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HUDSON RIVER PCBs REASSESSMENT RI/FS
RESPONSIVENESS SUMMARY FOR
VOLUME 2D - BASELINE MODELING REPORT

FEBRUARY 2000

For

U.S. Environmental Protection Agency
Region 2
and
U.S. Army Corps of Engineers
Kansas City District

Book 1 of 1

TAMS Consultants, Inc.
Limno-Tech, Inc.
Menzie-Cura & Associates, Inc.
TetraTech, Inc.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 2
290 BROADWAY
NEW YORK, NY 10007-1866

February 22, 2000

To All Interested Parties:

The U.S. Environmental Protection Agency (EPA) is pleased to release this Responsiveness Summary to the Baseline Modeling Report for the Hudson River PCBs Superfund site.

For most Reassessment reports, EPA modifies the Review Copy of a particular report through the Responsiveness Summary for that report. In the case of the May 1999 Baseline Modeling Report (BMR), EPA decided that it would be more appropriate to issue a revised report in addition to the Responsiveness Summary. The Revised BMR was released in January 2000, and supercedes the May 1999 BMR. The Revised BMR incorporates changes made to the models based on comments received during the public comment period on the BMR and from additional analyses that were conducted to refine the models for predicting future PCB levels in sediment, water and fish.

This Responsiveness Summary explains how significant comments on the May 1999 BMR were addressed. Many of the responses direct the reader to the appropriate sections of the text, tables or figures in the Revised BMR where the issue is addressed. For complete coverage, the Revised BMR and this Responsiveness Summary should be used together.

The Revised BMR is being peer reviewed by a panel of independent experts. The peer reviewers will discuss their comments on the Revised BMR at a meeting that will be held on March 27 and 28, 2000 at the Sheraton Saratoga Springs Hotel and Conference Center. Observers are welcome and there will be limited time for observer comment.

If you need additional information regarding the Responsiveness Summary to the Baseline Modeling Report, please contact Ann Rychlenski, the Community Relations Coordinator for this site, at (212) 637-3672.

Sincerely yours,

Richard L. Caspe, Director
Emergency and Remedial Response Division

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I. INTRODUCTION AND COMMENT DIRECTORY

1. INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) has prepared this Responsiveness Summary to address comments received during the public comment period on the Phase 2 Baseline Modeling Report (BMR) for the Hudson River PCBs Reassessment Remedial Investigation/Feasibility Study (Reassessment RI/FS), dated May 1999.

For the Hudson River PCBs Reassessment RI/FS, USEPA has established a Community Interaction Program (CIP) to elicit on-going feedback through regular meetings and discussion and to facilitate review of and comment upon work plans and reports prepared during all phases of the Reassessment RI/FS.

Because of the large number of CIP participants and associated costs of reproduction, the BMR is incorporated by reference and is not reproduced herein. A Revised BMR was released in January 2000. The Revised BMR supercedes the May 1999 BMR and incorporates the responses to comments found herein. Many of the responses within this document direct the reader to section of the Revised BMR where the issue is addressed. For complete coverage, the BMR and this Responsiveness Summary should be used together.

The first part of this four-part Responsiveness Summary is entitled, Introduction and Comment Directory. It describes the BMR review and commenting process, explains the organization and format of comments and responses, and contains a comment directory.

The second part, entitled Response to Comments on the Baseline Modeling Report, contains USEPA's responses to all significant written comments received on the BMR. Responses are grouped according to the Chapter and Section number of the BMR to which they refer. For example, responses to comments on Chapter/Section 3.2 of the BMR are found in Chapter/Section 3.2 of the Responsiveness Summary. Additional information about how to locate responses to comments is contained in the Comment Directory.

The third part, entitled, Comments on the Baseline Modeling Report, contains copies of the comments submitted to USEPA. The comments are identified by commenter and comment number, as further explained in the Comment Directory.

The fourth part is a commentary, prepared by USEPA, on the modeling report prepared by General Electric Company (GE) entitled *PCBs in the Upper Hudson River (QEA, 1999).* The GE modeling report is incorporated by reference and is not reproduced herein. USEPA has considered the GE modeling report as comment on the May 1999 BMR.

2. COMMENTING PROCESS

This section documents and explains the commenting process and the organization of comments and responses in this document. Readers interested in finding responses to their comments may skip this section and go directly to the tab labeled Comment Directory.

2.1 Distribution of BMR

The BMR, issued in May 1999, was distributed to federal and state agencies and officials, participants in the CIP, and General Electric Company (GE), as shown in Table 1. Distribution was made to approximately 100 agencies, groups, and individuals. Copies of the BMR were also made available for public review in 16 Information Repositories, as shown in Table 2, and the Executive Summary was made available on the USEPA Region 2 Internet webpage, entitled - Hudson River PCBs Superfund Site Reassessment, at www.epa.gov/hudson.

2.2 Review Period and Public Availability Meetings

Review of and comment on the BMR occurred from May 18, 1999 to June 23, 1999. On May 18, USEPA held a Joint Liaison Group meeting open to the public at the Holiday Inn at Latham, New York. Subsequently, on June 16, USEPA sponsored an availability session at the Marriott Hotel in Albany, New York to answer questions from the public regarding the BMR. Minutes of the Joint Liaison Group meeting will be available for public review at the Information Repositories listed in Table 2.

As stated in USEPA's letter transmitting the BMR, all citizens were urged to participate in the Reassessment process and to join one of the Liaison Groups formed as part of the CIP.

2.3 Receipt of Comments

Comments on the BMR were received in two ways: letters and oral statements made at the May 18, 1999 Joint Liaison Group meeting. USEPA's responses to comments raised at the Joint Liaison Group meeting are provided in the meeting minutes.

All significant written comments received on the BMR are addressed in this Responsiveness Summary. Comments were received from eight commenters. Total comments numbered just over 200.

2.4 Distribution of Responsiveness Summary

This Responsiveness Summary will be distributed to the Liaison Group Chairs and Co-Chairs and interested public officials. This Responsiveness Summary will be placed in the 16 Information Repositories and is part of the Administrative Record.

TABLE 1
DISTRIBUTION OF BASELINE MODELING REPORT

HUDSON RIVER PCBs OVERSIGHT COMMITTEE MEMBERS

- USEPA ERRD Deputy Division Director (Chair)
- USEPA Project Managers
- USEPA Community Relations Coordinator, Chair of the Steering Committee
- NYSDEC Division of Hazardous Waste Management representative
- NYSDEC Division of Construction Management representative
- National Oceanic and Atmospheric Administration (NOAA) representative
- Agency for Toxic Substances and Disease Registry (ATSDR) representative
- US Army Corps of Engineers representative
- New York State Thruway Authority (Department of Canals) representative
- USDOI (US Fish and Wildlife Service) representative
- New York State Department of Health representative
- GE representative
- Liaison Group Chairpeople (4)
- Scientific and Technical Committee representative

SCIENTIFIC AND TECHNICAL COMMITTEE MEMBERS

The members of the Science and Technical Committee (STC) are scientists and technical researchers who provide technical input by evaluating the scientific data collected on the Reassessment RI/FS, identifying additional sources of information and on-going research relevant to the Reassessment RI/FS, and commenting on USEPA documents. Members of the STC are familiar with the site, PCBs, modeling, toxicology, and other relevant disciplines.

- Dr. Daniel Abramowicz
- Dr. Donald Aulenbach
- Dr. James Bonner, Texas A&M University
- Dr. Richard Bopp, Rensselaer Polytechnic Institute
- Dr. Brian Bush, New York State Department of Health
- Dr. Lenore Clesceri, Rensselaer Polytechnic Institute
- Mr. Kenneth Darmer
- Mr. John Davis, New York State Dept. of Law
- Dr. Robert Dexter, EVS Consultants, Inc.
- Dr. Kevin Farley, Manhattan College
- Dr. Jay Field, National Oceanic and Atmospheric Administration
- Dr. Ken Pearsall, U.S. Geological Survey
- Dr. John Herbich, Texas A&M University
- Dr. Behrus Jahan-Parwar, SUNY - Albany
- Dr. Nancy Kim, New York State Dept. of Health
- Dr. William Nicholson, Mt. Sinai Medical Center
- Dr. George Putman, SUNY - Albany
- Dr. G-Yull Rhee, New York State Dept. of Health
- Dr. Francis Reilly, The Reilly Group
- Ms. Anne Secord, U.S. Fish and Wildlife Service
- Dr. Ronald Sloan, New York State Dept. of Environmental Conservation

TABLE 1
DISTRIBUTION OF BASELINE MODELING REPORT (cont.)

STEERING COMMITTEE MEMBERS

- USEPA Community Relations Coordinator (Chair)
- Governmental Liaison Group Chair and two Co-chairs
- Citizen Liaison Group Chair and two Co-chairs
- Agricultural Liaison Group Chair and two Co-chairs
- Environmental Liaison Group Chair and two Co-chairs
- USEPA Project Managers
- NYSDEC Technical representative
- NYSDEC Community Affairs representative

FEDERAL AND STATE REPRESENTATIVES

Copies of the BMR were sent to relevant federal and state representatives who have been involved with this project. These include, in part, the following:

- The Hon. Daniel P. Moynihan
- The Hon. Charles Schumer
- The Hon. John Sweeney
- The Hon. Nita Lowey
- The Hon. Maurice Hinchey
- The Hon. Ronald B. Stafford
- The Hon. Michael McNulty
- The Hon. Sue Kelly
- The Hon. Benjamin Gilman
- The Hon. Richard Brodsky
- The Hon. Bobby D=Andrea

16 INFORMATION REPOSITORIES (*see* Table 2)

TABLE 2
INFORMATION REPOSITORIES

Adriance Memorial Library
93 Market Street
Poughkeepsie, NY 12601

Catskill Public Library
1 Franklin Street
Catskill, NY 12414

• Cornell Cooperative Extension
Sea Grant Office
74 John Street
Kingston, NY 12401

Crandall Library
City Park
Glens Falls, NY 12801

County Clerk=s Office
Washington County Office Building
Upper Broadway
Fort Edward, NY 12828

* • Marist College Library
Marist College
290 North Road
Poughkeepsie, NY 12601

* New York State Library
CEC Empire State Plaza
Albany, NY 12230

New York State Department
of Environmental Conservation
Division of Environmental Remediation
50 Wolf Road, Room 212
Albany, NY 12233

* • R.G. Folsom Library
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

Saratoga County EMC
50 West High Street
Ballston Spa, NY 12020

* Saratoga Springs Public Library
49 Henry Street
Saratoga Springs, NY 12866

*• SUNY at Albany Library
1400 Washington Avenue
Albany, NY 12222

* • Sojourner Truth Library
SUNY at New Paltz
New Paltz, NY 12561

Troy Public Library
100 Second Street
Troy, NY 12180

U.S. Environmental Protection Agency
Region 2
290 Broadway
New York, NY 10007

White Plains Public Library
100 Martine Avenue
White Plains, NY 12601

* **Repositories with Database Report CD-ROM (as of 10/98)**

• **Repositories without Project Documents Binder (as of 10/98)**

3. ORGANIZATION OF BMR COMMENTS AND RESPONSIVENESS SUMMARY

3.1 Identification of Comments

Each submission commenting on the BMR was assigned the letter "B" for BMR and one of the following letter codes:

F - Federal agencies and officials;
S - State agencies and officials;
L - Local agencies and officials;
G - GE; and
C - Community.

The letter codes were assigned for the convenience of readers and to assist in the organization of this document. Priority or special treatment was neither intended nor given in the responses to comments.

Once a letter code was assigned, each submission was then assigned a number, in the order that it was received and processed, such as BF-1. Each different comment within a submission was assigned a separate sub-number. Thus, if a federal agency submission contained three different comments, they would be designated as BF-1.1, BF-1.2, and BF-1.3. Written comment letters are reprinted following the fourth tab of this document.

The alphanumeric code associated with each reprinted written submission is marked at the top right corner of the first page of the comment letter. The subnumbers designating individual comments are marked in the margin. Comment submissions are reprinted in numerical order by letter code in the following order: BF, BS, BL, BG, and BC.

3.2 Location of Responses to Comments

The Comment Directory, following this text, contains a complete listing of all commenters and comments. This directory allows readers to find responses to comments and provides several items of information.

- The first column lists the names of the commenters. Comments are grouped first by: BF (Federal), BS (State), BL (Local), BG (GE) or BC (Community).

- The second column identifies the alphanumeric comment code (*e.g.*, BF-1.1)

- The third column identifies the location of the response by BMR Chapter/Section number. For example, comments raised on Chapter/Section 3.2 of the BMR can be found in the corresponding Chapter/Section 3.2 of the Responses, following the third tab of this document.

- The fourth, fifth, and sixth columns list key words that describe the subject matter of each comment. Readers will find these key words helpful as a means to identify subjects of interest and related comments.

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Responses are grouped and consolidated by chapter number of the BMR in order that all responses to related comments appear together for the convenience of the reader interested in responses to related or similar comments.

For the convenience of the reader, comments have been reproduced directly above their respective responses. Where it was not practical to reproduce an entire comment, EPA reproduced portions of the comment which the Agency believes capture the major points raised by that comment. In order to read the comments in their entirety, however, readers are encouraged to refer to the original comment letters reproduced in Section III of this Responsiveness Summary.

4. COMMENT DIRECTORY

4.1 Guide to Comment Directory

This section contains a diagram illustrating how to find responses to comments. The Comment Directory follows. As stated in the Introduction, this document does not reproduce the BMR. Readers are urged to use this Responsiveness Summary in conjunction with the BMR, as well as the Revised BMR.

Step 1	Step 2	Step 3
Find the commenter or the key words of interest in the Comment Directory.	Obtain the alphanumeric comment codes and the corresponding BMR Chapter / Section.	Find the responses following the Responses tab. See the Table of Contents to locate the page of the Responsiveness Summary for the BMR Chapter/Section.
Key to Comment Codes:		
Comment codes are in this format BX-a.b B = BMR X = Commenter Group (F = Federal, S = State, L = Local, G = GE, C = Community) a = Numbered letter containing comments b = Numbered comment		

Example:

COMMENT RESPONSE ASSIGNMENT FOR THE BMR

AGENCY/ Name	Comment CODE	REPORT SECTION	KEY WORDS		
			1	2	3
NOAA /Rosman	BF-1.14	1.3.2	Fractured bedrock	Seeps	PCB droplets

322008

4.2 COMMENT DIRECTORY

AGENCY/ NAME	BOOK NUMBER	COMMENT CODE	BMR REPORT SECTION	KEYWORDS		
				1	2	3
NOAA/Rosman	BOOKS 1 & 2	BF-1.1	General Comments-Book 1	Uncertainty	Data	Differences
NOAA/Rosman	BOOKS 1 & 2	BF-1.2	General Comments-Book 1	Oversimplification	Resuspension	Underestimation
NOAA/Rosman	BOOKS 1 & 2	BF-1.3	8.2.2	Boundary condition	High flow	Loading
NOAA/Rosman	BOOKS 1 & 2	BF-1.4	General Comments-Book 1	Floodplain	High flow	Underestimation
NOAA/Rosman	BOOKS 1 & 2	BF-1.5	General Comments-Book 1	Fish advisories	Congeners	HUDTOX
NOAA/Rosman	BOOKS 1 & 2	BF-1.6	General Comments-Book 1	100 year event	Flood	Development
NOAA/Rosman	BOOKS 1 & 2	BF-1.7	General Comments-Book 1	Flow	Tri+ PCBs	Transport
NOAA/Rosman	BOOKS 3 & 4	BF-1.8A	General Comments-Book 3	Goodness of fit	Uncertainty	Predictive tool
NOAA/Rosman	BOOKS 3 & 4	BF-1.8B	4.1.3	Nearshore exposure	Bioaccumulation model input	
NOAA/Rosman	BOOKS 3 & 4	BF-1.9	General Comments-Book 3	Water concentration	Summer average	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.10	General Comments-Book 3	Growth rate	Species specific	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.11	General Comments-Book 3	Lipid content	Spatial	Temporal
NOAA/Rosman	BOOKS 3 & 4	BF-1.12	General Comments-Book 3	Variability	Validation	HUDTOX
NOAA/Rosman	BOOKS 3 & 4	BF-1.13	General Comments-Book 3	Goodness of fit	Uncertainty	Predictive tool
NOAA/Rosman	BOOKS 1 & 2	BF-1.14	1.3.2	Fractured Bedrock	Seeps	PCB droplets
NOAA/Rosman	BOOKS 1 & 2	BF-1.15	4.3.1	Coarse	TIP	Cohesive
NOAA/Rosman	BOOKS 1 & 2	BF-1.16	4.3.1	Surficial	Median	Mean
NOAA/Rosman	BOOKS 1 & 2	BF-1.17	4.4.2	High resolution cores	Interpolation	Vertical mixing
NOAA/Rosman	BOOKS 1 & 2	BF-1.18	5.2.2	DOC	Forcing function	Water-column
NOAA/Rosman	BOOKS 1 & 2	BF-1.19	5.2.3	Mass balance	HUDTOX	Material
NOAA/Rosman	BOOKS 1 & 2	BF-1.20	5.2.3	Sediment	Particle Mixing	Vertical mixing
NOAA/Rosman	BOOKS 1 & 2	BF-1.21	5.2.3	Particle mixing	Cohesive	Non-cohesive
NOAA/Rosman	BOOKS 1 & 2	BF-1.22	5.2.3	Sediment	Bed handling	Vertical mixing
NOAA/Rosman	BOOKS 1 & 2	BF-1.23	5.2.3, Figs. 5-2 and 5-3	Scour	Burial	Dilution
NOAA/Rosman	BOOKS 1 & 2	BF-1.24	5.2.3	Temperature	Partitioning	Data source
NOAA/Rosman	BOOKS 1 & 2	BF-1.25	6.3.1	Bias	Correction factors	Differences
NOAA/Rosman	BOOKS 1 & 2	BF-1.26	6.4.3	Solids	Load	Discrepancy
NOAA/Rosman	BOOKS 1 & 2	BF-1.27	6.4.3	Tributary load	Rating curve	Adjustment factor
NOAA/Rosman	BOOKS 1 & 2	BF-1.28	6.4.4 & Table 6-18	BZ#4	BZ#52	Tri+
NOAA/Rosman	BOOKS 1 & 2	BF-1.29	6.4.4	Boundary condition	Pulse loads	Resuspension
NOAA/Rosman	BOOKS 1 & 2	BF-1.30	7.2.2	Calibration	Strategy	Congener
NOAA/Rosman	BOOKS 1 & 2	BF-1.31	7.3.1, Table 7-1	Solids	Resuspension	Sensitivity
NOAA/Rosman	BOOKS 1 & 2	BF-1.32	7.3.2, Table 7-5	Calibration	Parameter	Congener
NOAA/Rosman	BOOKS 1 & 2	BF-1.33	7.3.1, Fig. 7-2	Resuspension	Settling	Rates
NOAA/Rosman	BOOKS 1 & 2	BF-1.34	7.3.2, Fig. 7-4	Temperature	Database	Phase 2
NOAA/Rosman	BOOKS 1 & 2	BF-1.35	7.3.2	Diffusion	Solids	Transport

AGENCY/ NAME	BOOK NUMBER	COMMENT CODE	BMR REPORT SECTION	KEYWORDS		
				1	2	3
NOAA/Rosman	BOOKS 1 & 2	BF-1.36	7.3.2	Temperature	Diffusive	Mass transfer
NOAA/Rosman	BOOKS 1 & 2	BF-1.37	7.3.2	Mass transfer	Contraints	Particulates
NOAA/Rosman	BOOKS 1 & 2	BF-1.38	7.4.2, Fig. 7-10a-c	Calibration	Underestimate	TSS
NOAA/Rosman	BOOKS 1 & 2	BF-1.39	7.4.2, Fig. 7-16	Congener	Linear scale	Underestimates
NOAA/Rosman	BOOKS 1 & 2	BF-1.40	7.4.3	Load	Ft. Edward	Schuyerville
NOAA/Rosman	BOOKS 1 & 2	BF-1.41	7.4.3	Surficial	Sediment	Data points
NOAA/Rosman	BOOKS 1 & 2	BF-1.42	7.4.3	Simulations	Surface	Sediment
NOAA/Rosman	BOOKS 1 & 2	BF-1.43	7.4.3	Calibration	Results	Vertical distribution
NOAA/Rosman	BOOKS 1 & 2	BF-1.44	7.5	TIP	Sediment	Trapping efficiencies
NOAA/Rosman	BOOKS 1 & 2	BF-1.45	7.5, Fig. 7-26	Dispersion	TID	Schuyerville
NOAA/Rosman	BOOKS 1 & 2	BF-1.46	7.5, Fig. 7-29	TIP	Particulate	PCB transfer
NOAA/Rosman	BOOKS 1 & 2	BF-1.47	7.5	TIP	BZ#4	BZ#52
NOAA/Rosman	BOOKS 1 & 2	BF-1.48	7.5	Hotspot	Low Resolution Coring Report	
NOAA/Rosman	BOOKS 1 & 2	BF-1.49	7.6	Uncertainties	Incomplete	Processes
NOAA/Rosman	BOOKS 1 & 2	BF-1.50	8.2.2, Fig. 8-4	Initial condition	TIP	Surficial
NOAA/Rosman	BOOKS 1 & 2	BF-1.51	8.3.2, Fig. 8-7	100 year event	TID flux	event
NOAA/Rosman	BOOKS 1 & 2	BF-1.52	8.3.2, Fig. 8-7	Resuspended	100 year	Redeposition
NOAA/Rosman	BOOKS 1 & 2	BF-1.53	8.3.1	100 year event	Simulation	High flow
NOAA/Rosman	BOOKS 3 & 4	BF-1.54	1.1	Fishing ban	Striped Bass	Consumption advisory
NOAA/Rosman	BOOKS 3 & 4	BF-1.55	3.3.2	Forcing functions	__	__
NOAA/Rosman	BOOKS 3 & 4	BF-1.56	3.3.2	Water column	Exposure	Formula
NOAA/Rosman	BOOKS 3 & 4	BF-1.57	3.4.1	PFCM	Seasonal	Exposure
NOAA/Rosman	BOOKS 3 & 4	BF-1.58	3.4.2	PFCM	Model structure	Near-shore
NOAA/Rosman	BOOKS 3 & 4	BF-1.59	3.4.2	Monte Carlo	Variability	Uncertainty
NOAA/Rosman	BOOKS 3 & 4	BF-1.60	3.4.5.3	Forage fish	Size	
NOAA/Rosman	BOOKS 3 & 4	BF-1.61	3.4.5.4	Fish diet	Invertebrate	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.62	3.4.5.4	Fish diet	Fish species	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.63	3.4.5.5	BSAF	--	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.64	3.4.5.5	Brown bullhead	BAF	BSAF
NOAA/Rosman	BOOKS 3 & 4	BF-1.65	3.5.2	Equation 3-8	--	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.66	General Comments-Book 3	Growth rate	Species specific	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.67	4.0	White perch	Trophic level	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.68	4.1.2	Exposure	Water	Brown bullhead
NOAA/Rosman	BOOKS 3 & 4	BF-1.69	4.1.3	Bias correction factor	USGS data	Near-shore
NOAA/Rosman	BOOKS 3 & 4	BF-1.70	4.1.4	Functional groups	Sampling locations	Lower river
NOAA/Rosman	BOOKS 3 & 4	BF-1.71	4.2	Regression	Sediment	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.72	4.2	Table 4-10	--	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.73	4.2	Log-log	--	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.74	4.1.2	Dissolved	Phase distribution	DEIR
NOAA/Rosman	BOOKS 3 & 4	BF-1.75	5.1	Lipid	Datasets	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.76	5.1.3	Dataset	NYSDEC	Aroclors
NOAA/Rosman	BOOKS 3 & 4	BF-1.77	5.2.1	Dataset	Sediment	Depth
NOAA/Rosman	BOOKS 3 & 4	BF-1.78	5.2.3	BSAF	Text	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.79	5.2.3	BSAF	Text	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.80	5.2.3	BSAF	Variability	River mile
NOAA/Rosman	BOOKS 3 & 4	BF-1.81	5.3.1	Novak	Chironomid	Water
NOAA/Rosman	BOOKS 3 & 4	BF-1.82	5.4.1	Forage fish	Spottail shiner	Epibenthic
NOAA/Rosman	BOOKS 3 & 4	BF-1.83	5.4.2	Forage fish	Figure 5-5	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.84	5.4.3	Variability	Concentrations	Coefficient of variation

AGENCY/ NAME	BOOK NUMBER	COMMENT CODE	BMR REPORT SECTION	KEYWORDS		
				1	2	3
NOAA/Rosman	BOOKS 3 & 4	BF-1.85	5.4.3	Source	Fish	Body burden
NOAA/Rosman	BOOKS 3 & 4	BF-1.86	5.4.3	Forage fish	Spottail shiner	Fish diet
NOAA/Rosman	BOOKS 3 & 4	BF-1.87	5.5	Model structure	Accumulation factor	Averaging
NOAA/Rosman	BOOKS 3 & 4	BF-1.88	5.5.1	Largemouth bass	Accumulation factor	Averaging
NOAA/Rosman	BOOKS 3 & 4	BF-1.89	5.7	Dates	Biomagnification	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.90	5.7	Model structure	Seasonal	Bioenergetic
NOAA/Rosman	BOOKS 3 & 4	BF-1.91	5.7	Goodness of fit	PFCM	Lipid normalized
NOAA/Rosman	BOOKS 3 & 4	BF-1.92	6.1	Datasets	--	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.93	6.1.1.2	Temperature	Near-shore	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.94	General Comments-Book 3	Datasets	Lipid	Spatial
NOAA/Rosman	BOOKS 3 & 4	BF-1.95	6.2	Goodness of fit	Relative percent difference	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.96	6.2	Seasonal	Fish diet	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.97	7.1.2	Model predictions	Target levels	ARAR
NOAA/Rosman	BOOKS 3 & 4	BF-1.98	8.1.2.2	Uncertainty	Feeding strategy	Variability
NOAA/Rosman	BOOKS 3 & 4	BF-1.99	8.2	BSAF	Biomagnification	Gobas
NOAA/Rosman	BOOKS 3 & 4	BF-1.100	8.2.1	Uncertainty	Sensitivity analysis	--
NOAA/Rosman	BOOKS 3 & 4	BF-1.101	9.0	ARAR	Target levels	Ecological
NOAA/Rosman	BOOKS 3 & 4	BF-1.102	9.0	Uncertainity	Old water column concentration	
NYSDEC/Ports	BOOKS 1 & 2	BS-1.1	Exec. Summ.	Forecast	Solids	Loadings
NYSDEC/Ports	BOOKS 1 & 2	BS-1.2	Exec. Summ.	Reactivation	Resuspension	100 year
NYSDEC/Ports	BOOKS 3 & 4	BS-1.3	General Comments-Book 3	Fish PCB Concentration	Stillwater Pool	TI Pool
NYSDEC/Ports	BOOKS 1 & 2	BS-1.4	3.3.1	Maximum Stress	Lower velocity	
NYSDEC/Ports	BOOKS 1 & 2	BS-1.5	4.4.2	Erosion	TIP	
NYSDEC/Ports	BOOKS 1 & 2	BS-1.6	6.4.4	Future work	Forecast simulation	HUDTOX model
NYSDEC/Ports	BOOKS 1 & 2 BOOKS 3 & 4	BS-1.7	7.4.3 General Comments-Book 3	Surficial sediment	0-4 cm	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.8	5.5	Seasonal variation		
NYSDEC/Ports	BOOKS 1 & 2	BS-1.9	7.5	Terminology	PCB transfer	
NYSDEC/Ports	BOOKS 1 & 2	BS-1.10	3.3.1	Flood plain		
NYSDEC/Ports	BOOKS 1 & 2	BS-1.11	7.4.2	Figure's quality		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.12	1.1	Fishing ban and advisories		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.13	2.2.3	Injestion of food/sediment	Other mechanisms	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.14	3.1	Eating preferences		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.15	3.4.2	Model structure	Simplification	Invertebrates
NYSDEC/Ports	BOOKS 3 & 4	BS-1.16	3.4.3	Summer foraging area		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.17	3.4.3	Rivermile	Federal dam	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.18	3.5.3	Overstatement	White perch	River distribution
NYSDEC/Ports	BOOKS 3 & 4	BS-1.19	4.0	Characterization	Largemouth bass	Yellow perch
NYSDEC/Ports	BOOKS 3 & 4	BS-1.20	4.1.1.3	PCB depuration	Egg expulsion	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.21	4.1.3	Consistency		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.22	4.1.4	Collection location	Shift	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.23	4.3	Age class	Pumpkinseed	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.24	5.1.1	Typo		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.25	5.2.3	BSAF		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.26	5.7	Peak	Fish concentration	

AGENCY/ NAME	BOOK NUMBER	COMMENT CODE	BMR REPORT SECTION	KEYWORDS		
				1	2	3
NYSDEC/Ports	BOOKS 3 & 4	BS-1.27	General Comments-Book 3	Lipid content	Variability	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.28	3.4.3	Rivermile	152 and 154	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.29	7.1.2	Population		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.30	8.0	Regression model	Uncertainity	Future prediction
NYSDEC/Ports	BOOKS 3 & 4	BS-1.31	9.1	Reference	Goldfish and carp	Food web model
NYSDEC/Ports	BOOKS 3 & 4	BS-1.32	9.2	Confusion	Data and location	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.33	9.2	Typo		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.34	General Comments-Book 3	Yellow perch		
NYSDEC/Ports	BOOKS 3 & 4	BS-1.35	9.2	Uncertainty	Fish conentration	Location and year
NYSDEC/Ports	BOOKS 3 & 4	BS-1.36	General Comments-Book 3	Model	Additional work	
NYSDEC/Ports	BOOKS 3 & 4	BS-1.37	General Comments-Book 3	Congener model		
NYSDEC/Ports	General	BS-1.38	General Comments	Model comparison		
SCEMC/Adams	General	BL-1A	General Comments	Peer Review	Model comparison	
SCEMC/Adams	BOOKS 1 & 2	BL-1.1	General Comments-Book 1	Data	Rationale	Discussion
SCEMC/Adams	BOOKS 1 & 2	BL-1.2	3.2.1	Mannings "n"	cohesive	non-cohesive
SCEMC/Adams	BOOKS 1 & 2	BL-1.3	3.3.3	Flows	DOSM	Lick
SCEMC/Adams	BOOKS 1 & 2	BL-1.4	3.3.4	Tributary flows	Rating curve	TIP
SCEMC/Adams	BOOKS 1 & 2	BL-1.5	3.5.1	Cross-section	Mid-point	USGS
SCEMC/Adams	BOOKS 1 & 2	BL-1.6	3.8	Calibration	Validate	Flow model
SCEMC/Adams	BOOKS 1 & 2	BL-1.7	4.3.3	Armoring	Non-cohesive	GE approach
SCEMC/Adams	BOOKS 1 & 2	BL-1.8	6.4.4	Missing PCB	Interpolation	Seasonal averages
SCEMC/Adams	BOOKS 1 & 2	BL-1.9	7.3.1 & Table 7-1	Calibration	Values	Parameters
SCEMC/Adams	BOOKS 1 & 2	BL-1.10	7.3.1, Fig. 7-2	Curve	Lines	Labels
SCEMC/Adams	BOOKS 1 & 2	BL-1.11	7.3.2	Adjustments	Partitioning	Flexibility
SCEMC/Adams	BOOKS 1 & 2	BL-1.12	7.3.2	Calibration	Mass transfer	Seasonal variabiltiy
SCEMC/Adams	BOOKS 1 & 2	BL-1.13	7.3.2, Fig. 7-6b	Sediment-water	Transfer rates	TIP
SCEMC/Adams	BOOKS 1 & 2	BL-1.14	7.4.1	Parameters	Calibration	Results
SCEMC/Adams	BOOKS 1 & 2	BL-1.15	7.4.3, Fig. 7-24	Bias	Overestimate	Projections
SCEMC/Adams	BOOKS 1 & 2	BL-1.16	7.5	Depositional	Burial	Cohesive
SCEMC/Adams	BOOKS 1 & 2	BL-1.17	7.5	Transfer	Characteristics	Regions
SCEMC/Adams	BOOKS 1 & 2	BL-1.18	7.5	TIP	Burial	Cohesive
General Electric	General	BG-1A	General Comments	Peer Review	Model comparison	
General Electric	General	BG-1.1	General Comments	Model runs	Report content	
General Electric	BOOKS 3 & 4	BG-1.2	General Comments-Book 3	Growth rate	Species specific	--
General Electric	BOOKS 3 & 4	BG-1.3	General Comments-Book 3	Lipid content	Fillet	--
General Electric	BOOKS 3 & 4	BG-1.4	General Comments-Book 3 / 3.5.2.1	Model structure	Assumptions	Fish Diet
General Electric	BOOKS 3 & 4	BG-1.5	6.2	Model predictions	--	--
General Electric	BOOKS 3 & 4	BG-1.6	3.5.2	FISHRAND	Water	Partitioning
General Electric	BOOKS 3 & 4	BG-1.7	General Comments-Book 3	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.8	General Comments-Book 3	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.9	4	Bivariate statistical model	Water	Datasets
General Electric	BOOKS 1 & 2	BG-1.10	7.4	Comparisons	TSS	Concentrations
General Electric	BOOKS 1 & 2	BG-1.11	7.4	GE model	Settling speed	Net erosion
General Electric	BOOKS 1 & 2	BG-1.12	7.4.1	Solids fluxes	Constrain	Representation

