control Agency.

HSPF has been successfully applied as the modeling framework for the Chesapeake Bay Watershed Model for nutrient loadings and evaluation of management alternatives (see numerous publications by Linker and Donigian in Appendix B). Moreover, it has been used on an ongoing basis over the past 10 years within the Chesapeake Bay Program to evaluate loadings impacts to the Chesapeake Bay of nutrient management alternatives, Clean Air Act impacts, forestry practices, and other alternative conditions (see www.chesapeakebay.net/model.htm, or contact Lewis Linker, 800-267-5741, ext 741; or linker.lewis@epamail.epa.gov).

The Chesapeake Bay Watershed Model results are on the CBP web site, as follows:

- www.chesapeakebay.net/pubs/238.pdf - WQ results, 1984-92, 10-12 watershed sites, 16 MB
- www.chesapeakebay.net/pubs/113.pdf - Hydrology results, 1984-92, 15 sites, 8 MB

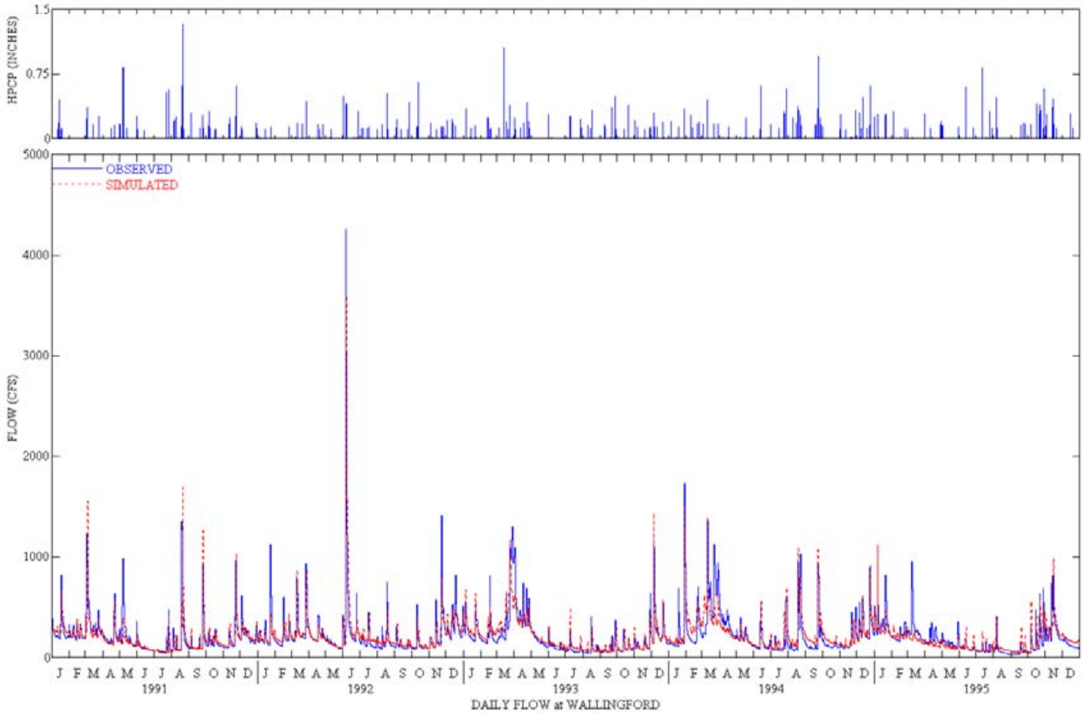
In a recent application for the Long Island Sound Program, HSPF has been used to simulate flow and pollutant loads for watersheds located in Connecticut (including the Housatonic River) that drain into Long Island Sound. Selected results from this project are presented for the Farmington and Quinnipiac Rivers as time series plots of model vs. data for streamflow, total organic carbon, total nitrogen and total phosphorus. These plots clearly demonstrate the ability of the model to reproduce observed data sets under a wide range of flow conditions recorded modeled from 1991-1995. Annual average ratios of model-to-observed data measured at USGS gage stations ranged from ~0.9 for flow to ~0.8 to 1.2 for TOC, TN and TP. HSPF has been used for over 10 years as the watershed model for the Chesapeake Bay Program. The period of record for the Chesapeake Bay Program modeling study included an extreme flood event (~100-500 year recurrence interval) recorded in the Potomac and Shenandoah River basins in November 1985. Although model vs. data results are not presented here for this extreme flow event in the Potomac River, the Peer Review Panel can examine these, and numerous other results for HSPF, at the Chesapeake Bay Program website (www.chesapeakebay.net/model.htm).

Clearly not all the references and applications have been peer-reviewed, although many have been summarized in peer-reviewed journals. However, HSPF has been widely applied, by a diversity of organizations, in varying climates and conditions throughout the U. S. and abroad under great scrutiny for at least a decade, and its use is expanding under the impetus of the TMDL program; this is, in effect, a testimonial to its acceptance as a useful watershed model.

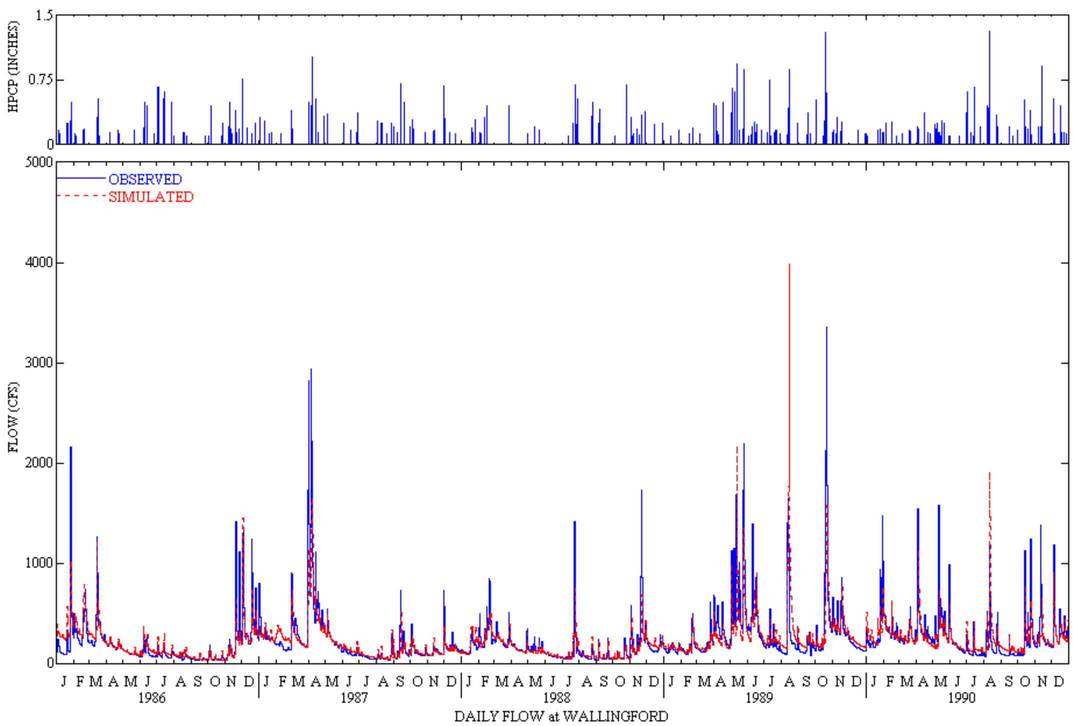
<u>Overall Modeling Framework</u>

Table 4.5 Observed and Simulated Daily Flow for the Quinnipiac River at Wallingford - Calibration and Verification (Top curves are Daily Precipitation)

Calibration Period



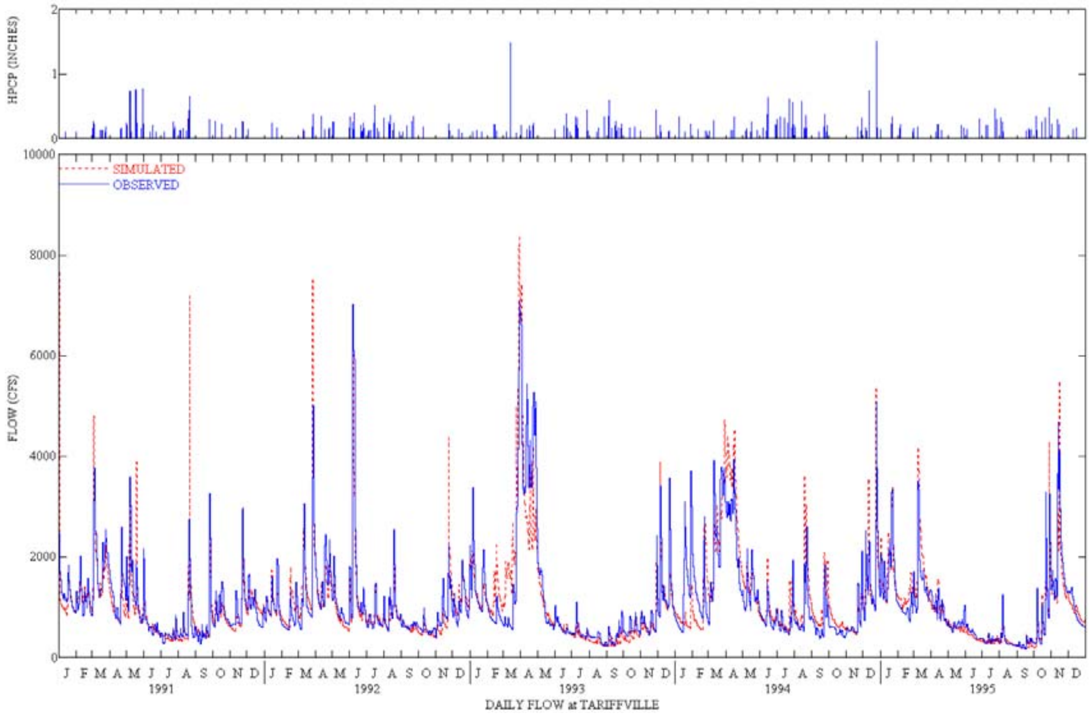
Verification Period



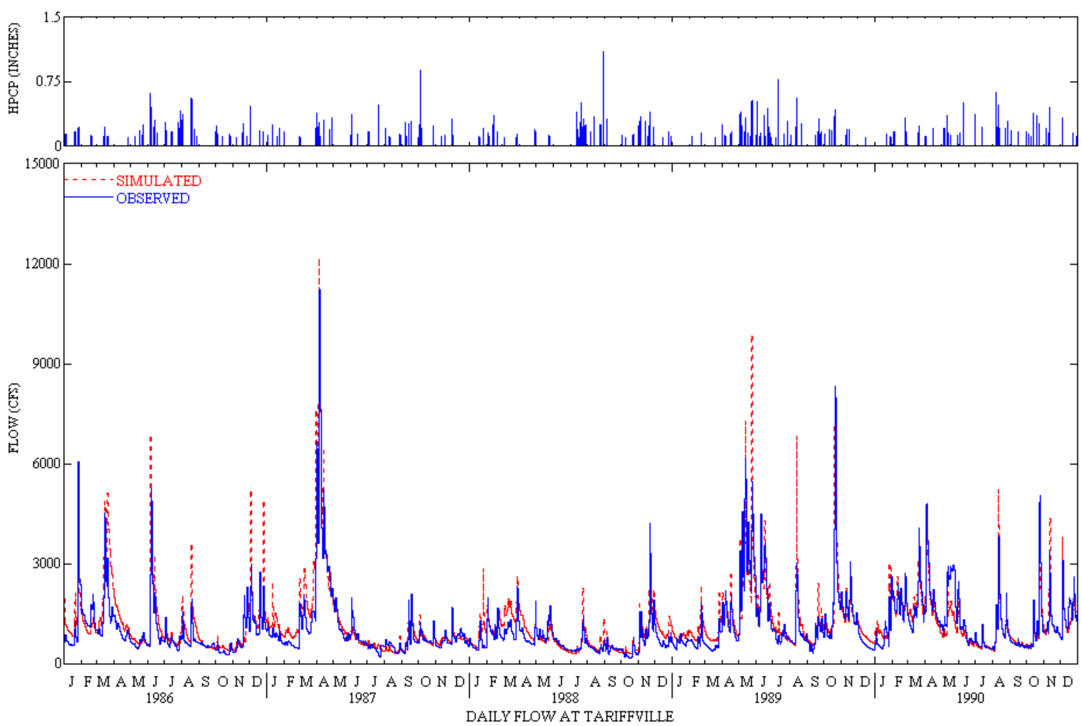
Overall Modeling Framework

Figure 4.11 Observed and Simulated Daily Flow for the Farmington River at Tariffville - Calibration and Verification (Top curves are Daily Precipitation)

Calibration Period



Verification Period



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57. HSPF: Has HSPF been previously applied to predict PCB boundary conditions in a river system? What evidence can be offered to support this application of the model? (DE5)

Response: HSPF has not been used to simulate PCB fate and transport in watersheds. However, HSPF and its predecessor models were originally developed to simulate chemical fate and transport, specifically for pesticides used in agricultural regions. It has been applied for pesticide and contaminant modeling in Iowa (Donigian et al., 1983; Bicknell et al., 1984; Donigian et al., 1983), Texas (Dean et al., 1984), Tennessee (Fontaine and Jacomino, 1997), and Quebec, Canada (Larouche et al., 1996). A study of pesticide fate and transport for Alachlor (Mulkey and Donigian, 1984) was performed for watersheds in Iowa, Ohio, and Georgia as part of the EPA Office of Pesticide Programs position on the re-registration of Alachlor (referred to as an RPAR – Rebuttable Presumption Against Registration). The success of these efforts and the lack of other modeling tools has established HSPF as the best available model for determining PCB boundary conditions for this study. Notwithstanding the simulation capability and history of HSPF, the existing PCB data for the upstream boundary of the PSA will be investigated and evaluated as part of the study effort to determine the most representative historical and future PCB loadings possible.

113. HSPF is a 0 dimensional model, in the sense that it does not spatially discretize the watershed. Was consideration given to a spatially discretized watershed model? (EA11)

Response: As described in the MFD (Section 4.3.1.1 and Appendix E), the Housatonic River watershed down to Great Barrington was initially discretized into 39 sub-watersheds (shown in Figure 4-2), also referred to as hydrologic response units or HRUs. Each of these sub-watersheds will be further subdivided into four to seven separate land use categories which will be modeled individually. However, the separate land uses will not be spatially defined within each sub-watershed; hence the connotation of a 0 dimensional mode within each subwatershed.

Currently, with higher resolution DEM and land use data up to 50 or more sub-watersheds will likely be applied, with the smaller sub-watersheds and greater spatial resolution in the areas adjacent to the PSA. This level of spatial definition was judged to be adequate for providing the flow and boundary loading conditions for the PSA, which is the primary function of the HSPF watershed model.

Typical spatially distributed watershed models that impose a grid on the watershed and simulate individual cells (e.g. MIKE-SHE) use a cell size of about 200 m (i.e. 200 m x 200m). This level of detail would require over 18,000 cells for the 282 sq. mi. Housatonic River down to Great Barrington, making a minimum 20-year simulation intractable. Increasing the cell size to 1 sq. km. results in cells about equal to the smallest sub-watersheds in the current HSPF sub-watershed delineation. Thus, a finer spatial resolution with a distributed, or discretized, watershed model was not considered appropriate or practicable for this effort.

<u>**Overall Modeling Framework**</u>

114. Most of the PCBs are apparently found in the 10-year floodplain that (from Figures 4-2 and 4-3) is a very small fraction of the sub-watersheds. How can HSPF accurately resolve the wash off of PCBs over such a fine spatial scale? (EA12)

<u>Response:</u> The spatial domain described by the 10-year floodplain will be simulated by the EFDC model, not HSPF. The boundary between the watershed drainage area and the river channel/floodplain is at the 10-year flood demarcation line. PCB contributions from the watershed are being passed from the East Branch and West Branch tributaries to the PSA at the upstream boundary condition, as described in the responses to Question's 20-22.

116. HSPF includes a relatively simple river model. As long as EFDC is going to be used to transport PCBs in the river, why worry about development/calibration of the river section of HSPF? Conversely, is it possible that the river section could be (substantially) augmented to handle the transport tasks asked of EFDC? (EA14)

<u>Response:</u> Transport and flow routing in a reach in HSPF is based on a relatively simplified, one-dimensional open channel flow model. The hydraulic model is driven by channel geometry and slope, bottom friction and upstream and lateral inflows from surface and subsurface runoff. It would be a major code development and testing effort to include the needed EFDC hydrodynamic capabilities in HSPF. The modeling team believes that this would not be an advantageous solution to the issues associated with this model analysis. The same types of linkage issues would still need to be addressed even though they would be handled internally in a single code. In addition, it is not clear that these extensive enhancements could be completed in a timely fashion consistent with the study schedule.

3. What criteria were used to select EFDC to conduct the hydrodynamic modeling of the Housatonic River? There are many public domain models, including several supported by EPA such as HSCTM2D, that could be more appropriate and perhaps more adequate for such riverine environment. (MG1)

<u>Response:</u> The EFDC (Environmental Fluid Dynamics Code) hydrodynamic model, developed over the past decade by John Hamrick (1992a, 1996a) at the Virginia Institute of Marine Science and Tetra Tech, Inc., is comparable to state of the art hydrodynamic models developed by Blumberg and Mellor (1987) and Johnson et al. (1993). The Blumberg-Mellor model, available in the public domain as the Princeton Ocean Model (POM) is also maintained as a proprietary version (ECOM-3D) of the model by HydroQual, Inc. Johnson's model (CH3D), developed at the Waterways Experiment Station for the Chesapeake Bay Program, is in the public domain but is not readily available. Although these models were originally developed for application to estuarine and coastal systems, the availability of this class of 3D hydrodynamic models, based on first-principle physics for the conservation of mass and momentum equations in 3D, has led to their use in applications for contaminant fate models for inland rivers (Lower Fox River, WI;

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Pawtuxet River, RI; Blackstone River, RI; Upper Hudson River, NY; Christina River, DE; Upper Mississippi River, MN), and lakes and reservoirs (Watts Bar Reservoir, TN; Lake Okeechobee, FL; TenKiller Lake, OK).

Since this class of hydrodynamic models are based on first-principle physics, the hydrodynamic regime of both small and large waterbodies can be simulated accurately as long as proper boundary conditions are imposed and an appropriate spatial discretization of bathymetry and shoreline is adopted for the computational grid. The practical constraint for the meandering Housatonic River is the spatial discretization needed to resolve the curvature of the meanders with the floodplain. Because the Housatonic River analysis poses a unique challenge in the requirement that the river channel must be coupled with the floodplain for the assessment of PCB fate and transport and maintenance of mass balance, any other hydrodynamic model (public domain or proprietary) would also require a comparable spatial resolution of the meanders and the floodplain.

Criteria that were considered in the selection of EFDC as the model for hydrodynamics, sediment transport and, secondarily abiotic PCB fate included the following:

- capability to represent key processes identified in conceptual model
- internal coupling of hydrodynamics with sediment transport and PCB fate
- track record of previous applications
- availability of pre- and post-processing software tools
- availability of technical support from model developer
- flexibility to represent 1D, 2D or 3D systems with same model
- flexibility to modify source code to enhance model capability
- degree of difficulty of using the model
- computational efficiency of numerical methods
- capability to dynamically couple flow, solids transport and PCB fate in the river channel and floodplain
- team experience with model

A brief discussion of the computational efficiency and track record of previous applications of EFDC is presented below. See Appendix G for the listing of EFDC applications.

Estimated CPU requirements was one of the criteria used in the selection of the model to be applied to the Housatonic River. The EFDC, POM, ECOM-3D and CH3D models are based on finite difference solutions. It is well known that numerical solution techniques based on finite differences are computationally faster than finite element models of hydrodynamics. Public domain finite element hydrodynamic models include the TABS-2 system of 2D/3D RMA models supported by the Waterways Experiment Station and HSCTM2D supported by EPA. For a given 2D problem setting, the performance of EFDC is 5-10x faster than HSCTM2D. In a benchmark study of model performance, EFDC has been shown to be computationally more efficient than ECOM-3D by about 2x (Hamrick and Wu, 1997). See Appendix H for EFDC runtime estimates.

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EFDC has a much more extensive application history than HSCTM2D. As the sediment transport and contaminant transport routines in HSCTM2D are essentially equivalent to those in EFDC, HSCTM2D is not more appropriate or more adequate than EFDC for application to a riverine system. In terms of numerical efficiency, and the ability to simulate sediment and contaminant transport during flood events in a riverine system, EFDC represents the state-of-the-art in multi-dimensional environmental hydrodynamic and fate and transport models. EFDC is therefore the public domain model of choice for modeling hydrodynamics, sediment transport and abiotic PCB transport and fate in the Housatonic River.

124. Are any problems with spurious diffusion anticipated due to the stretched (sigma) coordinate formulation of EFDC? If so, how will they be handled? (EA22)

Response: When a sigma-stretched grid is applied to a steeply sloped bottom and strongly stratified flows, an artificial diffusion along an s-grid cell can occur. This effect is most apparent if the water body has strong density gradients whose isopycnal surfaces do not correspond to the sigma stretched grid surfaces. Additionally, the horizontal pressure gradients can be truncated due to the slope of the grid surface.

Woods Pond is the only area currently being investigated with respect to 3D modeling, therefore, it is the only area that could be impacted. This effect may be noticeable along the edge of the Woods Pond deep hole under the most stratified times. If this is determined to be a significant effect, higher spatial resolution could be applied.

4. Pg. 4-19, 4-20 Code enhancements are still being considered. The implication is that this model has not been used in this flow configuration before. Is this inference correct? (JL1-7)

117. (p. 4-19) I am concerned about the need to engage in code enhancements in the middle of a tight schedule. Could a simpler model with less computational requirements be used? (EA15)

120. Will the model developer (John Hamrick) be available as a consultant to the project? (EA18)

Response: During the conceptual model development and model selection process it was determined that no currently available off-the-shelf model will meet all the demands that the sediment and PCB transport application requires in the Housatonic River. The EFDC model was selected as the public domain model that met the greatest number of requirements for the project. Therefore, from the project onset it was expected that some code modifications would be required for EFDC to meet all the objectives of this study. The following list summarizes the modifications to EFDC that are necessary for application to the Housatonic River:

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1) A modification to the Everglades version (Hamrick, 1994b) of the wetting and drying scheme within EFDC to more realistically handle the variable floodplains found in Reach 5.
2) A modification of the grid nesting scheme utilized in the Everglades version. (See Figure in response to Question 54, showing an example of a meandering River of the same approximate depth and dimensions of the Housatonic River). This example demonstrates the channel nesting scheme for the main channel, the treatment of proximal floodplain, and the connection to the floodplain cells).
3) The addition of three bed load approaches [Meyer-Peter and Muller (1948), Bagnold (1956) formulas and their derivatives, van Rijn (1984a)], that are consistent with the EFDC formulations.
4) Modification of the sediment erosion characteristics to reflect critical shear stress as a function of bulk density.
5) Incorporation of an active layer/minimum bed thickness (HBEDMin).
6) A variable time-stepping approach to account for the wide range of forcing functions driving the sediment and contaminant transport in the Housatonic River, and to enhance computational efficiency.
7) Modification of the contaminant partitioning approach to allow the option to specify the organic carbon fraction of solids for partition calculations based on Koc and the octanol-water partition coefficient (Kow).

These modifications to EFDC were identified during the initial development of the conceptual model and discussed with the author of the code, Dr. John Hamrick over two years ago. Dr. Hamrick has been working on these modifications under contract to the EPA work assignment manager Susan Svirsky since that time, with third-party testing being performed by ZZ Consulting, LLC, with oversight from EPA-ORD Athens and WES. The code-testing is well underway, and the modeling team does not envision that the modifications will impact the project schedule. It is expected that Dr. Hamrick will remain available to EPA for consultation on the use of EFDC throughout the duration of this project. Test cases, coupled with analytical solutions are being developed, along with testing of site-specific situations during the test reach work. The code testing and associated QA is summarized in the QAPP (Section 4.10) on page 4-65.

No modifications were necessary to HSPF, and the testing of the modifications to AQUATOX has been completed.

5. Pg. 4-21 "sediment bed MAY be represented as a single layer or multiple layers". The implication is that this code has not been used before in this context. Is there peer-reviewed and documented calibration and use of this code in prior applications? If so, where can it be found? (JL1-8)

Response: This is the first application of EFDC to a multiple layer bed, although this concept has been included in the code for some time. Code testing is ongoing to ensure the validity of the algorithm and its implementation within the EFDC. Once the testing is complete, a testing memorandum will be issued to document the verification of this implementation and included in the calibration report.

6. Pg. 6-2 If GSTARS is satisfactory in describing the sediment patterns in streams, then why not use it in place of EFDC? (JL1-17)

119. EFDC was developed for generalized 3D simulations, and not rivers per se. If other models such as GSTARS work well for riverine sediment transport, why not use them? (EA17)

Response: The currently available version of GSTARS is Version 2.0 (Yang, 1998). While this version of the model is very useful for streams application as is proposed in the MFD in Section 6, it has several major drawbacks for the general application of sediment and contaminant transport needed for the Housatonic River analysis. Version 2 of the model currently has the following two significant limitations for an application as postulated in the question:

1) Floodplain Interactions - The stream tube design of GSTARS does not lend itself to effectively modeling the floodplains around the Housatonic River. GSTARS is optimized for the use of hydraulics and sediment transport within the river channel proper. The stream tube design and the channel focus is what enables GSTARS to make even a crude attempt at modeling stream bank erosion. This focus limits the use of GSTARS in applications such as what is proposed for the Housatonic River where the floodplains are of interest with respect to both sediment deposition/resuspension and PCB transport.
2) Contaminant transport - GSTARS is currently a hydraulics and sediment transport model and does not have the capability of conducting contaminant transport. With the transport and distribution of PCBs in the river sediments and the floodplains of critical interest to the study, the inability to model contaminant transport invalidates the use of GSTARS for the general application to the Housatonic River.

8. pg C.3-1 Why were no peer reviewed applications of this model included? The references are all to descriptions of the model and do not include examples of prior applications, or the success or failure thereof. Where are the examples of model successes and failures if any? The Blumberg-Mellor-Yamata formulation was notoriously unsuccessful in the application to the Santa Barbara Channel for the Bureau of Land Management; and to my knowledge that report was never published. Are there peer-reviewed published reports that compare the outcome of EFDC modeling and actual field data? I could not find any. (JL1-23)

Response: Not knowing the composition or focus of the Peer Review Panel, it was difficult to anticipate the areas of interest and associated level of detail to be provided in the MFD. Again,

Overall Modeling Framework

EPA welcomes the opportunity to provide the additional information. The peer-reviewed reference list and other references are included as Appendix C.

The B-M-Y turbulence model has had many more successes than failures. Its record of matching field data for stratified estuary flow is well documented. Good agreement with field data for rivers (e.g. Blackstone (Tetra Tech, 1999) and Duwamish (Tetra Tech, 1998) has been documented, see Appendix I for example plots). Two of the peer-reviewed publications, Jin et al., (2000) and Hamrick and Mills (in press) show results for temperature-stratified lake flow. Also the model testing conducted for the Housatonic River has show agreement between predicted and observed two-layer secondary circulation in the 270-degree bend experiments of Jin and Steffler (1993).

