



**U.S. Army  
Corps of Engineers**

New England District  
Concord, Massachusetts



**U.S. Environmental  
Protection Agency**

New England Region  
Boston, Massachusetts

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**FINAL**

**MODELING FRAMEWORK DESIGN:**

**Modeling Study of PCB Contamination  
in the Housatonic River**

DCN: GE-042104-ACDP

April 2004

**Environmental Remediation Contract  
GE/Housatonic River Project  
Pittsfield, Massachusetts**

Contract No. DACW33-00-D-0006

Task Order No. 0003

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Prepared for

**U.S. ARMY CORPS OF ENGINEERS**

New England District  
Concord, Massachusetts

and

**U.S. ENVIRONMENTAL PROTECTION AGENCY**

New England Region  
Boston, Massachusetts

Prepared by

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## LIST OF ACRONYMS

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µg/g	microgram per gram
µg/g-ww	microgram per gram-wet weight
µg/L	microgram per liter
µm	micrometer (or micron)
ACO	Administrative Consent Order
ADCP	Acoustic Doppler Current Profiler
ARM	Agricultural Runoff Management
BAF	bioaccumulation factor
BD	bulk density
BMPs	best management practices
BOD	biochemical oxygen demand
BP	Before Present
BSAFs	biota-sediment accumulation factors
C-14	carbon-14
CAWQC	Chronic Ambient Water Quality Criterion
cfs	cubic feet per second
Cl/BP	chlorines per biphenyl
cm	centimeter
cm/s	centimeter per second
CMS	Corrective Measures Study
COCs	contaminants of concern
CP	capture probability
CR	resistance factor
CTDEP	Connecticut Department of Environmental Protection
CWA	Clean Water Act
DEHP	di-2-ethylhexyl phthalate
DEM	digital elevation model
DO	dissolved oxygen
DOC	dissolved organic carbon
DOJ	U.S. Department of Justice
DOM	dissolved organic matter
EDS	energy dispersive system
EE/CA	Engineering Evaluation/Cost Analysis
EFDC	Environmental Fluid Dynamics Code
EIA	"effective" imperviousness

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## LIST OF ACRONYMS (Continued)

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EOEA	Massachusetts Executive Office of Environmental Affairs
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EqP	equilibrium partitioning theory
EqP-based	equilibrium partitioning-based
ERDC	Engineering Research and Development Center
FCM	Food Chain Model
FESWMS-2D	Finite Element Surface Water Modeling System
foc	fraction of organic carbon
fps	feet per second
Fr	Froude number
ft	feet
g/L	gram per liter
g/m <sup>2</sup>	gram per square meter
g/m <sup>3</sup>	gram per cubic meter
g/min	gram per minute
GE	General Electric Company
GIS	geographic information system
gpd/ft <sup>2</sup>	gallons per day per square foot
GUI	Graphical User Interface
HEM3D	three-dimensional hydrodynamic-eutrophication model
HSA	hydrologic study area
HSCTM-2D	Hydrodynamics, Sediment and Contaminant Transport Model
HSPF	Hydrological Simulation Program-Fortran
HSWA	Hazardous and Solid Waste Amendments
IADN	Integrated Atmospheric Deposition Network
km	kilometer
L/kg	liter per kilogram
LA	load allocation
LDA	laser-Doppler anemometer
LR	linkage reach
m/m	meter per meter
m <sup>3</sup>	cubic meter
MDEP	Massachusetts Department of Environmental Protection
MDPH	Massachusetts Department of Public Health

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## LIST OF ACRONYMS (Continued)

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MFD	Modeling Framework Design
mg/kg	milligram per kilogram
mg/L	milligram per liter
mi <sup>2</sup>	square mile
mm	millimeter
MSE	mean squared error
msl	mean sea level
MT	metric ton
MT/yr	metric ton per year
NAWQA	National Ambient Water-Quality Assessment Program
NEA	Northeast Analytical Laboratories
NO <sub>2</sub>	nitrite
NO <sub>3</sub>	nitrate
NPL	National Priorities List
NPS	nonpoint source
NWS	National Weather Service
OC	organic carbon
Pa	pascal
PCA	principal components analysis
PCBs	polychlorinated biphenyls
PES	particle entrainment simulator
PET	potential evapotranspiration
POC	particulate organic carbon
POM	particulate organic matter
ppm	parts per million (mg/kg)
PSA	Primary Study Area
PSD	particle size distributions
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QEA	Quantitative Environmental Analysis
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RM	river mile
SEM	scanning electron microscope

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## LIST OF ACRONYMS (Continued)