AGENCY/ NAME	BOOK NUMBER	COMMENT CODE	BMR REPORT SECTION	KEYWORDS		
				1	2	3
General Electric	BOOKS 1 & 2	BG-1.13	7.4	Accuracy	Resuspension	Deposition
General Electric	BOOKS 1 & 2	BG-1.14	7.4.1	Mass balance	Spring floods	Data
General Electric	BOOKS 1 & 2	BG-1.15	7.4.2 (Figs. 7-9 and 7-10)	TSS	Compressed scales	Comparisons
General Electric	BOOKS 1 & 2	BG-1.16	7.5	Sedimentation rates	Predicted	Cs-137
General Electric	BOOKS 1 & 2	BG-1.17	7.4.3	Comparisons	Sediment	Calibration
General Electric	BOOKS 1 & 2	BG-1.18	7.4.3 (Fig. 7-25)	Comparisons	Sediment	Resolution
General Electric	BOOKS 1 & 2	BG-1.19	7.4.3	Scale	Bias	Data
General Electric	BOOKS 1 & 2	BG-1.20	7.2.2	Data	Calibration	Flow periods
General Electric	BOOKS 1 & 2	BG-1.21	6.3.2	Initial concentrations	Methodology	Assumptions
General Electric	BOOKS 1 & 2	BG-1.22	6.4.4	Pulse loads	Interpolation	Boundary
General Electric	BOOKS 1 & 2	BG-1.23	7.4.3	Sediment types	Comparisons	Methodology
General Electric	BOOKS 1 & 2	BG-1.24	7.4.3 (Fig. 7-24)	PCB flux	Assumptions	Methodology
General Electric	BOOKS 1 & 2	BG-1.25	7.3.2 (Table 7-4)	Data	POC	DOC
General Electric	BOOKS 1 & 2	BG-1.26	7.3.2 (Table 7-5)	Molecular weight	Henry's constant	Congener distribution
General Electric	BOOKS 1 & 2	BG-1.27	7.3.2 (Table 7-5)	Partition coefficients	Basis	POC
General Electric	BOOKS 1 & 2	BG-1.28	7.2	Sensitivity analyses	Calibration	Importance
General Electric	BOOKS 3 & 4	BG-1.29	6.2	Model predictions	--	--
General Electric	BOOKS 3 & 4	BG-1.30	3.5.2.1	Model structure	Assumptions	
General Electric	General	BG-1.31	General Comments	Model	Report content	
General Electric	BOOKS 1 & 2	BG-1.32	7.4.2	Validity	Overestimates	Bias
General Electric	BOOKS 1 & 2	BG-1.33	7.4.3	Comparisons	Over-predicts	Surface sediment
General Electric	BOOKS 1 & 2	BG-1.34	7.4.2	Surface sediment	Calibration	Hindcast
General Electric	BOOKS 1 & 2	BG-1.35	7.5	Parameters	DOC	Temperature
General Electric	BOOKS 3 & 4	BG-1.36	General Comments-Book 3	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.37	General Comments-Book 3	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.38	3.5.2.1	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.39	3.5.2.1	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.40	3.5.2.1	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.41	General Comments-Book 3	Model structure	Assumptions	
General Electric	BOOKS 3 & 4	BG-1.42	General Comments-Book 3	Input concentrations	Sediment	Water
General Electric	BOOKS 3 & 4	BG-1.43	General Comments-Book 3	Input concentrations	Sediment	Water
General Electric	BOOKS 3 & 4	BG-1.44	6.2	Model predictions	--	--
General Electric	BOOKS 1 & 2	BG-1.45	5.2.3	Gross settling	Empirical	Particle settling
General Electric	BOOKS 1 & 2	BG-1.46	5.2.3	Settling speed	Cohesive	Non-cohesive
General Electric	BOOKS 1 & 2	BG-1.47	5.2.3	Probability	Theory	Deposition
General Electric	BOOKS 1 & 2	BG-1.48	5.2.3	Load transport	Formulations	Non-cohesive
General Electric	BOOKS 1 & 2	BG-1.49	7.3.1	Bottom	Shear stress	Variability
General Electric	BOOKS 1 & 2	BG-1.50	7.3.1	Armoring rate	Resuspension	Non-cohesive
General Electric	BOOKS 1 & 2	BG-1.51	7.3.1	Resuspension	Properties	Variation
General Electric	BOOKS 1 & 2	BG-1.52	7.3.1	Gross settling	Speed	Flow-velocity
General Electric	BOOKS 1 & 2	BG-1.53	7.3.1 (Table 7-2)	Drainage areas	Flow rates	Inconsistent
General Electric	BOOKS 1 & 2	BG-1.54	5.2.3	Shear stress	Cohesive	Resuspension
General Electric	BOOKS 1 & 2	BG-1.55	7.4.2	Seasonality	Exchange mechanisms	Schuylerville
General Electric	BOOKS 1 & 2	BG-1.56	7.3.2 (Figure 7-6)	Transfer coefficient	Pore water	Uncertainty

AGENCY/ NAME	BOOK NUMBER	COMMENT CODE	BMR REPORT SECTION	KEYWORDS		
				1	2	3
General Electric	BOOKS 1 & 2	BG-1.57	7.6 (Figure 7-6)	Transfer coefficient	Pore water	Data
General Electric	BOOKS 3 & 4	BG-1.58	General Comments- Book 3	Lipid content	Fillet	--
General Electric	BOOKS 3 & 4	BG-1.59	3.5.2.1	Fish diet	Spottail shiner	--
General Electric	BOOKS 3 & 4	BG-1.60	General Comments- Book 3	Growth rate	Species specific	--
General Electric	BOOKS 3 & 4	BG-1.61	3.5.2	FISHRAND	Water	Partitioning
General Electric	BOOKS 3 & 4	BG-1.62	3.4,5.4	PFCM	Water	Contribution
Fort Edward/Pulver	General	BC-1	General Comments	Peer Review	Model comparison	
Scenic Hudson/Lee	General	BC-2.1	General Comments	Remediation		
Scenic Hudson/Lee	General	BC-2.2	General Comments	Target Level	Fish	
Scenic Hudson/Lee	General	BC-2.3	General Comments	No side-by-side peer review	Comparison	
Scenic Hudson/Lee	General	BC-2.4	General Comments	GE information	Peer Reviewer	
Citizen Group / Schmidt-Dean	General	BC-3	General Comments	Peer Review	Model comparison	
SUNY-Albany/Putman	BOOKS 1 & 2	BC-4.1	7.5	Loads	Uncertainty	General Electric
SUNY-Albany/Putman	BOOKS 1 & 2	BC-4.2	7.5	PCB Model	Low Resolution Coring	
SUNY-Albany/Putman	BOOKS 1 & 2	BC-4.3	7.5	Scour effect	Model prediction	
SUNY-Albany/Putman	BOOKS 1 & 2	BC-4.4	4.4.2	100 year event	Scour depth	Cs-137
SUNY-Albany/Putman	BOOKS 1 & 2	BC-4.5	General Comments- Book 1	Peer Review	PCB Model	Data

Responses

II. Response To Comments

GENERAL COMMENTS

BC-1 *...Let's resolve the fact that this side-by-side peer review [of EPA's and GE's models] will only make the science better.*

BC-3 *An independent peer review of <u>both</u> [EPA's and GE's] models must take place.*

BG-1A *We reiterate our request for simultaneous peer review [of EPA's and GE's models]...*

BL-1A *If the EPA disagrees with the EMC's recommendation, the EMC will re-emphasize its previously stated position, recommending that a side-by-side peer review of EPA's model and GE's model is nacessary.*

The peer review for the BMR will not include a side-by-side comparison of EPA's and GE's models. Consistent with EPA's Science Policy Council Peer Review Handbook (EPA 100-B-98-001, Jan. 1998), the purpose of the peer review is to have independent experts review EPA's Reassessment science in order to evaluate whether that science is technically adequate, competently performed, properly documented, and satisfies established quality requirements. The peer review is not a forum in which reviewers are asked to judge between two different models for the site. Nevertheless, the peer review panel for the BMR will be provided with a copy of this Responsiveness Summary, which includes copies of General Electric Company's comments on the BMR, and EPA's responses to GE's comments and EPA's review of GE's model. EPA also will provide the peer reviewers with a copy of GE's modeling report so that the peer reviewers can refer to that report if they believe that such reference is needed for their review of EPA's modeling work, although the reviewers will not be tasked to review GE's model.

BC-2.1 *As with previous EPA Reassessment documents, the findings of the BMR, indicate the need for remediation of PCBs in the Upper Hudson River. Such remediation is necessary to accelerate recovery of the River so as to protect human health and the environment. All of the EPA's findings to date inidcate that remediation is necessary.*

EPA's remedial decision for the Site will not be based on a single Reassessment Report. EPA's Record of Decision, in which EPA will select an appropriate remedial action for PCB contaminated sediments at the Site, will be based upon the administrative record for this Site. The administrative record will include, among other information, the Reassessment Remedial Investigation reports (Preliminary Model Calibration Report, Data Evaluation and Interpretation Report, Low Resolution Sediment Coring Report, Baseline Modeling Report, and Baseline Human Health and Ecological Risk Assessments), the Feasibility Study, the Proposed Plan, and the responsiveness summaries for each of those documents.

BC-2.2 *Health officials in the State of Connecticut recently adopted 0.1 parts per million (ppm) for determining fish advisories... We would encourage EPA to disregard the use of the Food and Drug Administration's 2 ppm target level. It is becoming increasingly clear that the FDA level is not appropriate for a site-specific case such as the Hudson. It is also increasingly clear that the 2 ppm level of PCBs in fish is not adequately protective of human health and the environment. We suggest that the EPA also use a level of 0.1 ppm*

EPA will determine target levels for PCBs in fish in the Feasibility Study. It should be noted that EPA does not set fish advisories within New York State

BC-2.3 To *date, EPA has indicated that the BMR will not be subject to a side-by-side peer review as suggested by the General Electric Company. We strongly support EPA's position on this.*

Comment acknowledged. See also response to BC-1.1.

BC-2.4 *[W]e encourage EPA to instruct members of the Peer Review committee to disregard any and all information submitted to them by the General Electric Company.*

As indicated in the response to BC-1.1, the purpose of the peer review is to determine whether EPA's science is technically adequate, competently performed, properly documented, and satisfies established quality requirements. The primary documents that will be provided to the peer reviewers are the Revised Baseline Modeling Report and this Responsiveness Summary to the Baseline Modeling Report. In addition, the peer reviewers will be provided with the May 1999 Baseline Modeling Report and General Electric's modeling report for reference and background but the reviewers will not be asked to include a review of those documents *per se*. USEPA will not place limits on other information that the reviewers may consult in connection with their review, but such consultation is beyond the scope requested by USEPA.

BG-1.1 *The work as documented in the EPA report is also not "transparent." The report does not discuss key assumptions in the model, explain the relationships between the various model runs...presents data-model comparisons on a compressed scale that obscures differences between data and model, and omits a number of key data-model comparisons...*

...This defeats the opportunity to comment that is required by the Administrative Procedure Act (APA), CERCLA and the National Contingency Plan. The data and analysis employed by EPA in the development of the model must be laid out in sufficient detail so that the public can provide meaningful and germane comments. United States v. Nova Scotia Food Products Corp., 568 F.2d 240, 252 (2d Cir. 1977) ("to suppress meaningful comment by failure to disclose the basic data relied upon is akin to rejecting comment altogether... When the basis of a proposed rule is a scientific decision, the scientific material which is believed to support the rule should be exposed to the view of interested parties for their comment"); Endangered Species Committee of the Building Industry

Association of Southern California v. Babbit, [852] F. Supp 32, 36-37 (D.D.C. 1994) ("where an agency relies upon data to come to a rule-making decision, it generally has an obligation under the APA to provide such data for public inspection."); see also Chemical Manufacturing Association v. U.S. EPA, 870 F.2d 177 (5th Cir. 1989).

BG-1.31 *The realism of the FISHRAND bioaccumulation model (as developed for the Upper Hudson River) cannot be determined as result of insufficient BMR description of the model development and calibration process.*

EPA's Reassessment Remedial Investigation does not constitute government rulemaking under the Administrative Procedure Act (APA), and the cases cited by the commenter therefore do not apply to EPA's release for public comment of the BMR. None of the cases cited by the commenter address public comment on an EPA remedial investigation report issued under CERCLA. Instead, the cited cases address the APA's notice and comment requirements for government rulemaking. The Reassessment Remedial Investigation, of which the BMR is one component, is a "removal action" conducted pursuant to Section 104(a) of CERCLA, 42 U.S.C. § 9604(a). See 42 U.S.C. § 9601(23) (definition of "removal") and Kelly v. E.I. duPont de Nemours and Co., 17 F.3d 836, 843 (6th Cir. 1994) ("the statutory definition of 'removal' includes 'all [Remedial Investigation and Feasibility Study] 'monitoring, assessing and evaluating activities.'"). EPA removal actions do not constitute rules subject to the notice and comment requirements of Section 553 of the APA. See Environmental Waste Control v. West Holding Co., 763 F. Supp. 1576, 1581-82 (N.D. Ga. 1991) (Health assessment conducted pursuant to CERCLA Section 104(a) does not constitute agency rulemaking subject to the APA.).

Section 117(a) of CERCLA, 42 U.S.C. § 9607(a), and Section 430(f)(3) of the National Contingency Plan (codified at 40 C.F.R. § 430(f)(3)), require a single public comment period after the Agency issues a proposed plan for remedial action a site, at which time the public is provided with an opportunity to submit comments on the proposed plan and its supporting analysis and information. See 40 C.F.R. § 300.430(f)(3)(i). EPA will comply with the public participation requirements of CERCLA and the NCP when it issues the proposed plan for the Hudson River PCBs Site, which is scheduled to be released in December 2000.

The Revised BMR, which was released in January 2000 and which supercedes the BMR, provides additional information about the Agency's modeling effort, including additional information sought by the commenter. Notwithstanding that the BMR did not include the computer codes, input files and output files used in the modeling effort, we believe that the detailed information presented in the BMR, Revised BMR and this Responsiveness Summary is sufficient for the public to provide meaningful comments on EPA's modeling effort. The commenter's request for the model codes and files for the BMR has been addressed separately in accordance with the Freedom of Information Act.

BS-1.38 *The responsiveness summary for the Baseline Modeling report should inlude a comparison of the General Electric and EPA models at least for the key assumptions and findings.*

See the USEPA Commentary on *PCBs in the Upper Hudson River* (QEA, 1999) included in this report.

GENERAL COMMENTS - BOOKS 1 AND 2

BC-4.5 *Again, I recommend that the matter of incorporating the LRC results into HUDTOX be submitted to peer review*

The entire revised baseline modeling effort is being submitted for peer review. EPA has considered this comment and included a specific question in the charge submitted to the peer review panel for the BMR.

BL-1.1 *When reviewing the EPA and GE model reports, it was apparent that the GE report provides much more detailed discussion of the rationale for the data used in the model. It would be helpful to the review if EPA did the same. It is recommended that this information be added.*

EPA agrees that it is important to provide sufficient discussion of the data and data processing used in the model to provide the reader with a clear understanding. Chapter 6 of Book 1 of the Revised BMR has been greatly expanded to provide a thorough description of the data development for model applications.

BF-1.1 *The report is unclear on two points (a) what is the uncertainty associated with both sets of data (modeled and observed), and how does that uncertainty affect the reality of the comparison; (b) what degree of difference in values is important. In many cases, small changes are taking place over long time periods, so that apparent agreement may still result in large differences in total amounts. For example, the compressed scale on some of the plots give visual assurance of a match, but in some cases, particularly for TSS and sediment, small differences may reflect large amounts of PCB-contaminated sediment.*

To examine the issues pointed out by the reviewer, a range of sensitivity simulations were conducted. Both the historical hindcast calibration and the forecasts were evaluated for the baseline modeling effort. These sensitivity analyses are presented in Chapters 7 (for calibration) and 8 (for forecasts) of Book 1 of the Revised BMR. In addition, in the Revised BMR, effort has been taken to enlarge the scale of the plots to the extent practicable.

BF-1.2 *Models represent an oversimplification of the system that is being modeled. For these models to provide useful and credible input to the decision-making process, the potential implications of this oversimplification should be addressed. For example, there are a number of aspects of the Hudson River system that these models are not addressing. The Depth of Scour model does not address sediment resuspension resulting from debris (including large rocks, trees and root* *masses), bank erosion, or ice scour during high flow events. The characteristics of the water in the river during high flow events may be different from water in a laboratory flume test or the river during low flow, due to the material moving with the water. The daily changes in water level associated with hydropower generation act as a regular tidal action in shallow water, nearshore sediments, which may increase the release of PCBs from these sediments. Temperature in the shallow nearshore areas, during the summer low flow period may be higher than the mid-channel, which would affect temperature-dependent partitioning. All of these factors may result in significant underestimation of resuspension of sediments and/or PCB loading to the river. The potential importance for the interpretation of model results should be addressed.*

Many of the processes mentioned by the reviewer may be factors affecting sediment and water PCB levels in the Upper Hudson River. Without data to constrain these processes and formulate mechanisms for each, they cannot be included in the model without decreasing the reliability of the model. Many of them are not well understood and occur at small spatial-temporal scales relative to the HUDTOX model. However, sensitivity simulations to examine the possible bounding effect of some of these factors on the revised baseline model calibration predictions have been examined, since the effect of these processes on in-river conditions is lumped within the existing revised baseline model framework and parameterization.

BF-1.4 *The model also does not address the potential loss of PCB-contaminated sediment to the floodplain during high flow events. Because this material is not accounted for in the model calibration, it may affect mass balance calculations resulting in an underestimation of the amount of PCBs resuspended during high flow events. In addition, this material may provide a continuing source of particulate PCBs back to the river from runoff during heavy rainfall and snow melt. Please clarify your decision to omit this term from the model.*

The baseline model is not intended to simulate PCB contamination outside the normal shoreline boundaries of the Upper Hudson River. The modeling objectives presented in the BMR (see page ES-1) focus on the need to evaluate PCBs in water, sediment and fish. Additionally, data is not available to support inclusion of floodplains within the baseline PCB model applications with any degree of reliability. Therefore, inclusion of floodplains would simply decrease the reliability of the baseline PCB model calibration and increase the uncertainty in the goodness-of-fit of the model.

BF-1.5 *The rationale for the selection of PCB forms should be consistent with the intended use of the HUDTOX model (i.e., p. 1-4 Modeling Goal and Objective #1: "When will PCB levels in fish populations recover..."). The BMR currently does not address the range of important PCB congeners in fish. This is currently a major shortcoming of the modeling effort, although, as per the original model plan, three additional congeners (BZ#28, BZ#101, and BZ#138) will be included. It is not sufficient to model total PCBs (i.e., Tri+)-the model should be able to reproduce the changes in composition and concentration that have been historically characteristic of PCBs in fish throughout the upper river.*

The revised baseline modeling effort for transport and fate includes all five PCB congeners (BZ#4, BZ#28, BZ#52, BZ#101[+90], and BZ#138) that were listed in the original baseline modeling plan. The applications of the HUDTOX model for these congeners are presented in Chapter 7 of Book 1 of the Revised BMR. The data are more limited for the bioaccumulation modeling of congeners.

BF-1.6 *The 100-year flood evaluation includes the implicit assumption that no changes in the frequency or magnitude of high flow events will take place. Is this a reasonable assumption considering the potential for future development in the watershed? The derivation of the flow scenarios used in the model forecasting and the uncertainties in the proposed scenario warrant more complete discussion.*

Upper Hudson River flow at Fort Edward is fairly well regulated by upstream dams. It is unlikely that the 100-year peak flow will increase substantially as a result of development, since maximum flows are largely associated with spring runoff due to snowmelt. As an indication of this regulation, note that the 100-year flood peak (47,330 cfs) is less than 50% greater than a once in 10-year flood. Characterization of the flood event hydrology for this river system was conducted as part of the Phase 1 effort for this Reassessment RI/FS (USEPA, 1991) and updated during Phase 2 work (Butcher, 2000a: attached in the appendix to this Responsiveness Summary).

BF-1.7 *The model results suggest that total PCB transport during low flow conditions is greater than during high flow events (>80% vs. <20%). Does this relationship hold true for Tri+ PCBs?*

The revised baseline PCB model results indicate that Tri+ PCB loading generally accounts for approximately 60% to 75% of the total in-river transport under flow conditions that result in minimal sediment scour (<10,000 cfs at Fort Edward), depending on which reach is being examined, (see Figure 7-22 in the RBMR). The details of the historical hindcast results of the revised baseline model calibration are presented in Chapter 7 of Book 1 of the Revised BMR.

SPECIFIC COMMENTS - BOOKS 1 AND 2

EXECUTIVE SUMMARY

BS-1.1 *Page ES-4 Book 1, The 21-year model forecast (1997 to 2019) was run using the same flow, solids loadings, and other external forcing functions for the 1977 to 1997 time frame. The solids loadings values for this time period should be examined to determine if they are representative and appropriate for use in the models. The period of the late 1970s to early 1980s represent a period of time shortly after the Fort Edward Dam removal and during some in river dredging activities. Applying the solids loadings measurements from the 1970s and early 1980s could misrepresent solids loading conditions occurring in the 1990s and the future...*

The revised baseline modeling assessed differences in the solids loading versus flow relationships over these periods. Indeed, Fort Edward solids loading conditions were found to be significantly different during the 1990s than during the 1970s and 1980s. However, no significant differences between the Fort Edward suspended solids data collected in 1978 and 1979 (no data was available for 1977) and data collected during the 1980s was found (see Figure 7-3a in the RBMR). Distinct pre- and post-1990 solids loading rating curves were developed and applied for the revised baseline model calibration to the 1977-1997 historical hindcast simulation periods. Chapter 6 of Book 1 of the Revised BMR presents the approach and results from the solids loading analysis. Additionally, the 1990s Fort Edward rating curve was used to describe the baseline solids loading for the 70 year forecast predictions presented in Chapter 8 of Book 1 of the Revised BMR under the assumption that this is the best currently available information to represent possible future conditions.

BS-1.2 *Page ES-5 Book 1, Second finding and Section 8; The referenced passages discuss the reactivation of deeply buried contaminated sediments following a major flood event. Specifically, the PCB flux from the 100 year flood is estimated to be 60 kilograms which are resuspended and transported from the Thompson Island Pool. Have the models been used to estimate the PCB flux below the Thompson Island Pool to Waterford and ultimately the lower river resulting from a 100-year flood?*

The revised baseline model has been used to generate estimates of PCB loads moving through various reaches of the Upper Hudson River for a range of forecast scenarios, including the 100-year flood event. These results are presented in Chapter 8 of Book 1 of the Revised BMR.

Chapter 1. INTRODUCTION

1.1. Purpose of Report

1.2. Report Format and Organization

1.3. Project Background

1.3.1. Site Description

No significant comments were received for Sections 1.1 to 1.3.1.

1.3.2. Site History

BF-1.14 *p. 1-3 Last Para: Fractured bedrock remains a route of migration for PCBs to discharge into the Hudson River. While recovery wells have been installed to extract PCBs from bedrock and turkey basters/siphons have been used to remove observable oil droplets at known seeps, droplets of*

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PCBs may still continue to discharge at unidentified locations.

USEPA acknowledges that oil droplets may continue to seep at unidentified locations and may continue indefinitely into the future. The BMR states that the leakage was largely brought "under control" in 1996 by remedial activities and that these activities "greatly reduced the release rate". Neither of these statements is incorrect. The BMR does not imply that elimination of this leakage was achieved through remedial activities. Additionally, the BMR refers the reader to a more complete discussion of PCB sources in the Data Evaluation and Interpretation Report (DEIR) (USEPA, 1997).

1.4. Modeling Goals and Objectives

No significant comments were received for Section 1.4.

Chapter 2. MODELING APPROACH

2.1. Introduction

2.2. Conceptual Approach

2.3. Hydrodynamic Model

2.4. Depth of Scour Model

2.5. Mass Balance Model

2.6. Mass Balance Model Applications

2.7. Hudson River Database

Chapter 3. THOMPSON ISLAND POOL HYDRODYNAMIC MODEL

3.1. Introduction

3.2. Modeling Approach

No significant comments were received for Sections 2.0 to 3.2.

3.2.1 Governing Equations

BL-1.2 *Section 3.2. 1. P. 10: Why aren't different values of "n" used for cohesive and non-cohesive areas? It seems unlikely they have the same roughness.*

Specification of different Manning's "*n*" roughness coefficients for non-cohesive and cohesive sediment was not attempted, since other factors within the sediment bed that may also be controlling the bulk friction loss. For example, a lower Manning's "*n*" may be expected to better represent friction losses for finer cohesive sediments, but these sediments are also generally located in near shore areas where emergent plants are growing in the bed.

3.2.2 Computational Procedure

3.3.Model Input Data

No significant comments were received for Sections 3.2.2 to 3.3

3.3.1. Model Grid

BS-1.4 *Page 19, Book 1, second paragraph; It is not clear why maximum stresses are observed in the flood plain, when the velocities are lower as shown in Figure 3-3[.] Lower shear stresses would be expected. Please check this and provide some explanation of this in the report if this is correct.*

BS-1.10 *[Section 3.3.1:] Figures 3-2, 3-3, and 5-4 Book 2; Figures 3-2 and 3-3 show the area of the river for which flow is modeled and the corresponding water velocity results (RMA-2V model). These figures show that the flood plain is included in these modeling efforts. Figure 5-4 shows the area of the river modeled for PCB fate (HUDTOX model), which does not include all of the area in Figures 3-2 and 3-3. The reason and implications for this difference should be discussed.*

Including the flood plain in the Depth of Scour Model (DOSM) application was necessary for generating realistic predictions of bottom shear stress in nearshore areas. Higher stresses may occur in flood plain areas because both depth and velocity are parameters in the equations used to estimate bottom shear stress. Higher stresses in these areas do not necessarily infer that scour is occurring. The conditions (e.g., soil type, compaction) of the flood plain soils and possible land covers (grasses, brush, trees, concrete, etc.) are factors which reduce the likelihood of scour from these areas under bottom stresses that would generate scour within the river. Also, please see the response to comment BF-1.19 (Section 5.2.3).

3.3.2. Manning's 'n'

No significant comments were received for Section 3.3.2.

3.3.3. Forcing Functions

BL-1.3 *Section 3.3.3. P. 13: Why was the model not checked versus the entire flow regime for the data available for the 1991, 1992, 1993, 1994 and 1995 periods listed in Table 3-2? This would seem to be a better check than just checking the peak flows.*

The TIP hydrodynamic model was run primarily to provide a two-dimensional bottom shear stress field for use in the DOSM application. The DOSM employs a form of the Lick et al. (1995) resuspension formulation that relates the depth of scour in cohesive sediments to the maximum bottom shear stress resulting from a peak flow. A lower flow condition (4,000 cfs), not described in Table 3-2, was also simulated with the TIP hydrodynamic model to generate relationships quantifying shear stress-driven resuspension relationship over the range of flows that could produce scour for the time periods simulated in the HUDTOX baseline model applications.

3.3.4. Boundary Conditions

BL-1.4 *Section 3.3.4, P. 13: From this discussion, it doesn't appear that tributary flows were included. If not, why not? Also, the rating curve explicitly used for the Thompson Island area should be included in the report.*

The USEPA concluded that it would be extremely difficult to accurately incorporate the effects of the tributaries in the TIP Hydrodynamic Model application. USEPA acknowledges that the predictions within these limited areas have a greater level uncertainty than predictions for other areas of the TIP. The water surface elevations used to specify the downstream boundary (i.e., TI Dam) condition for the hydrodynamic model were based on a regression between flow and water surface elevation (as measured by NYS DOT Barge Canal Gage 118). The elevations for the flows simulated are shown in Table BL-1.4 (similar to BMR and RBMR Table 3-2). The rating curve for flow at Ft. Edward is included in the appendix to this Responsiveness Summary (Butcher, 2000a).

Table BL-1.4
Modeled Hudson River Flows at the Upstream Boundary of TI Pool and TI Dam Downstream Boundary Water Surface Elevations

Flow Description	River Discharge (cfs)	Elevation (feet)[1]
Peak flow during spring and fall surveys, 1991	8,000	120.2
Peak flow for GE high flow survey, April 23-24, 1992	19,000	121.9
Peak flow for USEPA Phase 2 survey, April 12, 1993	20,300	122.1
Peak flow for spring 1994 (USEPA, 1994)	28,000	123.4
Peak flow in 1983	35,000	124.7
5-year high flow	30,126	123.5
25-year high flow	39,883	125.2
100-year high flow (Butcher, 2000a)	47,330	126.1
100-year high flow (out-dated FEMA estimate)	52,400	126.5

Sources: USGS Gaging Records; Butcher, 2000; and NYS DOT Barge Canal Records

3.4. Model Calibration

3.5. Model Validation

No significant comments were received for Sections 3.4 to 3.5.

3.5.1. Rating Curve Velocity Measurements

BL-1.5 *Section 3.5. 1, P. 14: Model results should be given and compared to USGS data for cross-section points, not just the mid-point.*

The available USGS data for comparison to velocity predictions for the April 18, 1993 peak flow simulation was fairly limited and did not warrant extensive comparison to the model predictions.

3.5.2. FEMA Flood Studies

3.5.3. 100-Year Peak Flow Model Results

3.6. Sensitivity Analyses

3.6.1. Sensitivity to Manning's 'n'

3.6.2. Turbulent Exchange Coefficient

3.7. Conversion of Vertically Average Velocity to Shear Stress

No significant comments were received for Sections 3.5.2 to 3.7.