9. At the top of page 4-20, it is stated "Changes to the code will undergo thorough third-party review and testing and will become a part of the calibration report." I did not see that the QAPP covered code quality assurance. Should it not? For that matter will codes be validated (i.e., will they be tested against analytical solutions or undergo similar tests to demonstrate that they are solving correctly)? (PS12)

Response: Section 4.10 (p. 4-65) of the Quality Assurance Project Plan (QAPP) for the modeling study discusses the QA procedures to be followed for code modifications and model enhancements. Implementation of these procedures is an integral part of development of new capabilities in the models. All new code is reviewed independently, mass balance is tested to within machine accuracy, and test cases are run against analytical solutions. The testing progress is monitored through the use of a regularly updated tracking system to insure that all steps have been completed to the satisfaction of all parties. At the conclusion of testing of each significant code modification, the testing methods and results are documented in a brief report which will be included in the calibration report

11. Why is there no effort to model this highly meandering river with a model that can truly capture the interaction between secondary currents and the streambanks? (MG10)

Response: As part of the Conceptual Model development and modeling framework development, velocity patterns, riverbank conditions, and the historical meander patterns were all considered during the development of the MFD. Plots of data for a velocity cross section from the ADCP work conducted on the river are included below. Summary statistics on this cross-section are:

Section Area: 43.9 (m^2), Max Depth: 2.13 (m)

Velocity Summary

Magnitude Avg: 0.1570 (m/s), Max: 0.2519, Min: 0.0000 (m/s)
Transverse Avg: 0.0005 (m/s), Max: 0.0424, Min: -0.0367 (m/s)
Vertical Avg: -0.0037 (m/s), Max: 0.0169, Min: -0.0230 (m/s)

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Total Flow is: 5.251 (m^3/s) @ 289.37 WS Elevation

These results are consistent with other studies of river bends (Jin & Steffler (1993) and Ye & McCorquodale, 1998). Jin & Steffler, in their study of modeling morphological change note that secondary currents are generally one order of magnitude less than streamwise velocities.

With respect to modeling the secondary currents, a 3D river channel model would be required. As part of this application, EFDC has been tested for a 270-degree bend (Ye & McCorquodale, 1998), and indeed, EFDC does predict these secondary currents. However, given that the main issue is not morphological changes, but cross section/floodplain erosion and deposition, lumping the secondary currents into the streamwise laterally varying currents (and thus laterally varying shear stresses) is postulated as a reasonable approach.

It is anticipated that, during supplemental work including the application of GSTARS and the Test Reach, the importance of bank erosion and channel meander will be evaluated further. If found to be significant, methodologies (e.g. using GSTARS to assist in developing proximal floodplain/bank erosion functions, E(Q,RM)) will be employed to address the sediment and PCB loads that would result from significant bank failures. The issue of the importance of river bank erosion is further discussed in response to questions 38, 39, and 42 below.

12. On page 4-19, it is stated that the computation may be burdensome. Can you provide a quantitative indication in terms of CPU time for this application or a computationally similar application of EFDC? (PS11)

Response: Appendix H contains a brief analysis of estimated EFDC runtimes. Efforts are underway to decrease runtimes through dynamic time stepping and parallel processing.

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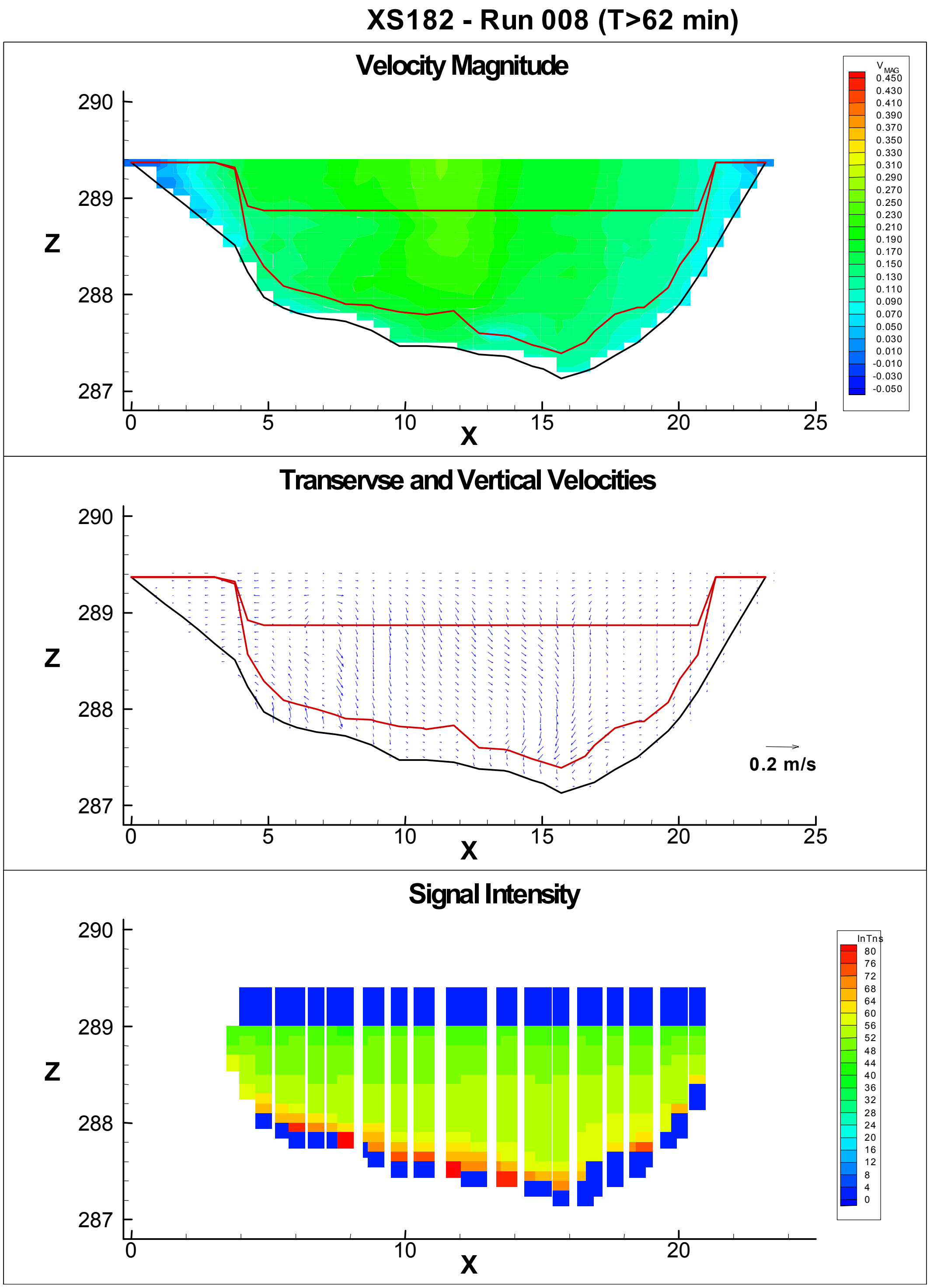

Model Linkage

General Response

As discussed in the introductory response to the Peer Review Panel, the proposed modeling framework was designed to address the specific objectives of the modeling study and the site-specific complexities. The specific models (HSPF, EFDC and AQUATOX) have been chosen to provide the types of data and information needed to meet these challenges and objectives. Since the constituents and temporal/spatial scales of each model are different, procedures are needed to link the models in a coherent framework. This linkage will ensure that the model results from an each upstream model are properly matched to the appropriate constituents and spatial/temporal scales of the receiving or downstream model. The key requirement for the model linkage is the necessity to maintain a careful mass balance of flow and constituent loads between HSPF, EFDC and AQUATOX. Linkage of the three models requires: (a) transformations of constituents, (b) integration and aggregation of constituents in time and space and (c) maintenance of a mass balance of constituents within the different spatial domains of each model. The questions posed by the Peer Review Panel ask for clarification of the details related to these three linkage requirements; additional information on these linkages is presented below.

Using precipitation data, the watershed model (HSPF) will provide streamflow and nonpoint source loads of solids, total PCBs, organic matter and nutrients to the Housatonic River. The hydrodynamic, sediment transport and PCB fate model (EFDC), in turn, will use the data provided by HSPF to simulate hydrodynamics, sediment transport and the transport and abiotic fate of total PCBs on a fine-scale spatial grid of the river channel, Woods Pond and associated floodplain. The EFDC results will be used to map detailed spatial and temporal distributions of total PCBs in the water column, floodplain and sediment bed of the river channel and Woods Pond to address the study objectives, including natural recovery, related to the transport and fate of abiotic total PCBs.

The PCB bioaccumulation model (AQUATOX) will use flow and inorganic solids results provided by EFDC, with nonpoint source loads of nutrients, organic matter and total PCBs provided by HSPF. With total PCBs provided by HSPF split into selected multiple congeners, chosen on the basis of either relative toxicity or representativeness, AQUATOX will simulate the bioaccumulation of selected multiple congeners of PCBs within relatively coarse scale reaches of the river channel and Woods Pond. The AQUATOX results will be used to provide information on the fate and effects of the selected PCB congeners distributed within the biota, including target species of concern. Using detailed biological submodels with detailed representations of the biochemical kinetic transformations and toxicity effects of the selected congeners, AQUATOX will provide the type of information needed to evaluate how long it will take for PCB levels in fish and other biota to be reduced to target criteria levels for human health and ecological risk.

Model Linkage

13. Model linkages: Many of the state variable linkages between models are based on regressions between observed parameters (i.e., grain size distributions used to relate HSPF suspended solids to EDFC solids classes, TOC:TSS, DW:C, etc.). For each linkage where such a regression is applied, please address the following:

- **Are sufficient representative data available to define these regressions? This should include consideration of spatial and temporal variability, statistical homogeneity, and analytical precision;**

- **Provide scatterplots demonstrating the correlation observed between parameters. (DE11)**

Response: The preparation and evaluation of scatter plots, regression relationships, and other data comparisons to support the linkage development is an ongoing process. The modeling team believes the sampling program was sufficient (taken with the historical data) to develop a representative data set with consideration of the variables noted (e.g. spatial and temporal variability). The cumulative data is represented by the data inventory prepared in response to the Panel's question regarding data availability, which was supplied to Marasco Newton on 4/3/01 for distribution to the Peer Review Panel.

The modeling team is currently in the process of evaluating the data sets for particular parameters and their adequacy for establishing the relationships needed to provide the linkages between the models. One early example of these analyses is the TOC:TSS relationship provided in 4 graphs supplied to Marasco Newton on 4/5/01 (two for monthly surface water events and two for storm water events) for distribution to the Peer Review Panel. In this case, the data does not appear to show a dependency between the two parameters and thus may require an alternate regression such as POC:TSS. (The information presented in the attachments has not yet undergone a complete evaluation of QA/QC issues and data useability.)

Also provided to Marasco Newton is an example of a basic regression of staff gage height (as a surrogate of flow) at the New Lenox Station versus the total suspended solids (TSS) for the three largest storms from the 1999 storm sampling program. This graph illustrates the change in TSS on both the rising and falling water levels during the storm.

Additional scatterplots are proved in response to subsequent questions.

Model Linkage

14. EDFC: Which version (simple or complex) of the toxic chemical submodel will be applied in the Housatonic? Will EDFC use the same organic carbon partitioning, volatilization, and sediment dehalogenation process descriptions as AQUATOX? If not, won't the 2 models produce different predictions of water column and sediment PCB concentrations? Would any such difference invalidate the model linkage scheme outlined in the MFD? (DE6)

Response: The complex version of the EFDC chemical submodel, allowing for the simulation of interacting chemical and solids transport and fate in both the water column and sediment bed, will be used for the Housatonic River study. The toxic chemical submodel of EFDC is based on the assumption of stable partitioning of a chemical contaminant with each solids class and first-order decay rates.

In EFDC, different partition coefficients can be assigned for each of the three size classes of solids in the water column and sediment bed. However, the toxic contaminant submodel of EFDC was not designed to allow for the specification of the organic fraction of each solids class and the organic carbon dependent partition coefficient (Koc) or the octanol-water partition coefficient (Kow). EFDC is being modified for the Housatonic River project so that solids-dependent partitioning can be simulated by specification of the organic carbon fractions for each solids class and an organic carbon-based partition coefficient. This code modification will allow, for example, the capability to define seasonal and spatial differences in the organic carbon fraction of each solids class to account for winter-summer differences in phytoplankton that are included as a component of field measurements of grain size distributions, TSS and POC. Specific modeling of volatilization and microbial degradation in EFDC is not envisioned other than as lumped first-order rates. EFDC does not model contaminant bioaccumulation. However, EFDC does incorporate interaction of water, solids, and PCBs with the floodplain.

AQUATOX simulates the partitioning of PCB congeners with dissolved and particulate organic matter as a function of the octanol-water partition coefficients (K_{ow}s). The model also simulates the uptake of PCBs within the biota using empirical relationships and the K_{ow}s, and bioaccumulation through the food web. AQUATOX also models volatilization and sediment and biotic dehalogenation of congeners, The models will predict differences in PCB distributions because of modeling total PCBs vs. congeners, equilibrium vs. kinetic relationships, and first-order vs. process-level losses.

The linkage between EFDC and AQUATOX is solely the passing of water flow, solids loads, and channel morphometry information. There is no linkage of PCBs between EFDC and AQUATOX. To reiterate, AQUATOX will not be simulating total PCBs, rather, only a subset of congeners, while EFDC will be simulating total PCBs. Each model uses its own spatial domain, state-variables, and appropriate processes to satisfy different modeling goals.

Model Linkage

15. The linkage scheme proposes that biotic and abiotic components of PCB transport and fate can be modeled separately; is this correct? For example, phytoplankton are large particles, but their sorption and transport properties are far different than coarse noncohesive sediments. Won t they be measured together in TSS, POC, and even grain size analyses? Are the operational definitions being used in the organic carbon linkages robust enough to separate them? Likewise, can the assumption that POC transport is analogous to cohesive sediment be validated? (DE12)

Response: EFDC will model abiotic processes and AQUATOX will model both biotic and abiotic processes. EFDC is intended to provide a fine spatial scale resolution of the model domain that is an appropriate scale for the hydrodynamic and sediment transport model and evaluation of remediation alternatives. AQUATOX is intended to provide a much coarser spatial resolution that is an appropriate scale for a bioaccumulation model. In AQUATOX, abiotic and biotic components of PCBs will be represented using multiple congeners, where the total PCB load simulated as output from HSPF will be split into a set of individual congener loads as an input to AQUATOX. The simulation of total PCBs will be maintained in EFDC, where total PCBs will be considered as an abiotic component with particle- related sorption and desorption the primary, but not the only physical-chemical mechanism for describing the transport and fate of the contaminant. Volatilization and biodegradation are additional processes that will be considered as a lumped first-order rate, or potentially disaggregated for the abiotic PCB model in EFDC.

With respect to phytoplankton, comparison of chlorophyll measurements with TSS measurements indicates that in the reaches 5a, 5b, and 5c algae (including sloughed periphyton) may comprise about 2.5% of the TSS, however the measurements in Woods Pond may be about 33-50%.

Numerous references in the literature indicate the co-occurrence of high organic content sediments with fine-grained particles. The assumption that POM deposition and resuspension processes represented in AQUATOX, can be inferred from the deposition and resuspension properties of the cohesive size class computed in EFDC, is based on the co-occurrence of fine-grain sediments with high organic content and the hydraulic equivalency of POM particles and fine-grained cohesive particles.

With the fine spatial scale resolution of the EFDC domain, the simulation will be able to identify patterns of high and low concentrations of total PCBs in the river bed and the adjacent floodplain for calibration and validation with field measurements. In contrast, AQUATOX is intended to provide time series simulations of long term changes in PCB levels in the water column, sediment bed and biota with field measurements and ecological reality represented over the much coarser spatial scale of AQUATOX reaches. AQUATOX cannot provide simulation results for PCB contamination of the floodplain. Information about the deposition of PCBs within the floodplain, not available from AQUATOX, will be obtained instead from EFDC.

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100. PCB loadings to each AQUATOX reach, or (b) HSPF is providing total PCB loadings to AQUATOX at the upstream boundary of the PSA and other tributary, point and non-point sources. Is this distinction clear? In other words, is AQUATOX simulating transport of PCBs down the river, or is this reach-to-reach transport being simulated by HSPF? Maybe this is obvious, but I cannot decipher the modeling framework description.

As long as I'm asking the question, I'm interested to know whether the answer is the same for the other AQUATOX state variables. (DE2-1)

Response: HSPF provides total PCB loadings to AQUATOX at the upstream boundaries of the PSA and other tributary and point sources. HSPF and EFDC simulate total PCBs, which will be separated into congeners for input to AQUATOX based on observed distributions of congeners in approximately 10% of the samples (see also the response to question #18).

HSPF will provide loadings for nutrients and organic matter to AQUATOX at the upstream boundaries of the PSA and other tributary and point sources in a similar manner.

16. The linkage to use EDFC simulations of overbank transport as a withdrawal/loss mechanism in AQUATOX seems tenuous. How will this linkage work, if PCB and suspended solids concentrations simulated in EDFC and AQUATOX differ at the time of flooding? (DE13)

Response: As discussed in other responses, PCB loads will not be linked from EFDC to AQUATOX. EFDC will provide AQUATOX with time series data for water volume and inorganic solids fluxes between the river channel and the floodplain. The water volume flux will be derived from the EFDC flow component across the boundary of the river channel and floodplain. The export flux of organic matter and PCBs associated with flood events will be computed in AQUATOX using the water volume fluxes and solids fluxes provided by EFDC and the internally simulated concentrations of these constituents in AQUATOX.

The fluxes to the floodplain of water volume, inorganic solids, organic matter and dissolved and sorbed PCBs exported from an AQUATOX reach during flood events will be assigned to a floodplain “storage reservoir”. The volume flux of water and dissolved PCBs will be returned to the river channel during recession of the flood event. The mass flux of solids and sorbed PCBs during recession of a flood event to an AQUATOX reach will be constrained by the mass of solids and sorbed PCBs that has been exported to the floodplain “storage reservoir”. A determination of how much of the solids mass and sorbed PCBs exported to the “storage reservoir” will be imported back into the AQUATOX river reach from the floodplain will be based on the mass flux of each solids class exported from the floodplain to the river computed in EFDC. The relative proportions of how much of each solids class is returned to the river computed in EFDC will be used by AQUATOX to estimate the mass flux of solids and sorbed PCBs returned to the river channel.

<u>**Model Linkage**</u>

17. The coupling of EFDC with Aquatox may lead to complex problems. For example, the fact that floodplain processes are not simulated in Aquatox gives conceptual problems as well as mass balance problems. Why not predict transport and fate of PCBs with modifications to EFDC and only use Aquatox for food chain modeling, etc? (WL3)

<u>Response:</u> Since the floodplain linkage between AQUATOX and EFDC is only a linkage of water and solids flow, and not PCBs, there are no foreseeable mass balance problems as a result of this linkage. AQUATOX will simulate congener lose to and return flow from the floodplain.

EFDC and AQUATOX are applied in a hierarchical strategy, to take advantage of their differing spatial and temporal scales. EFDC is especially useful in providing high-resolution distributions of total PCBs, aiding in the analysis of remedial alternatives, and in evaluating the issues associated with PCB contamination in the floodplain. On the other hand, EFDC does not have the biotic realism of AQUATOX for modeling seasonal and long-term exposure within an aquatic system over the larger spatial and temporal scales observed in real life. Both concentrations of PCBs in the floodplain and realistic representation of the aquatic system are very important factors which must be accounted for within the modeling framework so that remediation alternatives can be evaluated. Rather than undertake very extensive modification of the code of either model to simulate processes for which it was not designed, careful coupling of the models is expected to give the best results.

AQUATOX simulates fate and bioavailability in much more detail than EFDC. The reason for using AQUATOX is that it simulates the important modes of production and interaction within the aquatic ecosystem and accounts for all pathways of uptake, transport, and loss of PCBs in a consistent manner which is of particular importance in the Housatonic River system. For example, macrophytes appear to be an important element in the Housatonic ecosystem, accounting for the production of significant quantities of organic matter and potential PCB uptake; they are modeled by AQUATOX but not by EFDC. In order to accurately represent trophic transfers of PCBs in the food web, seasonally varying transfer of PCBs from periphyton to grazers is likely to be important and is simulated within AQUATOX, but not EFDC. Microbial degradation of organic matter and of PCBs is dependent on temperature and dissolved oxygen (aerobic/anaerobic conditions) and is modeled in more detail by AQUATOX than by the simple temperature-dependent decay rate in EFDC. The fate of selected PCB congeners is of particular importance to this study because of the tie to the risk assessments. AQUATOX has been designed to account for the type of kinetic interactions between chemicals that can be used to describe the fate of congeners. The modifications needed to enable EFDC to account for the multiple congeners of PCBs and their kinetic interactions, as well as the modifications needed to explicitly incorporate the DOC and POC derived from the planktonic related processes are extensive.

The 'modifications' needed to include the important PCB fate and transport processes in EFDC, particularly those associated with sorption of PCBs to cohesive and non-cohesive inorganic solids, as well as DOC and POC (detrital organic matter + planktonic organic matter) are also very extensive. EFDC currently includes a water quality submodel that simulates multiple

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groups of water column algae, detrital POC, and DOC. The state of the art water quality submodel of EFDC is functionally equivalent to the COE-WES Chesapeake Bay model (CE-QUAL-ICM) and the water quality model of Hydro Qual, Inc. applied to estuarine and freshwater systems such as New York Harbor and Long Island Sound, Massachusetts Bay, and the Upper Mississippi River. Neither EFDC, CE-QUAL-ICM or HydroQual's water quality model, however, are designed to represent particle settling, deposition or resuspension of living algal-related POC and detrital POC in a way that is consistent and coupled with the representation of the complex processes incorporated in the sediment transport submodel for cohesive and non-cohesive solids. Such a major modification to the EFDC code is not feasible within the time and funding constraints of this study. These processes are, however, adequately represented in AQUATOX.

The modeling team believes the proposed approach, based on the linkage of HSPF, EFDC and AQUATOX, is the most desirable of the alternatives and will avoid essentially the creation of a "new" model.

18. A critical link appears to be the distribution of total PCBs from EFDC and HSPF into congeners for AQUATOX. Please describe in greater detail how this will be done. (PS14)

Response: The starting point for the model inputs for total PCB concentrations will be data collected in the river. The PCB concentrations in most of the samples to be used to estimate initial conditions are based on total PCB or Aroclor measurements. However, the project analyzed all samples of water, most biota (some ecological risk assessment studies rationed analyses beyond total PCBs), and approximately 500 sediment/floodplain soil samples for total PCBs, Aroclors, homologs, and congeners measured on sample splits. The data are being evaluated to determine the dominant congeners using a variety of procedures, including Euclidian distance and principal component analyses, to determine the degree of homogeneity of the congener distributions, as well the changes in congener distributions over time and space. The results of these analyses for the sediment and water samples will be used to estimate the congener distributions in other samples where only tPCBs or Aroclors were measured, and similarly to the output of modeled components where only total PCBs are being tracked.

70. The linkage testing in Section 4.9.3 of the Modeling QAPP emphasizes testing of comparability and consistency of state variables between the models. Given the complexity of the linkages, this testing will be critical to success of the proposed modeling framework. However, the tests being applied to evaluate spatial and temporal aggregation and averaging seem to emphasize constant, uniform conditions. Are these tests adequate to ensure that model linkages perform correctly under dynamic, spatially-variable conditions such as a sediment/contaminant transport event? (DE14)

Response: A series of tests of increasing spatial and temporal complexity will be performed in a sequential approach to ensure the accuracy and reliability of the approach designed to link HSPF,

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EFDC and AQUATOX. The preliminary tests of the model linkage will be based on simple 1D and 2D uniform channel geometry forced by idealized constant flow and pollutant loads (Test #1). Following successful testing of the model linkage with simple idealized geometry and constant inputs, the second phase of tests will be based on the actual spatial domain of EFDC grid cells and HSPF and AQUATOX reaches and idealized forcing of flow and loads (Test #2). In this second phase of tests, flow and load inputs will be assigned initially as time-invariant forcing functions to spatial locations of the EFDC grid cells and AQUATOX reaches based on the actual spatial domain. After successfully linking the models in the actual spatial domain with constant flow and load inputs, time varying straight line flow and load data sets will be used to represent an idealized sequence of (a) baseflow ; (b) increasing flow; (c) peak flow; (d) decreasing flow; and (e) baseflow rate. Two cases of time varying flow and load data sets will be used for testing the time dependency of the linkage scheme: (1) bankfull flow and (2) overbank flood flow. The final phase of model linkage tests will be performed with actual time varying flow and loading data sets generated by HSPF over some period of time selected from the calibration period (test #3). The plan for testing the HSPF, EFDC and AQUATOX model linkage is summarized as follows:

Test #1 Idealized uniform geometry, idealized constant flow and loads
- (a) 1D river channel, 1 lateral cell, 1 water column layer
- (b) 2D river channel, 3 lateral cells, 1 water column layer
- (c) 3D Woods Pond, multiple horizontal cells, 2 water column layers

Test #2 Actual Housatonic spatial domain of EFDC grid cells and AQUATOX reaches; idealized flow and loads
- (a) constant inflows and pollutant loads
- (b) time varying flow and loads with maximum of bankfull flow
- (c) time varying flow and loads with maximum of overbank flood flow and recession of flood event

Test #3 Actual Housatonic spatial domain of EFDC grid cells and AQUATOX reaches; actual flow and loads
- (a) time varying flow and loads from HSPF for low-flow to high-flow time periods (weeks, months) extracted from calibration period

<u>External Forcing Functions and PCBs</u>

General Response

For the PSA, the primary forcing functions are located at the confluence of the East and West Branches. The GE facility is located on the East Branch, which has undefined sources of dense and light NAPL, former oxbows, and ongoing source control and remediation activities. The West Branch has some limited PCB contamination that is under investigation by the in the vicinity of Dorothy Amos Park, the site of a previous response action by GE. Therefore, the boundary condition was established at a point below where these undefined (yet under remediation) inputs occurred, which could be monitored (prior to remediation activities) and provide an integration of upstream source loadings.

The HSPF model, supplemented with storm event and routine monitoring data for sediments and PCBs, provides the best approach to addressing the modeling objectives. This approach integrates the unknown source processes in the upper reaches and provides a means of filling in data gaps through continuous simulation provided by HSPF.

19. What is the effective or dominant flow discharge for the Housatonic River? What is the return period associated with it? (MG3)

<u>Response:</u> The dominant discharge is generally defined as “bank full” discharge, which has a return interval of ~1 ½ to 2 year. For the Housatonic River at Coltsville, the 0.5 probability of occurrence (i.e. 2-YR storm) is 1146 cfs. Within the Rest-of-River, the dominant discharge is in the range of 1500-2000cfs (the West Branch nearly doubles the flow in the study area from the Coltsville gage flows). The dominant discharge, of course, varies over the study area.

The May 1999 storm had a maximum flow of 1410 cfs at the Coltsville gage. The peak flow during this event was greater than the dominant discharge. This event resulted in observed out of bank conditions in Reach 5a and Reach 5b and possibly elsewhere. The estimated return period for a storm this size is between 2-5 years, based on the 1937-1999 daily average flow record.

20. PCB loading measurements: How many direct measurements have been made of PCB loading from the Housatonic River above the confluence (including the West Branch)? Have any attempts been made to relate these loadings to predictive variables such as flow and/or suspended solids? (DE4)

21. Tributary loadings: There is a statement on page 3-61 that suggests that possible or known PCB loadings from tributary sediments are being neglected; the West Branch is offered as an example. Is this true? How can a loading source be excluded from a mass balance? Please clarify this statement or offer justification. (DE18)

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22. About mid-page on page 3-61 it states "As discussed in preceding sections, tributary loading of PCB-contaminated sediments is excluded as an important process because there is no indication in the data of PCB sources in the tributary watersheds, although it should be noted that contributions are likely from the West Branch." Please clarify this seemingly self-contradicting sentence. Will contributions from the West Branch be included in the model? (PS5)

<u>Response:</u> PCB loadings were measured at the West Branch station during 3 storm events, at the Pomeroy Ave. station during 7 storm events, and at both locations as well as at additional stations on the East Branch during the 15 monthly surface water monitoring events (see Figure 3-3 in the MFD for locations). Based upon review of the historical data, the West Branch was not though to be a source of PCBs to the PSA in the initial scoping of the storm-event protocol. EPA sediment samples, collected for the purpose of establishing a reference area on the West Branch, detected PCBs, at which time PCB measurements were added to the storm-event sampling protocol at the West Branch monitoring station.