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SNL	Sandia National Laboratories
SOP	Standard Operating Procedure
STORET	STORAge and RETrieval
SWAT	Soil and Water Assessment Tool
TEF	toxic equivalency factor
TMDLs	total maximum daily loads
TOC	total organic carbon
tPCB	total PCB
TSCA	Toxic Substances Control Act
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VDCs	vertical definition cores
VSS	volatile suspended solids
WES	Waterways Experiment Station
WESTON	Weston Solutions, Inc.
WIFM-SAL	WES Implicit Flooding Model, constituent transport finite difference model
WMS	Watershed Model System
WQAM	Water Quality Assessment Methodology
WQC	water quality criteria
WWTP	Wastewater Treatment Plant
XRD	X-ray diffraction
yd <sup>3</sup>	cubic yard
YOY	young of year



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## LIST OF ACRONYMS (Continued)

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NAWQA	National Ambient Water-Quality Assessment Program
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OC	organic carbon
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PCA	principal components analysis
PCBs	polychlorinated biphenyls
PES	particle entrainment simulator
PET	potential evapotranspiration
POC	particulate organic carbon
POM	particulate organic matter
ppm	parts per million (mg/kg)
PSA	Primary Study Area
PSD	particle size distributions
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QEA	Quantitative Environmental Analysis
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WES	Waterways Experiment Station
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WMS	Watershed Model System
WQAM	Water Quality Assessment Methodology
WQC	water quality criteria
WWTP	Wastewater Treatment Plant
XRD	X-ray diffraction
yd <sup>3</sup>	cubic yard
YOY	young of year

# 1 EXECUTIVE SUMMARY

## 2 ES.1 PURPOSE AND OBJECTIVES OF THE MODELING FRAMEWORK DESIGN

3 Evaluation of the risks posed to human health and the environment from contaminated sediment  
4 often requires the application of coupled watershed/hydrodynamic/water quality models and  
5 contaminant fate and bioaccumulation models to address the full range of migration pathways of  
6 contaminants released to the environment. The use of an integrated modeling framework is  
7 needed to produce a scientifically defensible application of models to support regulatory  
8 decisionmaking.

9 The modeling study was developed to: (1) represent the full range of physical, chemical, and  
10 biological processes of concern for polychlorinated biphenyl (PCB) fate, transport, and  
11 bioaccumulation in the Housatonic River watershed; and (2) address each of the following site-  
12 specific study objectives:

- 13       ▪ Quantify future spatial and temporal distribution of PCBs (both dissolved and  
14       particulate forms) within the water column and bed sediment.
- 15       ▪ Quantify the historical and relative contributions of various sources of PCBs on  
16       ambient water quality and bed sediment.
- 17       ▪ Quantify the historical and relevant contribution of various PCB sources to  
18       bioaccumulation in targeted species.
- 19       ▪ Estimate the time required for PCB-laden sediment to be effectively sequestered by  
20       the deposition of “clean” sediment (i.e., natural recovery).
- 21       ▪ Estimate the time required for PCB concentrations in fish tissue to be reduced to  
22       concentrations that no longer pose either a human health or ecological risk based on  
23       various remediation and restoration scenarios, including allowing for natural  
24       recovery.
- 25       ▪ Quantify the relative risk(s) of extreme storm event(s) contributing to the  
26       resuspension of sequestered sediment and the redistribution of PCB-laden sediment  
27       within the area of study.

## 1 **ES.2 MODELING STUDY OVERVIEW**

2 Historical releases of certain classes of organic and inorganic contaminants into waterbodies  
3 have left a legacy of aquatic sediment enriched with these contaminants. In some sediments  
4 these contaminants have accumulated to concentrations that may pose an unacceptable human  
5 health and ecological risk. Of particular concern is the historical release to waterbodies of  
6 compounds known as polychlorinated biphenyls (PCBs), given that they are toxic, persistent, and  
7 bioaccumulate in the food chain.

8 PCBs historically were released to the Housatonic River from the General Electric Company  
9 (GE) facility in Pittsfield, MA. Over a period of decades, these compounds have accumulated in  
10 the river's bed sediment and impoundments. High-flow events have transported PCB-laden  
11 sediment onto the adjacent floodplain. Data collected from 1980 to the present have documented  
12 the magnitude and extent of the PCB contamination of the sediment and floodplain soil adjacent  
13 to the Housatonic River downstream of the GE facility, into Connecticut. The extent of the PCB  
14 contamination falls within the 10-year floodplain of the Housatonic River.