3.8. Discussion

BL-1.6 *Section 3.8, P. 19: This discussion shows no attempt to calibrate or validate the flow model for the River below the Thompson Island Dam. There also seems to be no discussion of such calibration/validation in subsequent sections. Why was calibration/validation below the Thompson Island Dam not done as it would seem to be necessary?*

The TIP was the primary focus of the effort to assess whether buried contaminated sediments are likely to become "reactivated" due to a major flood event because of the high occurrence of highly contaminated hot spots within this reach of the river. The USEPA did not apply a hydrodynamic model downstream of TI Dam. It was assumed that the TI Pool results provide an upper bound on the likely scale of PCB resuspension for all locations downstream. This assumption is based upon the following. The TI Pool contains the greatest number of the hot spots identified by NYSDEC and thus represents a very large fraction of the total PCB inventory of the Upper Hudson. Secondly, the TI Pool is the first catchment below the former Ft Edward dam and thus is likely to contain the densest accumulation of sediments related the dam removal. Furthermore, although it has been over 25 years since the dam removal, it is likely that the sediment deposits in the TI Pool related to the dam removal are the most vulnerable to erosion as compared to similar sediments downstream

Chapter 4. THOMPSON ISLAND POOL DEPTH OF SCOUR MODEL

4.1. Introduction

4.2. DOSM Model Development

4.2.1. Conceptualization

4.2.2. Formulation for Cohesive Sediments

4.2.3. Formulation for Non-Cohesive Sediments

4.2.4. Temporal Scale

4.3. DOSM Parameterization

No significant comments were received for Sections 4.0 to 4.3.

4.3.1. Data

BF-1.15 *Section 4.3.1, p. 26 Para 2: Toward the end of the paragraph it is stated that "No sediments described as "coarse" were listed for Thompson Island Pool." This is followed by "The area of non-cohesive sediments in TIP is approximately three times that of cohesive sediments." Please explain the apparent contradiction in these two sentences.*

Non-cohesive sediments in the Thompson Island Pool were listed under the "coarser" category. The text is slightly modified in the Revised BMR to make it clear that both "coarse" and "coarser" are listed as possible sediment classifications that may result from the side-scan sonar analysis. The text in Chapter 4 of Book 1 of the BMR is modified in the Revised BMR to clarify this issue.

BF-1.16 *Section 4.3.1, p. 28 Para 1: The median PCB concentration in cohesive surficial sediments was 32.5 mg/kg. What is considered surficial for this analysis? What was the median PCB concentration in noncohesive sediments?*

"This value was used to approximate ...throughout TIP..." Why was the median used rather than the arithmetic mean, which should provide a better estimator of the "range for the mass of PCBs eroded from the sediments of TIP..."?

The 32.5 mg/kg surface (approximately, 0-25 cm or 0-10 inches) cohesive sediment concentration for 1984 that was presented in the BMR was an estimated average value for the TIP. The text in the BMR incorrectly referred to this concentration as a median value. Because the DOSM predictions vary spatially through the TIP, we agree with the commentator that application of an average value to calculate the mass of PCBs eroded from the cohesive sediments produces a more conservative upper bound estimate than use of a median value. However, EPA also notes that the estimate has been updated based on revisions to the GIS coverages used in developing the average value. The revised estimated 1984 average PCB concentration for the TIP cohesive sediments is approximately 43.7 mg/kg based integrating information from GIS coverages containing: Theissen polygon delineations, formed about the 1984 sediment sampling locations (separately for cohesive and non-cohesive samples, based on visual texture classification), and side scan sonar-based delineation of cohesive and non-cohesive sediment areas. The use of these coverages for estimating 1984 TIP PCB inventories in cohesive and non-cohesive sediment is discussed in Appendix B of the Responsiveness Summary for the Low Resolution Sediment Coring Report (USEPA, 1999a). Further details on the techniques used (e.g., polygonal declustering) are provided in the Data Evaluation and Interpretation Report (USEPA, 1997). The average 1984 PCB concentration of 43.7 mg/kg in the upper 25 cm of cohesive sediment was generated based on applying a 58 percent allocation of the PCB mass to the upper 25 cm of the bed. This percentage was based on evaluation of the vertical distribution of PCBs in the available cohesive sediment data. Also, note that an average 1984 PCB concentration of approximately 11.2 mg/kg was determined for the non-cohesive sediments in a similar fashion, assuming a 73 percent allocation of PCB mass to the top 25 cm of sediment.

The revised estimate of 43.7 mg/kg for the average PCB concentration in the TIP upper 25 cm of cohesive sediments results in an approximate range of gross PCB erosion of 66 to 87 kilograms for the 100-year peak flow. This range is an update of the 49 to 65 kilogram range presented in both the BMR and RBMR (Section 4.4.3).

EPA also notes that these average values do not correspond precisely to the 1984 data presented in Figure 7-15a of the RBMR for the 0-25 cm sediment layer. In Figure 7-15a, the data were processed to display data variability (+/- 2 standard errors) in a consistent manner across the available sediment historical sampling programs. More specifically, the 1984 data were processed without using polygonal declustering techniques, and with the same assumptions employed in developing the data for application of the HUDTOX model regarding cohesive and non-cohesive sediment solids specific weight (see RBMR Section 6.7.2). With regard to the commentators' request for the 1984 median PCB concentration in the non-cohesive surface sediments, the value is approximately 3.5 mg/kg. Additionally, the actual 1984 median concentration for cohesive sediments is approximately 16.5 mg/kg. As would be expected, the median concentrations are significantly lower than the estimated mean values.

4.3.2. Parameterization for Cohesive Sediments

No significant comments were received for Section 4.3.2.

4.3.3. Parameterization for Non-cohesive Sediments

BL-1.7 *Section 4.3.3, P. 29: The GE model approach to armoring of the non-cohesive bed uses d50 as a parameter and then calculates armoring depth. The resulting relationship compares very well to the data without the large spread of Fig. 4-3. EPA should consider using the GE approach.*

The HUDTOX model is not comparable to the fine-scale sediment transport model applied by GE due to differences in space-time scales and model processes. The revised baseline model incorporates only those features of the GE sediment transport model that can be reasonably scaled to the level of HUDTOX model application. Detailed non-cohesive sediment transport theory cannot be incorporated directly into the HUDTOX model. Therefore, the revised baseline modeling has made use of the long-term results (e.g. burial rates and trapping efficiencies) of the GE sediment transport model as a guide for calibration. This is a reasonable simplification, given the very large uncertainties associated with tributary solids loads to the river. The revised baseline model calibration is presented in Chapter 7 of Book 1 of the Revised BMR.

4.4. DOSM Application

4.4.1. Application Framework

No significant comments were received for Sections 4.4 to 4.4.1.

4.4.2. Model Application to High Resolution Coring Sites

***BF-1.17** Section 4.4.2, p.30: ...Because these 5 high resolution cores cannot be considered representative of cohesive sediments in the Upper Hudson River, the information on potential scour of cohesive sediments gained from this comparison may be misleading. ...The high-resolution core locations used in this analysis are highly unusual in that they represent locations with continuous undisturbed deposition according to the [radionuclide] analysis; most cohesive sediment areas would not show this kind of pattern (that is, they would be subject to some degree of vertical mixing). How were the results from these 5 non-representative locations interpolated over the large spatial area representing the Upper Hudson River? Could the same type of analysis be conducted considering specific hotspot locations and the results compared to those obtained from the Low-Resolution Core Report?*

***BS-1.5** Section 4, Book 1: The Depth of Scour Model for Thompson Island Pool (TIP) was applied to the High Resolution Core results. It is unclear how erodibility of the TIP can be applied to five cores which are only descriptive of a very small portion of conditions in the TIP. These areas by definition are not conducive to erosion and may only represent a small percentage of the surface of this reach. We assume that this parameter is highly variable and uncertain in the model and also recommend that this be indicated in the text of the report and/or the responsiveness summary.*

DOSM was applied, not calibrated, to predict the range of expected scour depths at five of the Phase 2 sampling high resolution coring sites. The DOSM parameterization and the site-specific data utilized for this are presented in Section 4.3 of the BMR and again in Chapter 4 of Book 1 of the Revised BMR. No adjustment of the DOSM parameterization was made as a result of ~~its~~ the DOSM's application to the high-resolution cores. This application is also independent of the pool-wide application of the model.

The surface slices of the Phase 2 low-resolution sediment cores were 7 to 9 inches in depth. This resolution is too coarse for comparison with the DOSM results.

BC-4.4 *The Hudson hydrodynamic model is being used to estimate high discharge event scour effects. The 1975-76, 1983, and 1998 events potentially would produce distinct sediment layer truncation boundaries where scour has occurred (that for '75-'76 was described by Tofflemire and Quinn; DEC, 1979, using 137Cs chronology). Have these been looked for in appropriate cores and locations as a check against model predictions?*

The assessment on relating available sediment core chronologies to high flow event scour penetration is presented in Chapter 4 of Book 1 of the Revised BMR.

4.4.3. Model Application Poolwide

Chapter 5. MASS BALANCE MODEL DEVELOPMENT

5.1. Introduction

5.2. Model Approach

5.2.1. Introduction

No significant comments were received for Sections 4.4.3 to 5.2.1.

5.2.2. Conceptual Framework

BF-1.18 *Section 5.2.2, p. 34: Are we to assume that most water-column PCBs are associated with dissolved organic carbon (DOC) since DOC concentration is used as a forcing function in the water column? This is in contrast to other Phase II documents...*

No. The amount of water column PCBs associated with DOC depends upon PCB partitioning to DOC, not on whether DOC is computed as a model state variable or specified as a forcing function.

5.2.3. Governing Equations

BF-1.19 *Section 5.2.3, p. 34-35: "The mass balance for the HUDTOX model accounts for all material entering and leaving the system by external loading, advective and dispersive transport, settling and resuspension, and physical, chemical and biological transformations." The model does not account for "all material leaving and entering the system" by the mechanisms listed, since the floodplain as a source or sink for PCBs, the effects of daily fluctuating water levels resulting from hydropower generation on releases of PCBs from the sediments, resuspension from ice scour, etc. are not considered.*

Please see the response to BF-1.2. In addition, it is agreed that HUDTOX does not explicitly address "all" material leaving and entering the system through a modeled mechanism. Mechanisms such as PCB deposition in the flood plain and subsequent erosion back into the system are accounted for only to the extent that the water-column and solids data used to calibrate the model reflect the impacts of such a process. There is no explicit consideration of such processes in the forecast runs.

BF-1.20 *Section 5.2.3, p. 40-42, Sediment Particle Mixing: The "improved sediment bed handling approach" appears to arbitrarily restrict the vertical mixing of the sediment. Also, the particle mixing coefficient is two orders of magnitude less at 4-8 cm than 0-4 cm. The report cites various researchers who have estimated biodiffusion coefficients but does not indicate what sediment depth the rates reported correspond to. Please explain how the mixing coefficients of 36.5 cm^2/yr for the top two sediment layers (0-2 and 2-4 cm), 3.65 cm^2/yr for the 4-6 cm and 0.365 cm^2/yr for the 6-8 cm were generated.*

The modified sediment bed handling approach implemented in HUDTOX limits the extent to which the standard WASP5 model bed handling arbitrarily imposes vertical mixing of sediment layers merely as a function of a sedimentation timestep. The bed handling modification allows the degree of vertical mixing to be controlled by the modeler through specification of particle mixing rates between the sediment layers. Chapter 7 of Book 1 of the Revised BMR presents a discussion of the selection of particle mixing rates used in the revised baseline model calibration.

BF-1.21 *Section 5.2.3, p. 41, Table 7-1: Why would you expect the particle mixing rate to be the same in cohesive and noncohesive sediments? The particle mixing rate is given for layers 1-2, 2-3 and 3-4, but the layer thicknesses are not defined. Does layer 1-2 represent 0-4 cm, while layers 2-3 and 3-4 correspond to the 4-6 and 6-8 cm slice?*

For the revised baseline model calibration, the depth to which particle mixing is specified was initially guided by site-specific sediment profiles and initial particle mixing rates were based upon literature. Final values for these parameters were determined through calibration, as presented in Chapter 7 of Book 1 of the Revised BMR.

The sediment segment layer thickness is discussed in Chapter 5 of Book 1 of the BMR and Revised BMR. Surface sediment segments in HUDTOX are variable volume, responding to net deposition or resuspension of solids over time. HUDTOX surface sediment segments initially start with a 2 cm thickness, which may become essentially depleted (due to net scour) or double (due to net deposition) in volume before a reordering of the vertical segment layers is triggered. All deeper sediment layers have a constant volume representing a 2 cm thickness.

BF-1.22 *Section 5.2.3, p. 41: The sediment bed handling approach mixing does not take place until specific changes in surface layer thickness occur due to either scour or deposition. Assuming that much of the vertical mixing results from bioturbation, this mixing will occur continuously throughout the spring and summer, regardless of the changes in surface layer volume or thickness.*

As discussed in the response to BF-1.20, the HUDTOX model does have user-specified particle mixing between sediment layers to represent bioturbation and other factors that result in vertical mixing of sediment layers. The modified bed handling approach does not eliminate this mechanism in any way.

BF-1.23 *Section 5.2.3, p. 41: Figures 5-2 & 5-3 depicts scour and burial of surficial sediments. For [time] t_1, the legend should indicate that "Surface sediment concentrations may increase, decrease or remain the same as settling occurs". The graphic suggests a strong dilution factor.*

The graphics presented in Figure 5-3 are illustrative, however the reviewer's concern regarding the legend is noted. The legend in this figure has been modified in Chapter 5 of Book 1 of the Revised BMR to clearly indicate surface sediment concentrations may be increasing or decreasing due to settling rather than simply "changing."

BF-1.24 *Section 5.2.3, p. 43, Bottom, Temperature dependent partitioning: What was the source of the temperature data used in the model? Was uniform temperature assumed throughout TIP, although during the summer the temperature in shallow protected areas may be higher than the temperature in mid-channel.*

Available data from the Phase 2 database were used to construct the seasonal water temperature time series used in the HUDTOX model. This information is presented in Chapter 7 of Book 1 of the BMR (p. 72 and Figure 7-4). Chapter 6 of Book 1 of the Revised BMR presents a more detailed description of how the temperature data were utilized for modeling purposes. Also, please note that these data were re-extracted and reprocessed for the revised baseline modeling application, resulting in slight variations from the temperature time series used in the original modeling effort.

The spatial coverage of the available temperature data is inadequate to distinguish temperature differences between shallow areas and the mid-channel. Thus, a laterally uniform temperature was applied in the baseline model applications presented in the BMR and the RBMR, varying only as a function of time and longitudinal location (see Figures 6-40 and 6-41 in the RBMR).

BG-1.45 *Section 5.2.3: ...The BMR incorrectly claims that "the gross settling mechanism in EPA's model is similar to the empirical relationship used to model particle settling in other river systems (Gailani et al., 1991; Gailani et al., 1996; Ziegler and Nisbet, 1996)" (BMR Book 1, page 37)...*

It is agreed that the gross settling mechanisms are not comparable. However, the BMR settling functions were implemented to capture the major aspects of the "effective" gross settling rates generated by the combined mechanistic and empirical approaches used to simulate solids dynamics on these systems. HUDTOX does not attempt to simulate multiple solids types and the spatial scale of the model is too coarse to implement the "mechanistic", empirically based approach used in the fine-scale solids dynamics model(s) applied to these systems.

BG-1.46 *Section 5.2.3: The EPA model incorrectly uses the same gross settling speed relationship in both cohesive and non-cohesive bed areas, ignoring the significant differences between the depositional environments of these two bed types. Typically, cohesive bed areas are lower energy environments than non-cohesive areas, making cohesive areas more conducive to deposition. Because of this difference, effective settling speeds are generally higher in cohesive areas than in non-cohesive areas, especially at high flow rates. Thus, assuming that the same gross settling relationship applies in both areas is fundamentally incorrect.*

EPA does not agree that the assumption applied for the gross settling relationship was "fundamentally incorrect". The assumption was simplistic, but given that suspended solids are represented by a single state variable in the HUDTOX model framework, the application of a single gross settling speed to represent long term average conditions was reasonable. The Revised BMR modeling approach is less simplistic and accounts for possible differential settling. Higher "effective" gross settling speeds have been specified over cohesive sediment areas than gross settling speeds over non-cohesive sediment areas. The details of the revised baseline model calibration are presented in Chapter 7 of Book 1 of the Revised BMR.

BG-1.47 *Section 5.2.3: Neglecting probability of deposition on settling causes the model to simultaneously simulate high deposition and resuspension fluxes during high flow events (see BMR Book 2, Figure 7-2). This is inconsistent with accepted sediment transport theory, for both cohesive and non-cohesive beds...*

The HUDTOX model segments were specified at a spatial scale over which deposition and resuspension may occur simultaneously. It is likely that aggregated fine-scale model predictions applied to a large-scale model would also result in simultaneous deposition and resuspension under some flow conditions. The USEPA agrees that simultaneous deposition and resuspension should not be occurring at any specific location in the sediment bed.

BG-1.48 *Section 5.2.3: Overall, the non-cohesive suspended load transport formulations are not scientifically credible. Previous comments by GE and the EPA modeling peer reviewers emphasized the need to include a viable non-cohesive sediment transport sub-model in the EPA modeling framework for the Upper Hudson River. In addition, GE provided to EPA a detailed presentation of a non-cohesive suspended load transport model, developed from the peer-reviewed literature. EPA did not rely on this information, instead using new formulations, (BMR Book 1 Equations 5-6 and 5-9, that are speculative and not based on laboratory or field data. Parameterization of the model is poorly constrained and use of spatially constant parameter values is dubious. Therefore, EPA's model simulation of non-cohesive suspended load transport is invalid.*

The reviewer's concerns related to the non-cohesive sediment transport formulations implemented in the BMR are acknowledged. In response, the modeling approach has been revised and the results from the GE sediment transport model's predicted long-term deposition rates have been used in non-cohesive and cohesive sediments as one of the metrics for calibration of the HUDTOX solids model. Additionally, solids and PCBs dynamics are fully coupled simulations in the HUDTOX model. Therefore, another metric for calibrating the revised baseline model included the historical hindcast surface sediment PCB trajectories. The revised baseline model calibration is presented in Chapter 7 of Book 1 of the Revised BMR.

BG-1.54 *Section 5.2.3: The BMR also contains an inaccurate statement about the critical shear stress for cohesive sediment resuspension (page 40 of Book 1)...*

...The statement on shear stress units is incorrect. In Zreik et al. (1998), flume tests were conducted for shear stresses ranging from 0.1 to 1.0 Pa. (Note that Pa stands for Pascals and 1 Pa= 1 N/m^2 = 10 dynes/cm^2.) Thus, the range of the Zreik experiments was 1 to 10 dynes/cm^2, which is a factor of 10 higher than stated in the BMR. In addition, even if the bottom shear stress exceeds the critical shear stress, resuspension will not necessarily occur because of bed armoring processes. Bed armoring depends on temporal variations in the vertical distribution of bed properties at a particular location.

This error in interpretation of the Zreik et al. 1998 paper is acknowledged. However, the statement that "even if the bottom shear stress exceeds the critical shear stress, resuspension will not necessarily occur because of bed armoring processes" is incorrect. Changes in bottom shear stress arise out of differences in sediment properties. By definition, flow driven resuspension cannot occur unless critical shear stress is exceeded. The USEPA agrees that bed armoring depends on temporal variations in the vertical distribution of bed properties at a particular location.

5.3 Model Spatial Segmentation

5.4 Model implementation.

Chapter 6. DATA DEVELOPMENT

6.1. Introduction

6.2. Hudson River Database

6.3. Model Application Datasets

No significant comments were received for Sections 5.3 to 6.3.

6.3.1 Water Column Datasets

***BF-1.25** Section 6.3.1, p.52-53: The sampling difference that was reported by QEA for the west shore of TID is described as a "bias" resulting from incomplete lateral mixing, due to the presence of a nearby hotspot. It is not clear that this may more accurately reflect differences between nearshore and mid-channel areas during summertime low flow. The correction factors should only be applied to calculations of mid-channel loading and not for input to the bioaccumulation modeling, since nearshore values may be more relevant for estimating exposure concentrations in fish.*

p. 53: "Monthly bias-correction factors were computed." What were these values? Is the model capable of reproducing these systematic differences in water column concentration between the channel and the nearshore?

Available data indicates that the "bias" is not simply a summertime low flow effect. The reason a correction factor was developed is due to the fact that the west shoreline TI Dam station was used for routine monitoring. Estimates of the PCB loading over the TI Dam must take this into account. Additionally, no correction factors were applied to the HUDTOX model results for the TIP reach prior to use in the bioaccumulation modeling presented in the BMR or in the Revised BMR. The HUDTOX model has limited ability to reproduce differences in water column PCB concentrations between near-shore and mid-channel areas of the TIP due to the spatial scale of the model segments and insufficient information to distinguish lateral temperature differences.

6.3.2 Sediment Datasets

***BG-1.21** Section 6.3.2: For the BMR, initial concentrations of PCB in the sediment were necessary for the 1991-97 calibration period and the 1977-1997 hindcasting. We assume that these numbers were determined from the 1991 GE composite survey and the 1977 NYSDEC sampling program, respectively. However, the BMR does not describe the methodology or assumptions used to aggregate the average data for the purpose of generating initial concentrations...*

A detailed description of the methodology applied to each historical sediment data set for generating both sediment PCB initial conditions and calibration targets is provided in Chapter 6 of Book 1 of the Revised BMR. Also, see Appendix A of Book 2 of the Revised BMR regarding the initial conditions utilized for the forecasts for each of the risk assessments.

6.4. External Loadings and Mainstem Mass Fluxes

6.4.1. Water Balance

6.4.2. Mainstem and Tributary Solids Loads

No significant comments were received for Sections 6.4 to 6.4.2.

6.4.3 Development of Long-Term Average Solids Balance

BF-1.26 *Section 6.4.3, p. 60-61: Solids load discrepancy: The estimated reach-wide average burial velocity for cohesive and noncohesive sediments was 3-15 cm and 0-3 cm respectively. Trapping efficiencies of 15% for TIP, 25% for TID-Stillwater, and 10% for Stillwater-Federal Dam were estimated. How do the large uncertainties in SS loading affect model output? Has a sensitivity analysis been performed on this parameter?*

Chapter 7 of Book 1 of the Revised BMR presents a sensitivity analysis of the HUDTOX model calibration in response to the uncertainties in estimated external solids loads.

BF-1.27 *Section 6.4.3, p. 61: An upward adjustment factor of 2.5 was invoked for the tributary loads between TID and Waterford relative to load estimates using unmodified rating curves. It was reported that the yields were high but within the range reported in the literature. Please provide the literature values and corresponding waterways.*

The development of external solids loads was revisited as part of the revised baseline modeling effort. Chapter 6 of Book 1 of the Revised BMR presents the development of the external solids load estimates in further detail, but an upward adjustment factor is still applied to the tributary rating curves downstream of the TI Dam. Chapter 6 of the Revised BMR documents the final solids yields and that these are within reported literature ranges.

6.4.4 Mainstem and Tributary PCB Loads

BL-1.8 *Section 6.4.4, P. 63: More information should be provided on exactly what was used for estimating the missing PCB concentrations, (i.e. when was linear interpolation used and when were seasonal averages used?).*

The method applied in the BMR to develop upstream PCB loads has been reassessed and refined for the revised baseline modeling. The details of the procedure used to develop the PCB loads for input to the HUDTOX model are presented in Chapter 6 of Book 1 of the Revised BMR.

BF-1.28 *Section 6.4.4, Table 6-18: How is it possible that, during 1991 and 1992, more data exist for BZ#4 and BZ#52 than for Tri+?*

The information in BMR Table 6-18 reflects tributary PCB data from different sources, as entered in the Phase 2 database records and does not reflect Tri+ concentrations that can be computed. Also note that for 1991 and 1992 Tri+ PCB concentrations are estimated largely from

USGS Total PCB measurements, which have far more days of available data than do PCB congeners BZ#4 and BZ#52. The information on available tributary data is more clearly presented in Chapter 6 of Book 1 of the Revised BMR.

BF-1.29 *Section 6.4.4, p. 65: "An unresolved issue...stochastic pulse loads...due to...loads from flow-driven resuspension between Hudson Falls and Ft. Edward." This appears to be a critical issue, and its significance needs to be explored further to determine the potential impact on the modeling results. The planned future investigations should address the potential effect of pulse loading on the No Action model assumptions about upstream boundary conditions. Can some upper boundaries be placed on the PCB loading as part of the uncertainty analysis?*

BG-1.22 *Section 6.4.4: EPA's method to develop PCB loadings at the model boundary near Fort Edward used both seasonal averages and data interpolation ("...where sufficient data frequency existed to support interpolation" - BMR Book 1, p. 63). The procedure also described the handling of random historical "pulse loads" by abandoning the interpolation method and using "best professional judgment" to apply the apparent pulse load over a limited amount of time and filling the gaps before and after the pulse with a year-specific seasonal average. This method should have been supplemented by a statistical analysis and a more phenomenological approach to the historical dataset...*

These possible pulses were not required for the revised baseline model calibration, but the likelihood that they may have existed and may continue into the future is not disputed. Data frequency for the 1991-1997 period was sufficient to reasonably constrain upstream PCB loads without resorting to inclusion of additional pulse loadings that would be of uncertain magnitude and timing. Additionally, the PCB measurements at Fort Edward are relatively sparse for 1977-1990 as compared to 1991-1997. The sparseness of the pre-1990s data, combined with the likelihood that the 1991 Allen Mills gate failure may have significantly affected the nature of the pulse loading events, makes application of a "phenomenological approach" highly uncertain. EPA decided to accept the level of uncertainty associated with the existing data for estimating upstream boundary PCB loads for 1977-1990, rather than include additional loads which, by their very nature, occur with uncertain magnitude and timing through this period.

BS-1.6 *p.65, Book 1, third paragraph: What is the "Future work planned to investigate the significance of these sources [sources above Rogers Island] and their potential implications for forecast simulations with the HUDTOX model."?*

Since the issuance of the BMR, the USEPA has conducted several analyses dealing with the uncertainty of the upstream source at Bakers Falls. Specifically, as documented in the revised BMR, three different upstream boundary conditions were utilized in the model forecast runs (*i.e.*, 0 ng/L, 0 ng/L and 30 ng/L as the upstream water concentration). The issue of pulse loads is discussed in the response to comments BF-1.29 and BG-1.22.

Chapter 7. MASS BALANCE MODEL CALIBRATION

7.1 Introduction

No significant comments were received for Sections 7.0 to 7.1.

7.2 Calibration Strategy

BG-1.28 *Section 7.2: ...Statements made in the BMR acknowledge the importance of sensitivity analyses in the PCB fate model calibration process (BMR Book I page 68):*
"Even with the constraints imposed by mechanistic process descriptions, calibration of the EPA's model required scientific judgement in specifying process coefficients and many

Despite this recognition, the BMR fails to present any model sensitivity analyses.

Sensitivity analyses of the revised baseline model calibration are presented in Revised BMR, Book 1, Chapter 7. Significant model parameters, as well as uncertain external forcing conditions are examined in the sensitivity evaluation presented in the Revised BMR. Selective sensitivity analyses are also carried forward into the revised baseline model forecasts presented in Chapter 8 of Book 1 of the Revised BMR.

7.2.1 Solids Calibration Strategy

No significant comments were received for Section 7.2.1.

7.2.2 PCB Calibration Strategy

BF-1.30 *Section 7.2.2, p. 69, Calibration Strategy: "...average properties were attributed to the congener mixture under investigation..." How were the average congener mixtures determined, and were they considered constant for all media and locations considered?*

Chapter 6 of Book 1 of the Revised BMR presents a detailed discussion of the procedure used to develop the physical-chemical properties applied in the revised baseline model calibration for each PCB state variable, including Tri+ PCBs, Total PCBs, and the five PCB congeners that were modeled .

BG-1.20 *Section 7.2.2: ...The BMR acknowledges that "...the juxtaposition of PCB behavior during high and low flow periods in more recent, high-frequency data sets (1991-1997) was also important for the iterative PCB calibration." (BMR Book 1, page 70). The BMR, however, does not to provide any high-flow model-data comparisons by which to make calibration judgements.*

Several different PCB calibration metrics were evaluated at both flood (high) and non-scour (low) flow conditions for the revised baseline modeling effort. These evaluations are discussed and presented in Chapter 7 (see Section 7.4) of Book 1 of the Revised BMR.

7.3 Calibration Parameters

7.3.1 Solids Dynamics Parameters

BL-1.9 *Section 7.3. 1, P. 71: Are the values in Table 7-1 the final ones used in the model? If so, which of the values were changed from those at the start of calibration. Were any further adjusted as the result of PCB concentration calibration runs? Is so, which ones? These questions are important because the capability of a model to predict the future is inversely related to how many parameters needed to be adjusted to calibrate the model to existing data.*

A discussion of specific calibration parameter adjustments for the revised baseline model is presented in Chapter 7 of Book 1 of the Revised BMR.

BF-1.31 *Section 7.3.1, p. 71: Table 7-1 (Bk 2) summarizes the HUDTOX solids model calibration parameter values. Background solids resuspension velocity was provided for cohesive (0.2 mm/yr) and noncohesive (0.4 mm/yr) sediments based on the model calibration. How representative are the model calibrated resuspension velocities of real world conditions? Was the 3.0 mm/yr maximum potential value reported by Velleux et al. 1996 (citation absent from reference section) based on lab, field or modeling estimates? Sensitivity analysis for this parameter would be useful.*

Chapter 7 of Book 1 of the Revised BMR presents a sensitivity analyses on the long-term solids dynamics to evaluate the issue of lesser or greater amounts of resuspension in the revised baseline model calibration. However, the revised model no longer includes any background resuspension in either cohesive or non-cohesive sediments.

The 3.0 mm/yr maximum potential resuspension velocity reported by Velleux et al. (1996) is based on calibration of a modified-WASP5 (the IPX model) for the Fox River in Green Bay, Wisconsin.

BL-1.10 *Section 7.3.1. P. 72: The presentation of Fig. 7-2 in the report makes it impossible to decipher which curve is which. Please provide a Fig. 7-2 which labels each curve as to what it represents.*

Figure 7-2 was inadvertently produced on a printer that does not support color gradations in shades of gray. Also, note that the revised approach used for modeling solids negates the need for this illustrative figure, so it is not included in the Revised BMR.

BG-1.49 *Section 7.3.1: Although EPA developed a hydrodynamic model for the TIP, it did not develop or apply a hydrodynamic model downstream of the TIP. Thus, bottom shear stresses cannot be estimated with any confidence in these reaches. Instead, the model uses a single relationship for bottom shear stress and flow rate for all segments downstream of the TIP, the derivation of which the BMR does not explain (BMR Book 2, Table 7-3). Use of this single relationship downstream of the TIP is invalid because it is inconsistent with the significant variability demonstrated by EPA's model within the TIP.*

It is agreed that the lack of a hydrodynamic model adds to the uncertainty in the cohesive sediment shear stress-resuspension relationship downstream of the TIP, but it is incorrect to state that the modeling approach is invalid.

BG-1.50 *Section 7.3.1: The β_5 parameter controls the non-cohesive bed armoring rate. In BMR Book 1 Equation (5-9), different values were used in the TIP (6.0) and downstream of the TIP (2.0). Decreasing β_5 by a factor of three causes a three-fold increase in non-cohesive resuspension rate in the downstream reaches for the same bottom shear stress as in the TIP. The BMR fails to explain this large increase in non-cohesive resuspension. In addition, the seven reaches between TID and Troy were assumed to have the same non-cohesive resuspension properties, as represented by one set of parameter values, which is an obvious gross over-simplification of non-cohesive sediment dynamics in those reaches (as evidenced by the parameter variation used within the TIP).*

The revised baseline model for non-cohesive sediments eliminates this parameter entirely. Please see the response to comment BG-1.48 (BMR Section 5.2.3).

BG-1.51 *Section 7.3.1: The model also represents cohesive resuspension properties downstream of the TIP by a single set of parameters with no description of parameter determination. Significant variation (up to five-fold) in cohesive resuspension properties exists between the seven reaches located downstream of the TID [QEA (1999)], which makes use of spatially constant parameters a poor approximation.*

Please see the above response to BG-1.49. Additionally, the shaker study data was based on cores collected from 20 locations in the Thompson Island Pool reach and 8 transect locations (two samples per location) for the seven reaches downstream of Thompson Island Dam. Based on the relative paucity of data for the downstream reaches the decision was made to employ the resuspension algorithm developed for TIP for these reaches. Analysis conducted for the downstream reaches utilizing the limited data would result in unacceptably large uncertainty bounds. The decision is also consistent with the general modeling approach to construct fine-scale tools in the TIP and apply them for the relatively data limited downstream reaches.