An example of the relationship between stage height and TSS is provided as Figure 3-5 in the MFD and in response to question 13. While other relationships have been examined for subsets of the data (some additional examples are shown in Figures 3-21, 3-22, and 3-23 of the MFD), a full evaluation of all possible relationships has not been completed at this time.

With regard to tributary loadings, the statement on page 3 - 61 of the MFD is misleading; it is meant to refer to tributaries other than the West Branch in the watershed. The reviewer is correct in observing that an important loading source cannot be excluded from a mass balance perspective. The West Branch was monitored for PCB loadings and these data will be used in establishing initial conditions, and in calibration and validation efforts. The other tributaries within the PSA drain State Forest/Wildlife Management Area and lightly developed (residential, agricultural) portions of the watershed; TSS was measured at representative tributaries.

23. Has the so-called "washload" been estimated for the Housatonic River? What percentage of the total suspended load is washload? Most PCB attach to the clay-size fraction that constitutes the washload. (MG4)

<u>Response</u>: Washload is used in a variety of different ways with different meanings in model applications; often it refers to the suspended load. From the nature of the question it appears that the term "washload" is being used as suspended load to the stream from the upland watershed and riverine reaches. Data are available to assist in estimating suspended load for the East and West Branches of the Housatonic River. Bedload is proposed to be collected to help define the upstream boundary condition for the coarse-grain material. This data will be used to define the Total Load. The particle size analyses performed on the sediment samples collected during these studies will allow calibration of models to the specified size fractions, and thereby provide the information for model calibration and validation.

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A recently published USGS report on suspended sediment characteristics for the Housatonic River for 1994-96 (WRI Report 00-4059, G. C. Bent, 2000) may provide further information on the subject.

24. Sediment size classes, cohesive sediments, and flocculation. Separating sediments into three or more size classes is necessary as stated in the report. The separation into the size classes as defined in the report seems reasonable, i.e., (a) d < 63 :m, fine; (b) 63 < d < 200 :m, intermediate; (c) d > 200 :m, coarse. The fine class is cohesive and flocculates. Contrary to what is stated in the report (3-17), fine-grained sediments can form flocs in fresh water under all conditions. The intermediate size class also behaves in a cohesive manner (Roberts et al., 1998) although less so than the fine sediments. For this intermediate size class, flocculation is less (but still present) and erosion occurs more as particle-by-particle. The coarse size class is non-cohesive, does not flocculate, and erodes particle-by-particle. Although these classes were defined in the report, how does this affect the proposed model? (WL6)

Response: The three size classes specified in the MFD were designed to be a balance between the representation of the continuum of observed sediments characteristics, PCB/solids coupling, deposition, erosion, and transport, and computational constraints. The midsize sediment range (63um<d50<250 um) is proposed to be modeled in the MFD as a non-cohesive sediment. At this time, sediment flocculation of the midsize sediment class is not expected to be a significant issue for the Housatonic River. While there is no argument as to the existence of flocculation in this size range, interpretation of the Housatonic River Sedflume data, site-specific data, and the calibration process will identify if flocculation of this intermediate grain size class will alter any gross effects of flocculation that will be accounted for in EFDC.

The modeling approach for the non-cohesive sediments in EFDC is summarized by Hamrick (2000) as:

> The approach proposed by van Rijn (1984a) is adopted in the EFDC model and is as follows. When the bed velocity is less than the critical shear velocity
>
> $$u_{*csj} = \sqrt{\tau_{csj}} = \sqrt{g' d_j \theta_{csj}} \qquad (5.10)$$
>
> no erosion or resuspension takes place and there is no bed load transport. Sediment in suspension under this condition will deposit to the bed as will be subsequently discussed. When the bed shear velocity exceeds the critical shear velocity but remains less than the settling velocity,
>
> $$u_{*csj} < u_* < w_{soj} \qquad (5.11)$$

sediment will be eroded from the bed and transported as bed load. Sediment in suspension under this condition will deposit to the bed. When the bed shear velocity exceeds both the critical shear velocity and the settling velocity, bed load transport ceases and the eroded or resuspended sediment will be transported as suspended load.

31. Settling speeds are of course modified by flocculation. The sizes of flocs and their settling speeds are functions of sediment concentration and fluid shear (Burban et al., 1989, 1990; Lick et al., 1993). Because of this, settling speeds of flocs should be measured (in the laboratory) as functions of these quantities and the resulting parameters then introduced into the model. Measuring settling speeds of flocs as they are in the river (3-49) is insufficient, since conditions and hence sizes and settling speeds of flocs change as a function of suspended sediment concentration and fluid shear, especially during big events during which measurements have not been made in the field. How will flocculation and settling speeds of flocs be treated in the model? Deposition is a function of suspended sediment concentration, settling speed, and flow rate. How will this process be modeled? (WL10)

Response: This issue will continue to be evaluated as the modeling analysis progresses. In an effort to further address this issue and other general particle/sediment settling velocity data needs, a column settling experiment was proposed as part of the Test Reach work. The results of this effort will be analyzed to determine if flocculation is a significant issue. The settling velocity study will provide settling data for the <62 um and the 62 um to 250 um ranges. Prior to analysis, the sediment sample will be fractionated into the three size classes. Only the two smaller size categories will be analyzed. The >250 range will not be analyzed.

The cohesive fraction settling velocity will be derived from this study, and will be used in the application of EFDC. For the mid-size class, the column studies will be used along with the van Rijn approach to make an initial estimate of settling velocities. In the calibration process this velocity may be adjusted, using the column work (acknowledging the water chemistry variation from natural conditions) and Van Rijn formulations as a guide. For the >250um class, settling velocities as computed by Van Rijn (1984), will be used.

25. Why will the modeling be limited to two sediment size fractions? If the field data will include analysis of several size fractions, ranging from clay size particles to cobbles, this effort should also be reflected on the numerical modeling of sediment transport in the Housatonic River. (MG5)

Response: Currently, the MFD proposes three size classes, one for cohesive sediment and two for non-cohesive sediments. The rationale for these sediment size classes is mentioned briefly in the response to Question 24. During the test reach work and calibration process, this approach will be evaluated to determine if it is still valid. If it is determined that more size classes are required, the particle data are available for any reasonable classification scheme.

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27. On p. 3-18, it states, Sedflume will be used to describe initiation of resuspension. Sedflume should be used for the measurement of erosion rates as a function of shear stress and depth in the bottom sediments as well as critical stresses. Please comment. (WL8)

Response: The Sedflume study, performed by the Waterways Experiment Station, was used to develop erosion rates (E) as a function of shear stress (τ) and depth (z). Bulk density (ρ) and grain size distribution was also obtained. A copy of the Sedflume report (Gailani, 2000) has been forwarded to the Peer Review Panel members.

The Sedflume procedure provides a measured erosion rate at specific shear stresses and depths (McNeil, 1996) for each sediment core. Twenty-four cores were collected and analyzed approximately every 2 cm with the Sedflume device. At each depth, the core was subjected to a range of shear stresses and the erosion rates were determined (Gailani, 2000). Bulk density is also obtained at each depth. Using these raw data, a relationship is developed of erosion rate (E) as a function of shear stress (τ) and bulk density (ρ):

$$E = A\tau^n \rho^m$$

where, A, n and m are empirically derived constants. From the raw erosion rates, the critical shear stress (τ_c) can be computed by defining a negligible erosion rate (e.g. E = 1E-4 cm/s), below which it is assumed no erosion occurs. Solving for τ_c produces

$$\tau_c = \left(\frac{E}{A}\right)^{1/n} \rho^{-m/n}$$

Using this expression, with the empirically determined coefficients A, n, & m, and the assigned E, results in defining the critical shear stress. For cohesive sediments, this value can be used to help define the critical shear stress for surface erosion. For the non-cohesive sediments, EFDC requires critical Shield's stresses, which can be determined from this information.

This approach will yield a $\tau_c(z)$, but what the model requires, because this relationship will not hold for long term simulations, is $\tau_c(\rho, d_{50})$. The relationship will be developed by correlating τ_c to each bulk density and d_{50} Sedflume data point. Using this relationship as input to EFDC produces an applicable and appropriate critical shear stress for use in this application.

In addition to the Sedflume data, the Gailani (2000) study also reported Particle Entrainment Simulator (PES, Tsai and Lick, 1986) results for the fine-grained sediments. These data will be used to assist in the parameterization of cohesive sediment erosive properties. No PES tests were conducted on the coarser sediments as the method is not appropriate for non-cohesive sediments.

External Forcing Functions and PCBs

28. Sediment transport. Suspended load and bed load are described as two separate processes. In reality, they are the two limiting end-points of a continuously varying mode of sediment transport. For example, for a particular d > 200 :m, sediments at low shears will travel as bed load; as the shear stress increases, more and more of the sediment will transport as suspended loads until, at very high shear stresses, all sediment in this size class will transport as suspended load. How will the model treat suspended/bed load? (WL9)

Response: We agree that the process is actually a continuum, reflecting the random nature of the actual bottom shear and the heterogeneity of the bed suspended sediments. However, the deterministic and discrete modeling approach proposed here must treat these processes as two distinct processes (see the response to Question 24 for more information on the EFDC bedload/suspended load logic). Due to the multiple size classes, the resulting gross sediment transport process will reflect both bedload and suspended load for most of the higher flow events. We are still in the process of choosing between van Rijn (1984b) and Garcia and Parker (1991) for suspended load, as noted in Pg 4-26 of the MFD, based upon results from the test reach. Bedload will be computed using van Rijn (1984a).

29. Bioturbation is referred to in several places. How will this be modeled? Is there any data on benthic organisms? On their activity as f (temperature)? (WL12)

109. Bioturbation is mentioned in several places. Can the data to evaluate bioturbation be provided? (EA7)

Response: Field data collected by the project ecologists were used to determine the presence, density and location of species that cause bioturbation (represented in the models as the active layer) in the Housatonic River ecosystem, and the limit of disturbance (LoD) due to bioturbation for the species of interest was estimated from the literature when developing the Conceptual Model. While not typically considered when modeling other river systems, biota other than benthic invertebrates are an active component of the Housatonic River ecosystem and their potential contribution to bioturbation was also evaluated. In addition, the available radioisotope data from deep cores were reviewed to provide additional insight into the depth of the active layer.

Aside from defining the depth of the active layer, an understanding of the likely bioturbation activity is necessary to determine biodiffusion coefficients for the exchange of pore water and solids with the overlying water. These may be made functions of temperature for dominant organisms (for example, see Thoms et al., 1995).

Benthic Invertebrates

Estimates of the bioturbation depth for the benthic invertebrate species collected in the Housatonic River were derived from the literature. Species were identified from two field studies: data were collected historically for GE by Chadwick and Associates in 1993; and by EPA at 9 locations in the PSA and 4 reference areas in 1999. Table 3-13 in the MFD lists the taxa observed, and Figure 3-28 displays the benthic biomass measured in the samples. Tubificid worms and burrowing chironomids are the species observed in the Housatonic River which are predominantly responsible for disturbing the deeper sediment, with average depths of disturbance of 8-10 cm and maximum depths of 20-30 cm.

Other Biota

Four separate electro-fishing events were conducted by EPA in the PSA from 1998 to 2000. Several fish species were commonly observed in the Housatonic River that, based upon review of the literature and field observations, are known to disturb the sediment. Common carp were collected, with some specimens up to 11 kg in size. Carp have been documented to move sediment to a depth of approximately 10 cm when feeding (Sibbing et al., 1986) and have been shown to penetrate to a depth of more than 12 cm in silty sediments typical of those observed in Reaches 5c and 6 (Suietov, 1939 cited in Sibbing et al., 1986). In addition to inhaling sediment as a feeding strategy, carp also feed on aquatic plants by uprooting them (Scarola, 1987). Spawning activities may also disturb the sediments (Smith, 1985, cited in Swee and McCrimmon, 1996). White suckers are common in reaches 5a, 5b and 5c; they are bottom feeders, and it is estimated that they disturb the sediment to a depth similar to common carp, with spawning activities “raising a cloud of silt and sand from the bottom” (Scarola, 1987). Brown and yellow bullheads are also bottom feeders that disturb surficial sediments by feeding activities; in addition, they bury themselves in soft mud and are inactive over the winter (Scarola, 1987).

Field surveys of beaver and muskrat were conducted within the PSA, with both species being estimated to be common to abundant (Woodlot, 2000). These species move sediment and floodplain soils during construction and maintenance of lodges, bank dens, canals and channels (Godin, 1977, Hodgdon & Lancia, 1983, Whitaker 1998).

Frogs and turtles also contribute to sediment disturbance by foraging along the bottom and hibernating buried in the sediment. For example, field observations document that snapping turtles are abundant in the shallow backwaters of the Housatonic River and Woods Pond (Woodlot, 2000). Snapping turtles spend most of their time buried in the mud in shallow water waiting for prey, and hibernate in mud just deep enough to cover themselves (Meeks and Ultsch, 1990). They are inactive from late September to mid-April, except for occasional movements during warm spells.

Radioisotope Data

A review of the distribution of radionuclide “markers” (where available) was performed on both the EPA and GE deep cores for evidence of mixing due to bioturbation and/or other processes which contribute to the existence of an active layer. EPA cores collected in Woods Pond and just upstream were analyzed for a series of radionuclides (Cesium, Beryllium, and Lead) and

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PCBs. These data have proven to be inconclusive as to the first occurrence and peak concentrations for Cesium and Beryllium, limiting the conclusions that can be drawn regarding the depth of the active layer. The variability in Cesium concentrations by depth suggests that mixing of the sediments has likely occurred, although the depth varies between cores, from 9 to 30 cm.

Beryllium was rarely detected. Given the short half-life (53 days) of Beryllium, its presence in a few cores at depth (11-32 cm) suggests mixing to those depths, similar to the observed depths for Cesium.

GE cores from the main channel of the Housatonic River in Reaches 5a, 5b, and 5c were also inconclusive regarding a discernable Cesium profile with depth. Cesium was detected to depths of 46 cm, with peak concentrations at depths less than 25cm. GE also evaluated the total mass of Cesium within the cores versus what would be expected from an "undisturbed" core. The comparison showed a wide variation in the Cesium mass in the cores in the main channel from the hypothetical core, suggesting the presence of an active layer.

Data from the GE cores collected in Woods Pond (Reach 6) exhibited more typical Cesium profiles, with peak concentrations similar to the depths observed in the EPA cores, generally within the top 30 cm. The GE cores were sectioned into slices that were 2.5 times thicker than the EPA method, therefore, evidence of mixing was less apparent from this data set.

Temperature

In the Housatonic River ecosystem, summer and fall have the highest level of observed activity/bioturbation followed closely by spring; the lowest level of activity occurs during the winter. In response to the question on temperature, given the abundance of invertebrates that feed all year, other biotic activity, and the poor correlation of bioturbation with temperature (cf. Di Toro, 2000), constant bioturbation depths were assumed.

Based upon the analysis of the field data and review of the cited literature, a depth of 15 cm is proposed for the active layer.

External Forcing Functions and PCBs

30. A stated objective of the model is to evaluate alternative remedial actions, yet there does not appear to have been explicit consideration of how remedial actions would be modeled. I am particularly concerned here with dredging as the most likely remedial action. How would the process of dredging, and potential for sediment release during dredging, be modeled? (PS1)

NOTE: This question was forwarded to GE for response. It was felt that it would be more appropriate for GE to draft the response. Although in the development of the Modeling Framework EPA considered the implications of modeling remedial scenarios, under the terms of the Consent Decree it is the responsibility of GE to model the various remedial alternatives proposed in their Corrective Measures Study.

Response: The model will be used to address various types of remediation including source control, capping, and dredging, alone or in combination. As with any model simulation, assumptions will be required to represent dredging within the mathematical framework. Model representation of dredging should be developed such that the net effect of the actions is properly accounted for at the spatial and temporal scales of interest. For a long-term model projection of a dredging project, several assumptions are required:

> Schedule: The schedule of a simulated dredging project in a model projection is first developed based upon engineering analyses. The project start date, the duration of the construction season, the estimated areal dredging rate (i.e., acres per month), and the upstream/downstream extent of the project are used to develop model inputs to represent when remediation would be completed for each model element.
>
> Sediment Bed Characteristics: Simulation of dredging requires that changes in sediment bed properties be accounted for in the model. Assuming the PCB-containing sediments are removed by dredging and then clean material is used to restore the bed elevation, the resulting change in bed properties is accounted for by modifying model inputs (e.g., organic carbon fraction, bulk density, and d50) and bed elevation.
>
> PCB Removal: Because dredging is never 100% efficient, an assumption needs to be made as to how to represent residual PCBs. Two possible approaches are to 1) use a removal efficiency (i.e., % mass removal) to calculate the residual concentrations based on simulated pre-dredging conditions or 2) specify a nominal residual concentration.
>
> Impacts on the Water Column: It is necessary to simulate the release of PCBs during dredging as a loading to the water column. Several approaches can be used (e.g., the release rate in g/d can be assumed constant or proportional to local sediment PCB concentrations). Ideally, site-specific data should be used because the release is dependent on a number of variables, including the dredging method, the technology used to control releases, hydrologic conditions, etc. In the absence of such data, bounding calculations can be developed to bracket the expected release rates.

External Forcing Functions and PCBs

Similar assumptions would be required to mathematically represent other types of remediation (e.g. production rates, residual PCB concentrations, etc.).

32. Bed armoring. Erosion rates can increase (sic) with depth due to (i) consolidation of sediments, (ii) deposition of coarser sediments from upstream, and (iii) erosion of finer sediments from the bed leaving coarser sediments behind. All of these processes can be significant and dominant at times. How will these processes be treated in the model? For your information, a uniformly valid description of these processes and their inclusion in a sediment transport model has recently been completed (Jones and Lick, 2001). (WL7)

Response: We agree with the reviewer that erosion rate will generally decrease with depth and age of sediment. See the response to Question 27 for more information on how Sedflume data will be used in this EFDC application. The referenced article was not available in time review prior to preparation of this response; it will be evaluated and the information will be incorporated into the Housatonic River analysis, as appropriate.

33. Consolidation studies are mentioned in several places. What are these studies? How will $\Delta(z,t)$ be determined or modeled? How will information from these studies be used to determine erosion rates of recently deposited sediments as a function of time after deposition? The connection is not clear. In previous studies, Sedflume was used to determine $E(z;\vartheta)$ for undisturbed river cores, where ϑ is shear stress. Consolidation studies were also done with well-mixed river sediments so that, for different consolidation times, $\Delta(z,t)$ and $E(z,t;\vartheta)$ were measured. Was this done, or will it be done? (WL11)

Response: The Consolidation tests were conducted by the Waterways Experiment Station on samples collected as part of the Sedflume study (Gailani, 2000). This report was forwarded to the Peer Review Panel for their information. The study was designed to obtain the functions for the cores of $\rho(z,t)$ and $E(z,t,\tau)$. However, due to the duration of the model time frame (>50 yrs), the data will be used in more of a parametric nature, rather than explicit application of E and/or τ as a function of horizontal (x,y) and vertical (z) locations. Rather, the data will be used in the determination of ρ as a function of time, $\rho(t)$, and τ as a function of density and time. The rate of consolidation will then be used to inform the development of the consolidation parameters in EFDC and AQUATOX and used as additional supporting data for the $\tau_c(\rho, d_{50})$ relationship.

Two sites were selected to supply the sediments for the consolidation tests, one just north of Woods Pond and one in Woods Pond. For the sediments tested, there were very few differences in bulk density either with depth or time over a 70-day period.

External Forcing Functions and PCBs

34. Please provide a detailed description of the EFDC algorithm for modifying bed layers over time (discussed on page 4-21). Recent experience with PCB models on the Fox River, Wisconsin has shown those models artificially introduce high rates of mass dispersion in the sediment as sediment bed layer thicknesses are modified during transient simulations. (PS13)

Response: The detailed discussion of the bed geomechanics is included in MFD Appendix C on page C. 3-26. The treatment of the sediment bed layers within EFDC is relatively straightforward. The following discussion relates to each cell within EFDC. Each sediment bed layer is initialized with a specified sediment and PCB mass and bulk density of sediments. The top ("active") layer is the only layer which interacts with the water column. During deposition the sediments for each size fraction are added to the corresponding size fraction in the top layer. During erosional periods, the appropriate size fraction is removed from the top layers corresponding to mass fraction (based on computed shear stress). At the end of each time step, based on bulk density and the remaining mass of each size fraction, the bed height is updated. If the bed height is greater than a specified maximum bed height (HBEDMAX), a new layer would be added. If the number of layers is equal to the maximum number of layers, the sediment will be allowed to accumulate within the top layer. Conversely, if the computed height is less than 0, a layer will be removed and the mass of sediments causing the negative bed height would be subtracted from the new top layer.

Given the dynamic nature of the Housatonic River sediments, the proposed approach to determining the active layer, and the need to address bed armoring, some modifications are being made to EFDC to better track the conditions observed in the Housatonic River. With respect to the bed layer addition/subtraction algorithm, a minimum bed height or minimum thickness has been added (HBEDMin). The minimum bed height is a user input parameter, as is the maximum bed height, and is anticipated to be in the order of 15 cm.

With this modification, as sediments are removed from the top layer, the heights are computed at the end of each time step. Once the bed height is less than the minimum bed height, the remaining top layer sediment is added to the layer just below (k-1). This layer then becomes the new top layer. In the event of removal of all the sediment in a cell, erosion will be stopped until new sediments are deposited in the cell. Development is still underway, but the minimum thickness will also be used as part of the bed armoring algorithm within the EFDC (Karim and Holly, 1986).

A series of AQUATOX and IPX Version 2.7.4 tests are being conducted to ensure that the new sediment bed submodel implemented in AQUATOX can reproduce results generated with IPX Version 2.7.4. These results will also be compared to results generated with the EFDC sediment bed submodel. The purpose of these tests is to ensure that the artificial numerical dispersion problems identified in the review of the WDNR Lower Fox River models are not repeated in either the AQUATOX or EFDC applications to the Housatonic River.

External Forcing Functions and PCBs

35. How will dispersion coefficients be determined? (PS17)

Response: The hydrodynamic model (EFDC) internally computes both horizontal and vertical mixing rates to account for dispersion. Horizontal mixing is dependent on the assignment of input of a spatially constant horizontal diffusion term that is then used to compute a spatially variable horizontal diffusion using the method of Smagorinsky (1963). Vertical mixing is computed from the turbulence closure scheme of Mellor and Yamada (1982) as modified by Galperin (1988) and implemented in EFDC.

Vertical dispersion coefficients assigned for the sediment-water interface and between the layers of the sediment bed sub-model will be based on the literature (e.g., Thoms et al., 1995) and calibrated, where data are available for depositional regimes such as Woods Pond, to sediment core profiles of radioactive tracers. Sediment cores from Woods Pond will be used to calibrate the values assigned for vertical mixing coefficients in the sediment bed.

River, Riverbank and Floodplain Interactions

General Response

Several questions were submitted regarding localized morphological features and processes in the river (gravel and point bars), riverbanks, bank failures, and proximal floodplain terraces. The modeling team recognizes that these features and processes are important to near-field sediment distribution and, possibly, PCB distribution. However, the degree of importance of these modeling domain sub-grid features in the model analysis on the spatial and temporal scale of interest in the modeling analysis warranted further evaluation.

An effort has been underway to evaluate this issue, using GIS tools and the electronic database, including both GE and EPA data sets. A description of the approach taken in developing this estimate is include in the response to Questions 96 & 110. Preliminary output from this effort (see Table below) focused on estimating the relative mass of PCBs in what have been defined by the sampling programs as river deposits (channel, terrace, and aggrading bars), what is operationally defined as the proximal floodplain (banks and the floodplain area most likely to be active for solids and PCB transport), versus the distal floodplain, and the river and backwater sediments. The evaluation was further segmented into the Modeling Reaches 5a, 5b, 5c, and Woods Pond to provide a sense of changes observed through the PSA.

As indicated in Section 3.3.4.2 of the Modeling Framework Document, it is true that samples from bars and terraces generally have a higher frequency of PCB "detects" and also have a higher concentration of PCBs as compared to samples from the four other terrain types specified in the MFD. However, as the table below indicates, these deposits comprise a very small percentage of the area in the river, and in fact hold well less than 1% of the total mass of PCBs in the system. Because such a small percentage of the PCB mass is associated with bars, terraces, and similar depositional areas, it was decided that lumping these individual features within the individual model cells, as opposed to representing them as subgrid features, would best serve the objectives of the modeling study.

Mass of PCBs in River Features by Reach

	Reach 5a	Reach 5b	Reach 5c	Woods Pond
Deposits	44 kg 0.03 %	7 kg 0.004%	6 kg 0.004 %	NA
Sediment	10,164 kg 6%	2,942 kg 2 %	49,699 kg 30 %	28,435 kg 17%
Proximal FP	10,394 kg 6 %	5,977 kg 4 %	11,753 kg 7 %	1,118 kg 0.7%
Distal Floodplain	23,469 kg 14 %	14,510 kg 9 %	9,828 kg 6%	NA
Total	44,071 kg	23,436 kg	71,286 kg	29,553 kg

Total Mass of PCBs in the PSA = 168,346 kg

River, Riverbank and Floodplain Interactions

A sediment bed map is being developed based on all of the PCB and grain size data. The initial conditions for sediment mass and associated PCBs in the river and floodplains will be developed from the sediment bed map. The sediment mass and associated PCBs calculated within the boundaries of each cell for each size class will be determined and assigned to the cell. A grid cell is expected to be several times larger than a typical bar. In this way, individual point bars will be aggregated into the total mass of the appropriate cell. No special attempt will be made to model the migration of the gravel or point bar explicitly. This approach best represents the balance of computational requirements, available data, and modeling objectives.

With respect to bank erosion and associated sediment loading to the river, observational data and preliminary analysis indicated that bank erosion could be a significant source of solids and PCBs to the river. To address these concerns, toe pins have been installed to monitor bank erosion/accretion rates at a number of bends as part of the Test Reach study (please see the toe pin locations noted on the second set of tile maps).

The GSTARS model is proposed in the MFD (page 6-3) as another tool that will be used to evaluate the importance of bank erosion on the sediment transport within the Housatonic River PSA. By combining the results of the GSTARS program with the observed data, an assessment can be made as to the importance and general magnitude of the mass of sediment loading resulting from bank failures. For the specific locations where significant bank erosion is predicted to occur in the test reach, comparisons will be made of 1) the predicted and measured bank erosion rates, and 2) these locations to known areas of high PCB concentrations These comparisons will enable an assessment of the importance of bank erosion on PCB transport to be made. If this process is deemed to be significant, an external force function will be added to simulate this loading. This approach would define a spatially and temporally varying external source function to represent solids loading from bank erosion. Field (toe pin) measurements taken in the Housatonic River test reach may provide data to quantify such a source function.

Although this approach for assessing bank erosion impacts on the sediment and PCB loads to the Housatonic River may be somewhat qualitative, we are not aware of a more robust method that could be applied at the scale of the modeling study.