15 In addition, PCBs in fish tissue have accumulated to concentrations that pose a risk to human  
16 health. A recent U.S. Geological Survey (USGS) report (Garabedian et al., 1998) notes that PCB  
17 concentrations in Housatonic River streambed sediment and fish tissue constitute some of the  
18 highest PCB concentrations of all of the National Water-Quality Assessment Program  
19 (NAWQA) study sites nationwide.

20 The State of Connecticut posted a fish consumption advisory for most of the Connecticut section  
21 of the river in 1977 as a result of the PCB contamination in the river sediments and fish tissue.  
22 In 1982, the Massachusetts Department of Public Health (MDPH) issued a consumption advisory  
23 for fish, frogs, and turtles for the Housatonic River. In addition, in 1999, MDPH issued a  
24 waterfowl consumption advisory from Pittsfield to Great Barrington due to PCB concentrations  
25 in wood ducks and mallards collected from the river by the U.S. Environmental Protection  
26 Agency (EPA) and Massachusetts Division of Fisheries and Wildlife.

27 The geographic focus of the modeling study is from the confluence to Woods Pond Dam because  
28 data indicate that this area contains the principal mass of PCBs (BBL and QEA, 2003).

1 **ES.3 REGULATORY FRAMEWORK**

2 In September 1998, after years of scientific investigations and regulatory actions, a  
3 comprehensive agreement was reached between GE and various governmental entities, including  
4 the U.S. Environmental Protection Agency (EPA), Massachusetts Department of Environmental  
5 Protection (MDEP), the U.S. Department of Justice (DOJ), the Connecticut Department of  
6 Environmental Protection (CTDEP), and the City of Pittsfield. The agreement provides for the  
7 investigation and cleanup of the Housatonic River and associated areas. The agreement has been  
8 documented in a Consent Decree between all parties that was entered in the U.S. District Court  
9 in October 2000.

10 Under the terms of the Consent Decree, EPA is conducting the following investigations:

- 11       ▪ Human health risk assessment.
- 12       ▪ Ecological risk assessment.
- 13       ▪ Modeling study of hydrodynamics, sediment transport, and PCB fate and  
14        bioaccumulation in the Housatonic River below the confluence of the East and West  
15        Branches and the encompassing watershed.

16 The Consent Decree also includes specific language that requires the risk assessments and  
17 components of the modeling studies to be submitted for formal Peer Review to help guide the  
18 effort and ensure consistency with EPA policy and guidance. This report, the proposed  
19 Modeling Framework Design (MFD), is the first component of the modeling study that was  
20 submitted for Peer Review in April 2001.

21 **ES.4 CONCEPTUAL MODEL OF THE HOUSATONIC RIVER**

22 A conceptual model of the Primary Study Area (PSA) of the river was developed to summarize  
23 the significant physical, chemical, and biological processes that may affect the transport and fate  
24 of PCBs. The conceptual model combines an evaluation of the available data relevant to the  
25 study area with a determination of which processes are significant for inclusion in the modeling  
26 effort, which processes should be excluded, and which processes require further evaluation.

1 The Housatonic River in the PSA is a mature, highly meandering river system with four distinct  
2 hydraulic regimes that affect sediment and PCB transport and fate. PCBs have been detected  
3 across the entire study area out to the 10-year floodplain boundary, with the highest  
4 concentrations detected in river sediment, along the riverbanks, and in adjacent floodplains.  
5 Woods Pond Dam, which defines the downstream boundary of the PSA, is the first impoundment  
6 downstream from the GE facility. The dam has created a backwater effect, resulting in  
7 significant deposition of sediment and PCBs in the pond and backwater areas immediately  
8 upstream. Extensive sampling of a wide variety of biota indicates that most of the biological  
9 components of the system are also contaminated with PCBs.

10 Data collected since 1998 have indicated that the bulk of sediment transport, and presumably of  
11 PCBs through the system, occurs primarily as a result of storm events rather than base flow in  
12 the river. It appears that both suspended sediment loads and, to a lesser extent, bed load  
13 contribute to much of the sediment and PCB transport. The data further show that sequestering  
14 of PCBs is not occurring to any appreciable extent. Data from Woods Pond show that the  
15 highest PCB concentrations occur at or near the sediment surface. Evaluation of relative PCB  
16 concentrations in water and sediment indicates that partitioning is not in equilibrium over  
17 portions of the study area, possibly as a result of the occurrence of PCBs as a coating on quartz  
18 sand grains.

## 19 **ES.5 MODELING FRAMEWORK**

20 Modeling studies are based on four fundamental principles: (1) conservation of momentum,  
21 (2) conservation of mass and energy, (3) thermodynamics, and (4) ecological interactions and  
22 processes.