BG-1.52 *Section 7.3.1: EPA decreased gross settling speed downstream of Schuylerville (RM 181.4) because "the flow-velocity relationships change as one moves downstream, these parameters have* *been established on a reach-specific basis according to cumulative drainage area (BMR Book 1, page 7 1). The BMR does not explain or justify how the flow-velocity relationship changes as one moves downstream or why and how these changes should affect the settling speed relationship.*

The revised baseline model calibration presented in Chapter 7 of Book 1 of the Revised BMR applies different effective gross settling rates to distinguish long-term average differences in hydraulic conditions over cohesive and non-cohesive sediment areas. These rates are spatially invariant over the length of the river, but result in effective differences in settling from reach to reach as the percent of cohesive versus non-cohesive sediment area varies.

BF-1.33 *Section 7.3.1, p. 72: Figure 7-2 depicts HUDTOX Spring 1994 high flow event settling and resuspension rates. There is a perceptible decline in the cohesive and non-cohesive resuspension velocity around April 15 without a drop in Ft. Edward flow or gross settling velocity. Please explain this phenomenon.*

Cohesive sediment re-suspension rates in the HUDTOX model implement a modified Lick (Lick *et al.*, 1995) formulation (see Chapters 4 and 5 of Book 1 of either the Revised BMR or the BMR). The resuspension velocity is dependent upon the rate of increase in the bottom shear stress above a critical value. The rate of increase in flow declined on about April 15 for the Spring 1994 high flow event. This resulted in an initial decline in the resuspension velocity, followed by a step drop once the maximum potential erosion depth was reached. The resuspension velocity again increases as the rate of flow increases rapidly on April 16, and the cohesive sediment erosion potential could reach to a greater depth in the sediment bed according to the formulations used in the HUDTOX model.

BG-1.53 *Section 7.3.1: Table 7-2 of Book 2 also appears to contain errors in the areas downstream of the Hoosic River because the drainage area increases and flow rates are inconsistent with upstream values. The drainage area increase for Segments 40-41 and 47 is only 0.16, which is considerably lower than the increases for Segments 29-39 (all greater than 1). Transition flow rates in Segments 40-41 and 47 are also much lower than transition flow rates in Segments 1-39. In addition, BMR Book 2 Table 7-2 provides no information for segments 42-46.*

Table 7-2 in the BMR is in error. Also, note that a different modeling approach was applied for gross settling in the revised model, so this table is not included in the Revised BMR.

7.3.2 PCB Model Parameters

BL-1.11 *Section 7.3.2, P. 72: Please explain what "adjustments" had to be made for partitioning to account for site specific data. Is this "flexibility" the "calibration flexibility" discussed starting at the bottom of P. 72? If so, this is an example of the concern expressed above in Comment #10.*

No adjustment of partitioning was made during calibration of Tri+ PCBs for the revised baseline modeling effort. Partitioning was determined from site-specific data. Sensitivity analysis simulations were conducted on the partition coefficients since these data based parameters have large variability.

BL-1.12 *Section 7.3.2, P. 75:_Were the "final HUDTOX calibration values for diffusive mass transfer rates and seasonal variability" fixed at the start of calibration or changed during calibration to get the "final" values?*

BL-1.13 *Section 7.3.2, P. 75: What is the reason(s) that sediment-water transfer rates depicted in Fig. 7-6b should be so much different for the Thompson Island Pool and regions below the Thompson Island Pool?*

BG-1.56 *Section 7.3.2: The BMR's pore water mass PCB transfer coefficient (kf) differs in cohesive and non-cohesive sediments (BMR Book 2, Figure 7-6a). EPA's justification for assigning a different kf to cohesive and non-cohesive sediments is purely speculative, as there are no site-specific data to support this hypothesis. Specifying a higher mass transfer coefficient in cohesive sediments results in poor estimates of sediment-water exchange. In addition, this hypothesis increases uncertainty in model results because it necessitates the use of an additional unconstrained parameter. Moreover, in the absence of supporting data, specification of spatially variable parameters is inappropriate.*

A single, seasonally varied sediment-water mass transfer coefficient for dissolved and DOC-bound Tri+ PCBs was determined from site-specific data for the revised baseline modeling effort (see Revised BMR, Book 1, Chapter 6). These rates were not adjusted in developing the model calibration presented in Chapter 7 of Book 1 of the Revised BMR.

Without data to the contrary regarding spatial variability of the sediment-water mass transfer rate outside of the TIP, a single rate function was applied to all other reaches. However, the limited data available to describe this factor is not adequate to ensure that it is constrained in reaches downstream of the TIP. Therefore, sensitivity analyses were conducted to evaluate the effect of the sediment-water mass transfer process on the revised baseline model predictions downstream of the TIP. These results are presented in Chapter 7 of Book 1 of the Revised BMR.

BG-1.25 *Section 7.3.2: Table 7-4 of Book 1 gives particulate and dissolved organic carbon content of the water, cohesive, and non-cohesive sediments. However, the BMR does not explain how data were used to generate the values provided.*

Chapter 6 in Book 1 of the Revised BMR describes the development of the particulate and dissolved organic carbon data for use in the revised baseline model in detail.

BF-1.32 *Section 7.3.2, p. 72-74: Table 7-5 (Bk 2) contains HUDTOX PCB model calibration parameter values. The Kpoc and Kdoc for Tri+ was 5.821 and 4.216, respectively. The Kdoc value, set at 10% of Kpoc should read 4.821. For total PCBs, the Kpoc was 5.6 and the Kdoc was 4.6. It* *is our assumption that a mean Kpoc was calculated from the sum of theoretical log Koc given in Table 3-9 of the DEIR. A description of the method used to calculate the total PCB Kpoc and Tri+ Kpoc is suggested. Is it more appropriate to take the Kpoc for each congener and average those rather than use the average based on congeners represented in 16 GE peaks? A value of 10% of the Kpoc was selected for the Kdoc based on the range of values reported by other researchers for natural systems. What was the range of Kdoc reported and for what natural systems?*

Table 7-5: Estimation of Kpoc for total PCBs and Tri+ was based on "apparent PCB congener distribution." How was this "apparent distribution" determined? Were these values altered by location to reflect changes in congener composition?

***BG-1.27** Section 7.3.2: In addition, the BMR does not clearly explain the basis for the particulate organic carbon normalized partition coefficients given in Table 7-5...*

The development of partition coefficients was reassessed and refined for the baseline modeling effort. Chapter 6 of Book 1 of the Revised BMR presents the details and results of the methods employed to determine these values.

***BF-1.34** Section 7.3.2, p. 72: Figure 7-4 displays monthly average water temperature by reach in the Upper Hudson River. Since temperatures were determined from the TAMS/Gradient Phase 2 Database, it is our assumption that these are mid-channel measurements [that] may not represent or include shallow, nearshore conditions.*

The sampling stations for which temperature data were available are not necessarily located in the mid-channel throughout the length of the Upper Hudson River study area, however the reviewer is correct in that the data may not well represent near-shore conditions. The RMBR presents the details on how the available water temperature data were processed for use in the revised HUDTOX model in Chapter 6 of Book 1. In addition, temperature is considered in the FISHRAND model because growth rate is dependent upon it. This is discussed in Book 3 of the RBMR in Chapter 6.3.1.2.

***BF-1.35** Section 7.3.2, p. 74: Two processes - diffusion of porewater PCBs and sediment to water PCB flux from particles - are proposed as the mechanisms for exchanging PCBs between sediments and overlying water and between the upper mixed sediments without causing net solids transport. Yet these processes are attributed to bioturbation, mechanical scour and other turbulence-generating activities. Please explain why net solids transport would not be an important consequence of these phenomena. Also please explain the relative importance of each of these processes within the model.*

The processes mentioned could result in localized sediment transport that may not be reflected in the data produced from routine water column solids sampling. As a consequence of this, a sediment transport model is unlikely to capture the effects of these phenomena. They must often be incorporated by other means within a PCB fate and transport model, such as through the use of sediment-water PCB mass transfer coefficients.

***BF-1.36** Section 7.3.2, p. 75, Top: Diffusive mass transfer rates varied seasonally due to dependence on temperature with slightly over a 50% rate increase in July and August. Since sediment temperatures were not recorded, temperatures were derived from applicable water column river segments for cohesive and non-cohesive sediments. Again, it is our understanding that these temperatures were from mid-channel measurements and do not include potentially higher values in nearshore shallow waters. What are the implications of higher temperatures in some areas on the diffusive mass transfer rates employed by HUDTOX and its output?*

In general, higher temperatures in near-shore areas will likely result in higher water column PCB concentrations as a result of the effect on the distribution of PCBs in dissolved, DOC-bound and particulate phases within the water and sediments. However, beyond simply making an assumption in this regard, there are not sufficient data to support adjusting the temperature forcing conditions in this manner.

***BF-1.37** Section 7.3.2, p. 75: The middle paragraph notes that the sediment-water mass transfer rate for PCBs from particulate phase was "determined by calibration to PCB observations after all other sediment-water exchange fluxes were specified." No analysis was presented as to the reasonableness of the values calculated or to alternative scenarios that could account for the observed congener patterns in the water column during low flow conditions.*

p. 75: Particle-mediated transfer was included in the model to achieve the BZ#4/BZ#52 ratios in the water column. Were other mechanisms tested without successfully constraining the model? Might other mechanisms be invoked to achieve the same results? Why, mechanistically, would the mass transfer rate for particulates be much greater within the TIP than downstream of TID (see Fig. 7-6b)?

The revised baseline modeling effort examines the issue of sediment-water mass transfer for PCBs in greater detail through an analysis of available data. This analysis is presented in Chapter 6 of Book 1 of the Revised BMR in order to support the sediment-water mass transfer rates that have been implemented in the revised PCB model calibration. The issue of diffusive versus particulate-mediated mass transfer is investigated through assessment of the PCB congener calibrations presented in Chapter 7 of Book 1 of the Revised BMR.

***BG-1.26** Section 7.3.2: Additionally, the molecular weight and Henry's Constant for total PCB are not adequately supported. Values given in Table 7-5 of Book 1 are purported to be based on PCB congener distribution, but the BMR makes no mention of how the congener distribution was developed nor the methodology used to develop these model parameters.*

Chapter 6 in Book 1 of the Revised BMR describes the literature and data-based development of these PCB physical-chemical properties for use in the revised baseline model in detail.

7.4 Calibration Results

BG-1.10 *Section 7.4: Although the BMR includes comparisons of predicted and observed TSS concentrations, it lacks important comparisons of the model calculations to data-based estimates of sediment mass balances.*

The revised baseline model sediment mass balance results were compared to estimates based on data for the 1994 Spring high flow event. These results are presented in Chapter 7 of Book 1 of the Revised BMR along with other appropriate model versus data comparison metrics.

BG-1.11 *Section 7.4: ... Using the EPA settling speed function in the GE model yields a prediction of 1,720 MT of net erosion, corresponding to an error of 280%. These results demonstrate that TSS concentration data alone are insufficient to evaluate model performance and infer the correctness of resuspension and deposition formulations; additional measures, including mass balance, are needed.*

It is unclear how GE could have incorporated EPA's settling speed function into GE's model without modification of other solids dynamics parameters, since EPA's and GE's models use different scales for sediment transport. EPA's revised baseline modeling approach presented in the RBMR used coupled simulation of solids and Tri+ to achieve calibration, with a primary emphasis placed on representing long-term historical rates of decline for Tri+ in the water column and surface sediments from 1977 to 1997. The revised calibration approach sought to describe mean high and low flow solids and Tri+ dynamics in the river. Calibration to short-term event dynamics was not emphasized because detailed representation of short-term event impacts was not necessary to answer the principal Reassessment questions. In addition, in Book 1 of the Revised BMR several measures were used for calibration, as presented in Chapter 7.

BG-1.13 *Section 7.4: ...More importantly, the only way to determine the accuracy of the model with regard to resuspension and deposition processes on a reach-average basis is to compare data-based and model-predicted mass balances. This is different from the solids flux analysis set out in the BMR in that it includes an assessment of tributary solids loading in addition to main stem loadings. The lack of such a mass balance comparison precludes a determination of the accuracy of predicted burial rates. In addition, it is unclear how the "data-based" estimates of long-term TSS fluxes were developed from the few measurements that exist at the Stillwater and Waterford stations for the period from 1991 to 1997. Presumably, these estimates are subject to considerable uncertainty associated with extrapolation of the few measurements to form what is presented as a continuous record.*

The use of computed and data-based mass balances as the only way to determine the accuracy of the model with regard to resuspension and deposition is overstated. Comparison to data-based mass balances allows assessment of model-predicted net solids exchange, but does not determine accuracy of actual resuspension and deposition processes. Long-term estimates of TSS loads past Stillwater and Waterford were developed in a similar manner as those for Fort Edward. This is explained in Section 6.4.2 of the BMR and in Section 6.5 of Book 1 of the RBMR. Additionally, besides the USGS TSS data at Waterford, there are 1993-1994 TSS data available from sampling programs conducted by RPI which are included in EPA's Phase 2 database (see Table 6-7 in the RBMR). The solids rating curves were used to estimate TSS concentrations for the hindcast period where concentrations were not measured. Because tributary loads were back-calculated to ensure a long-term solids balance, presentation of a mass balance of tributary and mainstem solids loads is not necessary to determine agreement between model and data-based mass balances. Comparison to mainstem in-river loading is sufficient. However, the reviewer is correct in noting that the data-based estimates of the TSS in-river loading do have considerable uncertainty. In fact, this uncertainty exists at all locations in the river, including the Fort Edward upstream boundary. For this reason, sensitivity simulations assessing the model response to different external solids loading conditions are included as part of the revised baseline model calibration presentation in Chapter 7 of Book 1 of the Revised BMR.

7.4.1 Spring 1994 Solids Results

BL-1.14 *Section 7.4. 1, P. 75: What parameters were adjusted during calibration to achieve the results shown in Fig. 7-7?*

The solids dynamics model parameters adjusted for calibration of the TSS predictions presented in Figure 7-7 of the BMR included the gross solids settling rates at high and low flow conditions (see BMR Table 7-2), and the non-cohesive resuspension formulation coefficients β_5 and β_6 (see BMR Equation 5-9 and Table 7-3). The revised baseline model employs a modified framework for describing solids dynamics, so these parameters are no longer applicable. A discussion of the solids calibration approach and the results are presented in Chapter 7 of Book 1 of the Revised BMR.

BG-1.12 *Section 7.4.1, 7.4.3: Comparing predicted and data-based estimate of the mass of solids passing a given station over a specific time period (solids fluxes) along the main stem of the Upper Hudson River (e.g. BMR Book 2, Figures 7-8, 7-11 and 7-22), also does not constrain the model's representation of resuspension and deposition dynamics in the river. This is because flux measurements cannot distinguish among the different mechanisms from which solids are derived within a reach: upstream boundary, tributary loadings and resuspension...*

Please see the response to BG-1.13 (Book 1, Section 7.4). Also, the revised baseline model calibration strategy uses the fully coupled simulation of solids and PCBs to mutually constrain the calibration by looking at long-term burial rates and surface sediment PCB trajectories, as well as water column TSS and PCB levels. Chapter 7 of Book 1 of the Revised BMR presents the revised modeling strategy and calibration results.

BG-1.14 *Section 7.4.1, 7.4.2: ...Sufficient data were available to construct mass balances during the 1993 and 1994 spring floods for the reaches downstream of the TIP and this information should have been used to evaluate model performance. Without such mass balance comparisons, the ability of the sediment transport model to simulate resuspension and deposition processes in the Upper Hudson River cannot be determined.*

As in comment BG-1.13, the requirement that comparison to mass balances estimated from data must be shown to evaluate model performance is overstated. Reasonable calculation of net deposition or erosion rates can be evaluated by comparison to mass balances for solids. However, these do not validate a model's ability to simulate gross resuspension and deposition rates. Simulation of solids dynamics with simultaneous comparison to long-term sediment PCB trends is another means of evaluating model representation of settling and resuspension. These comparisons were presented in the BMR. Furthermore, the BMR places less emphasis on describing short-term variations in sediment transport dynamics than on correct simulation of long-term PCB trends and relative magnitudes of high and low flow solids transport in the river.

7.4.2 Results for 1991-1997 Calibration Period

BF-1.38 *Section 7.4.2, p. 76, Figures 10 a, b, c: The log-normal 1993 total suspended solids HUDTOX calibration results consistently underestimate the peaks and troughs. This is most apparent at Fort Edward but is also noticeable at West TID and to a lesser degree at Stillwater and Waterford. These figures do not appear to support the claim that the model is capable of capturing both high flow event peaks of TSS and low-flow depositional periods.*

Two factors affected the results presented in BMR Figure 7-10 a, b and c. First, the upstream boundary at Fort Edward for TSS was plotted against data at a frequency that was inconsistent with how this was specified as input to the model. The input upstream TSS loading time series actually does match the boundary condition data during high flow event peaks.

The inability of the model to capture the variability of low TSS concentrations is largely due to assumptions that must be made regarding the concentration of external TSS loads. The available data are not adequate to capture the variability of these loads during lower flow conditions, and this is reflected in the model predictions.

Also, please note that the approach to calculating external solids loads was modified for the revised baseline modeling effort. The procedure and results are presented in Chapter 6 of Book 1 of the Revised BMR.

BF-1.39 *Section 7.4.2, p. 77, Fig. 7-16: Displaying congener ratios on a linear scale does not allow full evaluation of the range in ratios. Ratios <1 are essentially not shown, which implies that samples where BZ#4 (or other congener) concentrations are less than BZ#52 are less important to display. The model also underestimates the ratio of water column BZ#4 to BZ#52 concentration at Stillwater and Waterford in 1991 and at the TIP in the latter part of 1993-94 and 1996. While a plausible explanation for the overestimates are provided, no discussion was provided for the underestimates.*

The BMR calibration for PCB congeners is superseded by the revised baseline model calibration presented in Chapter 7 of Book 1 of the Revised BMR. Underestimation of the BZ#4 to BZ#52 ratio may be related to differences in water column and sediment partitioning. Chapter 6 of Book 1 of the Revised BMR presents a discussion of this specific technical issue and how it relates to the modeling PCB congeners presented in Chapter 7 of Book 1.

BS-1.11 *Section 7.4.2 and 7.4.3, Figures 7-14 to 7-16, 7-23 Book 2, the figures are very cluttered and therefore difficult to read. The figures are presented to show how well the model simulates the data. The figures need to be revised or the figure's quality needs to be improved.*

BG-1.15 *Section 7.4.2: In addition, some of the TSS comparisons provided in the BMR are presented on compressed time and concentration scales that impede model-data comparisons...*

The figures mentioned by the reviewers have been superseded by those presented in Chapter 7 of Book 1 of the Revised BMR. The formatting of the revised baseline model calibration figures has been changed to make them easier to read.

BG-1.32 *Section 7.4.2: An important measure of the validity of a model is its ability to reproduce PCBs measured in the water column at various locations. EPA's model fails this test. The model overestimates the PCB flux at TID. As shown in BMR Figure 7-19, after about September 1992, the model diverges from the data, demonstrating a high bias in the model's estimate of PCB fluxes from the TIP...*

It is not disputed that the baseline model presented in the BMR for Total PCBs appears to show a slightly high bias in terms of the data based estimated cumulative load across the TI Dam. Because of agreement with previous comments (BG-1.24 regarding the significant uncertainty involved in estimating long-term cumulative in-river loads based on low sampling frequencies (weekly to bi-weekly), it cannot be stated that the model "fails the test." There is too much uncertainty in these estimates to assess the model on a pass/fail basis. Another factor that must also be considered is that different data sources (i.e., USGS, GE and EPA) have been combined to construct both inputs (e.g., upstream loads) and targets for the baseline modeling applications. Significant differences in sampling methodologies between these different sources may result in calibration targets, such as cumulative in-river PCB fluxes, that are inconsistent. For example, outside of the 1993 EPA Phase 2 sampling period, most of the TI Dam data were collected by GE whereas most of the Stillwater and Waterford data are from USGS.

BG-1.34 *Section 7.4.2: Surface sediment PCB concentrations produced by the 1991-1997 calibration and the 1977-1997 hindcast appear to produce grossly different predictions of surface sediment PCB concentrations in 1998 for Reaches 2 through 7. Surface sediment PCB levels are lower at the start of projections in Reach 6-7 and higher at the start of projections in Reaches 2 through 5 than at the end of the 1977 to 1997 hindcast. This discrepancy renders the model unusable for projecting future PCB levels in water and sediment.*

The significant differences between the 1977-97 hindcast predictions and the 1991-1997 predictions in the BMR resulted because sediment PCB initial conditions for the 1991-1997 simulations were specified strictly based upon the 1991 GE sediment data and without consideration of the hindcast sediment predictions from 1977-1991. There is no way to achieve a totally consistent calibration between the two simulations over the 1991-1997 period when this approach is used to assign initial conditions. The method and development of sediment initial conditions for the revised baseline modeling is fully described in Book 1, Chapter 6, of the Revised BMR.

BG-1.55 *Section 7.4.2: Available data show that sediment-water PCB exchange mechanisms are similar in TIP and TID-ND, which is contrary to the representation in EPA's model. The TID-ND loading exhibits seasonality similar in magnitude to that of the TIP load (Figure 12). EPA's mean monthly loading (as calculated with EPA's model parameters) from TID-ND sediments is approximately 0.3 lb/d, as shown in Figure 10. In contrast, 1997-99 water column data collected from the Schuylerville station (just downstream of the Northumberland Dam) indicate that water column loads measured at Schuylerville are consistently greater than those measured at TID (Figure 11). In fact, the incremental loading from TID-ND is approximately 0.6 lb/d (Figure 12). The EPA's model calibration period (1991-97) had very little water column PCB data collected downstream of TID, and therefore, the model has not reproduced sediment PCB loadings in these reaches. EPA should refine [~~the~~] its model calibration to include the 1997- water column PCB data collected from Schuylerville.*

The revised baseline model calibration takes the reviewer's comment into account. The same sediment-water PCB mass transfer rate is applied to each reach of the river. The development of this rate is presented in Chapter 6 of Book 1 of the Revised BMR, and the revised calibration is presented in Chapter 7 of Book 1. The hindcast calibration period for the model has not been extended beyond September 1997. The 1998 processed sediment PCB data presented in the GE modeling report (QEA, May 1999) was used for comparison with the revised baseline model PCB surface sediment levels at the end of the hindcast simulation.

7.4.3 Results for 1977-1997 Calibration Period

BF-1.40 *Section 7.4.3, p. 78: "additional load at Ft. Edward" Although the text suggests a couple of alternative scenarios, why was it assumed for the calibration that all of the missing load derived from above Ft. Edward and not, at least in part, from other locations above Schuylerville?*

This additional PCB load included in the baseline model presented in the BMR is not included in the revised baseline model calibration. Please see the response to comments BF-1.29 and BG-1.22.

BF-1.41 *Section 7.4.3, p. 79: How were the surficial sediment concentrations shown as individual data points in Fig. 7-25 derived?*

It is acknowledged that the procedure used to develop the surficial sediment concentrations was not well documented in the BMR. Chapter 6 of Book 1 of the Revised BMR presents a detailed discussion of the procedure used for the revised baseline model application.

BF-1.42 *Section 7.4.3, p. 80, Para 1: "Accurate simulations of surface sediment" can be achieved in different ways, as described in the text. The planned future work should include different approaches to vertical mixing.*

The depth and intensity of vertical mixing was evaluated during the revised baseline model calibration effort. A sensitivity analysis for these parameters was conducted and the results are presented in Chapter 7 of Book 1 of the Revised BMR.

BF-1.43 *Section 7.4.3, Calibration Results: Because the sediment reservoir is an important source, the model must be able to predict its behavior (i.e., the vertical distribution of PCBs). If it cannot be demonstrated that the model can predict vertical distribution as well as surface sediment concentrations, it would question the reality of the quality of the fit for other components.*

Chapter 7 of Book 1 of the Revised BMR presents comparisons between data based estimates of sediment Tri+ PCB concentrations at depth and the model predicted concentrations. Please note that there are large uncertainties in the data-based estimates, so this type of model data comparison should be interpreted as only a qualitative assessment of the model predictions.

BL-1.15 *Section 7.4.3, P. 79: Fig. 7-24, discussed herein, shows an increasing high bias for the model over the data-based estimate as time goes by. This raises the concern that the model will increasingly overestimate PCB concentrations for time projections beyond 1997.*

The revised baseline model calibration is compared to several different metrics, allowing the model to be more highly constrained than is possible through a comparison to uncertain in-river loading estimates. These additional model calibration metrics are presented in Chapter 7 of Book 1 of the Revised BMR.

BS-1.7 *Section 7.4.3, Page 79 Book 1; Figure 7-29 Book 2: Surficial sediments are defined as 0-4 centimeters (cm) in the fate and transport model. The PCB concentrations for this depth of sediment in the fate and transport model [are] then used as the sediment concentrations available to the biota in three of the biological models. Thus, the use of the 0-4 cm depth as surface sediments may be interpreted to define the depth at which PCBs are considered to be isolated from the river. However, the depth of biological activity in sediments has been studied in other systems relevant to the upper Hudson River. These studies show that while most taxa are restricted to the upper few centimeters, there are some exceptions which are notable because of their size and numbers, which could influence the amount of bioturbation they can cause and their role in the food chain. Hexagenia mayflies typically burrow down to 8 cm (Charbonneau and Hare, 1998). Chironomus midges may burrow down to 8-40 cm (in the literature review of Ford 1962) and tubificidae worms may penetrate to 200 cm (Ford 1962). Naididae worms may penetrate as deep as 20-70 cm in coarser sediments Learner et al (1978). The macroinvertebrate survey conducted in September of 1997 by Exponent (1998) indicated that all of these taxa are common in the upper Hudson River, as does the 1986 survey by Simpson et al (1986) of the freshwater portion of the lower river.*

What is the reasoning for this definition, and is there any actual data to document that 4 cm is the maximum depth of biological penetration and bioturbation in the upper Hudson River?

A definitive way to demonstrate the depth of bioturbation is to collect field data designed to measure the depth of penetration, either by coring or photographic techniques. Lacking these data, and since there is documentation that several of the common taxa of macroinvertebrates typically penetrate and extensively mix the sediment down to 8 cm, we suggest that the model be run using the same high mixing rate down to at least 8 cm to test the model's sensitivity to this parameter. The additional work mentioned on page 80 of Book 1 should be described.

As stated in the BMR, the approximate 4 cm exposure depth was selected in consultation with the bioaccumulation modelers as the most appropriate spatial scale for representation of sediment PCB exposures to benthic organisms. This 4 cm exposure depth should not be interpreted as defining a depth necessary to sequester PCBs from the river system, since both particle mixing and diffusion act on sediments below this level in both the modeling presented in the BMR and for the revised baseline modeling applications (see RBMR . Book 1, Chapter 7). Also, note that using a maximum possible depth of biological penetration and bioturbation would likely misrepresent average population exposure levels for benthic organisms. Sensitivity analyses on particle mixing depths for non-cohesive sediments for both the revised model calibration (Chapter 7 of Book 1) and for model forecasts (Chapter 8 of Book 1) are presented in the RBMR.

BG-1.17 *Section 7.4.3: ...The BMR model-data sediment comparisons, however, do not demonstrate the model's capacity to reproduce surface sediment trends. The BMR does not include any comparisons between the 1991-97 calibration results and measured sediment PCB concentrations. The omission of this key calibration target precludes an assessment of the model's capability to represent river conditions accurately. In addition, comparisons between the results of the 1977-97 hindcast and sediment data (BMR Book 2, Figures 7-25a-d) do not validate the 1991-97 calibration results since the results generated from these two model calibrations may be inconsistent (see Section 4). Further, calibration of surface sediments in the TIP should be evaluated using GE's 1998 sediment survey data.*

The reviewer's comments are acknowledged. The revised baseline model calibration results are compared to available surface sediment data over the entire hindcast period, including a comparison of the end of simulation results to the 1998 GE sediment data, in Chapter 7 of Book 1 of the Revised BMR.

BG-1.18 *Section 7.4.3: Second, the model-data comparison of the 0-4 cm. sediment PCB concentrations includes the 1984 and 1994 data sets (BMR Book 2, Figure 7-25). The vertical resolution of these two surveys is too coarse to permit comparison to the 0-4 cm layer...*

It is agreed that the resolution of the 1984 and 1994 sediment data set is too coarse for a quantitative assessment of model predicted PCB concentrations within the 0-4 cm surface sediment layer. Comparisons of sediment predictions and data presented for the revised baseline modeling in Chapter 7 of Book 1 of the Revised BMR take this observation into account.

BG-1.19 *Section 7.4.3: ...BMR Book 2 Figures 7-13 to 7-15 presents results at TID, Stillwater, and Waterford on a scale that is too compressed and obscured to judge whether the model reproduces the observations without bias. Additionally, these figures include GE and EPA data, but omit USGS data collected at Stillwater and Waterford.*

The reviewer's comments are acknowledged. The calibration figures presented in the Revised BMR have been revised to make the easier to read and to incorporate the USGS data that was inadvertently omitted.

BG-1.23 *Section 7.4.3: ...The BMR presents model to data comparisons for large areas often covering different sediment types, which indicates that some type of data averaging occurred (e.g. BMR Book 2, Figure 7-25). However, the BMR does not present the methodology behind the averaging used to produce these data points. As noted above, the assumptions and procedures involved in averaging spatial data are numerous and complex and should be presented in sufficient detail so as to allow reproduction of the calculation.*

The methodology used to average the sediment PCB data used as calibration targets is presented in Chapter 6 of Book 1 of the Revised BMR.

BG-1.24 *Section 7.4.3: The data shown in BMR Book 2 Figure 7-24 are also questionable. The primary concern deals with the assumptions and methodology used to develop cumulative PCB flux over the 21-year period plotted in BMR Book 2 Figure 7-24. For all 3 stations shown, very limited data exist, both historically and in the 1990's...*

The uncertainties associated with both the in-river load estimates and upstream load estimates are acknowledged. The sampling frequency was deemed sufficient to allow reasonable estimation of cumulative in-river flux estimates, however these estimates have a considerable degree of uncertainty and therefore do not serve as a primary calibration constraint of the model. Acknowledging the high level of uncertainty, it is still reasonable to examine how the model reproduces these estimates. Additionally, in order to more tightly constrain the model results a series of other metrics to the model calibration has been applied, as presented in Chapter 7 of Book 1 of the Revised BMR. These include comparison of data-estimated and model-predicted cumulative Tri+ in-river fluxes during approximate scour vs. non-scour flow conditions (see Figure 7-22 in the RBMR).

BG-1.33 *Section 7.4.3: As indicated by the model/data comparisons (Figure 3),[ ] EPA's model performs well within the TIP. The model's calculations are close to the 1998 observed PCB levels. The model calculates a reduction in Reach 6-7 between 1991 and 1998, a trend consistent with the TIP data. However, the model grossly over-predicts surface sediment PCB3+ levels in Reach 5 and Reaches 2-4. The predicted 1998 reach average surface sediment PCB3+ levels are a factor of 2-3 higher than the observed 1991 data within these reaches.*

Results from the revised baseline model calibration compare well with surface sediment PCB time trajectories at different locations in the river for both cohesive and non-cohesive sediments. These results are presented in Chapter 7 of Book 1 of the Revised BMR.