10. pg. 4-45 This discussion seems to imply that this model has not previously been used in meandering streams. Since the bars are the primary in-stream storage of the high concentration PCB a failure to model the bar transport will not provide much confidence in the assessment of the future of the PCB, insofar as downstream is concerned. Has anybody, anywhere, previously successfully modeled the meandering transport of sediment bars in a stream? If so where are the results published ? Has anybody, anywhere, successfully modeled the bank collapse and terrace formation that occurs in major storm events? If so, where is it published? (JL1-11)

River, Riverbank and Floodplain Interactions

42. Where in the literature can I find a documented application of the success of any known model to sediment bank erosion and terrace movement, in particular for the EFDC model? (JL2-8)

38. What is the impact of streambank erosion in terms of contaminated sediment input into the Housatonic River? How will it be assessed? (MG9)

39. Is there data to show bank erosion is important? If so, how do you intend to model it; and, of course, defend the parameters in that model? (WL5)

Response: This is the first application of EFDC to a meandering river, and the first application of any modeling study that includes hydrodynamics, sediment transport, and chemical fate and bioaccumulation in a system such as the Housatonic River.

The modeling team disagrees that the bars and similar deposits represent the primary instream storage of PCBs, and that they need to be modeled on an individual basis, rather than as a lumped parameter with the rest of the sediment in a grid cell.

The importance of bank failure and input of solids and PCBs may be significant, and will be explored further. Documentation of the use of any model addressing the fundamental processes behind bank erosion/terrace formation is limited. Streambanks erode and fail for a variety of reasons and by various mechanisms. Past attempts to model these processes have oversimplified both the characteristics of the bank and the processes leading to bank erosion. While a large number of slope stability models have been developed which have been applied analyzing the stability of eroding cohesive riverbanks, these models typically address only one or two of the many bank failure mechanisms that are common to streambanks.

Fewer models have been developed which attempt to address the loss of soil from streambanks due to erosion processes with subsequent bank failure. However, there have been studies in which empirical relationships have been applied to characterize the loss of banks and subsequent channel migration. In these cases, the underlying physical processes are not represented in the model; rather, the sediment influx is handled as a lumped input parameter.

40. pg. 6-3 If it is difficult to predict changes in embankments with GSTARS then why isn't it also difficult for EFDC? Has EFDC previously been used anywhere to predict bank changes? If so, where are the results and the field data to substantiate the modeling? (JL1-18)

Response: The channel boundaries of the EFDC grid cell domain are fixed and do not change during the simulation. It is impossible for EFDC to predict either bank erosion or channel meanders that result from such erosion. Consequently EFDC has never been applied for analyses of bank erosion. Unlike GSTARS, which is designed to account for channel evolution, EFDC is not designed to account for the erosion of solids from unstable channel banks during high flow events. GSTARS, however, has been successfully applied by Ted Yang of the US

River, Riverbank and Floodplain Interactions

Bureau of Reclamation (Yang et al., 1998) to numerous rivers characterized by non-cohesive sediments, primarily in the western United States, to simulate the evolution of a changing river channel embankments and river bed.

26. Pg. 4-38 - How is the transport of bar scale material (gravel bottom river) taken account of when the particle sizes used fall into two classes, with only one class greater than 0.25 mm? (JL2-5)

Response: As stated in the MFD on page 4-25, three size classes are proposed, one for the cohesive fraction, and two representing the non-cohesive fraction.

41. pg. 6-4 Man-made changes to bank stability- how will these be assessed and compared with natural changes that we can expect to be occurring? (JL1-19)

Response: If man-made changes or channel modifications are applied to a particular area, the corresponding EFDC model cell soil properties will be modified accordingly. For example, if a stretch of river includes a bridge abutment, the soil properties for the corresponding cell(s) will be modified to limit/eliminate erosion. The bed elevation can then be plotted to determine its long term behavior, which of course should not change.

45. Pg.3-54 shows that high concentrations of PCB are in the bars and terraces and the riverbank, which are areas not within the usual flow plain. How will the hydrodynamic modeling predict the fate of this material, which is not included within the normal flow patterns that are being modeled? (JL1-4)

Response: As stated earlier, based on a calculation of PCB mass in the bars, terraces, and other depositional areas, the modeling team believes that the relative importance of the PCBs in bars, terraces, and other identifiable deposits appears to be low. While bars, and terraces are not explicitly modeled, the mass of solids and PCBs contained in them is accounted for through the sediment bed construction in the grid cell as outlined in the general response above. The evaluation of the river banks and proximal floodplain is still underway, an approach has been proposed as to how these features could be accounted for in the model analysis.

46. Pg. 4-51, line 10-11 It is taken that EFDC will provide sediment fluxes. However, the major sediment fluxes will occur during storms, when bank erosion and bar movement will occur. Are these the predominant sources of high concentration PCB's? Where is the assurance that the EFDC code can model such erosion and transport? Has it ever been done before? If so, where can we see the results and comparison with field data? (JL1-13)

Response: We agree that major sediment fluxes throughout the model domain will occur during storm events. However, we do not believe that bank erosion and bar movement are dominant sources to the overall sediment load. Rather, the channel bottom, which comprises over 98% of the wetted area of the river, is believed to be the dominant source of the total sediment load generated instream. The evaluation of the PCB mass summarized in the table above suggests that the proximal floodplain does contain a significant mass of PCBs, however, this mass includes much more area than what is typically considered "riverbank".

As mentioned above, no attempt will be made to specifically model sub-grid scale features and processes. They will be aggregated through the spatial- and mass-weighted averaging into model cells. The parameterization of the aggregate or net processes within a model cell is part of the overall calibration process.

The Test Reach work and calibration efforts will address the potential impacts of the processes in question on water column TSS and bed sediment distribution. As described in the general response to this section, the magnitude of bank erosion is being evaluated as part of the Test Reach study and through the use of GSTARS.

47. The major issue seems to be that the high concentrations of PCB's are in locations (terraces, river banks, and river bars) the erosion of which has (to my knowledge) never been successfully modeled previously. It is difficult to see how these models can accomplish predictions of natural attenuation if the major events that result in transport of the PCB have never previously been successfully modeled. Are there documented successful (or unsuccessful) applications of the model to such eroding flows, where there is a clear comparison with field data? (JL1-25)

Response: While these structures are not specifically treated, given the spatial and temporal scale of the model domain, the implicit incorporation of these features within the model cells is appropriate. Natural attenuation and active remediation options will be evaluated, not with a bar by bar or bank by bank approach, but on a much larger scale over an extended period of time. Given the length of time proposed for the alternatives analysis (>50 years) maintaining the precise expression of individual river features is thought to be less important than the overall outcome (i.e. fate) of sediment mass and associated PCBs for each grid cell. This approach will be revisited as necessary during the test reach study and the calibration/validation process.

36. How will floodplain sediment dynamics be modeled? Does the floodplain constitute a source or sink of contaminated sediments to the Housatonic River? (MG7)

Response: During flood flow events, water flow within the floodplain will be coupled with flow in the river channel using a nested grid approach. The sediment transport submodel will be used to represent deposition and resuspension processes to simulate the import or export of solids and sorbed PCBs between the floodplain and the river channel. Although a floodplain usually acts as a sink for sediments and sorbed contaminants (hence the high concentrations of PCBs observed, particularly in the floodplain of the Housatonic River), an *a priori* determination of whether the floodplain serves as a source or a sink of contaminated sediments will not be made for this study. Rather, the hydrodynamic and sediment transport models will be used to dynamically simulate the movement of sorbed PCBs from the floodplain according to the model processes.

37. What is the fate of the washload in the floodplain? Can existing field data be used to assess this? (MG8)

Response: The floodplain domain will be represented by the EFDC model, which will simulate scour and deposition within the floodplain. Particle size data from floodplain samples will help to determine if the grain size distribution is properly represented. Representation of floodplain scour and deposition amounts will be evaluated by indirect comparisons of simulated depositional patterns to measured PCB and grain size data.

<u>Impacts of Rare Flood Events</u>

General Response

One of the objectives of the modeling study is to quantify the relative risk of extreme storm event(s) contributing to the resuspension of sequestered sediment or the redistribution of PCB-laden sediment in the study area. These events are important as they cause high shear stresses and as a result produce significant erosion, transport and deposition of large quantities of sediment downstream and out onto the floodplains. Twenty years of historical USGS flow data (1980 to 2000) will be used to validate the models. One 100-year event was recorded within the validation period at the upstream Coltsville gage, a second was recorded at Great Barrington in 1984.

While extreme events are the primary mode of transporting PCBs large distances away from the channel, smaller events have a significant effect on resuspension and redistribution of sediments and associated PCBs onto the proximal floodplain and within the channel. Data were collected from the two existing USGS gages and eight stage gages installed as part of this assessment. An example of flow and stage height is presented on Table 3-6 in the MFD. While the data show that most of the measured storms were less than 5-year re-occurrence intervals, these smaller storm events play an important role in mobilizing sediments and associated PCBs in the PSA as shown in the MFD Figure 3-5. The figure shows the rapid response to river stage and resulting increased suspended sediment loads along the PSA from the September 1999 storm. This storm had an estimated return period of between 1 to 2 years.

Analysis previously conducted by GE suggests that the PCB concentrations greater than 1 mg/kg are within the 2 to 5-year floodplain. EPA data suggest that the influence may extend to greater expanses of the floodplain, but due to the influence of the railroad easement to the west and mountains to the east, the extent of contamination is clearly defined, yet can not be categorized to a recurrence interval.

44. One of the stated purposes of the model is to understand the effects of "extreme" storm events. What is intended by extreme in terms of recurrence interval? In this regard, Table 3-6 on page 3-33 of the MFD lists only storms less than the 10-year event. Is this database adequate to model extreme events? Also, can Table 3-7 on page 3-35 be expanded to include the 1-year, 2-year, and 5-year storm flows in order to put the available data in perspective? (PS4)

<u>Response:</u> While the exact definition of "extreme events" is not available, it has been generally interpreted as flows whose probability of exceedance in any one year is 10% (i.e. 10 yr recurrence interval).

Within the validation period of 1980 to 2000, a 100-year event was observed at Great Barrington in 1984 and at Coltsville in 1990, and a 25-year to 50-year event occurred at Coltsville in 1987. Thus, flow simulations will be compared to flood events ranging from 25-year to a 100-year frequency during the validation period for the HSA, which lies between Coltsville and Great

Impacts of Rare Flood Events

Barrington. The storm events monitored (summarized in MFD Table 3-6) are mostly less than a 5-year event, as that was what occurred during the period of sampling. The data from these events will be used to calibrate hydrodynamic variables and water quality constituents. Since extrapolations of the model results are necessary beyond the calibration conditions, every attempt will be made to assess the uncertainty in these predictions. A revision to MFD Table 3-7 is shown with the requested storm data added; a peak flow value of 3,850 for the August 1990 event at Coltsville was added based on recent communications with the USGS (T. Shepard, USGS-Northborough, MA, personal communication, 2001). The flows used to generate these data shown in Table 3-7 are based on daily average flows supplied by the USGS.

Table 3-7
Summary of Historical Flows for the USGS Gages

		USGS Gage at Coltsville Station 1197000	USGS Gage at Great Barrington Station 1197500
Period of Record		1937-97	1914-1997
Years of Daily Data		61	84
Flood Events (cfs)	Return period		
	100-yr	3,790	10,603
	50-yr	3,276	9,137
	25-yr	2,791	7,786
	10-yr	2,186	6,142
	5-yr	1,745	4,975
	2-yr	1,146	3,428
	1.01-yr	385	1,492
Peak Flows and Years in Current Record			
		4,350 – 1949	11,101 – 1949
		3,110 – 1938	11,000 – 1938
		2,860 – 1987	9,940 – 1984
		3,850 – 1990[1]	
Average Daily Flow (cfs)		107.2	525.8
Average Daily Flow/sq. mi.		1.86	1.86

[1] Flow Estimated by the USGS.

Impacts of Rare Flood Events

43. Big events. Large amounts (several feet) of contaminated sediments seem to have been deposited sometime in the past in the river (in what is generally stated to be a non-depositional area) and on the floodplain. This is probably the result of a big flood (possibly the flood in 1987 or previous ones in 1938 and 1949) with resulting deposition of sediments after the peak of the flood as currents decrease. Other evidence on PCB concentrations is consistent with this. The report (3-57) indicates that Reaches 5a and 5b are net erosional, but this is inconsistent with the deposition in these areas. Will this 1987 event and possibly other big events be modeled for better understanding of sediment and contaminant transport in the river? Note that big events happen quite often with three 100-year flows in the last 62 years! These flows are 20 to 40 times larger than average flows. For these large flows, the bottom shear stress may be on the order of 25 N/m2 and possibly more; these stresses are huge. The resulting sediment and PCB transport would also be huge. (WL15)

Response: We agree with the observation that storm events have resulted in deposition of PCBs in the floodplains and to a lesser extent (on what appears to be an episodic basis in the aggrading bars) in the river itself in areas of Reaches 5a and 5b.

Resurveys of individual channel morphology transects indicate both erosion and deposition within these immediate areas, suggesting a reworking of sediments rather than large areas of deposition or erosion. With respect to the river channel proper, Reaches 5a and 5b contain many aggrading bars. PCB distributions within these bars, and more recent history on observed erosion and deposition, show that indeed these bars have moved. The data indicate that both large and small storms rework channel sediments, however, the distance of movement is dependent upon both the size and duration of the storm. Transects resurveyed after five months indicate erosion and deposition of up to 1 ft in some areas. This is a significant observation.

The reviewer's question asks whether the hydrodynamic and sediment transport model can successfully simulate the response of the river to high flow events. It is expected given the documented performance of the models that this will be achieved. In order to demonstrate that the model(s) can represent the redistribution of large quantities of solids resulting from flood flow events, the validation period selected for the model includes several high flow events as part of the continuous simulation. Within the 20 year validation period from 1980-2000, two storms events with flows near or greater than the 100 year flood, have been recorded at Great Barrington in 1984 and at Coltsville in August 1990. In 1987 a >25 year event was also recorded at Coltsville. The long-term effects of these very large flow events on the solids balance in the river will be a primary focus of the validation effort.

Impacts of Rare Flood Events

48. Has EFDC been validated for sediment transport in floods in a published peer reviewed journal article? Are there published comparisons, such as there are presented in Figures 4-2, 4-3, and 4-4 for AQUATOX, available for EFDC ? (In any case, I seem to recall being criticized for using the Kolmogorov-Smirnov test for equivalence of distributions, for statistical reasons that I cannot remember.) (JL2-6)

Response: A list of peer-reviewed applications can be found in Appendix C. EFDC has been used to model storm events. One application of this type is for the Blackstone River in Rhode Island. EFDC was applied for an evaluation of hydrodynamics, sediment transport and transport and fate of heavy metals. In this application, the shallow, 48-mile long river, characterized by 14 low-head dams, was represented as a 1D system where the well mixed water column was coupled with a surficial sediment bed layer. The simulations generated by EFDC resulted in good agreement between observed and measured TSS and heavy metals concentrations during a storm event represented in the model application. Appendix I presents figures of flow, TSS and heavy metals for storm events from the Blackstone River. The technical report prepared by Tetra Tech (1999a) has been submitted by Ji et al. (2000) for peer-reviewed publication in the ASCE Journal of Environmental Engineering.

Regarding the Kolmogorov-Smirnov test for equivalence of distributions, an overview by project statisticians suggests that it is conservative measure, and is the preferred test for random samples that are independent and identically distributed.

104. Floods are apparently very important for transport. Since contamination has occurred over many decades, why would all of the contamination be within the 10-year floodplain. (EA2)

Response: The floodplains surrounding the PSA are heavily vegetated, therefore, transport velocities are progressively reduced as flow is distributed away from the channel, resulting in preferential deposition of sediments (and PCBs) as a general rule in the proximal floodplain. In several areas of the PSA, transport of sediments in the floodplain is controlled by topographic features such as October Mountain on the east side of Reaches 5c and 6, and an elevated railroad bed along the west side of part of Reaches 5b and 5c, as well as secondary features such as utility easements across the floodplain.

125. If storms are important for transport, can this model be accurately run with daily time steps? (EA23)

Response: Only AQUATOX is proposed to run as a daily time step. AQUATOX uses a 4-5th order variable-step Runge Kutta routine to solve the differential equations; the solution steps may be on the order of minutes to deal with discontinuities such as storms. The AQUATOX segments are large enough and the travel times are long enough that daily time steps for loadings

Impacts of Rare Flood Events

from HSPF and EFDC are not anticipated to be an issue.. Internally, if a concern arises regarding an inaccurate solution, rates are saved for each solution step; the reporting step can also be decreased to less than a day, although usually the time-integrated results are saved for one or two days. The model has been used in past applications, including East Fork Poplar Creek (Oak Ridge, TN) and Procter and Gamble Experimental Stream Facility (Little Miami River, OH), where there were no difficulties noted in modeling flashy stream applications.

<u>**Spatial and Temporal Definitions/Scales**</u>

49. The spatial domain of the model proposed for simulating PCB transport and fate (i.e., rest of river) will not address remedial actions taken in the Housatonic River above the confluence. Remediation of river sediments adjacent to the GE facility is underway, and additional actions are planned for the river reaches above the confluence. Monitoring conducted in 1998-1999 will not reflect any reductions in PCB transport from upstream due to remedial actions. I presume that remediation is expected to reduce the magnitude of this transport; but, by how much? How will the effects of remediation on PCB transport be estimated? To ask a broader question, how can the modeling goal of "determining if remediation of areas contaminated with PCBs in the Lower River is necessary, and if so, to what extent" be accomplished in a framework different from the (unknown) one being used to address the same question for the Upper River? (DE2)

50. Why is the modeling exercise limited to a relatively short reach of the river? Could it be extended farther upstream? (MG2)

51. During these big events, the main source of PCBs probably was the contaminated sediments near the GE facility. For a satisfactory understanding of PCB dynamics in the past and the effects of big events in the future, the proposed modeling should be extended to include the region near the GE facility. From a modeling viewpoint, it is unfortunate that data on sediment properties as they were in the past probably is not available, or at least insufficient, but some attempt at modeling this source and its effect on the rest of the river should be made. Since the area is being cleaned up, this should also be reflected in the model and help our general understanding of sediment and PCB dynamics. Would you please comment on this? (WL16)

106. Another objective should be to assess the impact of the study area of ongoing remediation in the upstream reaches closer to the GE facility. Can this be done without including these reaches in the study area? (EA4)

<u>Response:</u>

EPA believes that it is necessary and appropriate to establish the upper boundary of the PSA at the confluence based upon a number of factors, including the current cleanups being implemented above the confluence, the lack of accurate information about complex historical loadings from the area around the GE plant site, the scope, feasibility, and timing of addressing the upstream reaches, and our belief that the proposed approach will accurately represent the flux across this upstream boundary, which is all the information necessary for evaluating no action and the effects of potential remedial alternatives in the PSA.

First, two separate cleanup actions have already been chosen for the river upstream of the confluence. EPA=s decision on remediation in the 2 -Mile Reach (cleanup currently underway) and the 12 -Mile Reach were based on risk to humans and the ecosystem from PCBs (as

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documented in the respective Action Memoranda for those reaches). In addition to removing PCB-contaminated sediment in both actions and placing a cap in the ½-Mile Removal Action and backfill with clean sediment in the 1 ½-Mile Removal Action, the other actions detailed in the Consent Decree include elimination and/or control of all sources to the river. Massachusetts DEP is currently evaluating what if any work will be required in the West Branch. Completion of the source control and sediment/bank removal actions is expected in 2006, when EPA anticipates that work can begin in the Rest of River if it is necessary. The decision on the Rest of River will use a risk-based framework, and a review of the impacts of the remedial alternatives under consideration, following the process outlined in the Consent Decree.

To properly evaluate the Upper Reaches as postulated by some of the Panel members would mean that the modeling analysis and decision for the Rest of River be put on hold for the foreseeable future while waiting for the completion of all of the upstream cleanup work, the return of the system to a state of dynamic equilibrium, the subsequent collection of additional data, the completion of the model calibration peer-review and validation peer-review, the development of the Corrective Measures Study, and the completion of EPA decision-making process. The result would be a major and unnecessary delay in the ultimate cleanup of any PCBs which are deemed to present unacceptable human and ecological risk

Second, there is a great deal of uncertainty associated with parameterizing the numerous historical point and nonpoint PCB sources, unquantified LNAPL/DNAPL inputs and groundwater PCB fluxes present in the source areas upstream of the confluence. When EPA was in the process of developing the Conceptual Model, the modeling team requested that GE provide some estimation of the inputs to the upstream reaches. GE’s response was that they were unable to provide any estimate, and, as a result, there are no data to bound calibration or validation of the historical inputs.

Therefore, EPA collected data on the upstream boundary conditions as defined at the confluence, which provides an integration of all upstream sources, prior to the commencement of these removal actions. The data were deliberately generated to represent a baseline (no remediation) scenario so that these data can be compared to the data collected historically by GE (representing a period after termination of the use of PCBs yet in the absence of remediation).

Third, to account for the effects of upstream removal actions for the purposes of modeling no action and other remedial alternatives, one can hypothesize various boundary fluxes ranging from a zero input condition to some minimal background PCB loading for the model forecast. For the calibration and validation periods, developing two upstream loading functions (i.e. for the West and East Branches) is more straightforward and provides fewer unconstrained variables to calibrate to.

In addition, the proposed Modeling Framework focuses on the stretch of the river from the confluence to Woods Pond Dam, where past reports prepared by GE as well as current data indicate that the significant mass of PCBs is located. In addition, it is EPA's understanding that GE has constructed and run a model far into Connecticut. Output from the EPA modeling analysis can be compared to GE's modeling efforts to inform decisions for reaches further downstream in the river, if unacceptable risk is found which warrants further consideration.

52. Pg. 4-42 – Gridding has not been used previously in such a flow configuration? Why do not the answers to these questions already exist? Has the model been used in this type of situation before? If so where can the documentation be found? (JL1-10)

54. Pg. C.1-3, line 41. Grid strategies for EFDC are still being tested? Has it not previously been applied in such a flow situation before? If so, where is the documentation? (JL1-22)

118. (p.4-47) Similarly, I am concerned about the issues of dual gridding, grid matching, etc. This sounds like interesting research that might not bear fruit in a timely fashion? Again, could a simpler model be chosen? (EA16)

Response: This is the first application of the EFDC to a highly meandering river system with a large expanse of associated floodplain. Due to the complexity of this study, a rigorous development and testing phase of both the EFDC code and its application to the Housatonic River is proposed for this modeling study. During the early phases of the MFD development, a wide range of options were considered. The primary focus of the grid development effort proposed in the MFD is on the use of a curvilinear grid for primary channel/proximal floodplain (called the "main channel") and a separate linked grid which represents the distal floodplain (see the following Figure, where the inner three cells represent the river channel, the outer two cells represent the proximal floodplain, connected to the distal floodplain cells). The significance of proximal versus distal floodplain is two-fold. First the proximal floodplain will be routinely (approximately every 2-5 years) inundated and in the "floodway". During these frequent storms, this area will experience relatively high shear stresses and will need to dynamically interact with the main channel. Momentum transfer between the proximal and channel cells will be important. Secondly, the proximal floodplain contains a significant portion of the PCB mass that needs to be addressed to achieve the modeling study objectives.

The proximal and the distal floodplain cells that are adjacent to one another will be linked. This linkage allows for the exchange of water, sediments and PCBs between the floodplain and the main channel. While mass is conserved between the two, momentum is not conserved due to limitations of the model. This should not pose a significant concern because of the slow velocities anticipated in the distal floodplains due to the significant vegetative roughness. During extremely high flows (>2-5 yr storms) the main flow will move down the channel/proximal floodplain and, as the water surface reaches the level of the adjacent distal floodplain, the distal floodplain will begin to accept water and transported mass through the linkage. Once water is in the distal floodplain cells, the water is again subject to complete hydrodynamics, including momentum. During the highest flow events, the boundary between

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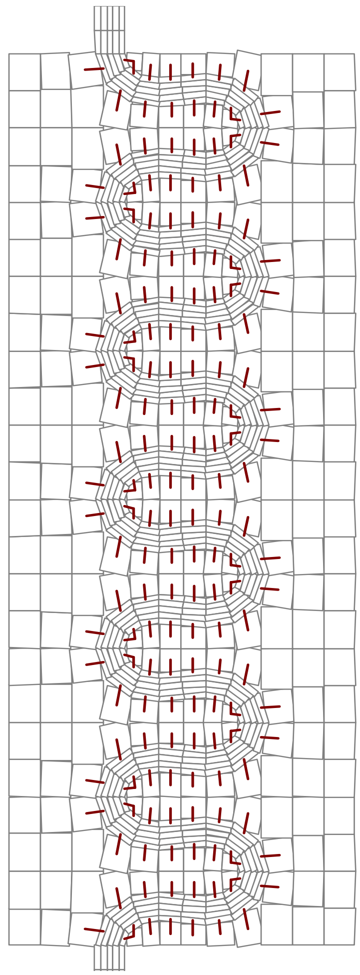

the proximal and distal cells will inhibit flows and will be subject to testing during calibration/testing.

The modeling team believes that this approach provides the best balance of grid resolution and computational speed required with model accuracy and model objectives.

53. pg. 4-47 line 17, line 25 What is PLAN "B" in the event that the computational feasibility proves intractable? Where is the contingency plan? (JL1-12)

<u>Response</u>: Computational feasibility is an issue for employing a fine-grid river model to this type and size of domain. Since the MFD was completed, preliminary tests of the nested-grid approach using a test case representation of a meandering river channel coupled with coarse floodplain grid, developed on a scale comparable to the features of the Housatonic River, are

encouraging. These results suggest that the strategy should be successful. The test report for this effort will be presented as part of the calibration documentation.

Further testing is needed however, using the actual computational grid of the spatial domain of the Housatonic River channel and floodplain, before the approach will be considered a successful strategy. This is one of the primary goals of the test reach program. The test reach program, as described on page 4-45 of the MFD progressively coarsens the grid to optimize computational efficiency until an unacceptable loss of information occurs. For example, if in-stream velocities become un-representative. Model testing suggests that this approach to grid development, coupled with other activities ongoing to improve computational efficiency, will result in an intense, yet tractable approach.

55. On page 4-12, it is indicated that daily rainfall data will be disaggregated into hourly records. Please discuss the procedure to be followed in more detail. Will spatial and temporal patterns be linked so as to properly represent passing storm fronts? (PS10)

115. (p. 4-12) To properly simulate run-off from local storms requires data well resolved in space and time. I would like to see more discussion of the method of extrapolating/interpolating precipitation data from one site to another and the disaggregation of data from longer to shorter time steps. (EA13)

Response: The procedures to be used to disaggregate the daily values to hourly involve using a nearby hourly record to provide the distribution for the daily gage value. For each day, the 24 hourly values are analyzed to calculate the fraction of the daily total that occurred in each hour; these 24 fractions, which sum to 1.0, are then used to distribute the total for the daily gage into 24 hourly values. These procedures have been used on a number of applications over the past decade; they were originally implemented in a USGS program called METCMP, and have recently been incorporated into the WDMUtil program supporting BASINS users (see www.epa.gov/ostwater/BASINS/support.htm). Special coding is implemented to accommodate periods of missing and/or accumulated data, and messages are provided to the model user when manual fill-in of data may be required. In addition, users can identify multiple hourly stations and the code will select the hourly station that has a daily total that most closely matches the total for the daily gage being distributed.

For the Housatonic River watershed, hourly precipitation data are available at Lanesborough, MA (through 1995) and the GE Pittsfield facility (1994 – present), along with a number of stations (with shorter records) surrounding the watershed at Becket 2 SW (MA), Littleville Lake (MA), and Copake (NY), and long-term stations at Albany and Hartford. The meteorological stations and their periods of record were listed in Table F-8 of the MFD; unfortunately, that table was incomplete in the published MFD, so a complete Table F-8 is attached as Appendix J.