23 An environmental modeling framework for a contaminant such as PCBs is designed to represent  
24 the most important physical transport processes; pollutant loads; and physical, chemical, and  
25 biological processes representing the fate of the chemical of concern, while maintaining mass  
26 balance. This type of modeling study is designed to describe how releases of a chemical are  
27 transported and become distributed throughout the watershed in the river, sediment bed,  
28 floodplain, and aquatic animals and plants. The primary components of an environmental  
29 modeling framework are quantitative descriptions of: (1) inputs of the contaminant and other

1 related constituents; (2) water motion from physical transport; and (3) kinetic transfers of the  
2 contaminant and other related constituents among the water column, sediment bed, floodplain,  
3 and biota.

4 To conduct a modeling study of the environmental impact of remedial scenarios in comparison to  
5 the baseline or “no action” alternative, the modeling framework must first be systematically  
6 tested (i.e., calibrated and validated) to ensure that the modeling framework is scientifically  
7 credible. During the model calibration process, values of some parameters and coefficients of  
8 the model, assigned from either site-specific data or the literature, are adjusted until the  
9 comparison of model results to data satisfies the established criteria. Model results are then  
10 validated by running the model over a longer duration using a second, independent set of data  
11 collected for a different time period. The “goodness of fit” of the model and data used for  
12 validation are evaluated using the criteria established for how well the model results agree with  
13 the data. Additional detail on model calibration and validation procedures and acceptance  
14 criteria are provided in the Modeling Study QAPP (WESTON, 2000).

15 In the calibration and validation of an environmental model, the fundamental test of any  
16 modeling study is to demonstrate that a “mass balance” has been achieved for each primary  
17 constituent being modeled. For this investigation, the primary constituents included in the  
18 assessment of mass balance are water, solids, and PCBs. The principle behind achieving a mass  
19 balance is to ensure that all inputs, outputs, and internal gains and losses have been properly  
20 accounted for by the descriptions of water motion and the kinetic pathways of solids and PCBs.  
21 Satisfaction of the mass balance principle requires an accurate representation of the relevant  
22 physical, chemical, biological, and geological processes within the model framework that will be  
23 used for this investigation.

24 The ability of any model to precisely answer questions and/or predict future conditions over a  
25 period of decades must be carefully considered. Consequently, in the final analysis, a “weight-  
26 of-evidence” approach will be taken, including all available information and tools in addition to  
27 the model output.

28 The modeling framework was specifically developed to address each objective of the Housatonic  
29 River PCB fate and transport modeling study described above and the requirements identified in



1 the development of the conceptual model. A modeling framework is needed because no single  
2 model is capable of representing all the physical, chemical, and biological processes pertinent to  
3 this investigation over the wide range of spatial and temporal scales that exist at the site.

4 The basic modeling framework for this study proposes the use of the Hydrological Simulation  
5 Program-FORTRAN (HSPF) as the watershed component, Environmental Fluid Dynamics Code  
6 (EFDC) as the hydrodynamic and sediment transport component, and QEAFDCHN (Food Chain  
7 Model [FCM]) as the PCB fate and bioaccumulation component.

## 8 **ES.6 HSPF–WATERSHED HYDROLOGY AND NON-POINT SOURCE LOADS** 9 **MODEL COMPONENT**

10 For the past 20 years, HSPF has been the state-of-the-art model available for developing  
11 watershed-based simulations of hydrology and water quality processes. HSPF has been widely  
12 accepted by experts in environmental modeling and has been used for hundreds of complex  
13 applications, including the development of a hydrologic model of the Housatonic River  
14 watershed for the State of Connecticut. HSPF has been selected by the EPA Office of Science  
15 and Technology as the watershed model component of the BASINS model framework.

16 The watershed model encompasses the largest spatial extent of the system in this modeling  
17 study. The physical domain of the watershed model includes 282 square miles of the drainage  
18 basin of the Housatonic River from the headwaters to Great Barrington, MA. The watershed  
19 model is designed to account for the hydrologic balance of the drainage basin between  
20 precipitation, infiltration, and streamflow runoff.

21 The principal use of HSPF is to establish certain external boundary conditions, primarily flow,  
22 for input to the hydrodynamic and sediment transport model (EFDC).

## 23 **ES.7 EFDC–HYDRODYNAMICS AND SEDIMENT TRANSPORT MODEL** 24 **COMPONENT**

25 EFDC is a public domain model developed with funding from the Commonwealth of Virginia  
26 and EPA. EFDC is a three-dimensional, state-of-the-art computational physics model that  
27 incorporates submodels for hydrodynamics, sediment transport, contaminants, eutrophication,

1 and water quality within a single source code. EFDC has been selected by the EPA Office of  
2 Science and Technology to provide the primary hydrodynamic, sediment transport, contaminant,  
3 and eutrophication model components for EPA.