7.5 Component Analysis

BC-4.1 *In reviewing the data and debate to date, I think there is general agreement that PCB and sediment loading observations at the TI dam can be representative; and that PCB loading of the water column generally increases during transit of the TIP. However, to adequately constrain TIP mass balance of both PCB and sediment, observations of equal quality for input loading are necessary at Ft. Edward/Rogers Is., and there are two problems that I still see as adding to model uncertainty, if not conceptual error.*

The first is representative water column sampling, as I have noted before. If the EPA accepts the GE "routine composite sample" procedure developed for this site (as implied, Responsiveness Summary 1-4-2, book 1, p DEIR 9,10), then use the GE results and use all of them for consistency. Second is the problem of estimating total mass flux in high discharge events. Again, GE data is probably the best obtainable, but considerable variance, especially for PCB loading, will be present (e.g. see the USGS study of the 1981 (?) event at the Stillwater *station by C. Barnes, and note the variability in PCB loading at this sample frequency). As a result, estimates of total PCB mass input to the TIP are poorly constrained, and a simple relationship of PCB concentration (or TSS for that matter) to discharge does not exist. Other than that both PCB concentration and TSS qualitatively tend to increase during high discharge events, there is little or no correlation of the two at any observation station (I have presented a review of this data at a prior STC meeting).*

Uncertainties related to specifying upstream and tributary loadings to the revised baseline model have been examined through sensitivity analyses presented in Chapter 7 of Book 1 of the Revised BMR. The issue of differences between datasets from different sources, and how this may affect both external loadings and in-river calibration targets has been explored as part of the work conducted in developing the revised baseline model.

BC-4.2 *Under these circumstances, the incorporation of the LRC results into the model calibration then becomes a forcing function that is likely to distort the TIP conceptual model and model output because short term PCB and sediment mass balance, and long term mass conservation, is insufficiently constrained. As HUDTOX stands, an assumption of a net PCB loss of 43% from the 0-10 cm sediment zone (what calibration period?) then translates to an implied TSS resuspension component, and the unknown mechanism of low flow PCB transfer to the water column (assumed resuspension) may be an artifact of this assumption. An assertion that the values of model variables appear to 'fit' together, or are internally consistent, is then circular reasoning and not a test of validity.*

The calibration of the baseline model presented in the BMR and the revised baseline model presented in Chapter 7 of Book 1 of the Revised BMR was developed independently of the net PCB loss estimates presented in the Low Resolution Sediment Coring report. The discussion presented in the BMR was an attempt to compare the separate findings at a more consistent scale. This comparison was not intended to be a test of the HUDTOX model validity.

BC-4.3 *If the EPA feels that changes is PCB congener pattern and PCB loading imply sediment resuspension (Waterford, March 1993, Responsiveness Summary book 1, 3-2-4, p. DEIR 25), what were the results at the TI dam? Given the HydroQual analysis of sediment sources and loading in the TIP, how do you know that resuspended sediment can be distinguished from tributary and upstream sediment flush?*

The issue of distinguishing a partially particulate-mediated sediment to water PCB fluxes versus a purely diffusional (truly dissolved and DOC-bound) flux is explored in detail through data analyses presented in Chapter 6 of Book 1 of the Revised BMR. Additionally, various PCB congener simulations conducted for the period of 1991-1997 are used to explore the issue further in Revised BMR, Book 1, Chapter 7.

BL-1.16 *Section 7.5, P. 80: The statements on this page that the Hudson River is [net] depositional, that the burial (or net deposition) rates for cohesive sediments in the Thompson Island Pool are much greater than for non-cohesive sediments and the presence of hot spots in the Thompson Island Pool all support the conclusion that burial of PCB's is and has occurred in the cohesive sediments in the river. Where does EPA find this conclusion to be illogical?*

It was not indicated that this conclusion is illogical. While PCBs may experience burial in many hot spot areas of the TIP, all of the sediments in the TIP remain a source of PCBs to the water column through a variety of mechanisms. A prime example of this is that available data indicate a net gain of PCBs from the TIP sediments at a rate much higher than can be accounted for by simple diffusion during flow conditions when sediment scour is expected to be negligible. Please see the discussion of the sediment-water PCB mass transfer data analysis in Chapter 6 of Book 1 of the Revised BMR.

BL-1.17 *Section 7.5. P. 81: What characteristics of the river would likely be the cause of the different dominant processes for PCB sediment to water transfer in different regions of the river cited here?*

Please see the response to BL-1.12 and BL-1.13 (Books 1, Section 7.3.2.).

BL-1.18 *Section 7.5 PP. 81-83: ...The principal conclusion in this section is that the model estimate of PCB loss from the Thompson Island Pool is very close to the estimated loss GE provided in 1998. Also, the use of a calculated average sediment bed elevation should not be used to draw conclusions about burial in the Thompson Island Pool. EPA, itself, cited in Section 7.5 on P. 80 the order of magnitude difference between the burial rates for cohesive and non--cohesive sediments. No one is saying burial occurs in non-cohesive areas, only in cohesive areas. Therefore, if EPA wishes to evaluate burial, it should concentrate on only the cohesive sediments and not use average values which include both cohesive and non-cohesive sediments.*

The discussion was not intended to either confirm or refute quantitative conclusions presented in the Low Resolution Sediment Coring Report (USEPA, 1998). However, the results of the revised baseline modeling effort suggest no basis for changing the statements made in the BMR regarding this comparison. Differences in findings between the modeling and the Low Resolution Sediment Coring Report are most likely due to the different spatial scales in which the data were analyzed. The important finding from both reports is that the PCBs in the sediments are entering the water column and/or being redistributed from the most highly contaminated areas.

BS-1.9 *Section 7.5, Page 40, Page 81 Book 1, and Figure 7-29 Book 2: These sections discuss the mechanisms which transfer PCBs into the water column. The terminology is not consistent. Clarify that the non-flow-sediment resuspension (text on page 40) or the combination of all particulate resuspension are the same components in the report (text on page 81 and Figure 7-29).*

The possible mechanisms for non-flow dependent sediment to water transfer of PCBs presented in the BMR were investigated in greater detail for the revised baseline modeling. The revised baseline model does not include background solids resuspension (as did the BMR model applications), since there are multiple possible mechanisms that may result in sediment to water PCB transfer during non-scour (lower flow) conditions. As discussed in Chapters 6 and 7 of Book 1 of the Revised BMR, the available data cannot quantitatively distinguish between the possible causes of this PCB mass transfer with a high degree of significance.

BF-1.44 *Section 7.5, p. 80: Please explain the discrepancy between TIP sediment trapping efficiencies, initially listed in Table 6-15. The TIP trapping efficiency per Figure 7-26 is 10.5% but in Table 6-15 is 15%.*

The data-based trapping efficiency for the TIP is based upon a much shorter period of available data than the trapping efficiency shown for the 21 year historical hindcast period in BMR Figure 7-26.

BF-1.45 *Section 7.5, Fig. 7-26: What does "dispersion" represent, and why is it only applicable to the TID to Schuylerville reach? How were the value(s) for dispersion determined?*

Water column dispersion coefficients were applied between model segments that are not separated by dams. This is why the TID-Schuylerville reach shows a small net dispersive loss of solids to the Schuylerville-Stillwater reach. A discussion of how these values were estimated is presented in the Chapter 6 of Book 1 of the Revised BMR.

BF-1.46 *Section 7.5, p. 81, Figure 7-29: Please explain the significant differences in particulate PCB transfer (other than the differences in rates shown in Fig. 7-6b) within TIP and downstream of the TIP.*

Please see our response to comments BL-1.12, BL-1.13, and BG-1.35 (BMR Section 7.3.2) regarding sediment-water PCB mass transfer. The issue is extensively evaluated in Chapters 6 and 7 of Book 1 of the Revised BMR.

BF-1.47 *Section 7.5, p. 81: The text discusses the contribution of BZ#4 and BZ#52 in sediments to the load gain across the TIP but Figure 7-31 depicts BZ#4 and BZ#5. It also appears that BZ#4 accounts for less than one third the net sediment release of total PCBS between 1991 and 1997, as opposed to the estimated one-half cited by the authors.*

Note that Figure 7-31 in the BMR has BZ#52 mislabeled as BZ#5. The contribution of individual PCB congeners relative to the total PCB lost from sediments has been reassessed in the revised baseline model calibration effort. These results are presented in Chapter 7 of Book 1 of the Revised BMR.

***BF-1.48** Section 7.5, p. 81-83: The results of the Low Resolution Coring Report and the BMR should be compared to assess the ability of the model to predict measured changes in hotspot PCB content.*

It is not possible to develop a quantitative comparison of the LRC results and the baseline PCB model predictions as a basis for assessing the ability of the model to predict changes in the PCB content of hot spots. Also, please see the response to comment BL-1.18 (BMR Section 7.5).

***BG-1.16** Section 7.5: The BMR presents little information concerning net sedimentation rates predicted by the model. One figure (BMR Book 2, Figure 7-27) presents predicted sedimentation rates in the TIP for the 21-year period from 1977 through 1997. These results could have been compared to measured rates, determined from ^{137}Cs-dated high-resolution sediment cores, to evaluate model performance...*

The modeled deposition rates for the TIP are not directly comparable to the sedimentation rates measure by the high-resolution cores because of different spatial scales between the analyses. The model segments in the TIP are approximately a half a mile long and the deposition rate for a high-resolution core would not be expected to apply for a complete model segment. The commentator should be reminded that the dated high-resolution sediment cores collected during the Phase 2 sampling program were specifically located where high deposition rates would be expected. This was done to ensure that as many of the cores taken as possible would have ^{137}Cs profiles that could be dated.

***BG-1.35** Section 7.5: Using parameters presented in this report (BMR Book 2, Tables 7-1, 7-4 and 7-5), the calculated fraction of total PCBs that is DOC-bound in the TIP is a factor of 1.5-2.0 higher than the dissolved fraction. Because the same temperature slope factor for PCB partitioning affects both phases equally and the sediment-water transfer rate is the same for both phases, the sediment-water mass transfer associated with the two phases should only differ by a factor 1.5-2.0. This is not consistent with the greater than 6-fold difference presented in BMR Book 2, Figure 7-29.*

The reviewer would be correct if the sediment-water mass transfer was solely governed by the porewater concentration of each phase. Instead, PCB diffusive flux is driven by the concentration gradient between the pore water and the overlying water column of each phase. The differences in dissolved and DOC-bound PCB fluxes reported in the BMR are consistent with this.

7.6 Conclusions

***BF-1.49** Section 7.6, p. 83: "the simulation of the river's recovery trajectory depends on an accurate representation of the processes controlling sediment-water interactions of PCBs and dynamics of solids in the system.". While the HUDTOX calibration and diagnostic analysis demonstrates to varying degrees the ability of the model to characterize the Hudson River system, knowledge about "PCB partitioning (particularly in sediments), non-flow dependent sediment-water PCB fluxes (both dissolved and particulate), and sediment dechlorination and biodegradation" is* *incomplete. Therefore, what are the uncertainties in the output given the assumptions surrounding these processes and constraints built into the model.*

A series of sensitivity simulations were conducted to evaluate the effect of these uncertainties on the revised baseline model calibration. The discussion of these results presented in Chapter 7 of Book 1 of the Revised BMR assesses the results of these analyses to provide a better understanding of the utility of the baseline model as a forecasting tool.

BG-1.57 *In addition to EPA's use of a spatially varying pore water PCB mass transfer coefficient, there are three fundamental problems with EPA's particulate sediment-water PCB exchange mechanism:*

1. There are no data to support simulation of this mechanism. Particulate mass transfer cannot be differentiated from pore water exchange, leaving the process (and model) inappropriately constrained.

2. There are no data to support different particulate phase mass transfer coefficients in different reaches of the river. The mass transfer rate used in the model is approximately 5 times greater in TIP than in the reach from TID to Northumberland Dam (BMR Book 2, Figure 7-6b). The mixing mechanisms represented by this process occur throughout the Upper Hudson River, and not just in TIP, and EPA's assumption that greater transfer occurs in TIP is purely speculative. This leads to an inappropriate focus on the TIP sediments as potential PCB sources and leads to an inconsistency between the model and data downstream of TID.

3. The mass transfer coefficient is uncertain because of uncertainty in the conditions under which partitioning occurs. The net PCB loading from this mechanism depends on the fraction of particulate phase PCBs that settles back to the sediments after partitioning to the water column. This fraction depends on the concentration of solids during partitioning, which, depending on the depth over which this exchange occurs, will vary greatly (the solids concentration in the bed is on the order of 1 kg/L, while that in the water column at low flows is typically less than 10 mg/L) (Figure 13). The assumed solids concentration under which this partitioning occurs can result in significant differences in how much particulate phase PCBs are transferred to the water column. The high sensitivity of the mass loading from the EPA's model particulate transfer mechanism adds significant uncertainty. The mass transfer coefficient that was calibrated in EPA's model depends on the assumed depth over which this exchange occurs. In this regard, the process is not well constrained. Therefore, the application of this mechanism in EPA's model and the mass transfer coefficients calibrated have little physical relevance and are best represented as a bulk process in conjunction within pore water exchange.

1. Observed low flow congener patterns at the TI Dam appear to be inconsistent with porewater patterns estimated using site-specific partition coefficients. This suggests that part of the PCB load gain across TIP is from particulate phase sources in the sediments. It also suggests that congener

mass balances may be used to differentiate pore water and particulate phase transfer mechanisms, and estimate their relative magnitudes.

2. Sediment-water mass transfer rates for TIP can be estimated using site-specific data for the observed PCB load gain between Fort Edward and TI Dam. In principle, the same approach applies to reaches downstream of TI Dam. An important difference, however, is that site specific data below TI Dam do not allow estimation of sediment-water mass transfer rates that are as tightly constrained as those estimated for TIP. This leads to two possible choices for sediment-water mass transfer rates downstream of TI Dam in the model calibration: first, use the same mass transfer rate estimated for TIP; or second, determine mass transfer rates by calibration to PCB load gain across individual downstream reaches. The first choice is premised on the assumption that mass transfer rates estimated for TIP should also be used downstream because there are insufficient data to prove otherwise. The second choice is premised on the assumption that mass transfer rates in downstream reaches should be varied as part of the calibration because they can not be tightly constrained by the available data. Both of these calibration choices are investigated in the revised baseline modeling effort.

3. Representation of sediment-water mass transfer as a bulk process in conjunction with pore water exchange or as a particulate phase exchange process are both uncertain. Neither process is well understood at a mechanistic level. In spite of uncertainties and lack of a thorough understanding of either process, the site-specific data clearly require a sediment-water mass transfer mechanism to successfully balance PCB mass. The revised baseline modeling effort investigates both pore water exchange and particulate phase exchange using Tri+ and individual PCB congener applications. The site-specific data are used to the fullest extent possible to determine the significance and relative magnitude of particulate phase sediment-water exchange.

Chapter 8: MASS BALANCE MODEL FORECAST SIMULATIONS

8.1 Introduction

8.2 No action.

No significant comments were received for sections 8.1 to 8.2

8.2.1 Approach

BF-1.50 *p. 87, Fig. 8.4: The initial condition for the TIP surficial sediment PCB concentration is about 15 ppm. Does this represent an average concentration as stated in the caption? Is this consistent with a median total PCB concentration for the cohesive sediment of 32.5 ppm reported earlier?*

The 15 ppm Total PCB concentration in BMR Figure 8-4 represents the model-predicted average concentration in the TIP for both cohesive and non-cohesive sediments. The 32.5 ppm PCB concentration is actually an estimate of average 1984 conditions in approximately the upper 10 inches (25 cm) of the TIP cohesive sediments. The reference to this value as a median concentration in the BMR, as well as in one location in the Revised BMR (Section 4..3.1.4), was in error.

The BMR model results are superceded by those presented in Chapters 7 and 8 of Book 1 of the Revised BMR. Additionally, a revised estimate of the average 1984 PCB concentration in the upper 25 cm of the TIP cohesive sediments should have been presented in the Revised BMR as 43.7 ppm (or mg/kg). The commentator is referred to the response to comment BF-1.16 (Section 4.3.1) for further details regarding this issue.

8.2.2 Results

BF-1.3 *The upstream boundary conditions used in the No Action alternative assume that there will [be] no flow-related change (increase) in loading during high flow events. For example, the modeling does not address potential impact of high flow events on the Interim Cap on the Remnant Deposits or other areas of high concentrations of PCBs that remain between the plant sites and Rogers Island.*

The upstream boundary condition was calculated as a constant concentration corresponding to a yearly annual average PCB load. In the modeling effort, it was not attempted to predict pulse loads across the upper model boundary created by high flow events. The commentator should also refer to the response for comment BG-1.22 (Section 6.4.4). The caps and shoreline protection for the remnant deposits were designed to withstand flows associated with a 100-year flood, which is the largest flow event evaluated by the model.

8.3 100-year Peak Flow

8.3.1 Approach

BF-1.53 *The 100 year event is simulated as occurring at the beginning of the simulation period. How different would the simulation be if the 100 year peak followed a 15 year high flow event such as in January 1998 where PCB loads upstream of Rogers Island were higher than model inputs or preceded a smaller but measurable high flow event?*

An objective of the baseline modeling effort was to examine the impact of a major flood event, not multiple flood events. It should also be pointed out that the 100 year event simulation was likely more extreme than a natural 100 year flood for predicting downstream transport of PCBs, because both upstream and tributary solids loads were not scaled-up. These addition solids loads would have a dilution effect on any scoured PCBs that either redeposit within the TIP or in downstream pools.

8.3.2 Results

BF-1.51 *p. 88 (Section 8.3.2) and the accompanying figure (Figure 8-7): The text indicates that a simulated 100-year flood event only increased flux across the TID by about 59 kg, while the figure appears to indicate an increase of over 150 kg higher PCB flux.*

BF-1.52 *The DOSM estimates a loss of 49-65 kg PCBs from resuspended cohesive sediments during a 100-year event (p. 31). This estimate matches closely with the predicted 59 (150?) kg PCB flux over the TID from the HUDTOX forecasting, but it doesn't account for non-cohesive sediments or redeposition of resuspended sediments. The HUDTOX and DOSM estimates are briefly discussed in terms of the differences in the approaches of the two models. A more thorough explanation should be provided. For example, is the magnitude of PCBs lost from non-cohesive sediments similar in scale to that redeposited?*

The PCB model forecast results have changed as a result of the revised baseline model calibration effort. The revised forecast results and comparisons presented relative to the DOSM scour loss estimates are presented more clearly in Chapter 8 of Book 1 of the Revised BMR.

8.4 Discussion

No significant comments were received for section 8.4.

REFERENCES

No significant comments were received for the References of Book 1 of the BMR. However, the 1994 and 1995 references for Velleux et al. should be deleted from the reference list.

REVISED REFERENCES

Velleux, M., J.Gailani, and D. Endicott. 1996. Screening-level approach for estimating contaminant export from tributaries. Journal of Env. Eng. 122(6): 503-514.

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GENERAL COMMENTS - BOOKS 3 AND 4

BF-1.8A *Overall, the "goodness of fit" of the models indicates that bioaccumulation modeling may be useful; however, application of the models as a predictive tool in a decision-making context should be entertained only if (a) the important uncertainties are addressed, and a field validation step is conducted to test whether the "predictive" ability of the models is retained with new data. This is especially important since HUDTOX model output is used as input to the bioaccumulation models. Because modeled results (rather than empirical data) are used for the environmental fate component, it is not clear to what extent the observed model fit is attributable to the environmental fate component versus the biologically-based food web model.*

In the model results presented in the BMR, the FISHRAND model was used to "predict" (or hindcast) all the historical data. None of the rate constants or uptake parameters were modified during calibration. Thus, the goodness-of-fit presented can be interpreted as a validation of the combined models.

In terms of the HUDTOX output as input: FISHRAND is a fully mechanistic model. It is time-varying and dynamic in nature, therefore, it is data intensive. It requires time-varying environmental (i.e., sediment and water) concentrations as inputs. The time-scale of the model can be set, that is, it could accept daily concentrations. However, after evaluating both the available data and the HUDTOX sediment and water results, it was determined that annual and monthly averaging periods would be appropriate for sediment and water, respectively.

None of the bioaccumulation models can be run using available observed data alone, as the observations consist of sparse, point-in-time measurements at a limited number of locations. Some type of interpolation from these point measurements to continuous exposure concentration fields is required. The HUDTOX model, which is calibrated to the observed environmental data, may be regarded as a mechanistic best estimate of the interpolated time course of exposures between observations. HUDTOX thus provides a valid basis for determining exposure concentrations for bioaccumulation modeling. It is true that any inaccuracies in HUDTOX estimates for the hindcast period will contribute to a lack of fit in the bioaccumulation model hindcast. Validation statistics presented for the bioaccumulation models may thus be assumed to be conservative, in that a better fit to fish tissue concentrations would be expected if uncertainty in HUDTOX predictions were reduced.

See also Response to BF-1.12 (validation sampling).

BS-1.3 *p. ES-6 Book 1, Fifth Finding: The model determined that the Stillwater Pool PCB fish concentrations would lag behind the predicted recovery levels of the Thompson Island Pool. This seems to be incorrect in comparison to what other source conditions indicate about the behavior of an established gradient in a riverine system. Since both areas of the river are undergoing some depletion of their PCB reservoirs, it is difficult to envision that the Thompson Island Pool will* *leapfrog ahead of the Stillwater Pool in that regard. Furthermore, it should be noted that yellow perch at Stillwater reached below 2 ppm in 1997.*

BS-1.34 *On p. 87, Book 3. The fifth bullet should be revised. Yellow perch reached below 2 ppm in 1997 at Stillwater.*

The results presented in the BMR have been updated to reflect refinements in the modeling approach. The Revised BMR shows that Stillwater Pool concentrations are always less than the Thompson Island Pool in terms of recovery. Predicted median yellow perch concentrations in 1998 are 1.7 ppm wet weight, consistent with the data.

BF-1.9 *The models rely exclusively on summer-averaged exposure conditions. We agree that the summer period would be the most important period for food uptake of PCBs, but water-borne exposures would occur year round, and appear to be an important source of PCBs to all fish species.*

The FISHRAND model uses monthly averaged water concentrations over the entire year rather than summer-averages. The Bivariate and Probabilistic models use summer-averaged water concentrations as the best steady-state representation of exposure. In both these models, uptake is represented by a series of transfer coefficients. Because of the way in which these coefficients are constructed, summer-averaged water concentrations are appropriate to use as the coefficients represent a steady-state relationship between the water and fish body burdens.

The Bivariate BAF approach is intended to be a simple scoping tool to inform the more sophisticated fish models. In this context, the summer average concentrations are believed to be the best summary indicator of exposure at an annually averaged scale that is available from monitoring data. Use of complete-year average concentrations in the BAF approach was rejected for two reasons: (1) the most significant exposure, both via food uptake and via direct gill exchange, is believed to occur during the warm weather period when fish activity is high, and (2) estimates of complete-year concentrations from limited observed data prior to 1991 are problematic, as the results may be biased high by targeted sampling of high flow events.

BF-1.10 *The model uses growth rate determined by Gobas (1993) for lake trout for all fish species. Given the different fish species under consideration in this modeling effort, and the likely differences in food webs and temperature in the Hudson River system relative to the Great Lakes, incorporation of species-specific growth rates should be considered.*

BF-1.66 *p. 31: Growth rate constants are temperature dependent but are species independent. Knowledge of species-specific growth rates should be incorporated into the model.*

BG-1.2. *FISHRAND used default fish growth rates computed with two generic weight-based regressions. EPA did not analyze the extensive data set of weight and age measurements for fish from the Upper Hudson River. The growth rates used in the model appear to be considerably greater* *than the values measured in the Upper Hudson River. This difference is important because growth rate dilution can have a large impact on the PCB concentration in the fish.*

BG-1.60. *EPA's use of default growth rates with the availability of the extensive data set of Hudson River fish is unwarranted. These default growth rates appear to be considerably greater than the values measured in the Hudson River. EPA should use the available site-specific data or fish growth rates.*

The model used the "generic" field-validated Gobas growth rate (which has been used in other applications for other species without modification) for the results presented in the May 1999 BMR. In the Revised BMR, growth rate coefficients for each species were calibrated to fit the observations. This was done by using the growth rate coefficient for each species as a calibration parameter for all locations. This work is presented in Chapter 6 (Book 3) of the Revised BMR.

BF-1.11 *Lipid content was assigned a distribution for each species disregarding locational and temporal differences since there was no differences within a species by location or year. Pattern analysis should have also examined lipid content for a given species at a given location over time, especially in light of the importance of lipids demonstrated by the sensitivity analysis. It may be more appropriate to establish distributions for each species at each location.*

BF-1.94 *p. 70, Section 6.1.2.1: Lipid data were combined across years and locations to create lipid distributions for each species. It may be more appropriate to develop lipid concentration distributions per species per location.*

BS-1.27 *P. 70, Book 3 The discussion about lipid content implies this biological parameter should be constant. However, large shifts are observed between locations, species and years. The reason why lipid content is so highly variable is not understood. To address this variability, the report uses a single distribution of lipid content for each species, derived from the entire database. However, this variability will still be a source of uncertainty in the modeling which should be acknowledged in the report.*

A detailed lipid analysis was conducted and presented in Chapter 6 of the Revised BMR. Although there are year-to-year variations within a given species, there is no consistent pattern or trend, and no basis upon which to justify a distinct lipid distribution by location in the Upper Hudson River. When the lipid data are aggregated across years, spatial differences in lipid content are not apparent. In terms of the predictive power of the model, it was important to establish the most consistent lipid distribution for each species that could be used for both hindcasting and forecasting. Thus, these species-specific lipid distributions remain the same for all modeling periods. A point estimate of lipid content was not used for any species. Lipid distributions were initially empirically defined as triangular in FISHRAND, but following the calibration procedure presented in the Revised BMR, these distributions were refined (typically normal or lognormal). These lipid distributions were calibrated separately for each location, based on this comment, but the analysis showed that the parameterization of the calibrated distributions are virtually the same from location to location.

Note that using a distribution for lipid content does not imply that the lipid content from year to year or location to location is constant. It implies that there is a distribution that represents the likelihood of a particular lipid content occurring in a given year and location.

BG-1.3 *The lipid contents of the fish used in the model were calculated directly from the values measured by NYSDEC. For largemouth bass and brown bullhead, these values were for fillets. Whole-body lipid contents are the correct values to use and are approximately 2.5 times greater than lipid levels in fillets in several species of fish. Therefore, the lipid contents used in the largemouth bass and brown bullhead models appear to be too low. In addition, one average lipid content was used for all locations and years, even though the data indicate that the lipid contents of the fish vary considerably year-to-year and by location. Differences among populations and between fillet and whole body levels are important because the lipid content of the fish impacts the PCB excretion rate, and therefore affects the degree of bioaccumulation.*

See response to comment BG-1.58 for lipid content of whole body vs. fillet. See response to comments BF-1.11 and BF-1.94 regarding the variation in lipid content from year-to-year and by location.

BG-1.58 *The lipid contents used in the Gobas model were calculated directly from the values measured by NYSDEC. For largemouth bass and brown bullhead, these values were for fillets. On average, whole-body lipid contents are approximately 2.5 times fillet levels in several species of fish. Therefore, the lipid content used in the largemouth bass model appear to be too low.*

It is true that the percent lipid values for the larger fish (largemouth bass, brown bullhead, white perch, and yellow perch) are for the standard fillet rather than the whole fish. Concentrations in the standard fillet are appropriate exposure concentrations for use in human health risk assessment. To maintain consistency with the available data and to be able to validate the model directly, the standard fillet lipid distribution was used. Essentially, this means that the model predicts a PCB concentration in the standard fillet. Consequently, we would expect the wet weight concentration of the whole fish to be higher. As described in the ecological risk assessment (USEPA, August, 1999), a factor of 2.5 was applied to the fillet model results for largemouth bass to obtain a whole fish concentration based on the ratio of the percent lipid in the whole fish versus the fillet. A factor of 1.5 was applied to brown bullhead fillet concentrations. These factors were obtained based on data from a USEPA document (United States Environmental Protection Agency (USEPA). 1997. The incidence and severity of sediment contamination in surface waters of the United States. EPA 823/R-97-006. Office of Science and Technology, Washington, DC.).

BF-1.12 *The text implies that the HUDTOX model may introduce a factor of two variability in exposure concentrations to the bioaccumulation model. There is little information provided to* *determine whether this qualitative estimate is reasonable. Ultimately, synoptically-collected sediment, water, prey tissue, and fish tissue data would be necessary to truly validate the developed models. Ideally, this validation of the modeling would include both total PCB and congener-specific analysis. This could be done for a limited subset of the river reaches.*

The HUDTOX model provides daily output for hindcasting years and output for every other day in the forecasting period. Averaging these daily results across some appropriate time period (i.e., monthly for water and annually for sediment) allowed for the estimation of a standard deviation, which is the measure of spread, or variability, introduced by the time-varying exposure concentrations. We did not mean to imply that a specific factor is introduced by the HUDTOX results.

It was our professional judgment that fish body burdens were likely to remain within a factor of two of the results presented in the BMR for most locations and species, allowing for refinements in the modeling approach. This estimate was based on a qualitative averaging of the relative percent difference between predicted and observed body burdens for each species at each location for all years. While it is true that synoptic data collection is one method of validation, no such data collection effort is planned in the forseeable future. Consequently, FISHRAND model validation relied on the approach presented in Chapter 6 of the Revised BMR. This approach involved:

- Using only a partial dataset (pre 1990 data) and recalibrating the model and then comparing both posterior distributions and model results between the partial and full dataset calibration.

- Running the calibrated model for river mile 154.

As presented in Chapter 6 of the Revised BMR, these approaches provided a degree of confidence in model performance.

BF-1.13 *The results of the FISHPATH/FISHRAND modeling are not adequately addressed. There is only one half page of discussion devoted to the quality of fit for these models (p. 72). This is an important omission, given that these models are the most important from a predictive standpoint, since they are mechanistically based. A more detailed discussion of where fit was good and where it was poor would help in the evaluation of the predictive ability of the models (i.e., which species and years were poorly predicted, and why?). For example, the model did not appear to have the same ability to model lipid-normalized PCBs and wet weight PCBs.*

The results of the FISHRAND modeling were not discussed at length in the May 1999 BMR. A more extensive discussion of the results is provided in the Revised BMR. In the Revised BMR, the FISHRAND calibration focused on the wet weight PCB concentrations because these are the values most often used by agencies in decision making

BS-1.36 *...EPA...noted that additional work will be performed for the models. The scope of the additional work should be provided to the model reviewers as soon as this information is available. This should facilitate a more timely response to any additional modeling work products.*

There is no formal scope of work for the additional model refinements that have occurred. The Revised BMR provides the details of the additional work that has been conducted.

BS-1.7 *...Surficial sediments are defined as 0-4 centiimeters (cm) in the fate and transport model... What is the reasoning for the 0-4 cm definition, and is there any actual data to document that 4 cm is the maximum depth of biological penetration and bioturbation in the upper Hudson River?*

All the bioaccumulation models incorporate the results from the first two vertical segments of the HUDTOX model, typically 0 – 4 cm (recognizing that the depth of the first segment can vary from 1 to 3 cm). These segments were selected as they represent an appropriate depth for surface sediments because this roughly corresponds with the depth of sampling in the ecological program (0 – 5 cm). This depth generally coincides with the aerobic layer, and is therefore the depth at which the bulk of benthic biological activity would be expected to occur. Although the actual bioturbation zone may be deeper for particular species, given the kinds of organisms likely to be consumed by fish, the range of organisms within the 0-4 cm range was considered appropriate for evaluating fish exposure from surface sediments.