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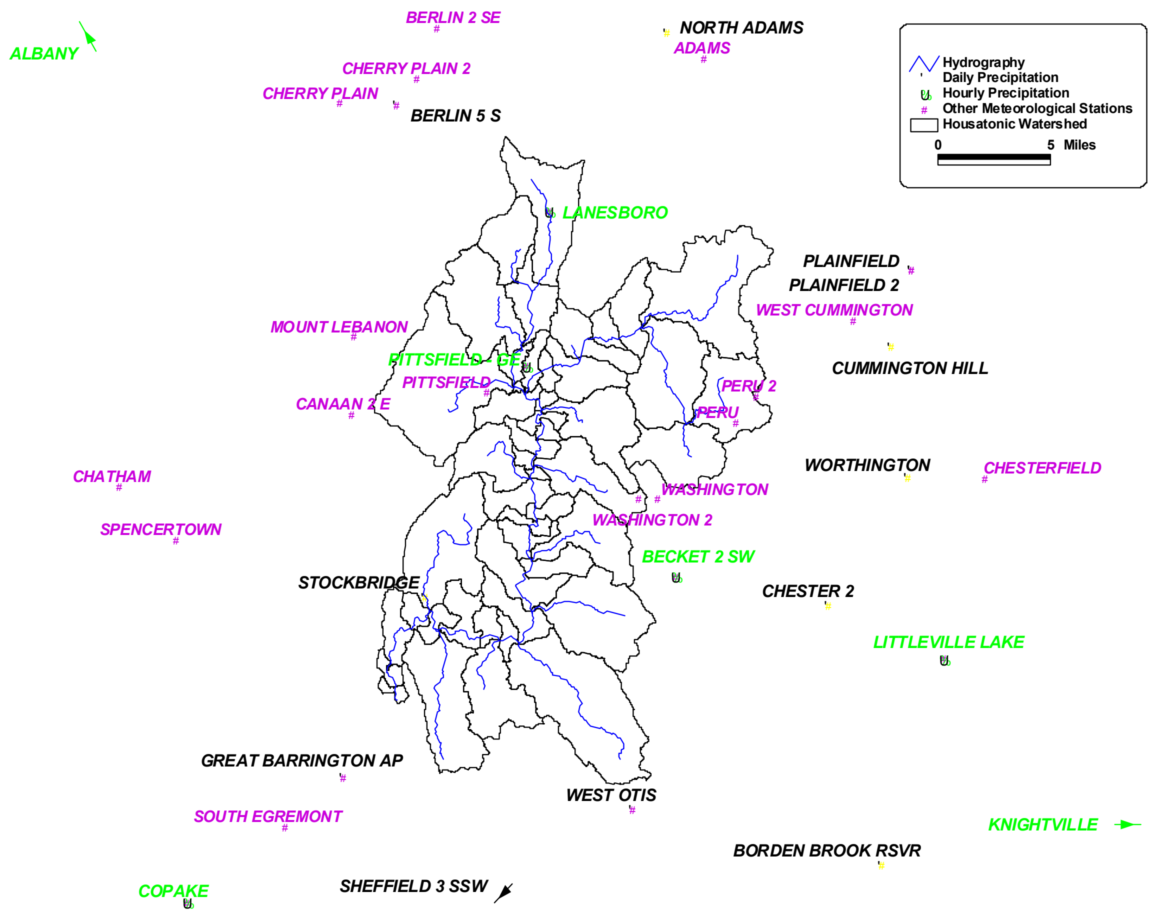
The extent to which passing storm fronts can be properly represented depends on whether the temporal and spatial patterns of the storms are adequately reflected in the observations of both the hourly and daily gages. There appears to be a good distribution/coverage of daily gages for all parts of the watershed. Also, the separate hourly stations noted above allows the exploration of the use of different temporal patterns (i.e. different hourly gages) in different portions of the watershed (e.g. north versus south) to assess the timing of storm passage. These issues will be addressed during the hydrology calibration efforts.



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121. (p. 3-16) Initial bathymetry (1980) will be developed using current bathymetry and subtracting sediment deposition inferred from Be-7, Pb-210, Cs-137, etc. Then when the model is run forward, the same deposited sediments will be added, presumably yielding current conditions. While this should provide a good history of recent morphology, it is not predictive of future changes. Are there any independent estimates of historical bathymetry? (EA19)

<u>Response</u>: As noted in the question, initial bathymetry (1980) will be developed using current bathymetry and subtracting sediment deposition inferred from Be-7, Pb-210, Cs-137, etc. EPA has actively looked for other historical information and is not aware of any historical bathymetric data for this area of the PSA.

122. Related to the above, what will be done to initialize bathymetry for areas of net erosion? (EA20)

<u>Response</u>: The Woods Pond area is predominantly net depositional. Therefore, we assume that the reviewer is referring to the riverine sections of the PSA as net erosional. The current approach for the riverine section of the PSA is to assume that it is in a state of dynamic equilibrium. Therefore, it will generally be assumed that the present conditions are representative of conditions present in 1980. All available data will be used to evaluate this approach. Based on this analysis, some sections may be modified, as appropriate.

Technical Rigor of Modeling Equations/PCB Fate and Transport

General Response

In the last two years the Modeling Team has reviewed the historical and recently collected data, developed a Conceptual Model of the system, initiated new sampling programs, and tailored the models to the requirements of the Supplemental Investigation. One of the pressing issues was to determine why the initial PCB data did not seem to fit the usual paradigm linking PCBs and fine-grained, organic-rich sediments. A sampling and analysis program was conducted; the final results and conclusions became available qualitatively before the MFD and QAPP were completed. Therefore, several questions that were forwarded by the Panel can now be addressed in detail.

Another related area of concern has been how to best represent abiotic and biotic partitioning in the modeling analysis. The MFD proposes an overall approach that combines detailed field sampling for congeners, Aroclors, and total PCBs (tPCBs) with roots in the theory based on numerous (and continuously expanding) detailed studies in the literature. Field studies have been conducted, and others are proposed to better define the partition coefficients (K_ds) that relate water, sediment, and pore-water concentrations of PCBs to organic content, grain size, and location. EFDC will model tPCBs to provide spatially explicit predictions of areas of deposition and erosion of PCBs. The system is modeled as being constantly in equilibrium based on site specific apparent K_ds. AQUATOX is being used to model the biotic and abiotic fate of selected PCB congeners, which will serve as surrogates for groups of congeners; equilibrium partitioning cannot be assumed for this purpose. Therefore, K_ds as functions of K_{OW} will be based on theoretical relationships from the literature and confirmed by field data insofar as possible. The kinetics of uptake and loss are modeled explicitly in AQUATOX, but are constrained by the K_ds so that the model is not overly sensitive to specific uptake and loss rate constants.

Time- and spatially-varying biological activity affects the fate of PCBs in the Housatonic River system in several ways. A large amount of data has been collected at the site historically and during the present investigation in a relative sense compared to most other modeling studies. However, it is impossible to collect data on many parameters such as biomass of all organisms, biological activity (including feeding preferences and depths of disturbance), and concurrent PCB concentrations for all seasons and stations. Therefore, the Modeling Team chose to collect synoptic biomass and PCB concentrations for all organisms at one or two points in time for each station rather than having no data at all to use these as reality checks during the calibration process. Labor-intensive gut analyses and studies of depth of disturbance over seasons was clearly beyond the scope of this site investigation. However, there is adequate literature sources on the feeding and other activities of invertebrates and vertebrates at comparable aquatic sites, and this literature has been reviewed and data have been incorporated into the modeling framework.

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56. Third-phase PCBs: The frequent mention of PCBs existing in neither dissolved nor organic carbon phases raises a number of questions, including: (1) has DNAPL-phase PCB been observed or measured in the Lower River?, (2) what physicochemical process is responsible for association of this chemical with predominantly coarse-grained solids?, and (3) what conceptual model is available to describe the transport and fate of "third-phase" PCBs? (DE3)

67. Page 3-65 of the MFD indicates there will be further evaluation of issues involving the representation of PCBs (immediately before the Partition Coefficients heading). Is there any progress to report in this regard? (PS6)

<u>Response:</u> A study was conducted to evaluate the nature of PCB occurrence and mineralogy in the sediments. Ten samples were selected from Reaches 5a and 5b, representing a range of PCB concentrations, organic carbon content, and dominant grain sizes. Three techniques were utilized to evaluate the sediment samples:

- optical microscopy using a binocular microscope,
- x-ray diffraction (XRD), and
- scanning electron microscopy (SEM) with an energy dispersive system (EDS).

Samples were first evaluated using optical microscopy, which revealed that quartz and mica dominated the mineralogy in all but one sample. Reddish-brown staining was observed on many quartz grains in the nine samples with quartz. An agglomerated material was observed in four samples. The XRD analysis produced results which were consistent with the optical mineralogy analysis.

For the SEM analysis, three aliquots from each sediment sample were prepared prior to the evaluation. One uncoated aliquot was placed directly in the SEM/EDS instrument while still wet and evaluated under a low vacuum condition. A second aliquot was dried, coated with an Au/Pd film and evaluated under high vacuum. A third aliquot was vacuum impregnated with epoxy, cut, polished and then coated with a conductive carbon coating. For each of the 30 total aliquots evaluated, 3-5 fields were viewed under the SEM and 1-5 grains/areas per field were analyzed for elemental composition using the EDS associated with the SEM. This resulted in 20-40 EDS elemental probe analyses for each of the original 10 sediment samples. These probe analyses produced a spectrum of elements present and relative abundance in the grain or field of view probed.

While the SEM/EDS study was not a quantitative evaluation, concurrent detection of carbon and chlorine in an EDS probe analysis was regarded as an indicator of the presence of PCBs. The SEM/EDS analysis indicated carbon and chlorine peaks were concurrently observed in association with organic coatings on numerous grains (especially quartz) in most aliquots.

Technical Rigor of Modeling Equations/PCB Fate and Transport

For the purpose of the modeling, the PCB "third phase" is assumed to be present in the PSA as coatings on coarse sediment grains and will be represented by site-specific apparent Kd's in the modeling study. While the exact physicochemical process responsible for the observed PCB association with coarse-grained solids is unknown, the proposed use of site-specific apparent Kd's allows representation of the observed condition without regard to the actual mechanism.

88. Throughout the document and for the river below the confluence, there are references to "free-phase PCBs", NAPLs, and third-phase, as if these are all related. Is there any evidence for NAPLs below the confluence? (WL1)

Response: During development of the conceptual model and while trying to understand the mechanism(s) behind the observed high PCB concentrations associated with large grains and low TOC, it was hypothesized that a "third-phase" could be present as an oil or NAPL. Subsequent evaluations indicated that PCBs are present as patchy coatings on sediment grains and not as "free-phase" or NAPL. No NAPL has been observed below the confluence.

58. AQUATOX: The sediment bed representation (including hardpan option) described in the MFD is different than I have seen in previous AQUATOX descriptions. Has this sediment bed computation been fully implemented and/or tested? (DE7)

Response: The sediment bed representation used in earlier versions of AQUATOX (Version 1.69 and earlier) was not adequate to address the issues (e.g., natural recovery) related to PCB transport and fate in the water column and sediment bed of the Housatonic River. Based on discussions with Mark Velleux, IPX Version 2.7.4 was chosen for developing an upgraded sediment bed submodel for AQUATOX because it addresses the serious drawbacks of the approach used in the Wasp4-Toxi4 (Ambrose et al., 1988) and Wasp5-Toxi5 (Ambrose et al., 1993) sediment bed submodels.

The new sediment bed submodel has been fully implemented and tested within AQUATOX with code verification, checking for mass balance, and simulating textbook analytical examples. The sediment bed submodel of AQUATOX is currently undergoing additional testing by comparison to results obtained using IPX Version 2.7.4 simulations. A series of tests are being conducted to ensure that the new sediment bed submodel implemented in AQUATOX can reproduce results generated with IPX Version 2.7.4. This will ensure that these issues will not affect Housatonic River model development efforts.

Technical Rigor of Modeling Equations/PCB Fate and Transport

59. AQUATOX: Will the temperature dependence of Henry's constant be included in the PCB volatilization computation? Which formulation will be applied? (DE8)

Response: Yes, although it has not been accounted for in previous versions of AQUATOX, the Henry's constant is sensitive to temperature changes. The conventional method based on the enthalpy change (Boethling and Mackay, 2000) is proposed as the approach, which is essentially what was used for the Hudson River PCB modeling (QEA, 1999).

60. AQUATOX: A sorption rate constant *kl* of 1200 L/kg-d (page D-42) seems very fast for PCBs. What data is this value based upon? (DE9)

Response: The value of 1200 L/kg-d represents a mid-range value selected based on literature studies of kinetics of hydrophobic organic chemicals, including PCBs. The value is about two orders of magnitude less than Sijm et al. (1998) found for phytoplankton, and it is about two orders of magnitude greater than Wang et al., (1999) found for periphyton. This value has been used in previous applications of AQUATOX for simulating PCB biaccumulation (EPA, 2000; Moermond and Koelmans, 1999). Preliminary tests of the model indicate that the output is not particularly sensitive to the value of the sorption rate constant. If application to the Housatonic River shows it to be sensitive, then we will obtain a set of congener-specific values based on a combination of the literature and calibration.

61. AQUATOX: Have any site-specific diet/gut content analyses been conducted in the Housatonic River? If not, then how will the trophic interactions simulated in the model food web be confirmed? Have there been any other significant food web bioaccumulation model applications where prey selection and consumption were based on an ecosystem simulation such as used in AQUATOX? (DE10)

Response: Site-specific gut analyses have not been conducted in the Housatonic River. Most fish species, while having preferences, are opportunistic feeders, eating whatever is available within broad preferences ranges. For that reason, very extensive sampling is necessary to characterize general preferences. Therefore, analyses performed by the National Biological Service (Johnson and Dropkin, 1995) in September, 1993, and in May and July, 1994, in the main channel and two reservoirs of the Sudbury River, Mass. (a river that is comparable to the Housatonic); data from the Hudson River, N.Y. (Exponent, 1998); and data from numerous other studies (many summarized by Leidy and Jenkins, 1977) will be considered.

In addition to empirical data from other river systems, general knowledge of fish feeding preferences is derived from the literature (e.g., Sternberg, 1996; Scott and Crossman, 1973) and combined with site-specific knowledge of habitat and plausible feeding preferences in consultation with local fisheries biologists. These information sources will be used to establish constraints in the AQUATOX simulations. For example, if small fishes are consistently shown to comprise only a minor portion of the overall diet of an opportunistic feeder, such as the brown bullhead, the model may be constrained to a maximum preference coefficient for that prey item. The trophic interactions will be monitored during and the impacts on biomass and PCB concentrations will be evaluated. The final confirmation will be in the ability to simulate the observed PCB concentrations in the key fish species.

AQUATOX weights the available prey for each species by preference coefficients normalized to 1.0 (and including 0 for potential prey that are not eaten) to determine time-varying consumption patterns. Because it accounts for seasonal availability and consequent feeding shifts that can be significant, this construct is more realistic than use of static preference matrices and constant trophic interactions. The ecosystem calibration process is designed to constrain the trophic interactions. Predicted seasonal and annual fluctuations in biomass of each compartment are compared fluctuations observed in other studies, and long-term simulations are performed to confirm that "drift" or unconstrained behavior does not occur.

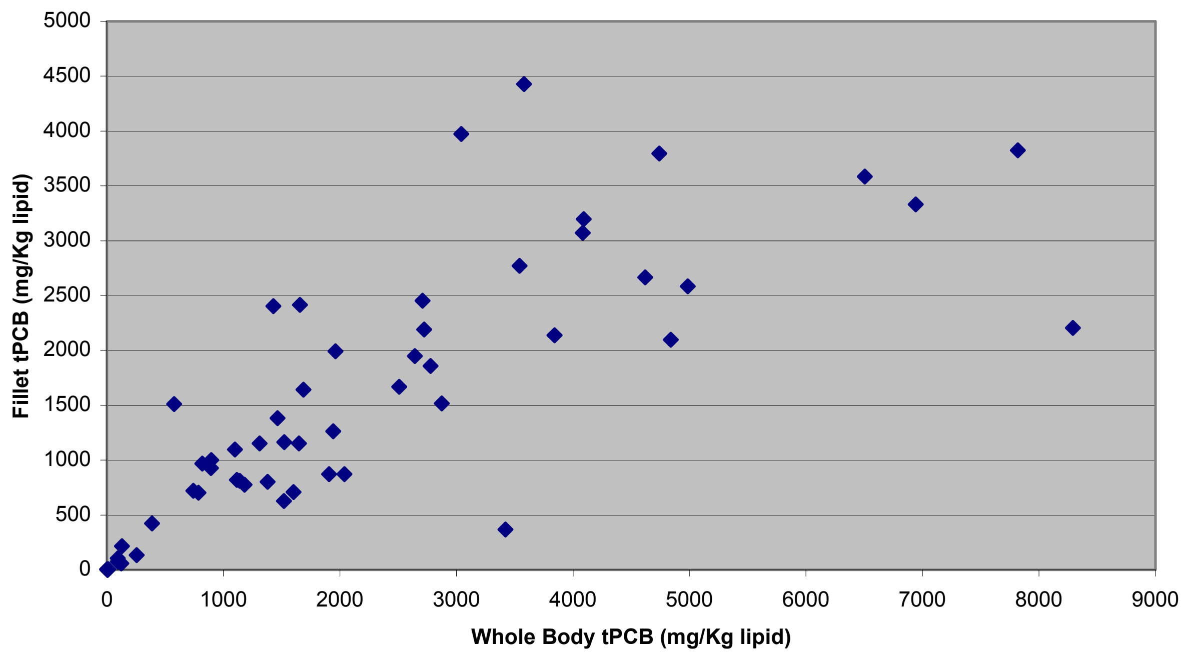
The relative preference construct was first proposed by O'Neill (1969) and was used in several early models (Park et al., 1974; Kitchell et al., 1974; Canale et al., 1976; Scavia et al., 1976). More recently, it has been used in applications of AQUATOX to PCB bioaccumulation in Lake Ontario (EPA, 2000) and in the Netherlands (Moermond and Koelmans, 1999). The construct is also an integral part of the SWACOM model (Bartell et al., 1988) and the CASM model (Bartell et al., 1992), which has had numerous applications (for example, Bartell and Wittrup, 1996; Miyamoto and Masunaga, 1997).

62. Relating PCB concentrations in whole fish vs. filets: Bioaccumulation models predict whole organism chemical concentration; human health-based risk assessment requires chemical concentration in the edible portion/filet. How will the former be converted into the latter? If a relationship based on data is planned, please provide a scatterplot to demonstrate the correlation. (DE16)

Response: The primary purpose of the model is not to support the human health risk assessment, which will precede the modeling of baseline conditions. However, the HHRA will inform the modeling team as to concentrations of concern as well as GE's proposal of IMPGs. There are multiple ways of deriving chemical concentrations in the edible portions of tissues. First, there are site-specific data, which include extensive fillet and offal analyses. These data can be used to generate empirical relationships between whole-body and filet concentrations for a number of species; these may be extrapolated to samples for which only whole-body predictions have been made. Second, a theoretical partitioning approach can be employed, whereby lipid-partitioning theory (lipid-based normalization technique) is used to partition PCBs between fish offal and fillet. Final selection of a method will consider these and other approaches, and consider the benefits and uncertainties in each method. For example, the former approach must consider the size and age of fish used in the development of correlation/regression analyses, while the latter must consider uncertainty in laboratory determinations of lipid content.

The scatterplots suggest a reasonable relationship between fillet and whole body PCB concentrations for the species of interest; however, the quantification of the relationship is subject to contingent investigation. The preliminary investigations shown in the scatterplots will be refined based on detailed examination of the data, including consideration of outliers, uncertainties in lipid determinations, and other factors. Non-linear functions will also be considered.

Largemouth Bass Whole Body vs. Fillet PCB Concentrations (r = .81)



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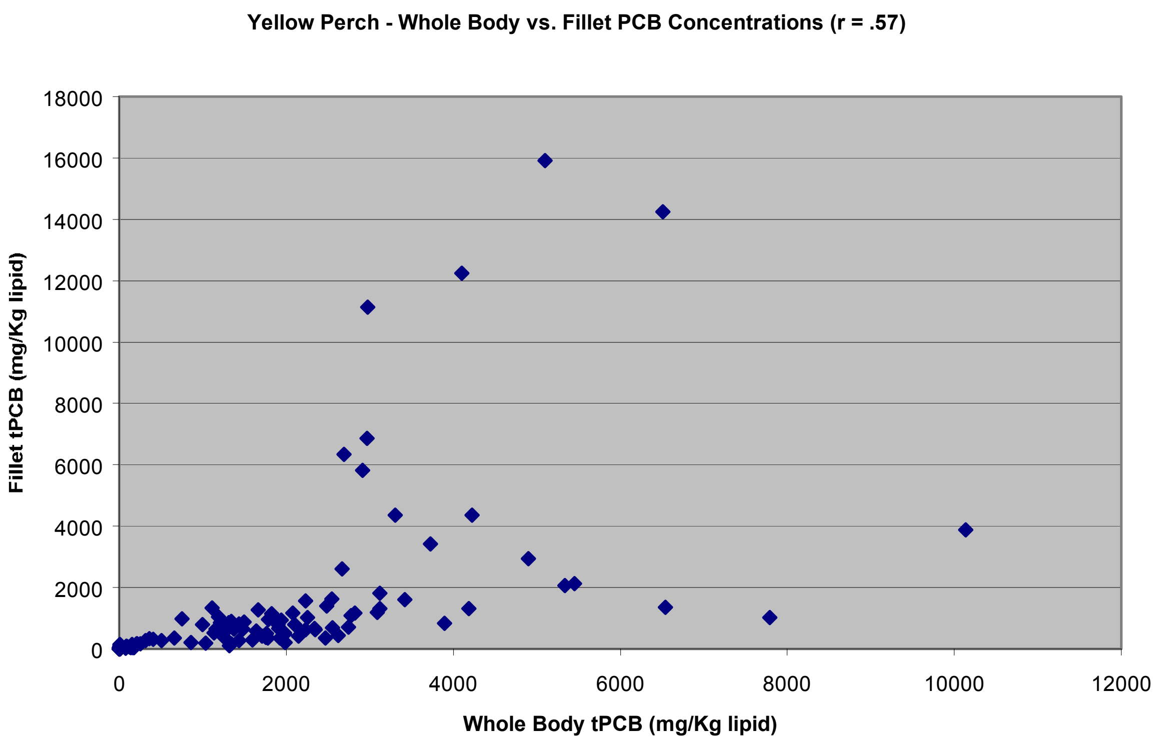

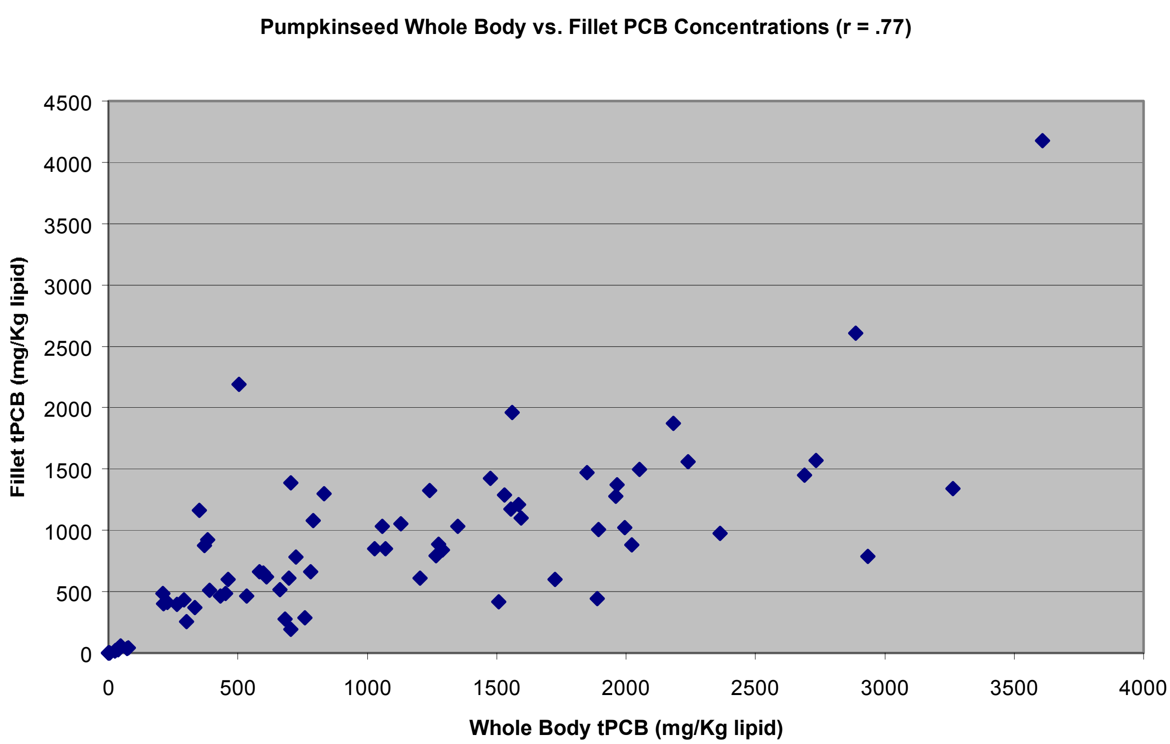

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63. Plankton bioaccumulation: Swackhamer and Skoglund's model of PCB bioaccumulation has been primarily applied to pure laboratory cultures (as far as I know). How can this model, which is proposed for AQUATOX, be applied in the river without extensive site-specific data? Has the Swackhamer/ Skoglund model been used in any field-scale food web bioaccumulation models? (DE20)

Response: The laboratory studies of Swackhamer, Skoglund, Sijm, and Koelmans have all been used to formulate and parameterize the phytoplankton constructs in AQUATOX. Some of these studies were with pure cultures, but particular attention was paid to experiments utilizing natural mixed phytoplankton assemblages under both growth and static conditions and validation of their formulation with field data (Skoglund et al., 1996). The AQUATOX model has been parameterized for periphyton using laboratory stream studies and modeling of Wang et al. (1999). The AQUATOX model has been used in field-scale bioaccumulation modeling of PCBs in Lake Ontario (EPA, 2000) and in Lakes Wolderwijd and IJsselmeer, Netherlands (Moermond and Koelmans, 1999).

It should be noted that implementation of the AQUATOX model also will take into consideration site-specific analyses of plant, algae, and plankton PCB concentrations. Sampling for macrophytes, filamentous algae, periphyton (macrophyte- and substrate-attached), zooplankton, phytoplankton, and detritus was conducted for multiple samples (a minimum of four) within Reaches 4a, 4b, 5a, 5b, 5c, 5d, and 6. Limited site-specific historical data are also available. These data will be used for reality checks during calibration of the model, keeping in mind that these are points in distributions with wide temporal and spatial variations.

64. Partitioning of PCBs: (a) Is one Kp sufficient to approximate the PCBs in the river? Kp's for different PCBs are often different by orders of magnitude. Averaging of quantities differing by orders of magnitude is usually not very accurate. (b) Adsorption and desorption are often slow processes compared with the transit time for particles. Will time-dependent sorption be included in the modeling? (c) The report (3-65) indicates Kd's for pore-water samples (bottom sediment samples?) are 102 to 103. This seems unusually low. Is there some explanation for this? A third phase (whatever that is) is mentioned, but have colloids been considered? How were the partitioning measurements done? (WL13)

68. At the bottom of page 3-65, the discussion of sediment partition coefficients is inconclusive. Has there been further progress in developing this formulation in the model? (PS7)

Response:

a. One K_d value is proposed for AQUATOX parameterization for each contaminant being modeled. For each of the congeners that will be modeled separately, the appropriate K_ds will be based on empirical relationships to K_{ow} and will be assumed to remain constant throughout the study area. There is ongoing discussion on the selection of specific congeners to be modeled, the parameters being evaluated include toxicity, representativeness, and persistence. Because of the modeling construct of EFDC, a single K_d value must be specified and total PCBs are modeled. Modeling a group of contaminants, particularly a group such as PCBs in which K_ds vary over several orders of magnitude, has inherent difficulties, however the representation of tPCBs in EFDC also provides a straightforward basis for comparison to the large body of historical field data (the majority of which is total PCBs). The potential variation of apparent K_d for total PCBs in the study area will be further evaluated in a supplementary partitioning study to be conducted in the spring of 2001.

b. Time-dependent sorption is not a feature of EFDC, which operates as though each substance being modeled is always in equilibrium based on the specified K_d. AQUATOX uses kinetic formulations for exchange, constrained by the K_ds. (See the response to Question 14 for additional discussion of the differences between EFDC and AQUATOX.) The congener-specific sorption and desorption rate constants that will be used are currently being established.

c. The measured K_ds in the pore water may reflect the presence of higher concentrations of both dissolved and colloidal organic matter in the pore water. Most of the samples were centrifuged to collect the pore water, a procedure recognized as leaving organic material in the suspended phase. The current data are being analyzed more completely and additional site-specific data will be collected to better determine the appropriate pore-water K_ds to use in the model.