4 The spatial area represented in the EFDC model includes the PSA of the Housatonic River  
5 extending 11 miles from the confluence of the East and West Branches of the river in Pittsfield  
6 to Woods Pond Dam. The physical domain includes the river channel, the sediment bed, the 10-  
7 year floodplain, Woods Pond, and the backwater areas of the Woods Pond impoundment.

8 The principal use of EFDC in the model framework is to provide exposure concentrations of  
9 total PCBs (tPCBs) and dissolved organic carbon and particulate organic carbon in the water  
10 column and the surficial (active layer) sediment bed as inputs to FCM. In the surficial bed, the  
11 simulated mass of tPCBs is normalized to the dry weight of solids, particulate organic carbon,  
12 and sediment bed surface area. The tPCB results provided by EFDC will also be used to provide  
13 concentrations of selected congeners for use by FCM based on site-specific relationships of  
14 tPCB concentrations and congeners. Because the spatial and time scales of the EFDC model are  
15 much more detailed than the coarse space and time scales used in FCM, the model results  
16 generated by EFDC will be integrated over a 24-hour time scale and summed over the multiple  
17 EFDC grid cells that correspond to each larger FCM reach.

## 18 **ES.8 FCM-PCB FATE AND BIOACCUMULATION MODEL COMPONENT**

19 The food chain model selected for application in the Housatonic River modeling study is  
20 QEAFDCHN Version 1.0 (FCM), a chemical bioaccumulation model that simulates the transfer  
21 of contaminants in aquatic food webs. Relevant previous applications include the calculation of  
22 PCB bioaccumulation in the Hudson River (QEA, 1999) and PCB bioaccumulation in the Lower  
23 Fox River and Green Bay (QEA, 2001).

24 FCM uses a bioenergetics-based approach to model uptake and elimination of PCBs in  
25 invertebrates and fish. The model represents several trophic levels including predatory fish,  
26 forage fish, bottom-feeding fish, and the invertebrates at the base of the food web that consume  
27 particulate material in the water column and sediment bed. Contaminant concentrations within

1 biota are tracked and output in units of micrograms per gram wet weight ( $\mu\text{g/g-ww}$ ). For the  
2 Housatonic River application, the model is being run using a daily time step.

3 FCM includes two submodels, an invertebrate uptake model and a fish uptake model. The  
4 invertebrate submodel is a steady-state model in which kinetic formulations are used to calculate  
5 the relationship between uptake and elimination processes. The fish uptake submodel also uses  
6 kinetic formulations to determine the rate of chemical uptake and elimination, but the total  
7 concentration of contaminant is solved using differential equations. The fish submodel also uses  
8 more complex equations to calculate food consumption due to bioenergetics and to calculate  
9 elimination processes within each species. Typically, invertebrate species are simulated using a  
10 single model compartment whereas fish species are simulated using an appropriate set of age  
11 classes.

# 1 1. INTRODUCTION

## 2 1.1 OVERVIEW

3 Historical releases of certain classes of organic and inorganic contaminants into waterbodies  
4 have left a legacy of aquatic sediment enriched with these contaminants. In some sediments,  
5 these contaminants have accumulated to concentrations that may pose unacceptable human  
6 health and ecological risks. Of particular concern is the historical release to waterbodies of  
7 compounds that are toxic, persistent, and bioaccumulate in the food chain, including  
8 polychlorinated biphenyls (PCBs).

9 PCBs historically were released to the Housatonic River (see Figure 1-1) from the General  
10 Electric Company (GE) facility in Pittsfield, MA. Over a period of decades, these compounds  
11 have accumulated in river sediment in Massachusetts and Connecticut. High-flow events have  
12 transported PCB-laden solids onto the adjacent floodplain. Data collected from 1982 to the  
13 present have documented the magnitude and extent of the PCB contamination of the sediment  
14 and floodplain soil adjacent to the Housatonic River downstream of the GE facility. The extent  
15 of the PCB contamination has been determined to fall within the 10-year floodplain of the  
16 Housatonic River (BBL and QEA, 2003).