BG-1.4 *The report, however, presents no analyses of the extensive gut content data and invertebrate population data collected in the Hudson River for the purpose of evaluating food web structure. The structure of the food web controlsthe relative importance of sediment and water column PCBs to the food web, and therefore the response of fish PCB levels to natural recovery and to remediation activities.*

BG-1.7 *The credibility of the bioaccumulation models is diminished by the lack of consistency between the models. The relative importance of water column and benthic PCBs to the food web is a critical parameter of the models. However, the composition of fish diet differs among models.... Such inconsistency provides no bais for choosing a prediction of fish diet in the future.*

BG-1.36 *The BMR states that the bioaccumulation models "provide complementary views of PCB uptake" (BMR Book 3, p. 11). To provide a valid basis for comparison among models, one must use a consistent set of assumptions.*

BG-1.37 *In addition, the composition of fish diet differs among the models. For example, the PFCM assumes that the spottail shiner consumes equal amounts of benthic and water column invertebrates (BMR Book 3, Section 5.4). In contrast, in FISHRAND it is assumed to consume 75% water column invertebrate (BMR Book 4, Figure 3-2).*

Given the uncertainties inherent in bioaccumulation modeling, the effort in the BMR was purposely constructed to provide a weight-of-evidence approach using a variety of models at different levels of complexity.

FISHRAND and the Probabilistic Food Chain Model (PFCM) are constructed on different theoretical bases and use the available data in different ways. Despite using different representations of sediment and water exposure concentrations (bulk dry weight sediment and freely dissolved water in FISHRAND and TOC-normalized sediment and whole water in the PFCM), both models predict similar fish body burdens. While the models were specifically designed to use different forms of the input data, the food chain structure, and representation of trophic relationships is similar in the two models. The models are constrained by the form and quantity of available data and in some cases, will represent the food web slightly differently because of data limitations. [See response to comment BG-1.38]. Recognizing the inherent limitations in the predictive power of the PFCM, the Revised BMR contains future modeled results from the FISHRAND model only.

The PFCM sets the feeding preferences of one trophic level as point estimates and constructs distributions of transfer coefficients based on these preferences. This exercise is constrained by available data as it is entirely empirical. For example, piscivorous fish (largemouth bass) are related to their diet through transfer coefficients of individual measured body burdens divided by an average concentration in the diet. Synoptic data are only available over time for largemouth bass and pumpkinseed. Fortuitously, pumpkinseed are amongst the most abundant forage fish in the river, and gut content analyses of largemouth bass show that pumpkinseed comprise a large component of the largemouth bass diet (described in Appendix A of the BMR and Revised BMR). The PFCM assumes that largemouth bass body burdens can be related to pumpkinseed concentrations, under the assumption that pumpkinseed body burdens are generally representative of forage fish body burdens.

BG-1.8 *One of the goals of the PFCM was to develop a method by which the variability in fish PCB levels could be calculated. This model is entirely empirical and has no mechanistic basis.... Therefore, the model does not correctly account for the sources of PCB concentration variability within fish populations.*

Variability in fish concentrations is attributable primarily to variability in exposure concentrations and differences in lipid content and uptake rates between individual fish in the population. The PFCM models the relationship between individual fish and an expected (average) dietary concentration. Although the model may not explicitly account for all sources of PCB concentration variability, the method captures observed variability by constructing empirical distributions between trophic levels for which individual data points are matched against average exposures. This method captures variability although it does not mechanistically model every source of variability.

BG-1.41 *Although the BMR states that agreement among the models provides a check on the various approaches, agreement is not sufficiently demonstrated. To the contrary, tThe BSM, the PFCM, and*

FISHRAND give significantly different predictions and indicate different relationships among PCB levels in fish, water and sediment (Figure 8)...

Only the FISHRAND model was used for future predictions (beyond 1998). For the historical period (1977 – 1997), all three models are compared to data and all three models perform comparably. The Revised BMR provides a comparison between the relative importance of sediment and water between the models, which shows a consistent relationship.

BG-1.42 *The bioaccumulation models use two sets of water and sediment PCB concentrations. The PFCM used the first set, shown in BMR Book 4 Figure 7-1 and 7-1 and FISHRAND used the second set, shown in BMR Book 4 Figures 7-9 and 7-10....*

The fate and transport section of the BMR presents results for total PCBs, while the bioaccumulation modeling relies exclusively on the results of the tri-chlorinated and higher PCB congeners (Tri+). Both the fate and transport modeling and the bioaccumulation models have been updated in the Revised BMR, and consistent exposure concentrations have been used (Tri+).

BG-1.43 *The BMR states that sediment concentrations predicted by the fate and transport model are relatively insensitive to the Fort Edward boundary concentration (see BMR Book 4, Figure 8-4). In apparent contradiction to this statement, a comparison of BMR Book 4 Figures 7-1 and 7-2 indicates that assumptions about PCB concentration in water at Fort Edward boundary concentration have a large impact on the sediment concentration..... Furthermore, the two sets of graphics inconsistently present the relative difference in sediment concentrations among the various reaches of the river.*

The FISHRAND model uses a weighted average of cohesive and noncohesive sediment concentrations and these weighted averages are shown in the figures in Book 4. Book 2, by contrast, presents the results for cohesive and noncohesive sediments separately. The impact of changes in the boundary condition on sediment concentrations will differ between cohesive and noncohesive sediments. In averaging these two sediment types, the figures shown in Book 4 present a different impression of the impact in the boundary condition.

BS-1.37 *The modeling work on specific congeners (BZ#28, BZ#52, BZ#101, BZ#138) should be completed and the conclusions reported. The available PCB congener fish data show a change in composition with distance from the source area. The PCB congener modeling work should be able to demonstrate these changes if the model is going to be used for predicting fish PCB congener composition into the future.*

EPA agrees that running the models for specific congeners, in addition to Tri+, provides further understanding of the capabilities of the models. While a hindcast of the HUDTOX fate and transport model was conducted for the five specific congeners (BZ#4, BZ#28, BZ#52, BZ#101 [+ 90], and BZ#138) in the Revised BMR, similar efforts were not conducted for the FISHRAND model. The main purpose of the congener hindcast was to gain better understanding of the environmental processes controlling PCB dynamics in the river and to strengthen and support the long-term historical calibration for Tri+.

The primary goal of the baseline modeling effort was to provide forecasts of PCB concentrations in sediment, water and fish for use in the risk assessments. Although there were several forms of PCBs used in the risk assessments, they were all derived from the Tri+ values predicted in the models. As such, a thorough evaluation of the Tri+ forecasts took priority over evaluating specific congeners, which were not essential for the baseline risk assessments. Therefore, when time constraints arose regarding the issuance of the Revised BMR, the congener-specific bioaccumulation modeling effort was not conducted. Following the release of the Revised BMR, EPA intends to conduct modeling efforts for specific congeners.

SPECIFIC COMMENTS - BOOKS 3 AND 4

EXECUTIVE SUMMARY

Chapter 1. INTRODUCTION

1.1 Background

BF-1.54 *p. 1 Para 3: "In August 1995, the Upper Hudson was re-opened to fishing for striped bass in the Lower Hudson River. This ban remains in effect." This sentence should be revised to read "In August 1995, the Upper Hudson was re-opened to fishing but the no consumption advisory remains in effect. The fish consumption advisory for the Hudson River was modified as of June 18, 1999. The new advisory from Federal Dam at Troy to Catskill is to eat no more than one meal per month of alewife, blueback herring, rock bass and yellow perch. The one meal per week advisory for American shad and the eat none for all other species remains in effect for this stretch of the river. Between Dobbs Ferry and Greystone a stricter advisory for American eel was also issued which now recommends no consumption (NYSDOH 1999). The commercial fishing ban for striped bass in the Lower Hudson River is being reconsidered.*

BS-1.12 *P. 1, Book 3 The description of the fishing bans and advisories is missing some text. Please insert the missing text.*

Comment acknowledged. However, as fishing advisories and bans often change, and such information is not essential in describing the modeling effort, discussion of the advisories has been removed from the Revised BMR text.

1.2 Purpose of Report

1.3 Report Format and Organization

Chapter 2. GENERAL BACKGROUND ON PCB UPTAKE

2.1 PCB Compounds

2.2 PCB Accumulation Routes

2.2.1 Direct Uptake from Water

2.2.2 Uptake via Food

No significant comments were received for Sections 1.2 to 2.2.2 of Book 3 of the BMR

2.2.3 Uptake from Sediments

BS-1.13 p. *8, Book 3 Ankley et al. 1992 indicated that ingestion of food or sediment produced higher PCB concentration in free roaming fish than in fish confined in aquaria. These data can also be interpreted to indicate other mechanisms. For example, reduced metabolism in confined fish may cause the differenece in field versus laboratory values, and that ingestion may not play a major role as is indicated.*

Comment acknowledged.

2.3 Food Web Models from the Literature and their Sensitivity to Input Parameters

No significant comments were received for Section 2.3 of Book 3 of the BMR

Chapter 3. MODELING APPROACH: FISH BODY BURDENS

3.1 Modeling Goals and Objectives

BS-1.14 *p. 13, Book 3, top of page. The species and the 'Characteristics' list at the top of the page needs some modification. Pumkinseed are readily eaten by anglers and brown bullhead are commonly rather than occasionally eaten. The continual characterization of brown bullhead as a sediment dweller is misleading (also see P. 27). It is not exclusively a sediment inhabitant. White perch are also eaten but they are not as highly favored as other species. Information on eating preferences can be found in the book "Freshwater Fishes of New York State" by Robert Werner, 1980.*

The modeling results show that brown bullhead concentrations are highly correlated with sediment concentrations. The FISHRAND model does include a non-benthic component in the brown bullhead diet. The size range of pumpkinseed (yearling) from the sampling program are not typically consumed by anglers but rather serve primarily as a prey base for piscivorous fish such as the largemouth bass. The characteristics list is appropriate for the modeling goals and for the available data.

3.2 Conceptual Basis for Hudson River Bioaccumulation Models

3.3 Bivariate BAF Analysis for Fish Body Burdens

3.3.1 Rationale and Limitations for Bivariate BAF Analysis

No significant comments were received for Sections 3.2 to 3.3.1 of Book 3 of the BMR

3.3.2 Theory for Bivariate BAF Analysis of PCB Bioaccumulation

BF-1.55 *p. 19, Para 4: It is stated that the main "external forcing functions" are water and sediment concentrations. Trophic structure is also a very important factor. Two different fish populations in similar water and sediment concentrations with different food webs would have different accumulation. Rasmussen et al. (1990), in a study of Ontario lakes, showed that much of the enormous between-lake variability in PCB levels in fish flesh result from differences in the length of pelagic food chains.*

We agree that trophic structure is a key factor in determining fish bioaccumulation. Trophic structure is not, however, an "external forcing function". That terminology refers to the inputs or boundary conditions of the bioaccumulation model, whereas trophic structure is an internal component of bioaccumulation models.

In the context of the bivariate statistical model, sediment and water concentrations are the primary forcing functions. The statistical nature of this approach allows an evaluation of the respective roles of sediment and water in a regression context without explicitly specifying trophic structure. Within the Bivariate BAF approach, each fish species is modeled separately using empirically calibrated bioaccumulation factors. Trophic structure is thus addressed implicitly, and reflected in the fact that bioaccumulation factors differ among species. Within the more sophisticated bioaccumulation modeling approaches, the trophic structure is represented explicitly in the model.

BF-1.56*. p. 20 (Equation 3-1): In the formula, the water column exposure component is represented by suspended solids PCB concentrations; however, the Bw parameter is for "water column concentration", not suspended solids. Since focw is apparently not available, all equation parameters should be expressed on a whole-water basis.*

The intent of Equation 3-1 is to express an optimal formulation for estimating fish body burden. Both *Bw* and *Bs* should be noted as relating to concentration *normalized to OC*. The fact

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that the organic carbon fraction of suspended solids is not usually available in the historic water column data does not change this idealized formulation; instead, it changes the way it must be implemented, requiring a compromise approach. As noted in the text, "While this formulation is theoretically optimal, foc_w is not available in the historic database for the Hudson River; as a result, *Bw* must be expressed on a whole-water basis as a matter of practical necessity."

Water column exposure in the empirical probabilistic model is represented on a whole-water basis. Water column exposure in FISHRAND is represented by freely dissolved water concentrations.

3.4 Probabilistic Bioaccumulation Food Chain Model

3.4.1 Rationale and Limitations

BF-1.57 *p. 21: The text points out that the models assume slow changes in water and surface sediments relative to uptake and depuration. Some comment needs to be made on the relative rate of seasonal change in environmental concentrations of PCBs versus rates of uptake/depuration in fish. PCBs may be readily assimilated in fish due to the hydrophobicity of the chemical and the abundance of organic carbon available in the fish; however, depuration tends to be very slow since PCBs cannot be quickly metabolized. Therefore, depending on the importance of the seasonality of PCB concentrations, it is possible that fish may reflect a historical PCB exposure that is not consistent with current data. This is particularly true for water column exposures, since PCB concentrations in water could conceivably change over the time scale of weeks to months.*

The BSM and the PFCM are constructed as steady-state models. That is, these two models assume slow changes in water and surface sediments relative to uptake and depuration. They are not designed to predict short-term responses to extreme events. Rather, fish in these models are assumed to integrate exposure over appropriate temporal and spatial scales. Note, however, that the FISHRAND model incorporates average monthly water concentrations, thereby reflecting the seasonality in exposure conditions attributable to water sources.

3.4.2 Model Structure

BF-1.58 *p.23 Model Structure: "Since feeding occurs primarily in the warmer months, the probabilistic model had been developed using summer averages. The fate and transport model results are averaged to provide summer water and annual sediment concentrations." While exposure may be greatest during the summer months, this does not preclude exposure throughout the year. Moreover, the monthly averaged water concentrations do not account for potentially higher PCBs in the nearshore fish habitats. These issues should be discussed here and in Sections 3.4.3 and 3.4.4, Spatial and Temporal Scales.*

Comment acknowledged. This is discussed in the Revised BMR. It is true that exposure to water column sources of PCBs can occur throughout the year, and this is explicitly accounted for in the FISHRAND model. The PFCM, however, relies on a steady-state assumption in which PCB concentrations in one trophic level are related to dietary concentrations for that trophic level. Under this assumption, dietary concentrations of PCBs effectively integrate exposures from both dietary and direct water column sources.

See also the response to Comment BF-1.9.

BF-1.59 *p. 23, Bottom: The description of the Monte Carlo modeling highlights the problem of discriminating between (a) variability in parameters estimates due to natural variation and (b) uncertainty associated with our lack of knowledge of key processes. Both of these get lumped together in the distributions. The distribution-based approach only adds value if the "uncertainty" component is small relative to the "variability" component. There are two aspects to be concerned about. First, from the perspective of the reality of the final output, using distributions rather than fixed values is helpful only if the distributions themselves are real. There are some data, e.g., the lipid concentrations, that represent both the true variability among individuals of a species (for a location and year), as well as the lab-generated uncertainty in the measurements. In this case, most likely the uncertainty is small compared to the variability, assuming the geographic and annual differences can be accounted for. However, other distributions can be created as best guesses or from literature values which may not be appropriate for the Hudson River. Second, the use of probability distributions also raises the question of why a distribution is more important than a fixed value. For example, using "maximum" values for at least some key variables (and for variables for which distributions are not well-established) might be used to generate a model that would predict a worst-case future.*

Consistent with the management goals for this site, the goal is to predict the population distribution of PCB concentrations in fish rather than focus on specific point estimates. However, the distinction between variability and uncertainty is duly noted. As a result, current modeling efforts have focused on separating uncertainty from variability in the parameter estimates. Lipid content, weight, etc. are all considered variable parameters (or at least parameters for which population heterogeneity - variability - dominates.) (See also response to comment BF-1.28 for a more detailed discussion of the uncertainty in lipid measurements between laboratories). Sediment and water concentrations are considered uncertain, because these are the two parameters over which decision makers may have some control. That is, we cannot change or impact lipid distributions or weight distributions in fish, but under particular remedial alternatives, we may be able to influence sediment and water concentrations.

The FISHRAND model can be run using a two-dimensional Monte Carlo analysis in which sediment and water concentrations are considered uncertain, and the remaining distributions are considered variable. This can be done within a nested framework. The procedure is that a sediment concentration and a water concentration are selected for each year (the uncertain parameters) and are fixed while the full variability distributions are run. This is done for several iterations for each year, resulting in a two-dimensional result (i.e., error bars on the variability distribution where the error is attributable to changes in sediment and water concentrations).

BS-1.15 *p. 22, Book 3 Under the description of the model structure there is an either-or-condition introduced regarding the type 'a' and type 'b' invertebrates. It may not be that simple as one is water influenced and the other sediment. In the more productive littoral zones, it may be nearly impossible, if not impractical, to separate the two exposure regimes.*

Modeling, by necessity, requires simplifying assumptions of the true complexity in the physical system. These simplifications are designed to capture the dominant and essential physical processes without characterizing every detail. One such assumption involves categorizing invertebrates into primarily water vs. sediment driven for the purposes of modeling, with the understanding there will be some overlap for certain species.

3.4.3 Spatial Scale for Model Application

BS-1.16 *p. 24, Book 3 top of page. The supposition about the summer foraging area may be unfounded since most of the adult fish are collected in the spring. The modifying influence may be that there is some year-to-year overlap in events whereby sampling is not truly independent between years. In that same paragraph regarding the unlocalized nature of the white perch, this observation is perhaps over stated. In evaluating fish data over the years, almost all species can exhibit the influence of localized conditions. The variability may be such that expanded sample sizes are necessary, but it is still possible to sort out a local condition. It may be better to simply state that the white perch is mobile over large stretches of the river.*

Comment acknowledged.

BS-1.17 *p. 24, Book 3. In Section 3.4.3, third paragraph, the notation of rivermile 154 being above the Federal Dam is incorrect. That rivermile is below the Federal Dam.*

BS-1.28 *p. 72, Book 3. The rivermile 152 and 154 locations are confusing as presented. Both should be below the Federal Dam and both should be below the confluence with the Mohawk. If there is a mistake in the database in terms of location descriptions and coordinates, it needs to be corrected.*

The designation river mile 154 is used to reference the stretch of river between the Federal Dam and Waterford rather than as a reference to specific discrete river mile.

3.4.4 Temporal Scales for Estimating Exposure to Fish

3.4.5 Characterizing Model Compartments

3.4.5.1 Sediment to Benthic Invertebrate Compartment

3.4.5.2 Water column: Water Column Invertebrate Compartment

No significant comments were received for Sections 3.4.4 to 3.4.5.2 of Book 3 of the BMR.

3.4.5.3 Forage Fish Compartment

BF-1.60 *p. 25: While Section 3.4.5.3 indicates that any species less than 10 cm may be consumed by a piscivorous fish, the report suggests elsewhere that only spottail shiners and pumpkinseeds are used in the model as forage fish.*

Spottail shiners and pumpkinseed are considered representative of a variety of forage fish that might be present in the Hudson River. Historically, these two species show the highest abundance. The relative importance of sediment versus water pathways differs somewhat between these two species, and thus pumpkinseed and spottail shiners are considered representative of the range of forage fish that might fall into these categories. This was done because the models are constrained by available data. It is not possible to predict body burdens for every forage fish or young of year fish found in the Hudson River. Since spottail shiner and pumpkinseed are most abundant, and data are available over the course of many years and several locations for pumpkinseed, and one year and several locations for spottail shiner, these two species were selected as representative of forage fish that might be consumed by piscivorous fish. However, there are other forage fish in the river that might also be consumed, but their abundance is far lower, and out of computational necessity, certain simplifying assumptions are required for the modeling.

3.4.5.4 Piscivorous Fish Compartments

BF-1.61 *p. 26, Section 3.4.5.4, Para. 2: According to Fig. 3-2, invertebrates comprise 65% of the adult yellow perch diet rather than 85%, as stated in the text.*

BF-1.62 *p. 27, Top: The percent dietary component for individual fish species is inconsistent with the values presented in Fig. 3-2. For example, Fig. 3-2 indicates that yellow perch diet consists of 65% benthos and 35% epiphytes compared to the 15% forage fish, 20% benthic invertebrates and 65% water column invertebrates given in the text. For largemouth bass, the values in the figure are 85% fish, 10% benthos and 5 % epiphytes while the text has a greater contribution from fish and benthic invertebrates and no epiphytes in their diet. Which values were used?*

The figure is correct; the text has been modified to reflect this in the Revised BMR.

BG-1.62 *The contribution of water column PCBs to the largemouth bass food web in PFCM is grossly overestimated.*

The largemouth bass is exposed to PCBs via direct water uptake as well as through the diet and integrates sediment and water sources of PCBs. Consequently, the role of water versus sediment in the diet of the largemouth bass plays a critical role in evaluating the influence of water-based sources relative to sediment-based sources. The largemouth bass diet consists primarily of forage fish, with a small proportion of the diet attributable to consumption of benthic invertebrates. The specific forage fish that the largemouth bass will consume depends on biomass estimates in the absence of preferential feeding; that is, the largemouth bass will consume primarily those fish of an appropriate size that are most abundant. Limited data for the Upper Hudson River suggest that young-of-year pumpkinseed and spottail shiner are the two most abundant forage fish available for consumption by largemouth bass.

An evaluation of the pumpkinseed diet suggests that these fish consume a large proportion of epibenthic or pelagic invertebrates. These invertebrates include a large proportion of invertebrates that might be found on submersed aquatic plants, or sprawling on the surface of the sediment. These organisms are assumed to have a relationship with the dissolved phase in the water column. The rationale for this is that invertebrates are exposed to water column concentrations that might be varying up and down on a daily basis, but that more or less consistently vary around some number (for example, a mean value). Under the assumption that the water column is itself in equilibrium or steady-state and these invertebrates are themselves approaching steady-state with the water column, then it does not matter which phase in the water column is used to predict invertebrate concentrations as all phases will be in steady-state.

In addition, the BAF analysis showed that the observed body burdens in pumpkinseed are more sensitive to summer average water-column concentrations than to sediment concentrations. A similar analysis is not available for the spottail shiner. The BAF analysis does suggest a significant water influence on largemouth bass body burdens, but this apparent effect could be a surrogate for year-to-year persistence in relatively long-lived largemouth bass (as sediment concentrations vary less from year to year than do water concentrations). In addition, the BAF analysis assumes a direct relationship between water and sediment and largemouth bass, whereas biologically the role of water in the accumulation of PCBs in largemouth bass is mediated in large part by the pumpkinseed, the primary prey item for the largemouth bass. Pumpkinseeds do show a direct and significant relationship with the water column in both the BAF analysis and the dietary analysis.

3.4.5.5 Demersal Fish

BF-1.63 *p. 27, Section 3.4.5.5: The BSAF formula assumes a diet solely of benthic invertebrates, but Fig. 3-2 includes a 10% epiphyte component.*

The BSAF, by definition, is a biota-sediment accumulation factor, and is therefore calculated relative to the benthic food chain pathway only. Epiphytes are considered more representative of water column exposures.

BF-1.64 *p. 27: Why are brown bullheads compared to both sediment and prey, for BAF/BSAF. This leads to two separate bioaccumulation values, and it is not clear which was used in the model.*

The BSAF was used. The BAF discussion will be removed.

3.5 FISHPATH and FISHRAND Mechanistic Modeling Framework

3.5.1 Rationale and Limitations

No significant comments were received for Section 3.5.1 of Book 3 of the BMR.

3.5.2 Model Structure

BF-1.65 *p. 28: Mistake in equation ("=" should be "+")*

Comment acknowledged and corrected.

BG-1.6 *The bioaccumulation model FISHRAND does not use the water column particulate PCB concentrations computed by the fate and transport model. Rather, water column particulate PCB concentrations are calculated from the water column dissolved PCB concentrations computed by the fate and transport model. The calculation yields concentrations much higher than those computed by the fate and transport model.*

BG-1.61 *To properly estimate the relative importance of water column and sediment PCBs to the food web, the concentration of PCBs on particulate matter must be calculated correctly. Because the particulates matter forms the base of the food chain. The concentration of PCBs on sediment particulate matter to which the food web is exposed in FISHRAND is computed by EPA's fate and transport model. In contrast, the concentration of PCBs on water column particulate matter is calculated by multiplying the dissolved PCB concentration computed by EPA's model by a partition coefficient... This incorrectly increase the degree of bioaccumulation and therefore the relative importance of water column PCBs.*

The partition coefficients used in the fate and transport model and FISHRAND represent partitioning between different model components. FISHRAND incorporates an octanol-water partition coefficient (K_{ow}) from a freely dissolved water concentration to both phytoplankton and water column invertebrates, while HUDTOX uses a K_{oc} to describe partitioning behavior within the water column The percent lipid in phytoplankton differs from that specified for the water column invertebrates, leading to differences in PCB accumulation. The FISHRAND model does not include a water column particulate pathway *per se*.

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3.5.2.1 Rate Constants

BG-1.4 *The report presents no analyses of the extensive gut content data and invertebrate population data collected in the Hudson River for the purpose of evaluating food web structure. The structure of the food web controls the relative importance of sediment and water column PCBs to the food web, and therefore the response of fish PCB levels to natural recovery and to remediation services.*

BG-1.30 *The BMR states that the dietary composition of the fish in FISHRAND was determined based upon "professional judgment and a careful analysis of all the available data" (BMR Book 3, p. 71). However, the analysis is not presented. Thus, the basis upon which spottail shiner and pumpkinseed were chosen to represent the diet of the largemouth bass in FISHRAND is not presented...*

BG-1.39 *The composition of the forage fish community was also developed in an inconsistent manner...*

BG-1.59 *In the BMR, the water column component of the spottail shiner diet is considered to be smaller than the water column component of the pumpkinseed (PFCM) or similar to the water column component of the pumpkinseed (FISHRAND). This contrasts with several lines of evidence that suggest that spottail shiner consumes a somewhat greater proportion of water column-based invertebrates than pumpkinseed.*

We presented a detailed analysis of the Exponent data as well as other available data on the gut contents of spottail shiners (and other fish species) in Appendix A. In this analysis, it was determined that the spottail shiner diet is best described by a triangular distribution in which the mode of the distribution for water column contributions is set at 70%, for sediment at 25%, and for phytoplankton at 5%. The spottail shiner diet differs from the pumpkinseed diet in that there is a greater potential for benthic sources in the spottail shiner diet, although the mode of the distribution is very similar to that for pumpkinseed. Pumpkinseed never consume more than 30% of their diet in benthic invertebrates, while spottail shiner can consume as much as 60% of their diet as benthic invertebrates (however, note that because the distribution is triangular, this value is rarely chosen in the Monte Carlo simulation).

Abundance data for the Upper Hudson River was obtained from a 1984 Malcolm-Pirnie report, as described in Appendix A. This report, as well as the constraints of available body burden data, professional judgment and personal knowledge of the Upper Hudson River by project team members, discussions with fisheries biologists, and the gut contents analyses, were all used to determine the dietary composition for each fish species, including the proportion of spottail shiner versus pumpkinseed in the largemouth bass diet.

BG-1.38 *In addition, 67% of the forage fish diet consists of water column invertebrates in PFCM (BMR Book 3, p. 26), while the value for FISHRAND is 75 to 80% (BMR Book 4, Figure 3-2).*

The PFCM is constrained by the available data. Time-series data are available for largemouth bass and pumpkinseed from the NYSDEC dataset, but no such data are available for spottail shiner. Largemouth bass, which are an opportunistic fish, will consume the forage fish biomass prey base that is available. As presented in Appendix A, the most abundant forage fish in the Upper Hudson River are pumpkinseed followed by spottail shiner. Since the empirical transfer coefficients represent the relationship between largemouth bass and its primary prey, the representative forage fish differ slightly between the two models depending on the available data.

BG-1.40 *Finally, the distributions of feeding preferences are uniform in PFCM and triangular in FISHRAND (p. 18). This inconsistency raises questions about the validity of the bioaccumulation models.*

Distributions of feeding preferences are incorporated in FISHRAND as triangular. However, the PFCM incorporates the mode of the distribution used for the particular species in FISHRAND as the point estimate. For example, in the PFCM, the feeding preference for the pumpkinseed was specified as 80% water column invertebrates and 20% benthic invertebrates (not a distribution) which are the same values specified as the mode of the feeding preference distribution in FISHRAND.

3.5.3 Spatial Scale for Model Application

BS-1.18 *P. 31, Book 3. In Section 3.5.3, to characterize white perch as ranging throughout the river overstates their distribution. Based upon DEC sampling work, white perch are only found in any numbers about as far upstream as Lock 1 and are not sampled at Stillwater or in the TIP. Below the Federal Dam, where it is tidal, they can be in both nearshore, shallow zones and main channel areas.*

Comment acknowledged

3.5.4 Temporal Scales for Estimating Exposure to Fish

3.5.5 Application Framework

3.5.5.1 Comparison with Gobas (1993) Lake Ontario Data: The Steady-State Case

3.5.5.2 Comparison with Gobas (1995) Lake Ontario Data: The Time-Varying Case

No significant comments were received for Sections 3.5.4 to 3.5.5.2 of Book 3 of the BMR

Chapter 4. BIVARIATE BAF ANALYSIS OF FISH BODY BURDENS

***BG-1.9** Finally, the Bi-variate Statistical Model ("BSM") is based upon a regression between PCB levels in fish collected in Spring (largemouth bass and brown bullhead) and PCB levels in water sampled throughout the same year. That is, most of the water samples were collected after the fish were sampled. Water column PCB concentrations have exhibited considerable year-to-year variation (BMR Book 4, Table 4-7), suggesting that this approach may have a significant impact on the results.*

The Bivariate BAF analysis is based on summer (May to September) average water column concentrations, not whole-year averages. The fish data used in the analysis have also been restricted to summer-collected data. It is true that, except for pumpkinseed, most of the fish samples were collected at the beginning of this period (May or June), so that some of the water samples used were collected after the fish samples. Given the small number of water column samples available (especially prior to 1991) it is believed that use of all available summer water column samples provides a better estimate of summer average concentration in a given year than using the few samples available for May and June only. In addition, experiments with regression models that included the previous-year water column concentration as an additional explanatory variable did not improve the predictive ability of the models for any of the studied species.

***BF-1.67** The trophic levels of 5 fish species are described. A description for white perch should have been included.*

The discussion inadvertently omitted a summary of the trophic level of white perch (*Morone americana*). Adult white perch are benthic predators, with older white perch becoming increasingly piscivorous, and utilize both shallow areas and the main channel bottom. The species is semi-anadromous, with spawning occurring in the upper reaches of the lower Hudson River and winter movement down river.

***BS-1.19** P. 34 Book 3. The characterization of largemouth bass versus yellow perch needs to be modified because both will exhibit directed movements for spawning. The use of goldfish as a trend species is problematic since the DEC database is limited for this species.......*

Comment acknowledged. The modeling analysis does not explicitly evaluate males separately from females. While it is true that during spawning, certain fish species will exhibit more directed movements, but these are incorporated as general variability in spatial scale.

4.1 Data Used for Development of Bivariate BAF Analyses

4.1.1 Fish Data

4.1.1.1 Locations and Species Analyzed

4.1.1.2 Lipid Normalization

No significant comments were received for Sections 4.1 to 4.1.1.2 of Book 3 of the BMR

4.1.1.3 Season, Age, and Sex

BS-1.20 *P. 35, Book 3. In Section 4.1.1.3, the point about expelling PCBs with eggs as a possible explanation for sex differences should be removed or modified because the theory of PCB depuration through expulsion of eggs is speculative at this point and requires further research*

Requiring further research does not diminish the fact that it is working hypothesis amongst numerous researchers that expulsion of eggs is a possible explanation for sex differences in PCB concentration. It is not presented as a definitive explanation, but rather one possible explanation out of a number of working hypotheses. Given the partitioning behavior of PCBs, and the lipid content of eggs, it is entirely plausible, and there are currently researchers evaluating this phenomenon.

4.1.1.4 Laboratories and Methods for PCB Analysis

4.1.1.5 Standardization of PCB Analytical Results

4.1.1.6 Theoretical "What if?" Analysis

4.1.1.7 Split Sample Comparisons

4.1.1.8 Interlaboratory Comparisons

4.1.1.9 Translation Methods

No significant comments were received for Sections 4.1.1.4 to 4.1.1.9 of Book 3 of the BMR.