Additional investigations of the PCB/sediment relationship completed since the MFD report have demonstrated that a third phase (as oil or NAPL) is not present in the sediments. While continued evaluation of existing data and additional studies are being performed, as noted in the response to Question 64, extraordinary or unusual approaches are not required to model the partitioning of PCBs in the sediments of any reach of the river.

65. PCB fluxes between sediments and overlying water are due to (i) resuspension/deposition, (ii) bioturbation, (iii) molecular diffusion, and (iv) pore-water convection. Each of these processes can be significant in some cases, although resuspension and deposition are probably most important. How are the fluxes due to the other processes to be modeled? (WL14)

Response: In EFDC, bioturbation is modeled as a modification to the ultimate bulk density of the sediments in the active bed layer, with an assumed thickness of 15 cm. Through calibration, the flux of sediments to the overlying water column is represented as resuspension and includes biological activity. Diffusion of pore water is treated as a lumped parameter and includes biodiffusion, molecular diffusion, and pore-water convection,

In AQUATOX, the rate of resuspension of sediments is provided by EFDC. Biodiffusion of pore water is modeled explicitly and can be varied as a result of modeled biological activity. However, similar to EFDC, molecular diffusion and pore-water convection are lumped with biodiffusion.

66. Appendix A- Where is the potential impact on the bird life considered as part of the environmental assessment? (JL1-20)

Response: Impacts on wildlife, including avian species, will be considered during the development of the Statement of Basis, which is the decision document that outlines EPA's proposal for remediation. An extensive ecological characterization effort has been performed to gather the baseline data for this purpose. The Modeling Study will not explicitly evaluate effects to avian species. AQUATOX will be modeling the PCB concentrations in macroinvertebrates, which are prey for tree swallows, one of the avian species that has been studied on the Housatonic River. The Ecological Risk Assessment will determine if there is a risk to tree swallows based upon the site-specific data, and if so, establish the PCB concentration in prey that would be expected to pose no significant risk. The ecological risk assessment will also evaluate risk to other birds through modeling their exposure to PCBs, particularly through prey items. If the diet for these birds is aquatic in nature, then the Modeling Study will consider the rest of these endpoints as well, as defined in the ecological risk assessment. In addition, during evaluation of remedial alternatives, impacts of the alternatives under consideration to wildlife will be considered.

69. Also on page 3-72, in Section 3.3.4.5, is a discussion of further evaluation of laboratory data with respect to dechlorination. Are there additional findings to report for this? (PS9)

Response: The distribution of congeners is still being evaluated to determine the importance of dechlorination; there are no additional findings to report at this time.

Supporting Data Required for Calibration/Validation

71. Fish movement: Fish moving out of the exposure model spatial domain would be problematic in terms of predicting bioaccumulation. Is it known whether any of the fish species in the food web move above the river confluence? Are there impediments to fish passage upstream? (DE 15)

Response: There are no impediments to fish movement immediately upstream of the confluence. However, consideration of species life histories indicates that movement is limited in scope and involves only a very small number of fish species. In particular, minnows exhibit some upstream movement, with much less movement by yellow perch and white suckers, possibly a little movement by bluegills and pumpkinseed, and no movement by largemouth bass. Based on the limited movement of most species and no movement for bass, upstream movement of fish populations is not addressed in the AQUATOX.

72. Lower food web PCB dynamics: Modeling of PCB bioaccumulation in phytoplankton and benthos will use a dynamic approach, yet no data is being collected to examine temporal variation in PCB concentrations in the lower food web. Is this true? If so, how can these model predictions be confirmed? (DE17)

Response: The dynamic approach used in AQUATOX to model bioaccumulation in lower trophic levels will simulate the temporal variations, as discussed in the response to Question 63. There is one set of data points with congener analysis, and some historical data with tPCB analysis available to bound the calibration. The test of the validity of this approach will be how effects from the lower food web are integrated into the predicted fish concentrations, for which there is a substantial data set.

73. pg. 5-5 Model validation – where are the validations for the modeling that has been done in prior applications of EFDC? (JL1-14)

Response: The EFDC model has been used extensively in a range of applications, many with extensive data comparisons as part of calibration and/or validation. These applications are referenced in Appendix E. In addition to these technical reports, the EFDC model and a number of its applications has undergone peer-review in over 16 publications, citations for which are provided in Appendix C. These documents represent a body of work that demonstrates the efficacy of EFDC as a model that can be and has been validated on numerous occasions.

74. Pg. 5-8 line 20-22. If there is "difficulty in comparing general model behavior over long periods- with rapid fluctuations due to storm events and algal blooms, seasonal fluctuations, and annual variability", then what is the point of the modeling exercise? Is it not the goal of the modeling to provide a description of precisely these events? (JL1-15)

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Response: The goal is to integrate these events into a prediction of long-term (> 50 years) PCB fate, especially sediment transport and deposition/resuspension and bioaccumulation. The model analysis will attempt to quantify those processes that significantly affect long-term PCB fate; a dynamic model has been chosen to enable simulation of shorter-term fluctuations as appropriate (e.g., algal blooms, storm events).

75. pg. 5-9 How will the geometry changes that occur during flooding be accommodated in the calibration and validation, especially changes in the meander pattern that are brought about by bank erosion? Do the data exist to provide a meaningful calibration and validation? (JL1-16)

Response: The only explicit changes in geometry modeled by EFDC will be bed/floodplain elevation changes corresponding to scour and deposition, and the associated bed layer thickness changes. As mentioned above, a supplemental effort is underway to assess the impact of bank erosion on sediment load and PCB loads to the river.

76. pg. 4-28, 4-29 - If only data sets from 1999-2000 are to be used for the calibration then how will the major flood events be incorporated into the plan? What were the ten storm events from May through September in relation to prior high flow events? Were any of these high flow events sufficient to cause over bank flow onto the terraces. Were any of the events high enough to cause bank erosion and/or major bar and terrace movement in the river? (JL2-1)

80. As previously noted, most of the high concentration material is located within the riverbanks, bars and terraces, which will only be moved during extreme flow events. How will the extreme events that have the potential to control the fate and transport of the PCB sediment movement be included in the calibration exercise? (JL2-7)

Response: The highest flow recorded during any of the storm events monitored was for the May 1999 storm, with a flow of 1410 cfs at the Coltsville gauging station. More rainfall did occur during monitored storm events later in the year, however, drier antecedent moisture conditions resulted in lower peak flows. Although the return interval of the May 1999 storm is approximately two years (the exact computed return interval depends on whether one uses daily flows, hourly flows or peak instantaneous flows), it resulted in significant out-of-bank flows from Pomeroy Avenue down to and below New Lenox Road. Ongoing monitoring of out of bank conditions is being conducted coupled with stage height measurements and corresponding records from the Coltsville and Great Barrington gauges. Numerous out of bank conditions have been observed to date during this study.

<u>**Supporting Data Required for Calibration/Validation**</u>

In addition to the storm event data, a detailed channel morphology study was conducted, and is being updated periodically. Transects resurveyed after five months indicate erosion and deposition of up to 1 ft in some areas (see Question 43).

77. pg. 4-31 , 4-33 - How will the sediment transport model be calibrated and validated, if the data apparently do not exist to perform long-term validations, especially in so far as data for bank erosion, which can be a major source of sediment for the river, do not appear to exist? Has the model ever been used to successfully predict bank erosion and bar and terrace formation in the past? If so, where are the results? (JL2-2)

<u>Response:</u> Calibration and validation of the Housatonic River EFDC model will be accomplished through the processes and approaches identified in the MFD and further clarified in this document. Again, it is not expected that an attempt will be made to explicitly model bank erosion or bar migration, therefore the model will not be calibrated or validated for these processes.

78. Given that the highest concentrations of PCB seem to exist in the bars, terraces and banks of the river (see Tiles 1-21), how can the transport and mass balance be validated in the absence of information as to how these potential sources have moved and contributed to downstream in the past? (JL2-3)

<u>Response:</u> The extensive sampling program within Reaches 5 and 6 has adequately characterized the distribution of contaminants at the present time. The current contaminant distribution integrates all historical primary and secondary sources of PCBs to the river system. Using these data and the best available historical data, estimates will be made of the migration of PCBs within the river system during the validation period. At this time, this is believed to be the only approach available for this modeling study.

79. PCB adsorption by epiphyton in the stream and located on the large diameter stones and boulders could be a significant factor in the storage and transfer of the PCB. Are there data on the amount stored in these biota and the cycling through this biotic source for use in the calibration? (JL2-4)

<u>Response</u>: Calibration data will be available for PCB congeners in periphyton along with detailed estimates of periphyton biomass at several locations in the Housatonic River. The periphyton submodel of AQUATOX has just undergone substantial improvements (including development of a realistic scour function) and verification with data from streams in Tennessee and Montana (Park, in prep.). That, coupled with a study by Wang et al. (1999) on periphyton bioaccumulation of PCBs in a laboratory microcosm, will provide information for this pathway in the Housatonic River.

Supporting Data Required for Calibration/Validation

81. Please explain the seeming mismatch between the domains for HSPF (to Great Barrington) and EFDC (only to Woods Pond). There would appear to be very useful data available from the U.S.G.S. Great Barrington gage for calibrating EFDC. These data include daily (and possibly more frequent) suspended sediment measurements from April 1979 through September 1980. Were these data considered in fixing the domain and calibration plan for the EFDC model? (PS2)

Response: The current data indicate that the significant mass of PCBs is upstream of the Woods Pond Dam. Therefore, the focus of the sediment transport and bioaccumulation modeling is on the PSA from the confluence to the dam at Woods Pond. The model domains established for EFDC and AQUATOX extend therefore from the confluence to the dam at Woods Pond. The reason for extending the domain of the hydrologic model (HSPF) downstream of the Woods Pond Dam to the Great Barrington gage was to provide a downstream boundary condition for the watershed model with measured flow and suspended solids records. Calibration and validation of the hydrodynamic and sediment transport model will be based on stage height and TSS measurements collected at the monitoring stations in the PSA during the 1999-2000 storm event surveys. Stage height data are being correlated over a range of stream flow measurements to develop rating curves for several station locations in the PSA.

HSPF will be calibrated to TSS and existing valid and available data will used. If the data referred to meets these criteria then they will be included. The results of the HSPF model will then be used as input to EFDC and AQUATOX.

82. It is proposed that the calibration and validation be done with independent data sets, yet the calibration and validation periods overlap. Please explain. (PS16)

105. One objective of the study is to assess natural recovery? Is this possible using only a two-year calibration period? (EA3)

Response: Initial model calibration will be based on the most recent, detailed monitoring data collected under storm flow conditions during 1999. Short-term event calibrations of the hydrodynamic model and sediment transport model (EFDC) will be developed using the 10 sets of storm event monitoring data. Using parameters determined from the short-term simulations, model calibration will proceed from the short-term storm event simulation time scale of approximately 10-30 days to the much longer inter-annual time scale from 1999-2000. Initial conditions for calibration of the models will be defined based on early 1999 field measurements. During this 2-year period, data are available from the monthly surface water monitoring program to allow model vs. data comparisons of flow, stage height, TSS and total PCBs in the water column and sediment bed for the calibration. Following the initial calibration using data from

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1999-2000, long-term simulations from 1991-2000 will then be prepared for HSPF, EFDC and AQUATOX.

Calibration of HSPF and AQUATOX will be based on model vs. data comparisons available for nonpoint loads (1996-2000) and bioaccumulation of PCBs (1995-2000).

Following calibration of the models using data from 1991-2000, the models will then be validated by assigning initial conditions based on data sets collected during 1979-1980. Model validation will be based on a long-term simulation beginning in 1979 and ending in 1990. The long-term simulation from 1979-1990 is intended to provide validation of the models with an independent data set. Continuation of the validation period of the simulation through 1991-2000 then provides an additional rigorous test of the predictive capability of the models using a continuous simulation against data available within a 20-year period. If the models can successfully reproduce the observed data sets over a 20-year period, then the credibility of the model for projecting the potential impacts of alternative remedial action scenarios >50 year decadal time scales will be greatly enhanced.

Since the primary objective of the model analysis is to evaluate the relative effects of remedial alternatives, including natural recovery, the models must be able to reproduce decadal scale responses to fluctuations in flow and solids transport and the resulting redistribution and burial of PCBs. The short-term simulation of only 2 years proposed for the model calibration is not sufficient for demonstrating natural recovery. This is why the modeling team believes that it is important to validate the models for the longest period of record for which data are available, to insure that they can successfully reproduce the observed data sets over the extended 20-year validation period.

83. I presume that the river was at one time modeled for the Federal Emergency Management Agency under the Flood Insurance Program. Will these data be obtained and employed? Will Manning's n values calibrated with the EFDC model be crosschecked against the Flood Insurance Study values? (PS18)

<u>Response:</u> We have received the FEMA study and have it in HEC-RAS format. We are in the process of evaluating the model and the Manning's n's used. While EFDC does not use Manning's n's directly, the FEMA models n's will be used as one of the guides to initializing the z_0's.

84. After the 1984 flood FEMA retained contractors to measure high-water marks in at least some of the state's rivers. If done for the Housatonic, this could be valuable calibration information. Has FEMA been contacted to determine what information they have available? (PS19)

Supporting Data Required for Calibration/Validation

Response: We have requested the available information and FEMA is providing the records. This is a good suggestion and, upon obtaining the available flood studies and high-water marks, the usefulness of the information will be evaluated.

107. What is the contingency if the model does not calibrate/validate well within the desired time frame? Will more time be allotted to improve calibration? (EA5)

Response: We have scheduled reasonable times to complete calibration and validation tasks, however, if necessary additional time will be allotted to meet calibration and validation objectives.

126. (p. 4-14) Under proposed calibration/validation tolerances, what does percentage accuracy mean with respect to temperature? Are you referring to temperature on an absolute scale (Kelvin?), temperature changes, or what? (EA24)

Response: Model results and field observations for water temperature will normally be on a Centigrade or Fahrenheit scale. For normal water temperatures of 40 to 60 degrees F, our calibration tolerance of 10% would mean that average differences between simulated and observed values would be less than 4 to 6 degrees F. In many cases, we would expect differences to be less than 3 to 5 degrees F.

Other Data Questions/Requests

85. Although not a question, I would like to request the data from sampling conducted in the river, specifically:

> **•August 1998-September 1999 (15 occasions/17 location) parameters including TSS, total and dissolved PCBs; if available, in the format of Figures 3-21 and 3-22.**

Response: Hard copy of the 15 graphs of all surface water sampling events for all stations has been provided to Marasco Newton for submittal to the Peer Review Panel. The requested information on TSS and PCBs are presented in the format of MFD Figures 3-21 and 3-22. The information presented does not include all evaluations of QA/QC issues or the evaluation of data suitability.

> **•Storm events in 1999 (10 events) same parameters + discharge; if available, in the format of Figure 3-23.**

Response: Hard copy of the 21 graphs of storm water data for TSS and PCBs has been provided to Marasco Newton for submittal to the Peer Review Panel. These include all of the seven storm water sampling events for the three primary stations where these data is available. Also included is a storm summary table for easy reference. The information presented does not include all evaluations of QA/QC issues or the evaluation of data suitability.

> **•Data used to calculate PCB partition coefficients in the water column and sediment, including the following parameters: total, dissolved, and particulate PCBs (which phases were measured?), suspended or bed solids concentrations, POC, and DOC. Also, information regarding sample volumes, replicate precision, and detection limits.**

Response**:** Appendix K contains a table of the pore water samples and the Kd calculations using both EPA and GE data.

> **•SEDFLUME data: parameters including erosion rate vs. shear stress, and corresponding bulk density and/or other sediment property measurements. (DE1)**

Response**:** The SEDFLUME data report was provided to Marasco Newton on April 1, 2001 for distribution to the Peer Review Panel.

86. PCB Congener distributions: Have congener concentration patterns been compared between different media (water, sediment, fish, benthos, plankton) and locations in the river? If so, please provide data analysis to illustrate the consistency of the congener concentration distributions. (DE19)

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Response: The congener data are not yet available for all media and these data are just beginning to be reviewed for difference in congener distributions within and among the different types of samples. Partial analyses have been conducted for homologs and congeners in some media (e.g., MFD Figures 3-31 and 3-32 present profiles for various Woods Pond fish species). As noted in the response to Question 18, procedures are in place to objectively compare the comparability of the congener patterns in individual and groups of samples, but these analyses are not completed yet.

87. If river bed armoring is to be modeled with the help of the Garcia-Parker entrainment function for sediment mixtures, data on grain size distribution of both bed material and suspended load will be needed? Is such data available? (MG6)

Response: Site-specific data are available to parameterize and calibrate the Garcia and Parker formulation, if selected. Grain size was determined on the majority of bed sediment samples and on water samples from the storm sampling events collected by EPA. The cumulative sample inventory was provided to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel. A subset (80 transects) of the bed sediment grain size distribution was provided to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel. The 21 tile maps of PCB results (supplied initially to the panelists) were converted to represent "TOC & Grain Size Results" (including the transect numbers for the grain size plots and a number of other features).These maps indicate the number of locations and depths where bed sediment grain size information is available, and also present the d50 and TOC values. These maps were provided to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel. The grain size distribution on the suspended load is being evaluated. There are two sources of data on suspended load. Multiple size class data are available for the five secondary stations (four of which are tributaries plus Hubbard Ave). For the three primary storm sampling stations (Pomeroy Ave, RM 135.2; New Lenox Rd, RM 129.1; and Woods Pond, RM 125.4), the TSS grain size data will be available in the following classes:

- 5 - 10 um
- 10 – 62 um
- 63 - 250 um
- > 250 um

89. As in the report, I also believe bed load is important, but are there any estimates or data for this belief? The effect of bed load on transport is probably significant, but probably more important is its effect on bed armoring (Jones and Lick, 2001). (WL4)

Response: Cross sections of the river were re-surveyed and the differences between the initial and resurveyed elevations indicate a substantial change in the bed elevations in some locations, as discussed in Question 43. Transects resurveyed after five months indicate erosion and

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deposition of up to 1 ft in some areas. One objective of the Test Reach sampling program is to obtain measurements of the bed load for a range of flows, these measurements will also be taken at the upstream boundary of the PSA. We agree that coarse-grain sediment moving as the result of bed load can have an impact on bed armoring. We will review the work of Jones and Lick, 2001 when it becomes available, to determine if any additional insights and/or approaches are applicable.

90. pg.3-16 Data from Cs-137, Pb-210, Be- 7, where are these data ? (JL1-1)

108. Are data available (markers, isotopic tracers, etc.) to assess the spatial distribution of natural deposition? If so, could such data be provided. (EA6)

Response: The three raw data files from Battelle of the isotope results for the sediments were forwarded to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel In addition, GE has been requested to provide their results to the Peer Review Panel.

91. Figures 3-10, 3-11, when were these data collected ? (JL1-2)

Response: Figure 3-10 represents the water column parameters at a relatively deep area of the river upstream of Woods Pond on July 21, 1999. Figure 3-11 is a similar profile in the "deep hole" area of Woods Pond on July 20, 1999.

92. Pg. 3-50 Particle size distribution Figure 3-12 – d50 exceeds the maximum sediment size modeled in the upper reaches of the river. The graph suggests that more than 55% are particle sizes greater than 0.5mm. How much of this is pebbles and boulders with algal slime coatings that are not included in the sediment analysis? (JL1-3)

Response: It is true that approximately 55% of the samples are of particle sizes greater than 0.5mm. However, while this part of the PSA is dominated by large grain-sized non-cohesive sediments it would not be characterized as a cobble- or gravel- type run. Observations made while periphyton samples were being collected indicate that periphyton mats are extensive on stabilized sand bedforms in the Housatonic River. These mats are subject to scour with higher flow regimes; therefore, a periphyton scour function based on predicted bedload transport is included in AQUATOX.

93. pg. 3-62 TOC is the TOC in the sediment samples taken; does this include slimes on the bedrocks and boulders in the stream? (JL1-5)

Response: The sediment TOC values do not include carbon contributed by slimes on bedrock or boulders. Nearly all of the sediment samples in the river were collected using plastic core liners

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or petite Ponar grab samplers (6x6 inch) and by their size would rule out boulders as part of the sampling effort. Within the PSA, the Housatonic River has few areas that have exposed bedrock or boulders.

94. pg. 3-79 Is the chlorophyll on the rocks and slimes and the plant life on the banks and terraces included in this summation of chlorophyll ? (JL1-6)

<u>Response</u>: The chlorophyll summation in MFD Figures 3-26 and 3-27 on pg. 3-79 does not include chlorophyll potentially present on the rocks and slimes, and the plant life on the banks and terraces. Chlorophyll contributions from slime/epiphytes were measured in 2000 and will be used to calibrate AQUATOX.

95. pg. 4-28 line 22 Where are the results of this evaluation (of site-specific data for PCB concentrations, sediment grain size, and organic carbon)? (JL1-9)

<u>Response:</u> Much of the preliminary evaluation results are presented in Section 3 of the MFD. Specifically, Figure 3-12, p. 3-50, presents sediment grain-size by river mile, Figure 3-15, p. 3-58 presents mean PCBs by river mile, Figure 3-16, p. 3-62 presents mean sediment TOC concentrations by river mile and Figure 3-17, p. 3-64 presents TOC-normalized PCB concentration by river mile. Figure 3-18, p.3-64, shows the poor correlation between PCBs/fines and TOC/PCBs in the upper portion of the PSA domain (Reach 5a) where larger grain sediments predominate and TOC concentrations are low. As noted in the response to Question 87 above, the 21 tile maps of PCB results (supplied initially to the panelists) were converted to represent "TOC & Grain Size Results" (and a number of other features) and therefore indicate the number of locations and depths where bed sediment TOC and grain size data is available. These maps were provided to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel.

96. Has the sediment data on Tiles 1 through 21 been integrated to develop an inventory of PCB that indicates how much PCB there is extant in the sediments per kilometer of river downstream of the confluence? (JL3-1)

110. Has the inventory of PCB mass been plotted as a function of distance downstream from the GE plant? (EA8)

GE has not provided an estimate of the total amount of PCBs released to the Housatonic River due to operations at their Pittsfield facility during the approximately 45-year period from 1932 to 1977. One estimate of the total PCB mass released has been developed from an interview conducted in September of 1990 by the Housatonic River Initiative with Ed Bates, who was the Manager of the GE Power Transformer Testing Department for much of the 45-year period. Bates estimated an uncontrolled loss rate to the river of approximately 600 gal/week of Pyranol (transformer oil), which contains approximately 7 lb of PCB per gallon. This equates to a total loss over the 40-year period of uncontrolled release (control measures were put in place in 1972) of just over 8.7 million pounds of PCBs. Clearly, much of this material has been recovered, remains in site soils, or is currently found in sediments above the area of the modeling study (i.e., in Reaches 2 and 3), but the 8.7 million pounds can be considered as a high upper bound of the amount of PCB that could be in the Primary Study Area of the river.

In their 1982 report to GE, Stewart Laboratories developed an estimate of PCB mass in the river based on sediment data collected in 1979 and 1980. The Stewart report calculated the total amount of PCB in the 7.81 miles of river between the GE Facility and the New Lenox Road bridge (approximately one mile downstream of the boundary between modeling reach 5b and 5c) to be 8,510 lb, with an additional 19,500 lb (6,500 lb in the river proper, 13,000 lb in backwaters) of PCB between New Lenox Road bridge and Woods Pond. Woods Pond was estimated to contain 7,240 lb of PCB. Combining these three numbers provides an estimated total mass of PCB in the river from the GE Facility to Woods Pond Dam of 35,250 lb. Based on the more recent and comprehensive data discussed below, this estimate is believed to represent the absolute lowest bound on PCB mass in these areas.

Estimates of the mass of PCB per kilometer (or mile) of river downstream of the confluence based on the current data set have not yet been calculated. However, total PCB mass for each of the four modeling reaches (5a, 5b, 5c, and 6) has been calculated for the river channel sediments (including bars and terraces) and proximal/distal floodplain soils, respectively. These results are shown in the following table (results have been displayed as pounds to facilitate comparison with earlier data discussed above).

Reach	River Channel	Proximal Floodplain	Distal Floodplain	Total
5a	22,767	23,283	52,571	98,621
5b	6,590	13,388	32,502	52,480
5c	111,326	26,327	22,015	159,668
6	63,694	2,503	4	66,201
Total	93,051	65,501	107,092	376,970

Estimates of Total PCB Mass (in Lbs) by River Reach and Floodplain Soil Location

These estimates were developed by segmenting the Primary Study Area into river channel (including backwater areas), proximal floodplain (that portion of the floodplain judged to be most susceptible to being influenced by the river based on elevation - generally within about 50 ft of the banks), and distal floodplain (the remainder of the 10-year floodplain). Using GIS tools and the extensive data base including both EPA and GE data, the total PCB concentration for all samples within a subreach for each of the three terrain features was averaged for each 6-in depth stratum and then multiplied by the volume of the stratum to obtain a mass estimate of PCBs in each of the modeling subreaches. The individual strata were then summed for each area to obtain the totals shown. Due to the limited data at greater depths, these estimates are based on

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the top 2.5 ft of soil in the floodplains and in the river channel for Reaches 5a and 5b; the top 6.0 ft of sediment in Reach 5c, and the top 9.0 ft of sediment in Woods Pond.

97. Have you consulted Schweitzer-Maudit to find if they have historical information Woods Pond? They are water-supply wells are located on the periphery of the Pond and they may possess some historical data on the Pond. (PS3)

<u>Response:</u> The modeling team is aware that Schweitzer-Mauduit has industrial supply wells adjacent to Woods Pond. Because the Pond elevation is controlled by the Woods Pond dam, it is unlikely that any of their well supply data would be of assistance to the Modeling Study. However, we will contact them to see if there is anything available, such as water quality information from Woods Pond.

98. On page 3-72, immediately before Section 3.3.4.5, is another reference to further evaluation that was being conducted. Again, is there anything new to report? (PS8)

<u>Response:</u> Up to four bedload sampling events are planned for 2001, however, no bedload data have been collected since preparation of the MFD. Bedload samples will be collected at 3 transects (Pomeroy Ave area, plus two locations in Reach 5b) with up to 5 locations across each transect.

99. Table 4-2 of the QAPP overlooks data available from Massachusetts state agencies. Information on traditional water-quality parameters and wastewater discharges is available from reports by the Division of Watershed Management of the Massachusetts DEP. The 1997-1998 Water Quality Assessment Report is available for download at http://www.state.ma.us/dep/brp/wm/wqatoc.htm. A list of past Division publications is available at http://www.state.ma.us/dep/brp/wm/files/99pdwm.doc and lists Housatonic River studies in 1968, 1974, 1985, and 1992. Were these data considered as a resource for the modeling study? Also, MassGIS provides land-use and soils delineation in far greater detail (and probably accuracy) than the EPA BASINS database. Were these considered for development of HSPF data? (PS15)

<u>Response:</u> This is a valuable suggestion. MA WQ Assessment Report, the list of publications, and selected coverages from the MassGIS site have been obtained and will be evaluated. Follow up on these additional information sources will be pursued where warranted.