17 In addition, PCBs in fish tissue have accumulated to concentrations that pose a risk to human  
18 health (EPA, 1998a; WESTON, 2003). A recent U.S. Geological Survey (USGS) report  
19 (Garabedian et al., 1998) noted that PCB concentrations in streambed sediment and fish tissue in  
20 the Housatonic River are some of the highest of all the National Water-Quality Assessment  
21 Program (NAWQA) study sites across the country. The State of Connecticut posted a fish  
22 consumption advisory for most of the Connecticut section of the river in 1977 as a result of the  
23 PCB contamination in the river sediments and fish tissue. In 1982, the Massachusetts  
24 Department of Public Health (MDPH) issued a consumption advisory for fish, frogs, and turtles  
25 for the Housatonic River. In addition, in 1999, MDPH issued a waterfowl consumption advisory  
26 from Pittsfield to Great Barrington due to PCB concentrations in wood ducks and mallards  
27 collected from the river by the U.S. Environmental Protection Agency (EPA) and Massachusetts  
28 Division of Fisheries and Wildlife.

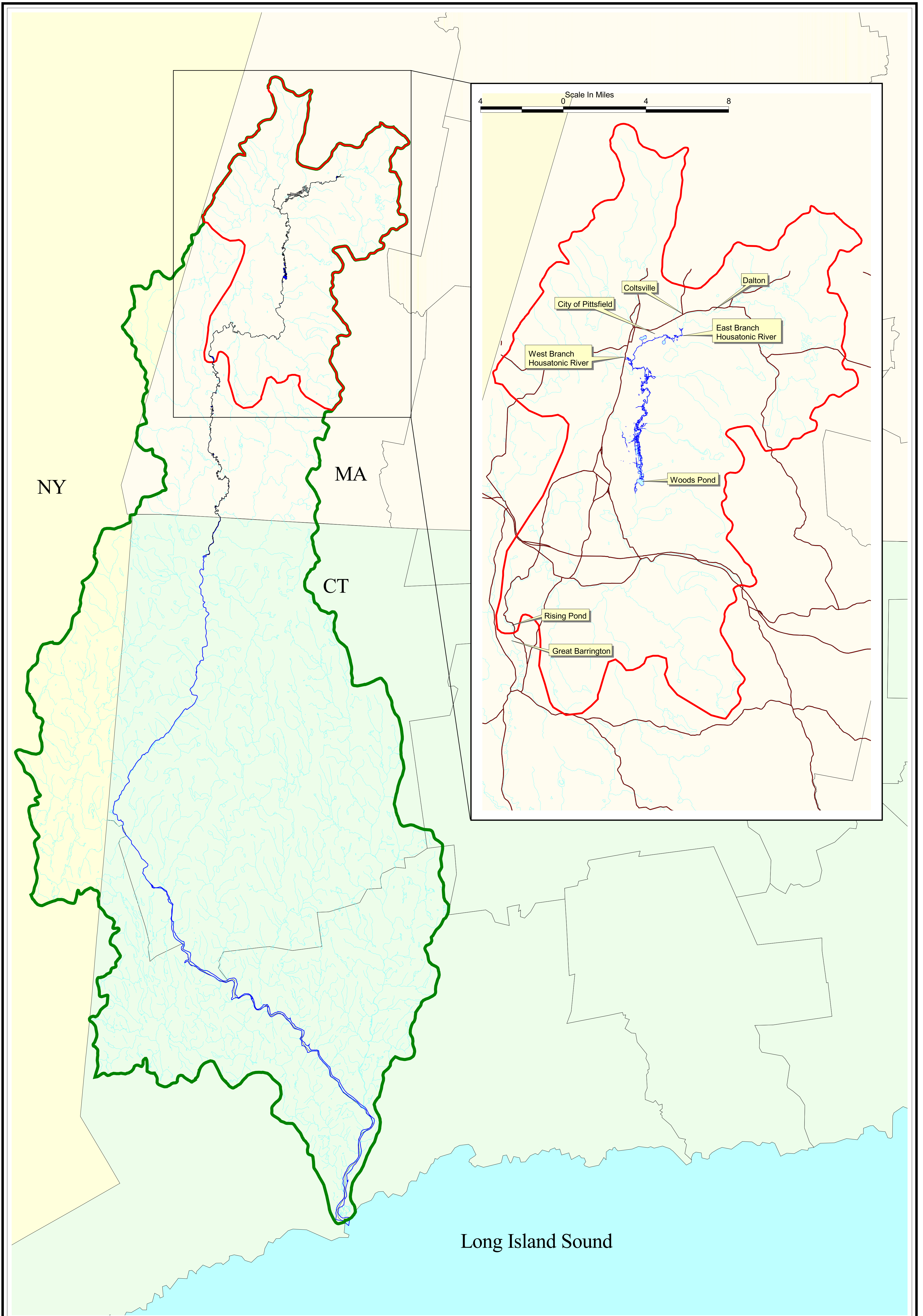
1 In September 1998, after years of scientific investigations and regulatory actions, a  
2 comprehensive agreement was reached between GE and various governmental entities, including  
3 the U.S. Environmental Protection Agency (EPA), Massachusetts Department of Environmental  
4 Protection (MDEP), the U.S. Department of Justice (DOJ), Connecticut Department of  
5 Environmental Protection (CTDEP), and the City of Pittsfield. The agreement provides for the  
6 investigation and cleanup of the Housatonic River and associated areas. The agreement has been  
7 documented in a Consent Decree between all parties that was lodged with the Federal Court in  
8 October 1999, and entered by the court in October 2000. Under the terms of the Consent Decree,  
9 EPA is conducting the human health and ecological risk assessments, as well as the modeling  
10 study of PCB transport and fate for the Housatonic River below the confluence of the East and  
11 West Branches (“Rest of River”) and the surrounding watershed.