4.1.2 Water Column Data

BF-1.68 *Section 4.1.2: The first sentence is misleading. Water column concentrations are predictive of fish PCB burdens only for those species which have exposure pathways dominated by overlying water. Brown bullhead concentrations would not be well predicted by water column concentrations.*

This comment is correct. The sentence in question should be revised to read: "As noted in the PMCR (USEPA, 1996) and earlier by Brown et al. (1985), a good predictor of annual average

PCB body burden *in some fish species* appears to be the summer average water column concentration."

***BF-1.74** p.51 An estimate for the dissolved fraction total water concentration (presumably averaged May-Sept) was determined to be "about 50%" for Tri+ PCBs in the Upper Hudson based on analysis of three-phase partitioning in the DEIR for representative congeners. This appears to be inconsistent with Book 1, p. E-7 DEIR findings that water-column PCB transport occurs largely in the dissolved phase, and the dissolved phase represents 80% of the water column PCB inventory in the Upper Hudson during most of the year (10-11 months).*

A distinction needs to be made between total PCBs and Tri+ PCBs to address this question. Total PCBs in the water column of the Hudson below TIP typically have a large component of mono- and di-chlorobiphenyls. These homologues tend to be present predominantly in the apparent dissolved fraction (truly dissolved plus DOC-sorbed fraction) in the water column (DEIR Table 3-8). As a result, Total PCBs are expected to have a larger dissolved fraction than Tri+.

Analysis of the Tri+ dissolved fraction is best based on a direct analysis of Tri+, rather than inference from a limited number of individual congeners. Three-phase partition coefficients were estimated for Tri+ as an entity, using the same methods as applied to analysis of individual congeners in the DEIR. These yielded estimates of $\log(K_{POC}) = 5.85$ and $\log(K_{DOC}) = 3.96$. At average water column concentrations for DOC and POC in the Upper Hudson and a temperature of 20° C, these coefficients correspond to a Tri+ distribution of 49.3% truly dissolved, 2.2% DOC-sorbed, and 48.5% POC-sorbed.

4.1.3 Sediment Data

***BF-1.69** "bias correction factor": As pointed out, this "adjustment factor" is needed to be consistent with mid-channel estimates from USGS. However, the nearshore measurements may be more appropriate for evaluating exposure concentrations for fish and their food webs, which probably rely to a much greater extent on the nearshore habitat than the channel habitat. Data from mid-channel locations should be adjusted to reflect nearshore concentrations.*

***BF-1.8B** Input from the HUDTOX model to the bioaccumulation models should focus on the nearshore areas, and, to the extent that concentrations in the water column have been adjusted to more closely match mid-channel values, they should be corrected to reflect nearshore exposure.*

We are in agreement with these comments regarding the empirical BAF model in the TIP. Within the TIP, GE has reported strong lateral gradients in PCB concentrations in water during low flow conditions, with higher concentrations in the near-shore area. As the commenter noted, the measured near-shore concentrations may be more representative of the exposure field experienced by most fish populations in the TIP.

To address this comment, the recalibration of the BAF approach contained in the Revised BMR uses actual near-shore measurements of Tri+ concentration in water to estimate the summer average water concentrations in Group 1 for 1991 on, rather than attempting to correct to center channel concentrations. This introduces a second problem of consistency, as downstream USGS measurements used to estimate concentrations in the TIP prior to 1991 are believed to be more representative of center channel concentrations than near-shore concentrations within TIP. Therefore, a correction to the estimates used prior to 1991 was required. Based on theoretical considerations and an analysis of the available near-shore and center channel data collected by GE, it was determined that lateral gradients in concentration are likely to be significant only at lower flows, approximately less than 4,000 cfs at Fort Edward. With flows less than 4,000 cfs and upstream concentrations greater than 17 ng/l total PCBs, center channel concentrations of Tri+ appear to be approximately 0.88 times those observed in the near-shore area. No bias is believed to apply for Tri+ at higher flows. To calculate approximate near-shore exposure concentrations from downstream USGS data at Stillwater or Fort Miller prior to 1991 (see BMR Tables 4-6 and 4-7), the individual USGS downstream measurements taken when flow at Fort Edward was less than 4,000 cfs were inflated by dividing by 0.88. Estimation of water column concentrations for use in Group 1 for the BAF model were then recalculated by the methods described in the BMR.

Use of these revised estimates of summer average water column concentrations provides a slight improvement in the fit of the BAF model relative to use of center channel concentrations.

BS-1.21 *P. 46, Book 3 The last sentence should be checked for consistency with the Fate and Transport model conclusions.*

The last sentence is consistent with the fate and transport modeling results.

4.1.4 Functional Grouping of Sample Locations for Analysis

BS-1.22 *P. 48, Book 3 The collection location shifted from above the Stillwater Dam to the Coveville Area in about 1994.*

Comment acknowledged. The database reflects this change (river mile designation changed from 168 to 175).

BF-1.70 *p.48 Section 4.1.4: Fish sampling locations were subdivided into four functional groupings representing RM 188 - RM 193, RM 168 - RM 176, RM 155 - RM 157, and RM 142 - RM 152. The number of functional groups should be increased to include major historical fish sampling locations in the lower freshwater Hudson, including Catskill and Poughkeepsie.*

It was not possible to include the additional freshwater fish data from the Catskill and Poughkeepsie areas in the empirical Bivariate BAF approach. The main reason is that historical records of water column concentrations within this reach are not available. In addition, the HUDTOX modeling grid does not extend to this reach, so predictions of the time course of surface sediment concentrations are also not available. Direct observations of water column concentrations are also not available for the reach from RM 142 - RM 152, but this reach was included because it is located immediately downstream of the Waterford sampling station and EPA concluded that summer average water column concentrations could be reasonably inferred by applying dilution calculations to Waterford observations. It would have been more difficult to extrapolate concentrations to the Catskill - Poughkeepsie area, and fish data from this reach therefore were not included in the empirical model.

4.2 Results of Bivariate BAF Analysis

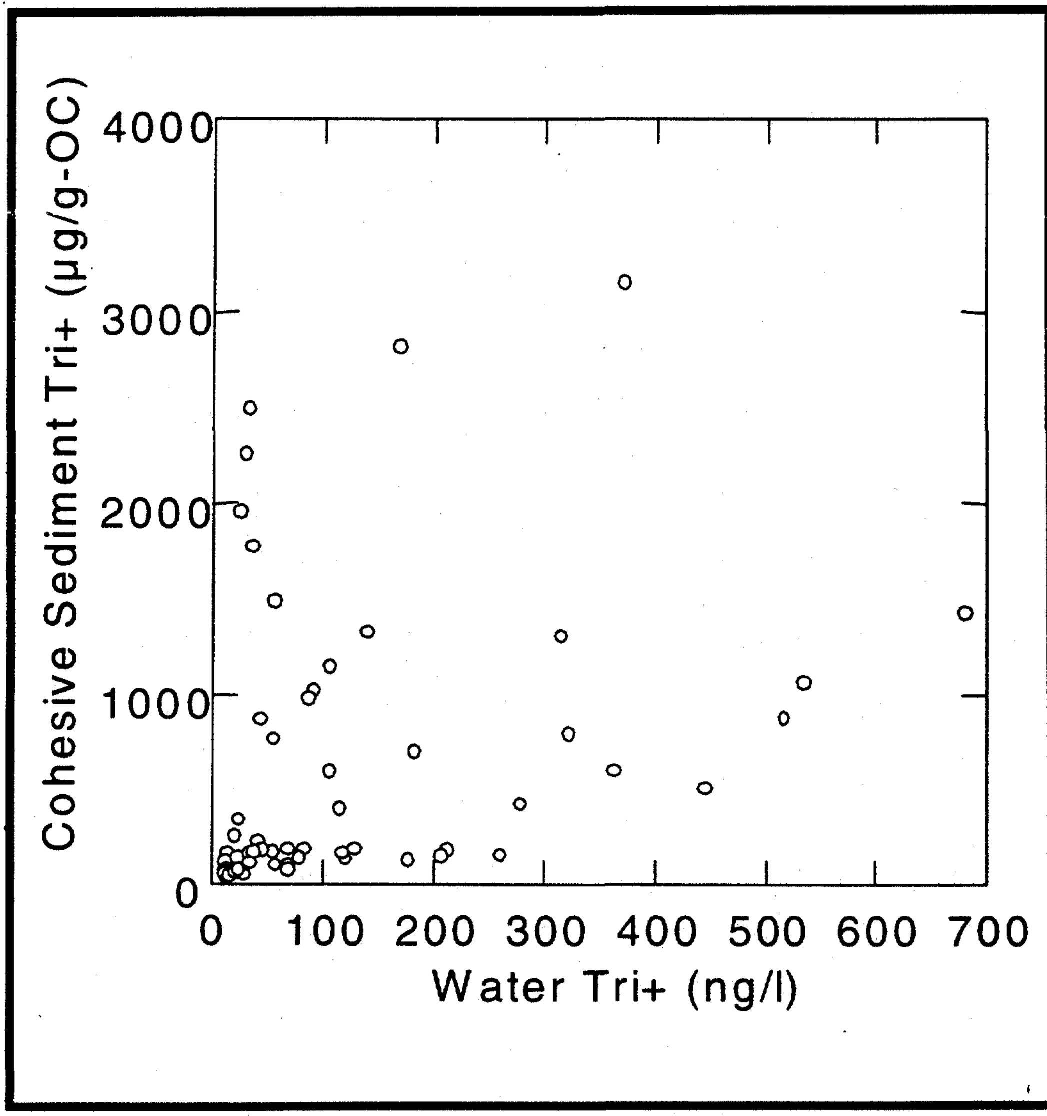
BF-1.71 *p.50 Par 1-3 The presented regression results compare [fish] to [water], and [fish] to [sediment] and [water] combined, but not [sediment] on its own. Why? Would it have been better to treat the analysis as a stepwise regression, to show the improvement of fit resulting from incorporation of water and sediment as explanatory variables. Also, since a regression approach was used, there is an inherent problem of intercorrelation (multicollinearity) of variables. For example, the Pearson correlation coefficient between average water column and sediment concentrations used in the Bivariate BAF analysis was 0.56. If intercorrelation is high, conclusions regarding the significance of the correlated "independent" variables are likely to be spurious. This is particularly important for evaluating the "relative importance of independent variables" as is discussed in Section 4.3.3. Interpretation of the "normalized beta coefficients" in Table 4-13 would seem to be very much complicated by this problem. It would also be interesting to see what effect the incorporation of an interaction term (between water and sediment) would have on the model.*

We agree with the suggestion to include regressions against sediment concentration only, and these results are included in the revised BMR. Neither univariate regressions on water or sediment alone provide model fits that are as good as those obtained from the bivariate model for most species, based on the adjusted multiple R^2. A model based on sediment alone provides reasonably strong predictive ability only for brown bullhead and largemouth bass.

Stepwise regression was used as tool in exploratory analysis for the development of the Bivariate BAF method. We feel that it is more informative and understandable, however, to present complete model results in the BMR. As noted, there is significant multi- co-linearity between the sediment and water exposure fields. The relationship is far from linear, however. Both the water and sediment exposure fields have been adjusted slightly for the revised BMR, and the Pearson correlation coefficient between summer average whole water concentration and organic carbon-normalized surface sediment concentration is now 0.32. The relationship between the (revised) sediment and water exposure fields is shown in the following figure. It is because there is only moderate co-linearity between the two exposure fields that inclusion of both variables in a BAF model increases goodness-of-fit significantly for those fish species in which PCB bioaccumulation is driven by both sediment and water column exposures.

Figure BF-1.71

Relationship Between Sediment and Water Exposure Fields for the Bivariate BAF Analysis



The presence of multi- co-linearity presents significant problems for the interpretation of the relative contributions of water and sediment to bioaccumulation in a given fish species. In the PMCR, relative contributions were assessed based on partial correlation coefficients (obtained from application of a stepwise regression model). One problem with this approach is that partial correlation coefficients have scale dependence, which makes it difficult to compare coefficients between variables. Therefore, the BMR presents the analysis in terms of normalized beta coefficients and elasticities, which are econometric methods, developed to avoid the scale dependence problem. All of these methods are similar in that they look at the effect on the dependent variable of a single independent variable with the other independent variable(s) held constant. The statistics are not invalidated by the presence of multi- co-linearity; however, as noted by the commenter, care is required in their interpretation because sediment and water exposure concentrations are not independent of one another.

An interaction term between water and sediment was included in some exploratory model applications. This was not, however, included in the final model because (1) it did not add significant predictive ability, and (2) the presence of an interactive term is not consistent with the simple theoretical model on which the Bivariate BAF approach is based.

BF-1.72 *Table 4-10 should read 4-11 and Table 4-11 should read Table 4-12. This is important because if one refers to the tables as presently labeled, the text (i.e. R^2 values) does not match the tabulations.*

We thank the commenter for pointing out these editorial errors. Problems in table references are corrected in the revised BMR.

BF-1.73 *The bivariate approach does not increase the R^2 for all species. According to Table 4-10, the R2 for white perch and yellow perch exhibit slight decreases when sediment is added into the regression equation.*

This comment is correct regarding the arithmetic Bivariate BAF model results presented in the May 1999 BMR. These results have, however, been replaced by revised models based on exposure fields incorporating modified interpretation of the water column concentration data and new HUDTOX predictions for surface sediment concentrations. The revised models show that the addition of sediment concentration to the model yields a slight increase in the goodness-of- fit for yellow perch, and continues to cause a slight decrease in goodness-of-fit for white perch. (The decrease occurs because of the multi- co-linearity between the explanatory variables). For white perch, the majority of observational data are from Group 4, and the range of different combinations of water and sediment exposures (which are available for other species) are not available for this species. In the case of yellow perch, sediment adds little improvement to the goodness-of-fit because fish body burdens appear to be strongly determined by water column exposures.

4.3 Discussion of Bivariate BAF Results

4.3.1 Comparison to Published BAF Values

No significant comments were received for Section 4.3.1 of Book 3 of the BMR

4.3.2 Fit of Bivariate Models to Observations

BS-1.23 *P. 52, Book 3. In the third paragraph there may have been some mixing of different age classes of pumpkinseed which may confuse some of the interpretation of results.*

Age classes were combined for the Bivariate BAF analysis.

4.3.3 Relative Importance of Sediment and Water Pathways

4.4 Summary

No significant comments were received for Sections 4.3.3 to 4.4 of Book 3 of the BMR.

Chapter 5. CALIBRATION OF PROBABILISTIC BIOACCUMULATION FOOD CHAIN MODEL

5.1 Overview of Data Used to Derive BAFs

BF-1.75 *p. 55: Overview of data used to derive BAFs. The analytical methods used to determine total PCBs and lipid content may not be directly comparable between studies. It appears, though not explicitly stated, that all total PCB and lipid values are treated as equivalent.*

Corrections were made to the historical NYSDEC dataset based on the algorithm presented in Chapter 4. However, other than those corrections, data across different studies were considered as equivalent.

In terms of the lipid data used in these analyses, information on the precision of lipid determinations in Hudson River fish data is provided by three sets of inter-laboratory comparisons performed for NYSDEC in 1989, 1992, and 1995. The 1989 comparisons involved 4 samples and 8 laboratories, the 1992 comparisons involved 5 samples and 12 laboratories, and the 1995 comparisons involved 3 samples and 4 laboratories. The two laboratories responsible for the majority of NYSDEC fish analyses (Hazleton and successors, and Hale Creek) participated in each of the inter-laboratory comparisons.

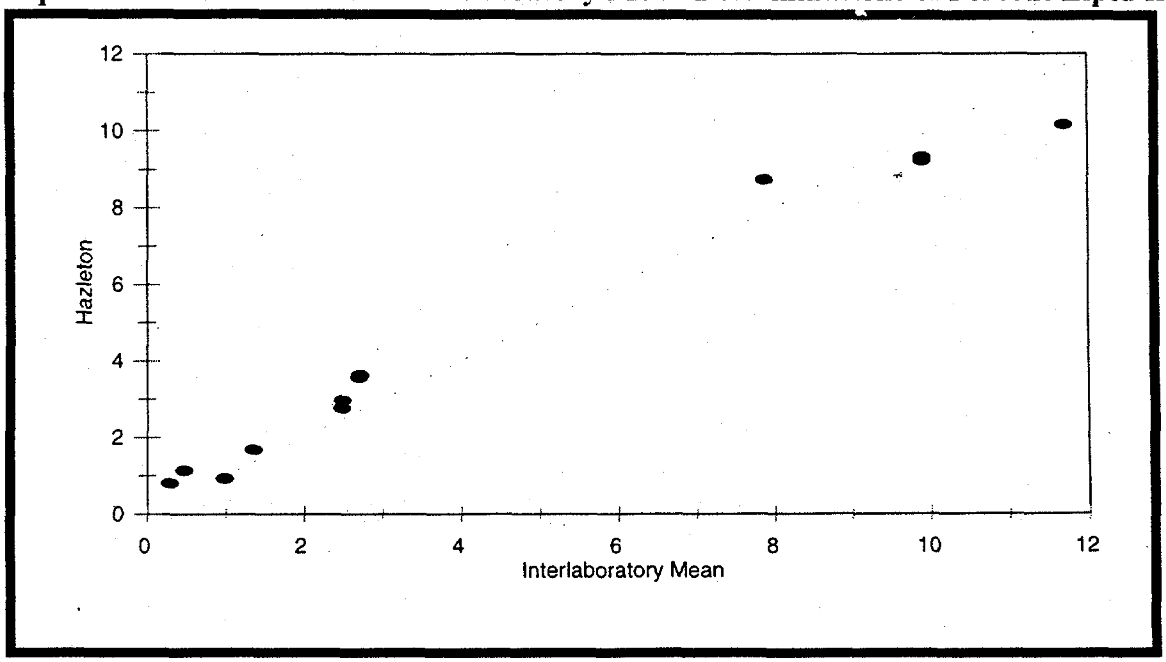
Over the 12 samples, standard deviations between laboratories on percent lipid determinations ranged from 0.052 to 0.52. The standard deviation is scale dependent, however, and it is more informative to examine the standard error (standard deviation divided by the mean). Standard errors on percent lipid ranged from 0.023 to 0.38, with an average of 0.099, indicating a relatively high degree of precision in lipid determinations.

Results reported by Hazleton appear to show consistent deviations relative to the mean across all laboratories. For the 1989 results, all Hazleton lipid determinations were less than the mean, with the discrepancy ranging from -0.75 to -3.88 standard deviation units on the percentage value, with an average of -2.55 standard deviations. For both 1992 and 1995, all Hazleton results were greater than the inter-laboratory mean, with an average discrepancy of 4.47 standard deviations. The discrepancies appear relatively large because the standard errors are small.

The inter-laboratory mean depends on the characteristics of the laboratories that participated in a given year. When Hazleton is compared to Hale Creek, however, the same pattern emerges: Hazleton results are consistently lower than Hale Creek in 1989, and consistently higher in 1992 and 1995. The Hale Creek lipid determinations do not show any consistent bias with time relative to the inter-laboratory mean. Across all samples, the discrepancies for Hale Creek versus the mean range from -1.0 to +0.99 standard deviation units, with an average of -0.29 standard deviations.

Figure BF-1.75

Comparison of Hazleton and Inter-laboratory Mean Determinations of Percent Lipid from



1989, 1992, and 1995 Inter-laboratory Comparisons

Hazleton results are compared to the inter-laboratory means in the preceding figure. While the discrepancies are sometimes large in terms of standard deviation units, the average absolute difference between Hazleton and the inter-laboratory mean is only 0.65 percentage points.

It should finally be noted that discrepancies among laboratories in lipid extraction efficiency are also likely to be reflected in PCB extraction efficiency. As a result, any errors in percent lipid determination will have the greatest impact on estimates of wet weight concentration, while concentrations on a lipid basis should be relatively stable to uncertainty in lipid determination.

5.1.1 Benthic Invertebrates

BS-1.24 *p. 55, Book 3. There appears to be a typo in section 5.1.1. The sentence "Benthic invertebrates were identified to the taxonomic group level for PCB analysis" does not make sense.*

Comment acknowledged. This sentence has been corrected in the Revised BMR.

5.1.2 Water Column Invertebrates

5.1.3 Fish

BF-1.76 *p. 56: "For the NYSDEC samples...." The Aroclors analyzed should be consistent with the previous chapter, which was more accurate.*

All of the NYSDEC fish data used in each of the models were processed the same way and incorporate the corrections designed to establish a consistent basis for comparison over time.

5.1.4 Literature Values

No significant comments were received for Section 5.1.4 of Book 3 of the BMR.

5.2 Benthic Invertebrate: Sediment Accumulation Factors (BSAF)

5.2.1 Sediment Concentrations

BF-1.77 *p. 57: The collection depth for the sediment samples should be stated, as well as the diameter of the sampling area for the samples per location.*

A complete description of the ecological sediment sampling is contained in Appendix B of the Baseline ERA (August, 1999).

The Phase 2B ecological sediment sampling was designed to provide sediment concentration data for the assessment of ecological risk to the biotic community. Surface sediment samples taken from the top 5-cm were collected from the same locations as the fish and invertebrates to provide an estimate of biological uptake of PCBs from the sediment. Pilot samples taken during field reconnaissances in October 1992 and May 1993 indicated that most biological activity was found in the upper 5-cm (2-in) of the sediment.

The sediment sampling was not intended to provide a definitive picture of PCB contamination along the Hudson River for feasibility study purposes. It does, however, examine a number of ecologically significant areas as determined by USEPA, NYSDEC, and NOAA. The high resolution coring technique (USEPA, 1997) was adapted to collect 2.5" diameter sediment samples. A total of ten (10) cores were collected at each station, excluding QA/QC samples. Two sequential 5-cm core sections were homogenized in a decontaminated stainless bowl and aliquots were taken for PCB congeners, TOC, and metals analyses. Grain size samples were obtained by using an Ekman Grab (6"x 6" x 6") with a clear acrylic liner. A stainless steel slicing plate was used to cut off the top 5 cm of sediment, which was then transferred into a 500-ml glass jar. All samples were collected within a radius of about 5 meters.

5.2.2 Approach

No significant comments were received for Section 5.2.2 of Book 3 of the BMR.

5.2.3 Calculations of BSAF Values for Benthic Invertebrates

BF-1.78 *p. 58, Section 5.2.3 Para 1: The text and Fig. 5-2 do not match. The BSAF for river mile (RM) 189 should read "3" not "6". The BSAF for RMs 100 and 189.5 should be "1.5" not "3". BSAFs for other RMs were less than or equal to 1.*

Comment acknowledged. These figures are correct in the Revised BMR.

BF-1.79 *p. 58, Section 5.2.3 Para 2: The BSAF for chironomids was about "2" not "4". "Gastropods" should be inserted for "Isopods" with a BSAF around"2" not "3". Remaining RMs have BSAFs of less than 2.*

Comment acknowledged. The text is corrected in the Revised BMR.

BF-1.80 *p. 58-59, Section 5.2.3: No explanation is provided for the trend of changing BSAF for invertebrates with location on the Hudson River. On p. 57 it is indicated that the sediment data were evaluated to determine "which river miles display significant heterogeneity and variability in concentrations." Were separate BSAF values for invertebrates used in model calculations for different reaches of the river? If so, this seems to be an arbitrary process that would improve model fit, but would not necessarily improve predictive ability of the model for future scenarios.*

BS-1.25 *P. 57 and 58, Book 3, Figure 5-2. The Benthic Invertebrate Sediment Accumulation Factor (BSAF) varies by river mile, with the highest values being in the Thompson Island Pool. Since the*

Thompson Island Pool has the highest sediment PCB concentrations, this suggests that the mechanism of exposure to the invertebrates is different in the Thompson Island Pool. The report should discuss why the BSAF would be expected to change as a function of location or level of PCB contamination.

Calculated BSAF from the EPA/NOAA 1993 dataset may change by species and location for some or all of the following reasons:

- True sediment exposure concentrations may be higher or lower than those estimated (the BSAF procedure involves dividing an individual measured invertebrate concentration by an average sediment concentration from the same sampling location. For the highly variable sediment concentrations, there are both high and low individual sediment values in the average. Thus, it may be that the true sediment concentration corresponding to the individual measured invertebrate concentration is higher or lower than the average.)

- Exposure for certain species may be derived from water column sources, particularly for those invertebrates which are surface scramblers and more like invertebrates that might be found on the vegetation.

Separate BSAF values for invertebrates were not used. In the PFCM, one distribution representing the potential relationship between sediment concentrations and resulting benthic invertebrate concentrations was used. In the FISHRAND/FISHPATH models, a BSAF-type calculation was used with a distribution for lipid content in benthic invertebrates and a distribution for sediment concentration. In the BMR, a distribution was also used for TOC in sediment. Following comments made at the June 1999 Science and Technical Committee Meeting, TOC values in the Revised BMR have been fixed by river reach at the exact same values used by the HUDTOX model to insure consistency between the models.

5.3 Water Column Invertebrate: Water Accumulation Factors (BAFs)

5.3.1 Approach

BF-I.81 *p. 60: The Novak (1988) citation is missing from the reference list. In this study, chironomid tissue had a PCB congener differing from the water column. Were the chironomid species identified? What feeding guild did they belong to?*

These are the missing references:

Novak, M.A., A.A. Reilly, and S.J. Jackling. 1988. Long-term monitoring of polychlorinated biphenyls in the Hudson River (New York) using caddisfly larvae and other macro-invertebrates. *Arch. Environ. Contam. Toxicol.* 17:699-710.

Novak, M.A., A.A. Reilly, B. Bush and L. Shane. 1990. In situ determination of PCB congener-specific first order absorption/desorption rate constants using Chironomus tentans larvae (insecta: diptera: chironomidae). *Wat. Res.* 24(3):321-327.

These two references were inadvertently left out of the references in the report, although they did appear in the Preliminary Model Calibration Report. The report itself is discussed on p. 60 of the May, 1999 BMR.

The Novak (1988) study placed laboratory-raised larval chironomid midges (*Chironomus tentans*) into a nylon mesh "envelope" suspended in the Thompson Island Pool. The goal of the study was to evaluate uptake dynamics from water only in the chironomid species following 96 hours of exposure.

The study found that the congener pattern of PCBs in *C. tentans* differed substantially from that in the water. Specifically, the whole water column concentrations were dominated by 2 or 3-dichlorinated congeners, contributing nearly 50% of the total concentration. The *C. tentans* samples were characterized by a greater number of congeners, with each congener contributing a much lesser proportion to the overall total (i.e., no single congener contributed greater than 10% to the total body burden), and higher chlorinated congeners dominated. For the 26 congeners evaluated, most congeners reached 90% equilibrium in less than 8 days.

The September results showed even higher *C. tentans* concentrations corresponding to lower water concentrations. The September results are considered suspect in the article due to suspected analytical error.

The chironomid species (*C. tentans*) were raised in the laboratory and only experienced water-based exposures in this study. They were, however, allowed to come into contact with detritus matter and the like in the water column. *C. tentans* is primarily a filter feeder or surface deposit feeder (Swindoll and Applehans; 1987; Wood et al., 1987).

5.3.2 Calculation of BAF $_{water}$ for Water Column Invertebrates

No significant comments were received for Section 5.3.2 of Book 3 of the BMR.

5.4 Forage Fish: Diet Accumulation Factors (FFBAFs)

5.4.1 Approach

BF-1.82 *p. 61: The spottail shiner collected were young-of-year -- is it reasonable to assume the equal benthic/water column invertebrate diet in adult spottail would apply? Are epibenthic organisms considered to be benthic organisms for this analysis?*

Adult spottail shiners are not modeled in any of the bioaccumulation models. It is assumed that piscivorous fish will consume primarily young-of-year fish. The fish feeding analyses presented in Appendix A of Book 4 consider organisms that primarily sprawl on sediments as more closely resembling invertebrates in the water column, such as invertebrates that might be found on plants. This class of organisms, which could be considered epibenthic as they are often on the sediment but not in the sediment, are assumed to derive the bulk of their exposure via water. A number of studies have shown that uptake in these kinds of invertebrates may be better approximated from water sources.

5.4.2 Forage Fish Body Burdens Used to Derive FFBAF Values

BF-1.83 *p. 62: Fig. 5-5 shows forage fish total PCBs at concentrations approaching 300 ug/g lipid, not wet weight.*

Comment acknowledged.

5.4.3 Calculation of FFBAF Values for Forage Fish

BF-1.84 *p. 62-63, Section 5.4.3, Para 1: "The data show that the greatest variability in fish concentrations exists within the TIP...." This is not the case if the coefficient of variation is used as the measure of relative variability. The greatest variability, excluding the reference area, is in the samples collected between Hudson Falls and Rogers Island. The stations with highest variability are mostly the stations where multiple species are included in the forage fish sample (River Miles 197, 194, 189, 89, and 59).*

The following table shows the coefficient of variation for the forage fish from the EPA/NOAA Phase 2 dataset sorted in order of decreasing coefficient of variation for total PCBs (wet weight), lipid-normalized total PCBs and lipid content. The numbers in parentheses refer to the number of samples at each station.

Table BF-1.84
Comparison of Coefficient of Variation by River Mile

Total PCB Wet Weight	
River Mile	Coefficient of Variation
196.9 (16)	146.1
TIP (24)	81.9
169.5 (6)	47.0
122.4 (3)	29.8
88.9 (8)	29.1
137.2 (3)	25.6
100 (3)	23.2
143.5 (7)	18.4
159 (3)	14.6
47.3 (3)	13.6
58.7 (6)	13.1
25.8 (3)	9.4
113.8 (3)	1.9

Total PCB Lipid Normalized	
River Mile	Coefficient of Variation
196.9	95.9
58.7	87.0
TIP	61.4
88.9	61.0
169.5	31.0
159	27.1
143.5	22.9
100	21.7
25.8	17.0
122.4	15.8
137.2	11.4
47.3	10.4
113.8	10.0

Lipid Content	
River Mile	Coefficient of Variation
58.7	94.6
TIP	70.0
122.4	46.0
88.9	42.0
169.5	40.8
159	37.7
196.9	34.6
143.5	28.1
100	20.1
25.8	20.0
137.2	18.2
47.3	13.3
113.8	11.9

Note: TID represent 3 stations in the TI Pool at RM 189.5, 191.5, and 194.1.

The wet weight coefficient of variation is attributable to absolute differences in PCB concentration while the lipid-normalized values are attributable to both lipid content and total PCB level. This relationship can be seen by comparing the columns in the table above. Note that the TIP station has a high coefficients in all three instances while station 58.7 has a low total PCB (wet weight) coefficient and very high lipid content coefficient, yielding a high lipid normalized total PCB coefficient for this station. The commentor is correct in noting that the highest coefficients variation are found in river mile 196.9. However, it also should be noted that the TIP and the other upper Hudson stations have among the highest coefficients as well. T is also true, in general, that the more different species at a sampling location, the greater the coefficient of variation.

BF-1.85 *p. 62, Bottom: "...and closest to the source of PCBs...". The sources of PCBs to fish are the water and sediment. '[C]losest to the Thompson Island Pool' would be more accurate, since fish between the Hudson Falls and Rogers Island showed much lower and less variable concentrations.*

This sentence was meant to reflect the environmental source of PCBs, rather than the specific exposure source for fish. The text is clarified in the Revised BMR.

BF-1.86 *p. 63, Para 1: "Data show that spottail shiners consume□ equal amounts of benthic and water column invertebrates." Was this derived from Appendix A, Table A-1? If so, it appears that* *their diet was dominated more by water column than benthic invertebrates as is suggested in Appendix A Section 1.7.1(p. A-16).*

The spottail shiner diet, as given in Table 6-1, is a triangular distribution for each of sediment sources, water sources, and phytoplankton. The water-based distribution has a mode of 70%, the sediment 25%, and phytoplankton 5%. Thus, the spottail shiner diet is predominantly derived from water column sources.