101. Questions in regard to the PCB maps that I was sent.

1. Do you have topographic/bathymetric maps for the same areas, preferably on the same scale?

Other Data Questions/Requests

2. What additional information is available at each core location, preferably with depth. In particular, do you have information on

(a) Grain size distributions?
(b) ^{137}Cs, ^{210}Pb, other radioisotopes?
(c) Organic content?
(d) Mineralogy?
(e) Erosion rates from Sedflume? Locations?
(f) Bulk density?

I would appreciate any and all of this information for specific cores that I've chosen as soon as possible so that I can compare with PCB distributions. (WL2-1)

102. Below is a list of cores where I would like information on the variables I listed previously. At the meeting, I said I'd pick 12 locations; there are actually 30. That's because I don't know what information is available at each core. Maybe someone could pick out 12 of the 30 cores with the most information and also generally representative. Either that or someone should get back to me with what information is available and I'll make the final choice. (WL3-1)

Tile	Core number
1.	SE000350
	4-90
2.	4-9H
	J6-3-1-SB-13
	4-10B
4.	5-l l
5.	SE000406
6.	FP4R-3
	SE000408
7.	5-3A
8.	S16C
9.	6-2A-2-CRD
10.	S17B2
11.	6-2J
12.	6-3A-1-CRD
	S17B5
13.	S17C3 (location on map is not shown)
14.	FP7A-L3
15.	7-1Q-CRD
	7-1S-1-CRD

<u>Other Data Questions/Requests</u>

<u>S17E9</u>
S17E8
17-E-15
16. S18G2
SE001013
18K1-2
SE001014
S18G2
SE001012
17. S18 I 1

<u>Response</u>: Plate 1 supplied with the MFD includes an inset with the bathymetry of Woods Pond. From the river cross sections, floodplain transects, and digital topographic maps, a Digital Elevation Model (DEM) has been developed for the entire river. An example of the DEM is found as MFD Figure 3-7.

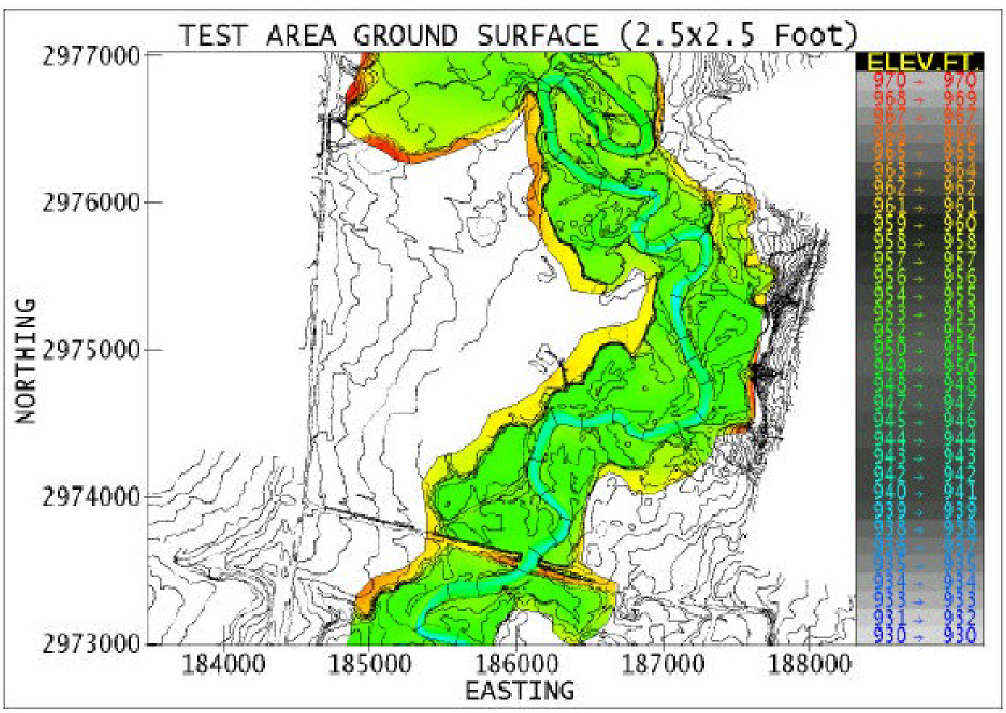

Figure 3-7 Topographic Map of One Area of the PSA

As noted in the response to Question's 87 and 95 above, the 21 tile maps of PCB results (supplied initially to the panelists) were converted to represent "TOC & Grain Size Results" (and a number of other features) at the same locations where PCB data were initially presented. These maps were provided to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel.

Other Data Questions/Requests

Regarding the availability of isotope data: EPA has collected isotope data on nine cores (all in Woods Pond). The three raw data files from Battelle of all of these isotope results for the sediments were forwarded to Marasco Newton on April 4, 2001 for distribution to the Peer Review Panel. Of the cores that you selected, there are isotope data for 3 EPA cores (SE001012, SE001013, and SE001014). A request has been forwarded to GE to provide the Peer Review Panel with the isotope data on their 17 cores (by our count) in the Primary Study Area. It appears that one of your selected cores, 5-3A, should have isotope data collected by GE. All of the EPA and GE cores (total of 26) are marked on the new 21-tile set of maps titled "TOC & Grain Size" with a green square inside of a green circle.

The following table is a quick summary of the data available on the 30 cores that you selected. There are a total of six EPA cores selected as part of the 30 that you selected. The TOC and D50 results for these cores are marked on the new 21 tile set.

111. The vertical profiles of PCB concentration indicate little vertical variation, suggesting little ongoing sequestration, but this is based on horizontal averaging. Could the vertical variation in concentration be summarized based on individual profiles? (EA9)

Response: The first set of maps provided to the Panel displays of the PCB concentrations as vertical profiles for all individual sample locations.

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

LIST OF APPENDICES

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

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Extensive field data comparison with good results

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Peer reviewed good data agreement

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APPENDIX F

EFDC WEB sites

Information on the EFDC application to Elliott Bay and Duwamish River can be found at

http://dnr.metrokc.gov/wlr/waterres/wqa/WQPAGE.HTM

This is the most complete application of EFDC involving hydro, sediment, and toxic contaminants. Specifically, the various reports (including the hydrodynamic and contaminant transport and fate model report) are under

http://dnr.metrokc.gov/wlr/waterres/wqa/wqrep.htm

Some preliminary results for the application of EFDC to South Puget Sound can be found under:

http://www.ecy.wa.gov/programs/eap/spasm/spasm_results.html

A comparison of EFDC with other surface water models at the USGS surface water modeling information clearing house can be found at:

http://smig.usgs.gov/SMIC/SMIC.html

The formal framework for application of EFDC to simulate riverine hydrodynamics, and sediment-contaminant transport is illustrated by the GE/Housatonic modeling framework document, which can be found at:

http://www.epa.gov/region01/ge/thesite/restofriver-reports.html

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APPENDIX G

List of Known EFDC Applications (as of November 2000)

Components of application in addition to hydrodynamics:
- sal/tem - salinity and/or temperature
- sed - sediment transport
- tox - sorptive toxic transport
- wq/eutro - water quality/eutrophication

Application Site	sal/tem	sed	tox	wq/eutro
Arabian Sea and Gulf of Oman	x			
Armanda Bayou, Texas	x			x
Arroyo Çolorado, Texas	x			x
Apalachicola Bay, Florida	x			
Bird River, Maryland	x			
Blackstone River, Massachusetts		x	x	
Brunswick Harbor, Georgia	x			x
Chattahoochee River, Georgia	x			
Conowingo Reservoir, Maryland	x			
Christina River, Delaware/Penn	x			x
Chesapeake Bay (full bay & major tributaries)	x			
Cape Fear River, North Carolina	x			x
Duwamish River/Elliott Bay, Washington	x	x	x	
East River, New York	x			
Everglades Nutrient Removal Project, FL	x	x		
Everglades Stormwater Treatment Areas 1, 2, 5, & 6, Florida	x			
Florida Bay, Florida	x			
Fenholloway River, Florida	x			
Great Wicomo River, Virginia				
Hillsborough River, Florida	x			
Housatonic River, Mass.		x	x	
Indian River, Florida	x	x		
James River, Virginia	x	x		
King Creek/Cherrystone Inlet, Virginia	x			
Lake Billy Chinook, Oregon	x			
Lake Okeechobee, Florida	x	x		
Lake Jessup, Florida	x			
Lake Worth, Florida	x	x		
Lake Wister, Oklahoma	x			x
Long Island Sound	x			
Lynn Haven Bay, Virginia	x			x
Kanghwa Bay, South Korea	x			x
Kings Sound, Australia				
Mobile Bay, Alabama	x	x		x

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Application Site	sal/tem	sed	tox	wq/eutro
Morro Bay, California	x	x		
Mid-Atlantic Bight, Virginia & North Carolina	x			
Nan Wan Bay, Taiwan	x			
Neuse River, North Carolina	x			x
Norwalk Harbor, Conn.	x			x
Peconic Bays, New York	x	x		x
Pictou Harbor, Nova Scotia	x			
Port Headlands Harbor, Australia	x	x		
Potomac River, Maryland/Virginia	x			
Rose Bay, Florida	x	x		
Santa Monica Bay, California				
Schuylkill River, Pennsylvania	x			
South Florida Water Conservation Area 1A	x			
South San Francisco Bay, CA	x	x	x	
Southern Puget Sound	x			x
Stephens Passage/Taku Inlet, Alaska	x	x		
St. Johns River, Florida	x			
St. Louis Bay, Mississippi				
Suwannee River, Florida	x			
Ten Killer Ferry Lake, Oklahoma	x			x
Vero Beach, Florida	x			
Wadden Sea, Germany	x			
Yazoo River, Mississippi	x			x
York River, Virginia	x	x		

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

APPENDIX H

EFDC Run Time Estimates

Reference Case: Test 8, highly sinuous channel with fitted floodplain

926 horizontal cells x 2 layers (approximately 1/3 cells used for floodplain)

maximum velocity constraint based on 1.2 m/s (give a 2-second time step)

run time was 30 min/day = 180 hours/year
Scale for PIV processor 5x reference machine
Run time = 180 hours *0 .2 = 36 hours/year

Scale for More Efficient bypassing of dry cells (assumes 1/2 cells dry under normal flow
And normal conditions occur 75% of time)
Run time = 36 hours *0 .677 = 24 hours/year
Scale for PIV vector optimization 2x above
Run time = 24 hours * 0.5 = 12 hours/year

Scale for typically larger time steps on average much larger i.e., typical velocities
On order of 0.4 m/s (i.e. a 6-second time step)

Run time = 12 hours * 0.333 = 4 hours
Factor in 3 sediment Variables being transported (assume 2X)
Run time = 4 hours X 2 = 8 hours

Prototype Case

1800 horizontal cells x 2 layers, similar geometry and flow constrains as test case
Scale for doubling of number of cells
Run time = 8 hours x 2 = 16 hours/year

Additional Factors

Scale for other code optimizations X 0.5
Run time = 16 hours X 0.5 = 8 hours/year

Summary

Best estimate is 8 to 16 hours per year, so use 12 hours. This is of course the modeler “dream time”, since a run launched at end of the day will be ready for analysis the next morning.

APPENDIX I

EFDC Example Calibration Plots

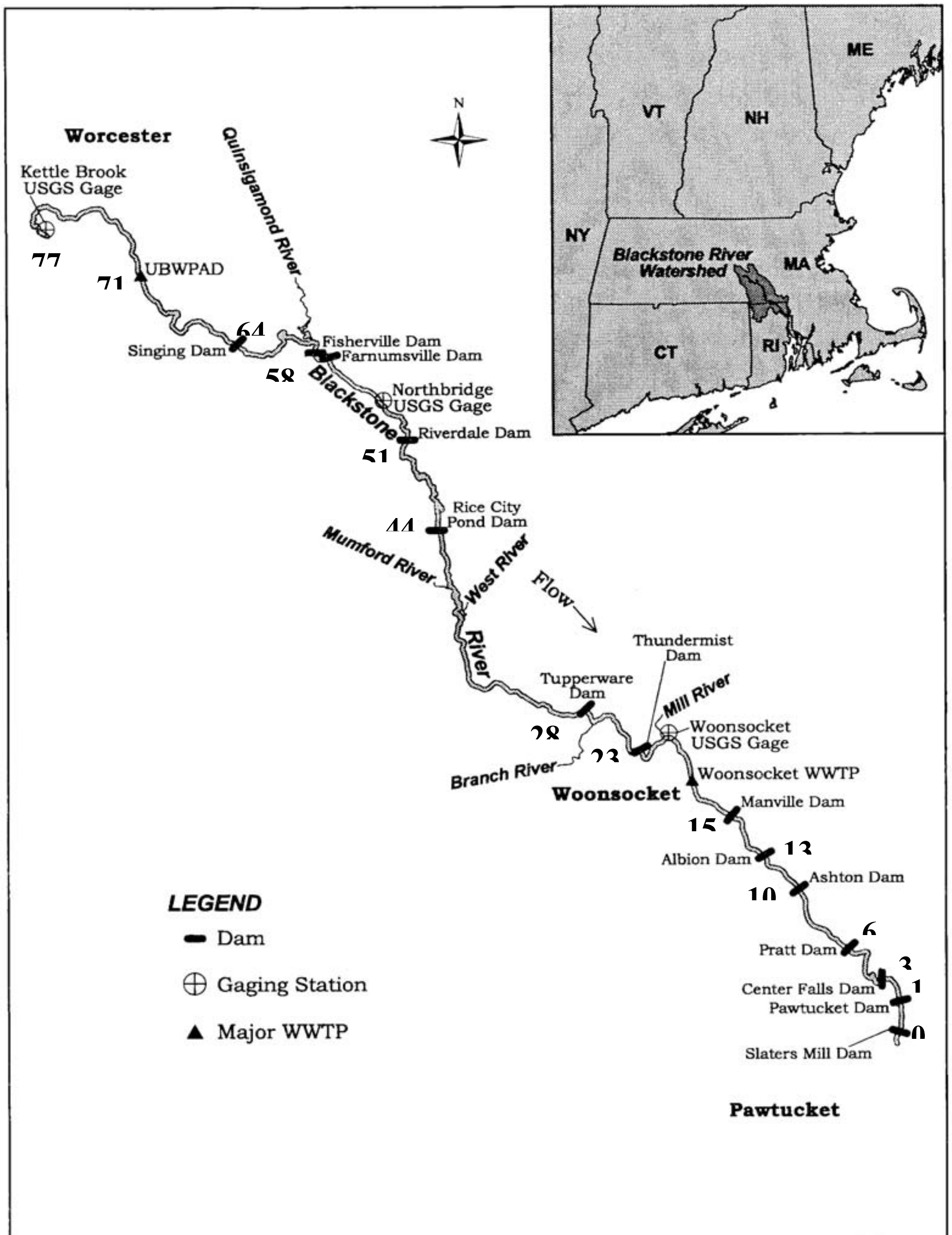


Figure 1 Blackstone River Map

APPENDIX I

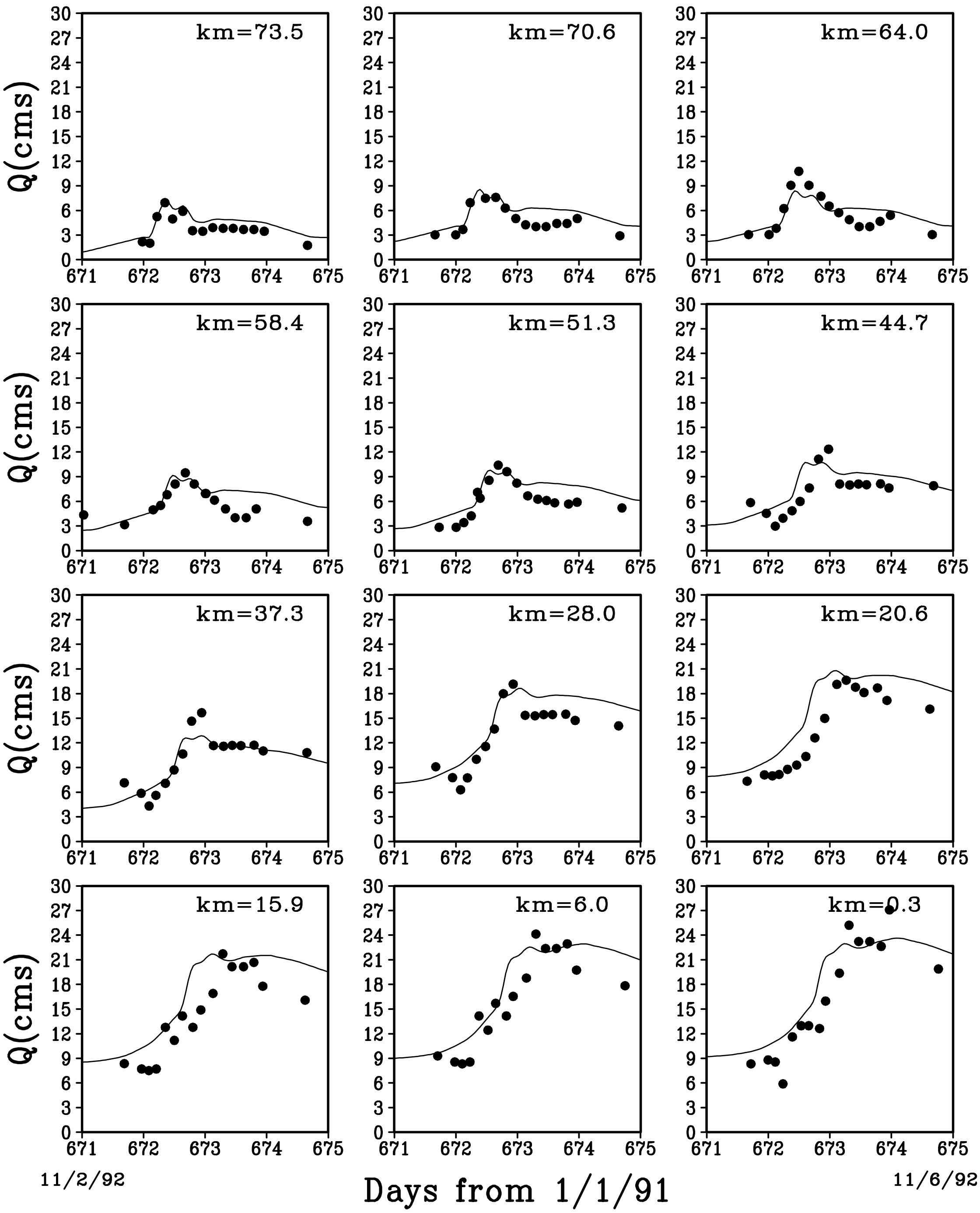


Figure 2 Blackstone River Calibration: Flows

APPENDIX I

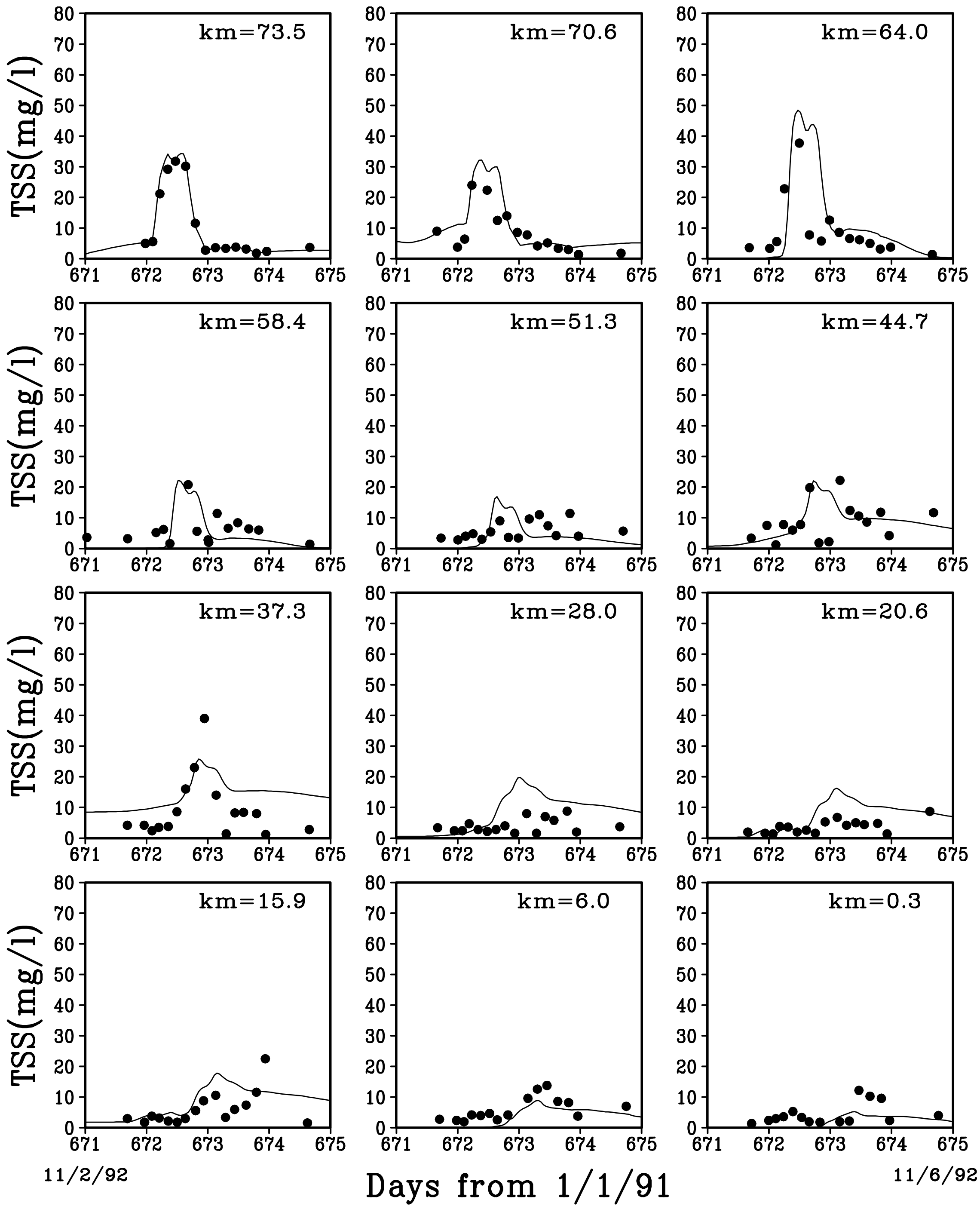


Figure 3 Blackstone River Calibration: TSS

APPENDIX I

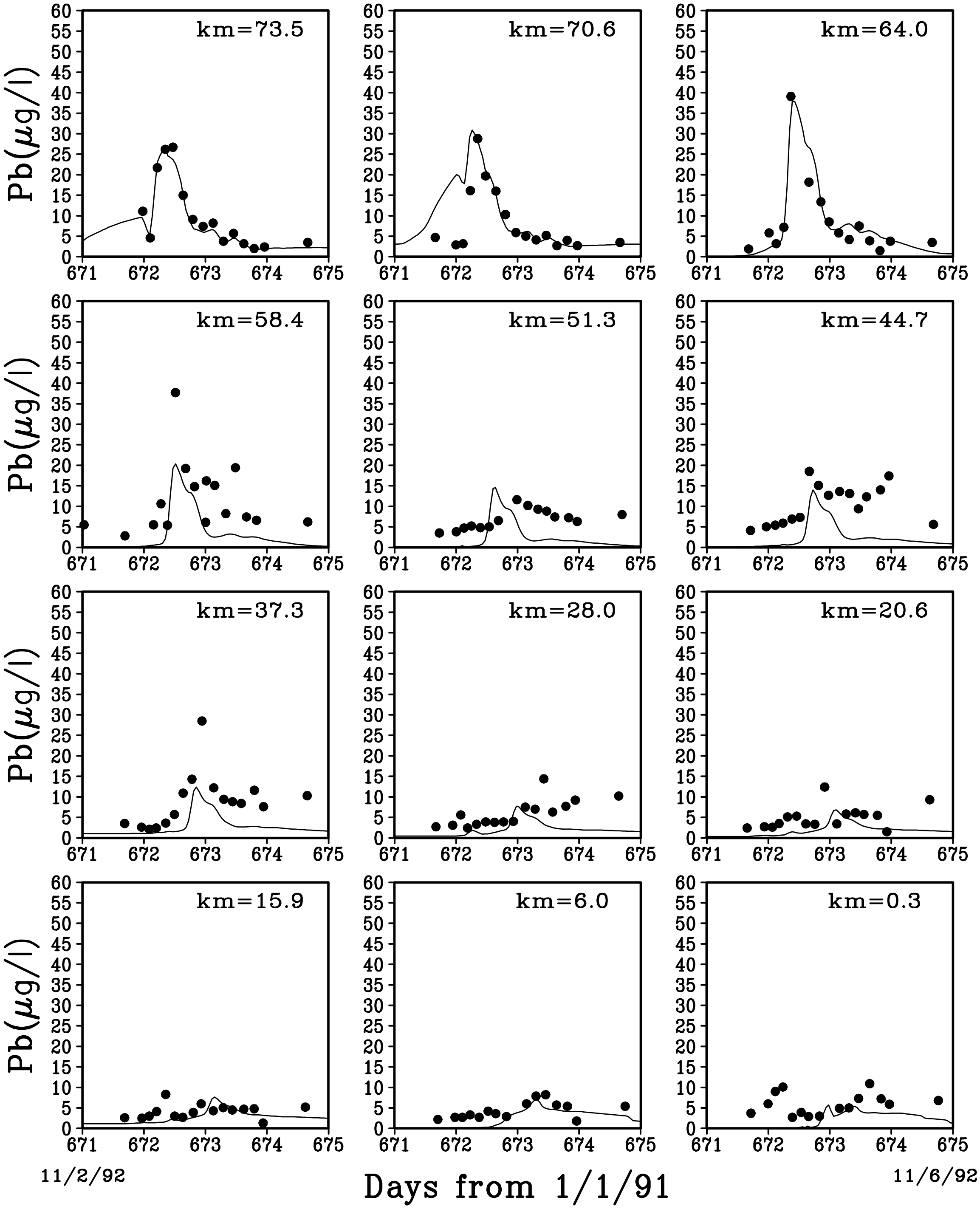


Figure 4 Blackstone River Calibration: Lead

APPENDIX I

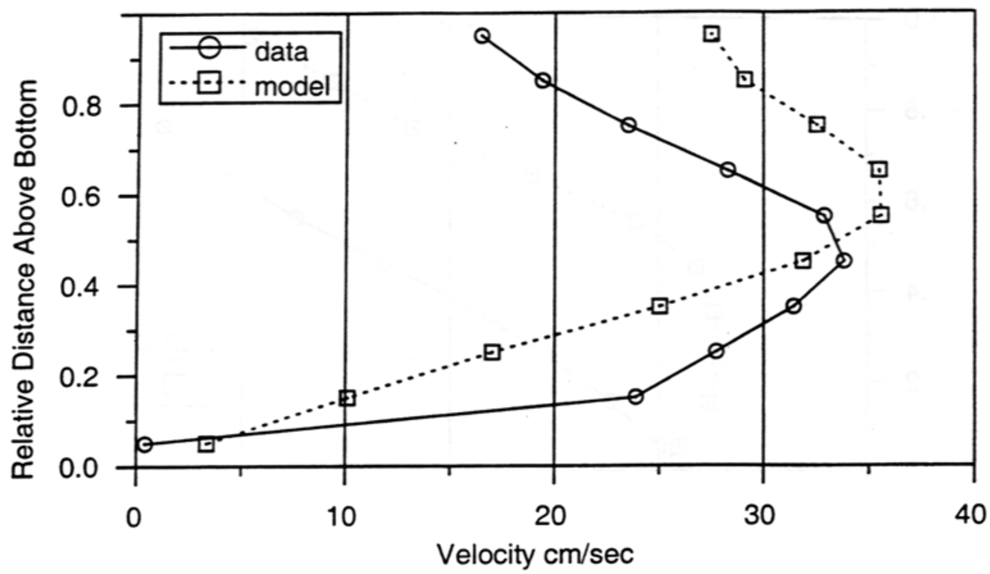


Figure E9. Amplitude of M2 Harmonic Component of Longitudinal Velocity at Station BOE

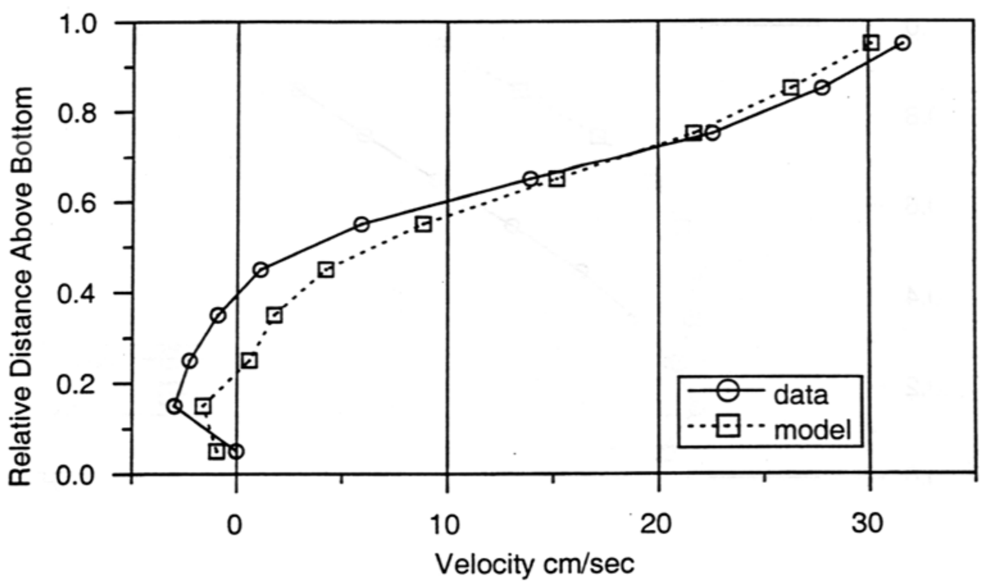


Figure E10. Mean Longitudinal Velocity at Station BOE between Julian Days 294 and 323, 1996.