12 The Consent Decree also includes specific language that requires the risk assessments and  
13 components of the modeling studies to be submitted for formal Peer Review. This report, the  
14 proposed Modeling Framework Design (MFD), was the first component of the modeling study to  
15 be submitted for Peer Review. The Peer Review was conducted in April 2001, and EPA issued a  
16 Responsiveness Summary in June 2002. This final MFD reflects the input of the Peer Review  
17 panel.

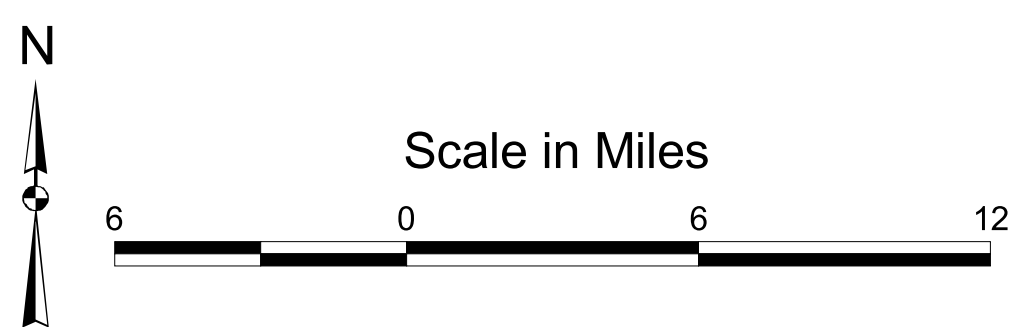
## 18 **1.2 PURPOSE AND OBJECTIVES OF THE HOUSATONIC RIVER MODELING** 19 **STUDY**

20 Evaluation of the risks posed to human health and the environment from contaminated sediment  
21 often requires the application of watershed/hydrodynamic/water quality models and contaminant  
22 fate and bioaccumulation models to address the full range of migration pathways of  
23 contaminants released to the environment, and potential exposures under future conditions. The  
24 use of a fully integrated modeling framework is needed to produce a scientifically defensible  
25 application of models to support regulatory decisionmaking.

26 The proposed modeling study design was developed to (1) represent the range of physical,  
27 chemical, and biological processes of concern for PCB fate, transport, and bioaccumulation in  
28 the Housatonic River watershed; and (2) address each of the following site-specific study  
29 objectives:



- LEGEND:**
-  Surface Hydrology
  -  Housatonic Watershed Boundary
  -  Watershed Area Above Great Barrington



**GE/Housatonic River Project  
Pittsfield, Massachusetts**

**FIGURE 1-1  
HOUSATONIC RIVER  
WATERSHED**

- 1           ▪ Quantify future spatial and temporal distribution of PCBs (both dissolved and  
2           particulate forms) within the water column and bed sediment.
- 3           ▪ Quantify the historical and relative contributions of various sources of PCBs on  
4           ambient water quality and bed sediment.
- 5           ▪ Quantify the historical and relevant contribution of various PCB sources to  
6           bioaccumulation in targeted species.
- 7           ▪ Estimate the time required for PCB-laden sediment to be effectively sequestered by  
8           the deposition of “clean” sediment (i.e., natural recovery).
- 9           ▪ Estimate the time required for PCB concentrations in fish tissue to be reduced to  
10          levels that no longer pose either a human health or ecological risk based on various  
11          remediation and restoration scenarios, including allowing for natural recovery.
- 12          ▪ Quantify the relative risk(s) of extreme storm event(s) contributing to the  
13          resuspension of sequestered sediment and the redistribution of PCB-laden sediment  
14          within the area of study.