Figure 5 Duwamish River/Elliott Bay Velocity Profile Comparison

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

APPENDIX J

MFD Table F-8: Summary of Housatonic Meteorological Data

Years: 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000 (Jan, May, Aug, Dec)

	General Location	Sample Type	REF / SOURCE
Precip	PITTSFIELD GE FACILITY	15-minute	GE
	PITTSFIELD GE FACILITY	Hourly	GE
	BECKET 2 SW	Hourly	Earthinfo
	LANESBORO	Hourly	Earthinfo
	LITTLEVILLE LAKE	Hourly	Earthinfo
	KNIGHTVILLE	Hourly	Basins
	COPAKE	Hourly	Earthinfo
	HARTFORD	Hourly	NRCC
	ALBANY	Hourly	NRCC
	BECKET 2 SW	Daily	Earthinfo
	LANESBORO	Daily	Earthinfo
	STOCKBRIDGE	Daily	Earthinfo
	BORDEN BROOK RSVR	Daily	Earthinfo
	CHESTER2	Daily	Earthinfo
	CUMMINGTON HILL	Daily	Earthinfo
	GREAT BARRINGTON AP	Daily	Earthinfo
	NORTH ADAMS	Daily	Earthinfo
	PLAINFIELD	Daily	Earthinfo
	PLAINFIELD 2	Daily	Earthinfo
	SHEFFIELD 3 SSW	Daily	Earthinfo
	WEST OTIS	Daily	Earthinfo
	WORTHINGTON	Daily	Earthinfo
	BERLIN 5 S	Daily	Earthinfo
	COPAKE	Daily	Earthinfo

Note: Colored gages intend to be used for watershed simulation

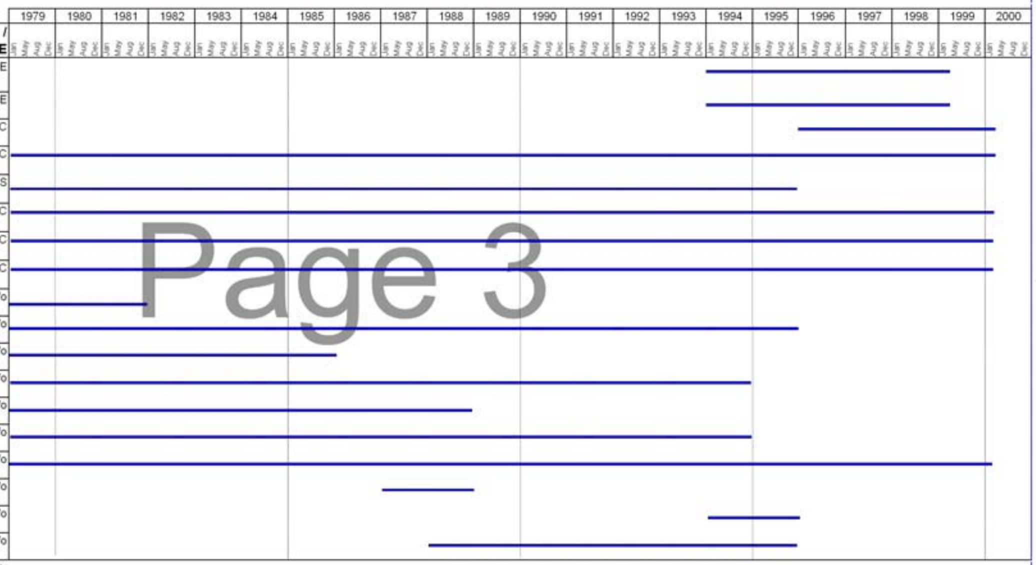
Years: 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000 (Jan, May, Aug, Dec)

	General Location	Sample Type	REF / SOURCE
Evap	HARTFORD	Daily	NRCC
	ALBANY	Daily	NRCC
	KNIGHTVILLE	Hourly	BASINS
	COVENTRY	Daily	Earthinfo
	NORFOLK 2 SW	Daily	Earthinfo
	VALATIE 1 N	Daily	Earthinfo
Dew Point	HARTFORD	Hourly	Earthinfo
	ALBANY	Hourly	Earthinfo
	KNIGHTVILLE	Hourly	BASINS
Cloud Cover	HARTFORD	Hourly	Earthinfo
	ALBANY	Hourly	Earthinfo
	KNIGHTVILLE	Hourly	BASINS
Wind	PITTSFIELD GE FACILITY	15-minute	GE
	PITTSFIELD GE FACILITY	Hourly	GE
	HARTFORD	Hourly	Earthinfo
	ALBANY	Hourly	Earthinfo
	KNIGHTVILLE	Hourly	BASINS
Solar Rad	PITTSFIELD GE FACILITY	15-minute	GE
	PITTSFIELD GE FACILITY	Hourly	GE
	HARTFORD	Hourly	NRCC
	ALBANY	Hourly	NRCC
	KNIGHTVILLE	Hourly	BASINS

Note: Colored gages intend to be used for watershed simulation

APPENDIX J

	General Location	Sample Type	REF / SOURCE
Air Temp	PITTSFIELD GE FACILITY	15-minute	GE
	PITTSFIELD GE FACILITY	Hourly	GE
	HARTFORD	Hourly	NRCC
	ALBANY	Hourly	NRCC
	KNIGHTVILLE	Hourly	BASINS
	WEST OTIS	Daily	NRCC
	BERLIN 5 S	Daily	NRCC
	PLAINFIELD	Daily	NRCC
	BECKET	Daily	Earthinfo
	LANESBORO	Daily	Earthinfo
	STOCKBRIDGE	Daily	Earthinfo
	BORDEN BROOK RSVR	Daily	Earthinfo
	CHESTER2	Daily	Earthinfo
	CUMMINGTON HILL	Daily	Earthinfo
	GREAT BARRINGTON AP	Daily	Earthinfo
	NORTH ADAMS	Daily	Earthinfo
	WORTHINGTON	Daily	Earthinfo
	COPAKE	Daily	Earthinfo



Note: Colored gages intend to be used for watershed simulation

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

APPENDIX K

Pore Water Samples and the Kd Calculations

Core	RM	Location ID	Program	Date Collected	Depth Collected	Lab/Analysis Date	Field Sample ID #	Depth Interval (ft)	Sample Type	PCB,TOTAL	Units	Flag	Lab	TOC	Units	Flag	Lab	TOC,Dissolved	Flag	Unit	Lab	PCB Aroclors	PCB Congeners	App IX Semivolatiles	Dioxin/Furan	Metals	Inorganics
1	Reach 4	SE000025	Physical Tests	1/28/99	.5 - 1	1/28/99 14:15	H2-SE000025-0-0000D1	0 - 0	Pore water after separation	11	UG/L	J	ITS	21.9	MG/L		ITS	N/A				Yes (ITS)	N/A	N/A	N/A	N/A	N/A
1	Reach 4	SE000026	Physical Tests	1/29/99	.5 - 1	1/28/99 14:15	H2-SE000025-0-0000D2	0 - 0	Pore water after separation	16	UG/L	J	ITS	N/A				N/A				Yes (ITS)	N/A	N/A	N/A	N/A	N/A
2	Reach 4	SE000032	Physical Tests	1/28/99	1 - 1.5	1/28/99 15:15	H2-SE000032-0-0000E1	0 - 0	Pore water after separation	6.8	UG/L	J	ITS	29.3	MG/L		ITS	N/A				Yes (ITS)	N/A	N/A	N/A	N/A	N/A
3	Reach 4	SE000018	Physical Tests	1/21/00	.5 - 1	1/21/99 14:15	H2-SE000018-0-0005C	0 - 0	Pore water after separation	1.9	UG/L	J	ITS	40.2	MG/L		ITS	N/A				Yes (ITS)	N/A	N/A	N/A	N/A	N/A
4	135.07	SE000775	WSU	9/9/99 & 9/13/99 & 9/15/99	0 - .16	9/20/99 16:00	HW-SE000775-0-0000AD	0 - .16	Sediment after separation	0.076	MG/KG	J	ITS	5400	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
4	135.07	SE000775	WSU	9/9/99 & 9/13/99 & 9/15/99	0 - .16	9/20/99 13:50	HW-SE000775-0-0000AW	0 - .16	Sample prior to separation	0.065	MG/KG	J	ITS	3660	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
4	135.07	SE000775	WSU	9/9/99 & 9/13/99 & 9/15/99	0 - .16	9/20/99 17:45	HW-SE000775-0-0000B	0 - 0	Pore water after separation	0.025	UG/L	J	ITS	13.9	MG/L		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	N/A	Yes (ITS)	Yes (SoilTech)
5	132.56	SE001050	Run of River	3/29/99 & 5/5/99	0 - .5	5/10/99 15:15	H3-SE001050-0-0000AD	0 - .5	Sediment after separation	5.1193226	MG/KG		PAC	N/A				N/A				Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
5	132.56	SE001050	Run of River	3/29/99 & 5/5/99	0 - .5	5/10/99 15:15	H3-SE001050-0-0000AW	0 - .5	Sample prior to separation	5.6573057	MG/KG		PAC	N/A				N/A				Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
5	132.56	SE001050	Run of River	3/29/99 & 5/5/99	0 - .5	5/10/99 16:45	H3-SE001050-0-0000B	0 - 0	Pore water after separation	1.345	UG/L		PAC	N/A				16.8		MG/L	ITS	Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
6	132.34	SE000774	WSU	9/18/99 & 9/15/99	0 - .16	9/7/99 9:30	H3-SE000774-0-0000AD	0 - .16	Sediment after separation	5.9	MG/KG		ITS	3150	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
6	132.34	SE000774	WSU	9/18/99 & 9/15/99	0 - .16	9/7/99 9:30	H3-SE000774-0-0000AW	0 - .16	Sample prior to separation	14	MG/KG		ITS	4050	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
6	132.34	SE000774	WSU	9/18/99 & 9/15/99	0 - .16	9/7/99 9:30	H3-SE000774-0-0000B	0 - 0	Pore water after separation	1.6	UG/L	J	ITS	11.5	MG/L		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	Yes (SoilTech)
7	131.34	SE001049	Run of River	4/26/99 & 3/29/99	0 - .5	4/30/99 15:50	H3-SE001049-0-0000AD	0 - .5	Sediment after separation	23.9742087	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
7	131.34	SE001049	Run of River	4/26/99 & 3/29/99	0 - .5		H3-SE001049-0-0000AW		Sample prior to separation																		
7	131.34	SE001049	Run of River	4/26/99 & 3/29/99	0 - .5	4/30/99 16:45	H3-SE001049-0-0000B	0 - 0	Pore water after separation	1.013	UG/L	J	PAC	N/A				98.3		MG/L	ITS	Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
8	130.32	SE000773	WSU	9/8/99 & 9/15/99	0 - .16	9/21/99 11:30	H3-SE000773-0-0000AD	0 - .16	Sediment after separation	8.3	MG/KG		ITS	2550	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
8	130.32	SE000773	WSU	9/8/99 & 9/15/99	0 - .16	9/21/99 11:05	H3-SE000773-0-0000AW	0 - .16	Sample prior to separation	8.7	MG/KG		ITS	2930	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
8	130.32	SE000773	WSU	9/8/99 & 9/15/99	0 - .16	9/21/99 16:50	H3-SE000773-0-0000B	0 - 0	Pore water after separation	1.1	UG/L	J	ITS	11.7	MG/L		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	Yes (SoilTech)
9	129.96	SE001048	Run of River	4/26/99 & 3/29/99	0 - 0.5	4/30/99 11:50	H3-SE001048-0-0000AD	0 - .5	Sediment after separation	2.6752768	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
9	129.96	SE001048	Run of River	4/26/99 & 3/29/99	0 - 0.5		H3-SE001048-0-0000AW		Sample prior to separation																		
9	129.96	SE001048	Run of River	4/26/99 & 3/29/99	0 - 0.5	4/30/99 12:30	H3-SE001048-0-0000B	0 - 0	Pore water after separation	1.655	UG/L	J	PAC	N/A				438		MG/L	ITS	Yes (PAC)	Yes (PAC)	N/A	N/A	N/A	N/A
10	129.01	SE001027	Run of River	4/14/99 & 3/25/99	0 - 0.5	4/20/99 15:00	H3-SE001027-0-0000AD	0 - .5	Sediment after separation	0.79	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
10	129.01	SE001027	Run of River	4/14/99 & 3/25/99	0 - 0.5	4/20/99 15:00	H3-SE001027-0-0000AW	0 - .5	Sample prior to separation	0.478	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
10	129.01	SE001027	Run of River	4/14/99 & 3/25/99	0 - 0.5	4/20/99 15:00	H3-SE001027-0-0000B	0 - 0	Pore water after separation	1.168	UG/L	J	PAC	N/A				270		MG/L	ITS	Yes (PAC)	N/A	N/A	N/A	N/A	N/A
11	128.05	SE001026	Run of River	4/14/99 & 3/25/99	0 - 0.5	4/16/99 16:30	H3-SE001026-0-0000AD	0 - .5	Sediment after separation	0.52	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
11	128.05	SE001026	Run of River	4/14/99 & 3/25/99	0 - 0.5	4/16/99 16:30	H3-SE001026-0-0000AW	0 - .5	Sample prior to separation	0.202	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
11	128.05	SE001026	Run of River	4/14/99 & 3/25/99	0 - 0.5	4/19/99 16:30	H3-SE001026-0-0000B	0 - 0	Pore water after separation	1.395	UG/L	J	PAC	N/A				23.6		MG/L	ITS	Yes (PAC)	N/A	N/A	N/A	N/A	N/A
12	127.03	SE001025	Run of River	3/25/99 & 4/14/99	0 - 0.5	4/19/99 12:00	H3-SE001025-0-0000AD	0 - .5	Sediment after separation	0.328	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
12	127.03	SE001025	Run of River	3/25/99 & 4/14/99	0 - 0.5	4/19/99 12:00	H3-SE001025-0-0000AW	0 - .5	Sample prior to separation	0.181	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
12	127.03	SE001025	Run of River	3/25/99 & 4/14/99	0 - 0.5	4/19/99 12:00	H3-SE001025-0-0000B	0 - 0	Pore water after separation	0.487	UG/L	J	PAC	N/A				10.6		MG/L	ITS	Yes (PAC)	N/A	N/A	N/A	N/A	N/A
13	126.38	SE000772	WSU	9/7/99	0 - .16	9/7/99 10:30	H3-SE000772-0-0000AD	0 - .16	Sediment after separation	110	MG/KG	J	ITS	61800	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
13	126.38	SE000772	WSU	9/7/99	0 - .16	9/7/99 10:30	H3-SE000772-0-0000AW	0 - .16	Sample prior to separation	93	MG/KG		ITS	60000	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
13	126.38	SE000772	WSU	9/7/99	0 - .16	9/7/99 10:30	H3-SE000772-0-0000B	0 - 0	Pore water after separation	180	UG/L		ITS	138	MG/L		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	Yes (SoilTech)
14	126.01	SE001024	Run of River	4/13/99 & 3/25/99	0 - .5	4/15/99 12:45	H3-SE001024-0-0000A	0 - .5	Solids prior to separation	0.474	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
14	126.01	SE001024	Run of River	4/13/99 & 3/25/99	0 - .5	4/15/99 12:45	H3-SE001024-0-0000B	0 - 0	Pore water after separation	2.709	UG/L	J	PAC	N/A				392		MG/L	ITS	Yes (PAC)	N/A	N/A	N/A	N/A	N/A
15	125.65	SE000771	WSU	9/2/99	0 - .16	9/7/99 15:00	H3-SE000771-0-0000AD	0 - .16	Sediment after separation	75	MG/KG		ITS	59600	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
15	125.65	SE000771	WSU	9/2/99	0 - .16	9/7/99 15:00	H3-SE000771-0-0000AW	0 - .16	Sample prior to separation	210	MG/KG		ITS	92600	MG/KG		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	N/A
15	125.65	SE000771	WSU	9/2/99	0 - .16	9/7/99 15:00	H3-SE000771-0-0000B	0 - 0	Pore water after separation	100	UG/L		ITS	22.1	MG/L		ITS	N/A				Yes (ITS)	N/A	Yes (ITS)	Yes (PDM)	Yes (ITS)	Yes (SoilTech)
16	Woods Pond	SE001004	Woods	3/18/99	0 - .5	3/24/99 12:45	H4-SE001004-0-0000AP	34 - .5	Solids prior to separation	N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
16	Woods Pond	SE001004	Woods	3/18/99	0 - .5		H4-SE001004-0-0000BP		Organic Carbon result																		
17	Woods Pond	SE001005	Woods	3/17/99	0 - .5	3/22/99 13:45	H4-SE001005-0-0000A	34 - .5	Solids prior to separation	N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
17	Woods Pond	SE001005	Woods	3/17/99	0 - .5	3/22/99 13:30	H4-SE001005-0-0000B	0 - 0	Pore water after separation	N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
18	Woods Pond	SE001007	Woods	3/17/99	0 - .5	3/22/99 14:25	H4-SE001007-0-0000AP	34 - .5	Solids prior to separation	N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
18	Woods Pond	SE001007	Woods	3/17/99	0 - .5	3/22/99 14:25	H4-SE001007-0-0000B	0 - 0		N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
18	Woods Pond	SE001007	Woods	3/17/99	0 - .5		H4-SE001007-0-0000BP		Pore water after separation																		
19	Woods Pond	SE001013	Woods	3/19/99	0 - .5	3/24/99 15:30	H4-SE001013-0-0000AP	34 - .5	Solids prior to separation	N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
19	Woods Pond	SE001013	Woods	3/19/99	0 - .5	3/25/99 15:30	H4-SE001013-0-0000B	0 - 0						N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
19	Woods Pond	SE001013	Woods	3/19/99	0 - .5		H4-SE001013-0-0000BP		Pore water after separation																		
20	Woods Pond	SE001015	Woods	3/19/99	0 - .5	3/25/99 13:30	H4-SE001015-0-0000AP	34 - .5	Solids prior to separation	N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
20	Woods Pond	SE001015	Woods	3/19/99	0 - .5	3/25/99 13:30	H4-SE001015-0-0000B	0 - 0		N/A				N/A				N/A				N/A	Yes (PAC)	N/A	N/A	N/A	N/A
20	Woods Pond	SE001015	Woods	3/19/99	0 - .5		H4-SE001015-0-0000BP		Pore water after separation																		
21	Woods Pond	SE001023	Run of River	3/25/99 & 4/13/99	0 - .5	4/15/99 13:30	H4-SE001023-0-0000A	0 - .5	Solids prior to separation	9.335	MG/KG	J	PAC	N/A				N/A				Yes (PAC)	N/A	N/A	N/A	N/A	N/A
21	Woods Pond	SE001023	Run of River	3/25/99 & 4/13/99	0 - .5	4/15/99 13:30	H4-SE001023-0-0000B	0 - 0	Pore water after separation	8.378	UG/L	J	PAC	N/A				55.3		MG/L	ITS	Yes (PAC)	N/A	N/A	N/A	N/A	N/A
				pulled from sample attribute forms & Geolis	from field notes	date collected in datamart	B=PCB by congeners only BP=OC only	this is what's in datamart																			

EPA Response to the Peer Review Panelist Questions on the Housatonic River Modeling Framework Design

APPENDIX K

FIELD SAMPLE ID	DATE COLLECTED	tPCB ug/l	dPCB ug/l	pPCB ug/l	TSS mg/l	pPCB/kg	Kd	SUSPENDED SOLIDS, DISS
AndrusRdBr-400am	20-Apr-82	0.15	0.08	0.07	7.5	9333.333	1.2E+05	
AndrusRdBr-700am	20-Apr-82	0.13	0.07	0.06	8.9	6741.573	9.6E+04	
DivisionSt-900am	20-Apr-82	0.1	0.04	0.06	19	3157.895	7.9E+04	
DivisionSt-1100am	20-Apr-82	0.09	0.04	0.05	17	2941.176	7.4E+04	
AndrusRdBr-500pm	20-Apr-82	0.08	0.05	0.03	7.8	3846.154	7.7E+04	
SchweitzerBr-1115am	20-Apr-82	0.07	0.01	0.06	90	666.6667	6.7E+04	
SchweitzerBr-220pm	20-Apr-82	0.05	0.01	0.04	91	439.5604	4.4E+04	
AndrusRdBr-1200pm	21-Apr-82	0.11	0.06	0.05	5.7	8771.93	1.5E+05	
DivisionSt-400pm	21-Apr-82	0.07	0.03	0.04	11	3636.364	1.2E+05	
DivisionSt-100pm	21-Apr-82	0.06	0.04	0.02	9.7	2061.856	5.2E+04	
AndrusRdBr-900am	22-Apr-82	0.08	0.02	0.06	6.6	9090.909	4.5E+05	
AndrusRdBr-900pm	22-Apr-82	0.08	0.02	0.06	9.4	6382.979	3.2E+05	
DivisionSt-1200pm	22-Apr-82	0.05	0.02	0.03	8	3750	1.9E+05	
AndrusRdBr-1000am	23-Apr-82	0.04	0.02	0.02	6.8	2941.176	1.5E+05	
AndrusRdBr-1200am	24-Apr-82	0.07	0.04	0.03	3.3	9090.909	2.3E+05	
LOC 05	20-Jul-89	0.096	0.064	0.032	7.7	4155.844	6.5E+04	
LOC 03	24-Aug-89	1.1	0.28	0.82	9.7	84536.08	3.0E+05	
LOC 01	24-Aug-89	0.89	0.32	0.57	10.4	54807.69	1.7E+05	
LOC 02	24-Aug-89	0.5	0.23	0.27	7.9	34177.22	1.5E+05	
LOC 05	24-Aug-89	0.43	0.26	0.17	6.3	26984.13	1.0E+05	
LOC 01	2-Nov-89	0.1	0.05	0.05	6.9	7246.377	1.4E+05	
LOC 02	2-Nov-89	0.1	0.07	0.03	10.7	2803.738	4.0E+04	
LOC 04	2-Nov-89	0.09	0.07	0.02	5.6	3571.429	5.1E+04	
LOC 05	2-Nov-89	0.07	0.06	0.01	8.6	1162.791	1.9E+04	
LOC 02	22-Feb-90	0.11	0.05	0.06	3.3	18181.82	3.6E+05	7.5
LOC 06	13-Jun-90	0.21	0.1	0.11	8	13750	1.4E+05	
LOC 04	13-Jun-90	0.16	0.12	0.04	5	8000	6.7E+04	8.9
LOC 5	3-Oct-90	0.26	0.078	0.182	6	30333.33	3.9E+05	
LOC 6	7-May-91	0.2	0.17	0.03	3	10000	5.9E+04	
LOC 4	4-Jun-91	0.16	0.073	0.087	7	12428.57	1.7E+05	5.7
LOCATION 11	15-May-96	0.392	0.06	0.332	13	25538.46	4.3E+05	19
LOCATION 9	15-May-96	0.357	0.055	0.302	4.1	73658.54	1.3E+06	
LOCATION 5	15-May-96	0.311	0.095	0.216	3.5	61714.29	6.5E+05	
LOCATION 10	15-May-96	0.279	0.064	0.215	5.5	39090.91	6.1E+05	
LOCATION 7	15-May-96	0.239	0.028	0.211	5.7	37017.54	1.3E+06	
LOCATION 3	15-May-96	0.073	0.033	0.04	2	20000	6.1E+05	
LOCATION 1	11-Jun-96	0.373	0.043	0.33	6	55000	1.3E+06	17
LOCATION 9	17-Jul-96	0.173	0.093	0.08	9.3	8602.151	9.2E+04	
LOCATION 11	17-Jul-96	0.169	0.134	0.035	5	7000	5.2E+04	6.6
LOCATION 10	17-Jul-96	0.127	0.05	0.077	10	7700	1.5E+05	9.4
LOCATION 13	17-Jul-96	0.091	0.031	0.06	14	4285.714	1.4E+05	7.8
LOCATION 5	17-Jul-96	0.091	0.065	0.026	8.5	3058.824	4.7E+04	
LOCATION 12	17-Jul-96	0.071	0.023	0.048	6.2	7741.935	3.4E+05	
LOCATION 4	17-Jul-96	0.036	0.022	0.014	8	1750	8.0E+04	90
LOCATION 9	13-Aug-96	0.625	0.172	0.453	3.1	146129	8.5E+05	11
LOCATION 3	13-Aug-96	0.301	0.058	0.243	2.5	97200	1.7E+06	3.3
LOCATION 7	13-Aug-96	0.28	0.139	0.141	1.6	88125	6.3E+05	
LOCATION 5	13-Aug-96	0.204	0.035	0.169	3.2	52812.5	1.5E+06	9.7
LOCATION 2	13-Aug-96	0.181	0.033	0.148	2.6	56923.08	1.7E+06	91
LOCATION 10	14-Aug-96	0.583	0.127	0.456	9.5	48000	3.8E+05	8
LOCATION 11	14-Aug-96	0.164	0.029	0.135	4.2	32142.86	1.1E+06	
LOCATION 2	27-Sep-96	0.046	0.025	0.021	3	7000	2.8E+05	6.8
LOCATION 12	28-Sep-96	0.148	0.028	0.12	3.8	31578.95	1.1E+06	