### 15   **1.3 BROADER MODELING STUDY OBJECTIVES**

16   In addition to meeting the site-specific objectives, the modeling study was designed to achieve  
17   even more basic objectives inherent to the successful execution of any modeling effort. These  
18   broader objectives are discussed below.

#### 19   **1.3.1 Achieving Mass Balance**

20   A fundamental test of any complex modeling study is to demonstrate that “mass balance” has  
21   been achieved for each of the primary constituents being modeled. For this investigation, the  
22   primary constituents being modeled are water, solids, and PCBs. The principle behind achieving  
23   a mass balance is to ensure that all inputs, outputs, and internal source/sink terms have been  
24   properly accounted for in the models, which requires an accurate representation of the relevant  
25   physical, chemical, biological, and geologic processes within the models.

##### 26   **1.3.1.1 Water Mass Balance**

27   The modeling study must achieve an overall water mass balance that reproduces the historical  
28   distribution of observed flows within the Housatonic River. This is an important component of  
29   the analysis, given the role hydrodynamics play in the physical transport of solids and PCBs. To

1 impose an appropriate external forcing function on the hydrodynamic model, a calibrated and  
2 validated hydrologic model must be developed. The hydrologic model accounts for tributary  
3 flows into the region covered by the hydrodynamic model as well as movement of water through  
4 the main river channel at the boundaries of the hydrodynamic model.

5 The hydrologic model establishes these external boundary conditions to the hydrodynamic model  
6 under both historical conditions and projected future conditions. The hydrodynamic model, in  
7 turn, uses the external boundary conditions to simulate the distribution of flows within the  
8 system and resulting internal forces acting on the sediment bed. To represent future conditions,  
9 an implicit assumption is made that historical conditions (e.g., spatial and temporal distribution  
10 of flow and solids) are representative of future conditions. A validated hydrologic model  
11 provides the technical basis for developing probability-based, future boundary conditions to the  
12 hydrodynamic model.

### 13 **1.3.1.2 Solids Mass Balance**

14 Because of the preferential adsorption of PCBs to solids, achieving mass balance of solids is  
15 important to the success of the model in accurately representing the conditions in the system. A  
16 change in the solids mass balance will ultimately affect the overall PCB mass balance. The  
17 purpose of the solids mass balance is to ensure that both short- and long-term transport of solids  
18 can be reproduced.

### 19 **1.3.1.3 PCB Mass Balance**

20 The PCB mass balance is the primary objective of this study. Numerous complex fate and  
21 transport processes influence the distribution of PCBs within the river and the floodplain.  
22 Definition of the PCB mass balance requires accurate source characterization and representation  
23 of the distribution of PCBs in the conceptual model for the site.



### 1 **1.3.2 Ability to Provide an Estimation of Future Conditions**

2 The primary objective that will be pursued after achieving acceptable mass balance in the models  
3 is to answer questions regarding the future spatial and temporal distribution of PCBs in the  
4 various media under baseline conditions and with different potential remedial scenarios.

5 The ability of any model to reasonably answer questions and/or predict future conditions that  
6 span a period of decades must be carefully considered. Consequently, in the final analysis a  
7 “weight-of-evidence” approach will be taken, including all available information and tools in  
8 addition to the model output.

### 9 **1.3.3 Evaluation of Uncertainty**

10 Any modeling study presumes that the fundamental questions to be answered with the assistance  
11 of models are known a priori. This is an appropriate assumption given that a scientifically valid  
12 modeling framework cannot be defined otherwise. Since the modeling framework provides the  
13 mathematical representation of the science underlying the study, it is necessary that the models  
14 applied within the framework are appropriate for the purpose of answering these questions. In  
15 other words, the models must incorporate algorithms that are credible representations of real-  
16 world processes.

17 Because natural systems inherently have complex, random, and nonlinear processes that cannot  
18 be accounted for in any model, any model formulation strives for a compromise between  
19 physical reality and practicality. This is particularly true of numerous physical, chemical, and  
20 biological processes occurring within this system. In many cases, no empirical or predictive  
21 methods exist that would allow a model to reproduce the consequences of these processes.

22 However, one cannot simply dismiss these processes as only introducing marginal or second-  
23 order error terms into the solids and PCB mass balance equations because no empirical  
24 relationships exist to predict their distribution and occurrence. Therefore, as stated above, model  
25 output will be augmented using a “weight-of-evidence” approach with other nondeterministic  
26 methods to reduce the degree of uncertainty associated with these processes. In addition, effort  
27 has been made to identify other areas of uncertainty such as changes in channel dimensions,

- 1 entrainment of slumped bank sediment, partitioning behavior of PCBs, population fluctuations,
- 2 and seasonal macrophyte die-back.