5.5 Piscivorous Fish: Diet Accumulation Factors (PFBAF): Largemouth Bass

BF-1.87 *p. 63 Para 3: The oversimplified food chain used in the model creates two problems. First, there is uncertainty arising from "averaging" the dietary characteristics of each organism type. Second, the truncation of certain size classes of fish biases the results. In Section 5.5, the data for largemouth bass are excluded because they do not represent the "correct" size. This problem would be avoided if the model incorporated different age classes of fish.*

The PFCM relies on a series of transfer coefficients between trophic levels. This empirical approach relies on the available data, which is primarily for adult largemouth bass of a certain size range. Under this approach, an age-class model is not appropriate. The FISHRAND model is designed as a mechanistic model to predict population distributions of PCB concentrations in each species. The upper trophic-level fish population of interest from a management standpoint are the larger fish likely to be consumed by humans and some ecological receptors. Given the available data, model structure, and the management goals for this project, the model incorporates a population-level growth rate rather than separate age-class modules. The only data that are excluded are the EPA/NOAA Phase 2 data, which were obtained for small largemouth bass. This is the only dataset in 20+ years worth of data that was excluded. None of the NYSDEC data were excluded.

Model structure is constrained by data availability and the level of detail necessary to capture the essential features of the system. The uncertainty of averaging dietary characteristics of each organism type is low relative to uncertainties in the true exposure field to which organisms are exposed. PCB concentrations at each trophic level will be largely dictated by the dominant food source for that trophic level; for example, if a fish consumes primarily water column invertebrates, exact specification of dietary preference will be less important than capturing the essential element that the particular fish prefers water column invertebrates.

BS-1.8 *P. 76 to 77 Book 1; Figure 7-13 to 7-15 in Book 2; p. 31 Book 3; Figure 7-9 Book 4; The report discusses the seasonality of the PCB concentration in the water column and the fluxes out of the sediment.... The seasonal variation could raise a concern about the timing of various data collection and their interpretation. Figure 5.6 Book 4 compares the ratio of PCB concentrations in bass to that of pumpkinseed, yet largemouth bass are collected in June while pumpkinseeds are collected in September. Is this comparison, which is used to derive transfer coefficients between prey and predator fish, valid if two species were collected under different PCB concentration* *regimes? ...The model should document more conclusively that these interspecies difference are tropic position dependent... Does the FISHRAND model, which uses monthly average water column PCB concentrations (p. 31 Book 3, figures 7-8 and 7-9 Book 4), suggest a seasonal variation in the fish PCB concentrations? This should be discussed, as it bears on the validity of the Figure 5.6 comparison, and may suggest potential management/sampling issues for the future.*

The FISHRAND model does suggest a seasonal variation in fish PCB concentrations. This variation can be as high as a factor of 2 within a year. The transfer coefficients in the PFCM (which are derived under the assumption that any individual largemouth bass is exposed to PCBs through the diet and consuming primarily pumpkinseed or pumpkinseed-like forage fish) implicitly incorporate seasonal variation. Insofar as these ratios are consistently constructed (that is, always a spring-caught piscivorous fish over the forage fish average from the previous fall), their application is valid. However, it is true that the ratios not only capture trophic level differences but seasonal differences as well.

5.5.1 Largemouth Bass to Pumpkinseed BAF for Total PCBs

BF-1.88 *p. 63: Individual largemouth bass PCB concentrations were lipid normalized while for pumpkinseed average lipid normalized PCB concentrations were used. The uncertainty in this approach should be discussed.*

The assumption is that individual largemouth bass are exposed to an average PCB concentration in the diet as represented by the average concentration in pumpkinseed. It is not possible to quantify the uncertainty in this assumption, but it is likely from a biological perspective that any individual largemouth bass consuming pumpkinseed would be exposed to an average pumpkinseed concentration (as opposed to "matching" individual largemouth bass with individual pumpkinseed, or taking the average largemouth bass to the average pumpkinseed).

5.6 Validation of Probabilistic Model Using Fate and Transport Model Output as Input

No significant comments were received for Section 5.6 of Book 3 of the BMR.

5.7 Discussion of Results

BS-1.26 *P. 64, Book 3 The document observes that peaks in fish PCB concentrations in the early 1990's were not captured well. Only the water concentration showed such dramatic increases in this time frame. This suggests that the model does not represent uptake from the water columns adequately. Analysis should be conducted to assess the impact of either direct uptake or accumulation through the water column food chain.*

A limitation of the PFCM, in that it is not mechanistic, is that it is less well-designed to capture short term fluctuations in concentrations.

BF-1.89 *p. 64, Para 3: The dates 1992 and 1993 should be substituted in the phrase "...model to capture 1991 and 1992 observed concentrations for largemouth bass".*
The last sentence in this paragraph seems to contradict the statement in Para 4. on p. 60 about biomagnification of PCBs in the aquatic food chain.

The corrections are included in the Revised BMR.

The last sentence in the paragraph states: "While 1992 shows a transient increase in whole water concentrations (see Figure 5-7), it is not high enough to be reflected in fish concentrations." Paragraph 4 on p. 60 is a discussion of water column invertebrate concentrations, specifically, the results of the Novak (1988) study. Water column invertebrates do respond quickly to changes in water column concentrations, but fish integrate exposures over wider spatial and temporal scales than do invertebrates. Thus, we would expect to see a faster response in invertebrates than in top-level piscivorous fish.

BF-1.90 *p. 64, Section 5.7: Section 4.1.1.3 (p. 34-35) states that PCB fish body burdens may vary with bioenergetic factors such as seasonal growth and spawning cycles. It was also noted that sex, age, weight, and length can affect PCB body burdens. These were not addressed in the BAF approach but should have been considered in the probabilistic and mechanistic models. The statement in Section 4.3.2. (p. 53 Para 1) highlights the importance of these factors and presumes that they will be included in the probabilistic and Gobas models. While the historic database may be incomplete with regard to these parameters, the models should be tested to determine if they can replicate available age, sex and weight/length data. The ability of the models to predict seasonal differences in PCB tissue concentrations can also be tested by splitting rather than lumping seasonal data. For example, May to September sampling events can be divided into spring and late summer/early fall collections rather than lumping these events together.*

The only data available to evaluate seasonal differences are NOAA data from 1995. In the models, May to September sampling events are never lumped together. Within a particular year, fish within a species have been sampled at the same time of year. That is, there are no data in which both spring and fall fish-collections were conducted except for the 1995 NOAA dataset, and these data are only available for a location below the Federal Dam at Troy (river mile 154) and thus are not comparable to any of the modeling locations.

FISHRAND predicts a monthly fish body burden. In the Revised BMR, model results are compared to data for the particular month, year, species and location of data collection. This comparison resulted in a lower relative percent difference between predicted and observed than did the comparison between annualized model output and data.

There are insufficient data available to support a full bioenergetic simulation. The number of assumptions required for this approach are not supported. The modeling approach taken here was selected to minimize the number of assumptions required and to maximize the information obtained from the available data.

BF-1.91 *p. 64, Para 4: "on a lipid-normalized basis, model predictions and observed data show excellent agreement. This agreement is less robust when evaluated on a wet weight basis." This is an overstatement of the concordance of the observed to predicted results shown in Fig. 5-8 through 5-10.*

Comment acknowledged.

Chapter 6. FISHPATH AND FISHRAND: TIME-VARYING MECHANISTIC MODELS BASED ON A GOBAS APPROACH

6.1 Model Input Data

BF-1.92 *p. 67: NOAA Phase II and NOAA 1995 fish data apparently were also used in development and validation of the models. In addition, there is no discussion of the differences in the quantification methods for total PCBs and lipid content, which make the data not directly comparable.*

NOAA Phase II data were used in the development and validation of the models, but not the NOAA 1995 data.

6.1.1 Non Species-Specific Parameters

6.1.1.1 Sediment and Water Concentrations

No significant comments were received for Sections 6.1.1 to 6.1.1.1 of Book 3 of the BMR.

6.1.1.2 Temperature

BF-1.93 *p. 68: Monthly average temperatures were required by FISHRAND, since growth rate is a temperature-dependent parameter. Temperature is also important to the partitioning of PCBs. An assumption of the FISHPATH and FISHRAND models was that fish spent most of their time (on average 75%) in areas with cohesive sediments and the nearshore areas were weighted more heavily in the TIP. However, the monthly averaged temperatures apparently were based on mid-channel measurements. To account for the potentially higher temperature in shallow nearshore areas, sensitivity analysis for the FISHRAND model was conducted by adjusting the temperature distributions upward by 20%. What is the basis for the 20% factor? Because the FISHRAND model* *uses the output from HUDTOX, simply assessing the sensitivity of the bioaccumulation model to temperature effects fails to consider the linkage between these models and does not fully address the potential temperature difference.*

The 20% adjustment was selected to represent the expected range in lateral temperature variation based on best professional judgment. It is true that temperature impacts not only the growth rate of fish but the partitioning of PCBs as well. Because of the influence on partitioning and to maintain consistency between the fate and transport and bioaccumulation models, the same reach and segment-specific temperatures are used in both models.

6.1.1.3 Total Organic Carbon in Sediment

6.1.1.4 Log Octanol-Water Partition Coefficient (K_{ow})

6.1.2 Species-Specific Data

6.1.2.1 Lipid Content

6.1.2.2 Fish Weight

6.1.2.3 Dietary Composition

No significant comments were received for Sections 6.1.1.3 to 6.1.2.3 of Book 3 of the BMR.

6.2 Results of the Calibration Exercise

BF-1.95 *p. 72 Para 1: Table 6-2 presents the summary of the relative percent difference between modeled and observed lipid-normalized and wet weight PCBs at four river mile locations for five fish species. There is inadequate discussion of the results. The statement "In general, the model is better at capturing lipid-normalized concentrations versus wet weight concentrations" minimizes the high bias associated with the wet weight results. Moreover, at the Science and Technical Committee meeting earlier this month, another set of tables indicated this bias was higher and more systematic than documented in the BMR.*

BG-1.5 *With regard to fish, the model results consistently over-predict the data points in the reach of the river downstream from the TIP, as presented in Book 4, Figure 6-4 of the report. Since the PCB levels in fish are ultimately derived from PCBs in sediments or water column, this suggests systematic error in fish diet, sediment, or water column calculations.*

BG-1.29 *The FISHRAND model computes a mean and distribution of PCB concentrations in fish was calculated on the basis of assumed distributions of parameter values. ……Because many of the* *data points overlap or over-plot, it is not possible to judge the mean or distribution of the data. Thus, it is impossible to assess the relationship between the model and the data*

BG-1.44 *BMR Book 4 Figure 7-13 shows that largemouth bass, yellow perch and pumpkinseed PCB levels are predicted to decline from 1998 to 1999 and then increase from 1999 through 2001 (pumpkinseed and yellow perch) and 2002 (largemouth bass).... However the graphics displaying the water and sediment exposure concentration (BMR Book 4, Figures 7-9 and 7-10) show no increase of this magnitude. In fact, the sediment PCB concentration monotonically decrease. The water PCB concentration decrease from 1998 through 200 and have no trend through 2002.*

There were no higher or more systematic differences in the tables presented at the Science and Technical Committee meeting than were present in the results presented in the BMR. There was a positive high bias present in the results from the BMR for certain locations and species, and this did not change in the corrected table presented at the STC meeting, although individual values were slightly lower.

In general, there is no positive high bias within the TIP for any of the species. At Stillwater and Waterford/Federal Dam, there is a positive high bias in the wet weight results for species that derive a significant portion of their exposure from the water column. However, note that the results from the lowest HUDTOX segment (just above Federal Dam at approximately river mile 154) were compared to fish concentration results obtained from *below* the Federal Dam at approximately river mile 152. As these two locations are not directly comparable, we would expect a bias arising from this comparison. These two locations were compared in the BMR since there isn't very much fish data available from river mile 154, and because only river mile 152 has seasonal data available (yellow and white perch collected in spring and fall of the same year). The comparison between the two locations was not included in the Revised BMR.

BG-1.29 *The FISHRAND model computes a mean and distribution of PCB concentrations in fish was calculated on the basis of assumed distributions of parameter values. ...Because many of the data points overlap or over-plot, it is not possible to judge the mean or distribution of the data. Thus, it is impossible to assess the relationship between the model and the data.*

The comparisons between model output and data were presented in a different form in the Revised BMR.

BF-1.96 *p. 72 Para 2: "The model shows that concentrations tend to increase in the late summer, when feeding is maximized." Is there a seasonal difference in fish feeding, i.e., feed more in the late summer?*

Fish feed throughout the warmer months, beginning in April and continuing through to September or October. Feeding drops off dramatically during the colder weather, and the food ingestion rate for fish contains a term for temperature to account for this phenomenon. Feeding will depend on a numerous factors in addition to temperature, such as competition, prey availability, and so on. In terms of the way in which fish feeding is modeled, the feeding rate depends primarily on temperature and the weight of the fish. So as a general trend, feeding will be greatest during the late summer when water temperatures are at their highest.

Chapter 7. PRELIMINARY BIOACCUMULATION MODEL PREDICTIONS

7.1 Probabilistic Empirical Model

7.1.1 Sediment and Water Concentration Inputs

No significant comments were received for Sections 7.1 to 7.1.1 of Book 3 of the BMR.

7.1.2 Preliminary Predicted Largemouth Bass Body Burdens under Zero Upstream Boundary Conditions

BF-1.97 *p. 73-76: Predicted fish body burdens are given under zero and constant upstream boundary conditions. Concentrations are compared to selected human health target levels such as the FDA Action Level and the Great Lakes Uniform Sportfish Advisory Task Force. Ecological target levels such as Newell et al. (1987) and IJC (1989) of 0.11 mg/kg and 0.1 mg/kg, respectively, should also be considered.*

The target levels in the Revised BMR are meant to explore a range of potential target levels for comparison purposes. Appropriate target levels will be determined as part of the Feasibility Study to be released in December 2000

BS-1.29 *P. 73, Book 3, last line: The text should be more explicit as to what population is being protected.*

Determining the specific fish populations to be protected and the desired level of protection is a risk management issue to be evaluated in the Feasibility Study. The results of this chapter were merely designed to show that predictions are provided for particular fractiles of the fish population and how to interpret those results without making a judgment as to what population is being protected. The "population" refers to the population of the specific species, for example, largemouth bass, as described elsewhere in the report, are large, adult, piscivorous fish greater than 25 cm in length typically consumed by humans and top-level ecological predators.

7.1.3 Preliminary Predicted Largemouth Bass Body Burdens under Constant Upstream Boundary Conditions

7.2 FISHRAND Results

7.2.1 Sediment and Water Concentration Inputs

7.2.2 Predicted Preliminary PCB Concentrations in Fish under Constant Upstream Boundary Conditions

7.3 Discussion of Preliminary Predictions

No significant comments were received for Sections 7.1.3 to 7.3 of Book 3 of the BMR

Chapter 8. DISCUSSION OF UNCERTAINTY

BS-1.30 *Chapter 8, Book 3: Given the uncertainties, would a simple regression model of the existing fish data provide another means to evaluate the fish data for future predictions?*

The Bivariate BAF model is one such regression model. However, this model was not used for predictions because with the passage of time (or under specific remedial alternatives), sediment and water exposure concentrations will decrease well outside the range of observed data. This means that the regression model would have to extrapolate beyond the range of observed data, which, as a general rule, is not typically advised for regression models. Further, insofar as the data reflect a variety of environmental conditions, these are captured in the regression relationships, but because the model is not mechanistic, it relies on the assumption that these relationships will hold in the future and over an observed number of environmental conditions.

8.1 Model Uncertainty

8.1.1 Model Uncertainties in the Fate and Transport Models

8.1.2 Model Uncertainties in the Bioaccumulation Models

8.1.2.1 Probabilistic Empirical Model and Bivariate Statistical Model

No significant comments were received for Sections 7.1.3 to 8.1.2.1 of Book 3 of the BMR.

8.1.2.2 FISHRAND and FISHPATH

BF-1.98 *p. 78, Bottom: (the rationale for not including incorporation of different feeding strategies) suggests that identification of probability distributions for model parameters negates the need to* *revise model structure. Adding distributions is only useful if basic model processes are well-described and does not improve model predictions. This tends to blur the distinction between variability and uncertainty.*

See response to comment BF-1.59.

8.2 Parameter Uncertainty

BF-1.99 *p. 79-80, Section 8.2: FISHPATH and FISHRAND utilize (a) an equilibrium partitioning approach rather than including a biomagnification mechanism via benthic invertebrate feeding preferences, and (b) a growth dilution approach rather than an age-class model for each year of the fish's life. They do not contain a pharmacokinetic model to incorporate metabolism. While these issues are discussed in Section 8.1.2.2, the document would benefit from a discussion of the uncertainty of excluding current revisions to the Gobas (1993). There is no reference to Tables 8-2 through Table 8-4 in the text.*

The uncertainties introduced by not considering an age-class model, or the pharmacokinetic updates to the Gobas model, are discussed in Section 8. This discussion is expanded in the Revised BMR. The FISHRAND modeling approach incorporates sediment concentration distribution and benthic lipid content distributions, the two factors contributing most to the observed variability in benthic invertebrate concentrations. This approach addresses the range of invertebrate concentrations expected from a range of sediment concentrations. Growth dilution versus an age-class model is discussed in the response to comment BF-1.40. FISHRAND does not contain a pharmacokinetic component within the fish, but metabolism, assimilation efficiency, and egestion are all terms that address PCB fate within the fish.

The Revised BMR contains appropriate table references.

8.2.1 Sensitivity Analysis

BF-1.100 *p. 80, Section 8.2.1: It appears that the discussion of Table 8-1 actually combines results presented in Tables 8-1 through 8-4. This paragraph should be rewritten for clarity in terms of the tables discussed and the table contents, i.e., the correlations are between lipid normalized PCBs and lipid content in various media, Kow, sediment organic carbon and % diet.*

This has been corrected in the Revised BMR.

8.2.2 Lipid Content

No significant comments were received for Section 8.2.2 of Book 3 of the BMR.

Chapter 9. SUMMARY AND CONCLUSIONS

***BF-1.101** p. 84: Appropriate target levels ("environmentally protective") should include values that are protective of aquatic, avian and terrestrial receptors as well as human health.*

The FDA action level was selected as one reference point against which to gauge PCB concentration reductions in fish. There are many others, and the report did not mean to imply endorsement of a particular target level. Target levels will be developed as part of the Feasibility Study.

***BF-1.102** p. 86: The report states that for the Bivariate BAF model, "much of the remaining unexplained variability is due to uncertainty in historic water column concentrations"; this conclusion is not supported in the report. For example, much of this variability could be due to errors in the HUDTOX model, lack of representativeness of sediment and water column measurement to fish habitat use, etc. the remaining variability could also be "white noise"; we have no assurance that improving the water column concentrations will eliminate most of the remaining uncertainty.*

The Bivariate BAF model did not use HUDTOX output for water column exposure concentrations. Instead, summer average water column concentrations were estimated directly from available data. As only a few samples were available for some of the 21 years of fish data included in the regression models, it is reasonable to assume that uncertainty in the estimation of historic water column concentrations is a major source of unexplained variability in the BAF model. Sediment concentrations were estimated from HUDTOX for the Bivariate BAF model application, and any lack of representativeness in HUDTOX estimates would contribute to variability in Bivariate BAF model results, as noted by the commentor. Finally, a significant portion of the variability in the Bivariate BAF results is surely due to the fact that this relatively simplistic model does not provide a complete representation of the factors controlling PCB bioaccumulation in fish. A more complete discussion of the sources of uncertainty in the Bivariate BAF approach is found in Section 4.3.2 of the Revised BMR. .

9.1 Summary of Food Web Models

***BS-1.31** Chapter 9, Book 3: In the summary and conclusions of the food web models there is no reference to goldfish and carp.*

Goldfish and carp were only used in the Bivariate BAF model, and were not among the original target species for modeling.

9.2 Principal Report Findings

BS-1.35 *The Principal Report Findings present estimates for wet weight concentrations for PCBs in fish by location and the year they are predicted to reach this level. When presenting these estimates, EPA should discuss the range of uncertainty for each of the estimates that are made by the models.*

In the Revised BMR, sediment and water input concentrations are treated as uncertain while the remaining parameters are considered variable. The modeling results presented in that report have focused on separating uncertainty from variability in the parameter estimates. Lipid content, weight, etc. are all considered variable parameters (or at least parameters for which population heterogeneity - variability - dominates.) Sediment and water concentrations are considered uncertain, because these are the two parameters over which decision makers may have some control. That is, we cannot change or impact lipid distributions or weight distributions in fish, but under particular remedial alternatives, we may be able to influence sediment and water concentrations.

The results in the Revised BMR reflect a two-dimensional Monte Carlo analysis in which sediment and water concentrations are considered uncertain, and the remaining distributions are considered variable. This is done within a nested framework. The procedure is that a sediment concentration and a water concentration are selected for each year (the uncertain parameters) and are fixed while the full variability distributions are run. This is done for several iterations for each year, resulting in a two-dimensional result (i.e., error bars on the variability distribution where the error is attributable to changes in sediment and water concentrations). Under this framework, the uncertainty associated with each percentile is explicitly quantified, and attributable to sediment and water concentrations. The uncertainty in lipid content, weight, etc. is considered low relative to inherent variability.

See also response to comment BF-1.59.

BS-1.32 *P. 86, Book 3. In the second bullet there is confusion over data and locations. Was this part of the model intended to capture something about the influence of the Mohawk River?*

This has been removed from the Revised BMR.

BS-1.33 *P. 86, Book 3. The second bullet should be checked for a typo.*

Comment acknowledged.

REFERENCES

No significant comments were received for the References of Book 3 of the BMR.

ADDITIONAL REFERENCES

Novak, M.A., A.A. Reilly, and S.J. Jackling. 1988. Long-term monitoring of polychlorinated biphenyls in the Hudson River (New York) using caddisfly larvae and other macro-invertebrates. *Arch. Environ. Contam. Toxicol.* 17:699-710.

Novak, M.A., A.A. Reilly, B. Bush and L. Shane. 1990. In situ determination of PCB congener-specific first order absorption/desorption rate constants using Chironomus tentans larvae (insecta: diptera: chironomidae). *Wat. Res.* 24(3):321-327.

Swindoll, C.M., and Applehans, F.M. 1987. Factors influencing the accumulation of sediment-sorbed hexachlorobiphenyl by midge larvae. *Bull. Environ. Contam. Toxicol.* 39:1055-1062.

Wood, L.W., Thee, G.-Y, Bush, B, and E. Barnard. 1987. Sediment desorption of PCB congeners and their biouptake by dipteran larvae. *Water Res.* 21:875-884.

Federal

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July 1, 1999

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Dear Doug:

Thank you for the opportunity to review the May 1999 Phase 2 Report - Review Copy, Further Site Characterization and Analysis, Volume 2D - Baseline Modeling Report, for the Hudson River PCBs Reassessment Remedial Investigation/Feasibility Study (RI/FS). The following comments are submitted by the National Oceanic and Atmospheric Administration (NOAA).

The Phase 2 Draft Baseline Modeling Report (BMR) was prepared as part of the overall Phase 2 Reassessment RI/FS activities currently ongoing to provide further characterization and analysis of the Hudson River PCB Site which extends from Hudson Falls, NY to the Battery in New York Harbor. The BMR presents results and findings from PCB transport and fate and bioaccumulation modeling. Modeling focused on the Upper Hudson River between Fort Edward and Federal Dam at Troy, with special emphasis on the Thompson Island Pool (TIP). Books 1 and 2 provide transport and fate model output for historical data and for forecast simulation. Books 3 and 4 contain the results from bioaccumulation modeling.

The BMR modeling effort was designed to answer three questions: 1) When will PCB levels in fish recover to acceptable human health and ecological risk levels under the current No Action status of the site? 2) Can remedial activities in the Hudson River other than No Action shorten this recovery period? 3) Will contaminated sediments currently buried become "reactivated" following a major flood and result in increased contamination to fish?

Specific goals of the transport and fate component are 1) to develop a mass balance model for PCBs in sediment and surface water of the Upper Hudson, 2) to calibrate the mass balance model to historical and Reassessment data, 3) conduct forecast simulations with the calibrated mass balance model to estimate long-term responses to continued No Action and impacts from a 100-year flood, and 4) estimate short-term, fine-scale erosion of solids and PCBs in TIP in response to a 100-year flood.

The objectives of the bioaccumulation modeling effort are as (1) to relate historical, current, and future body burden data to water and sediment concentrations, (2) to provide estimates for the human health and ecological risk assessments, and (3) to provide bioaccumulation modeling tools that can be coupled with fate and transport model output.

Model calibrations were performed on the Upper Hudson River Toxic Chemical Model (HUDTOX). Fate and transport of PCBs were investigated as total PCBs, Tri+, BZ#4 and BZ#52. Total PCBs, Tri+, BZ#4, and BZ#52 calibration focused on the relatively data rich years of 1991-1997. Hindcasting utilized Tri+ PCB data from 1984-1997. The 21-year forecast was only conducted for total PCBs. The forecast simulation assumed no future PCB load increases from any upstream sources and set the loading boundaries as 0 and 9.9 ng/l (1997 annual average). It was concluded that the HUDTOX model was capable of describing hydrology, solids dynamics and PCB dynamics of the Upper Hudson River over the historical record tested.

The Depth of Scour Model (DOSM) suggested that there was a high probability that a 100-year flood would scour TIP cohesive sediments to an average depth of 0.3-0.4 cm. The total solids scoured during such an event was also estimated at ranging between 1,5000,000 and 2,000,000 kg. Based on these predictions, the 49-65 kg total PCBs was estimated to be scoured, assuming median surface PCB concentration of 32.5 mg/kg. The upper bound estimate of anticipated average erosion from non-cohesive TIP sediments is 13.1 cm for a 100-year flood.

The fate and transport report presents two conclusions related to PCB loading. There was a declining trend in total PCBs, Tri+, BZ#4 and BZ#52 over time, and greater than 95% of PCB load enters the Upper Hudson River at Fort Edward compared to the minor contributions from tributaries. Between 1991 and 1997, the majority (81-94%) of the PCB load entered the Hudson River at Fort Edward at flows less than 11,000 cfs and suspended solids less than 10 mg/l. The model also estimated a loss of 2000 kg Tri+ from TIP sediments concurrent with a net deposition of 1.6 cm sediments poolwide.

Forecast findings from HUDTOX included the observation that surficial sediment PCB concentrations are primarily driven by sediment-to water flux and exchange between deep and surficial sediments rather than by upstream PCB loads. In contrast, water column PCBs were influenced by upstream PCB loadings. The relative influence increases over the 21-year forecast period as surficial sediment concentrations declined. It was also concluded that water column and sediments had not approached steady-state conditions with current upstream PCB loads. The 100-year flood worst case scenario resulted in relatively minor, short-term changes in total PCBs resuspended from cohesive TIP sediments which the authors did not believe would significantly alter the river's rate of recover.

Bivariate BAF Analysis, an Empirical Probabilistic Food Chain Model, and the Gobas mechanistic time-varying model were utilized in the bioaccumulation modeling effort to describe the relationship between PCBs in fish, sediment, and water. Modeling efforts focused on Tri+ PCBs which were considered equivalent to total PCBs in fish.

The Bivariate BAF Analysis explained about 80% of the observed variability in Tri+ summer average lipid-normalized fish tissue concentrations from the freshwater Hudson River. The Probabilistic Food Chain Model captured the mean fish concentrations from NYSDEC data from sediment and water inputs. The deterministic (FISHPATH) and probabilistic (FISHRAND) Gobas models duplicated steady state and dynamic results.

Time predictions are provided for when given fish species will achieve PCB body burdens relative to certain available criteria. For example, mean body burdens do not fall below 0.5 ppm at any location for any species within the 21-year forecast period while for specific species at certain locations PCBs in fillets may drop below 1.1 ppm or 2 ppm.

General Comments

Because of the importance of these models in predicting future conditions and responses to alternative remedial scenarios, the development and implementation of a comprehensive monitoring plan is essential to validate key assumptions and predictions.

In many places in the report (as listed below) the BMR states that future work is planned on the fate and transport and bioaccumulation models. It would be useful to provide a detailed description of these tasks, as well as an indication of how the data from these analyses will be incorporated into the models.

- calibration of additional individual congeners (BZ#28, BZ#90+101, BZ#126) within the HUDTOX models (Book 1 p. 7),
- magnitude and temporal pattern to the TID bias as a function of upstream flow and PCB load at Fort Edward (Book 1 p. 53),
- potential bias in USGS water column PCB data at stations downstream of Fort Edwards and significance to HUDTOX model results (Book 1 p. 53),
- alternative scenarios for solids dynamics in the Upper Hudson River, including net erosion as a source for the observed gain in solids loading (Book 1 p. 60),
- significance of the analytical bias on USGS data in terms of PCB loads(Book 1 p. 62),
- significance of PCBs sources above Rogers Islands that could be activated by high flow events and implications to forecasting activities including assumptions about upstream boundary conditions (Book 1p. 65, 86),
- significance of water-air exchanges at dams on PCB dynamics in the Upper Hudson River (Book 1 p. 46, 77),
- sensitivity of surficial sediment PCB concentrations to dechlorination and vertical mixing in the sediment bed (Book 1 p. 80),
- alternative scenarios for upstream conditions for continued No Action will be designed and additional forecast simulations conducted as part of the FS (current scenario assumes 1997 PCB levels at Hudson Falls GE plant and no large releases such as occurred in 1991) (Book 1 p. 86),
- additional analysis on lipid content along with detailed rationale (Book 3 p. 71),
- modeling individual congeners at several locations to demonstrate its ability of capturing biomagnification dynamics (Book 3 p. 86, 88), and
- updating bioaccumulation modeling effort to reflect revisions to fate and transport model outputs (Book 3 p. 88).

General Comments on Volumes 1 and 2

The report does a good job of explaining the model and the calibration, but does not address key uncertainties in the model or the data used to calibrate the model.

The criteria used to determine whether the model output fits the data are not explicitly defined. What qualifies as agreement? The criteria should attempt to reflect whether the agreement is good enough for the intended use of the model in remedial decision-making, specifically the principal RI/FS questions that the model was intended to address [i.e., 1) When will PCB levels in fish recover to acceptable human health and ecological risk levels under the current no action status of the site? 2) Can remedial activities in the Hudson River other than No Action shorten this recovery period? 3) Will contaminated sediments currently buried become "reactivated" following a major flood and result in increased contamination to fish?].

The report is unclear on two points (a) what is the uncertainty associated with both sets of data (modeled and observed), and how does that uncertainty affect the reality of the comparison; (b) what degree of difference in values is important. In many cases, small changes are taking place over long time periods, so that apparent agreement may still result in large differences in total amounts. For example, the compressed scale on some of the plots give visual assurance of a match, but in some cases, particularly for TSS and sediment, small differences may reflect large amounts of PCB-contaminated sediment. **BF-1.1**

Models represent an oversimplification of the system that is being modeled. For these models to provide useful and credible input to the decision-making process, the potential implications of this oversimplification should be addressed. For example, there are a number of aspects of the Hudson River system that these models are not addressing. The Depth of Scour model does not address sediment resuspension resulting from debris (including large rocks, trees and root masses), bank erosion, or ice scour during high flow events. The characteristics of the water in the river during high flow events may be different from water in a laboratory flume test or the river during low flow, due to the material moving with the water. The daily changes in water level associated with hydropower generation act as a regular tidal action in shallow water, nearshore sediments, which may increase the release of PCBs from these sediments. Temperature in the shallow nearshore areas, during the summer low flow period may be higher than the mid-channel, which would affect temperature-dependent partitioning. All of these factors may result in significant underestimation of resuspension of sediments and/or PCB loading to the river. The potential importance for the interpretation of model results should be addressed. **BF-1.2**

The upstream boundary conditions used in the No Action alternative assume that there will no flow-related change (increase) in loading during high flow events. For example, the modeling does not address potential impact of high flow events on the Interim Cap on the Remnant Deposits or other areas of high concentrations of PCBs that remain between the plant sites and Rogers Island. **BF-1.3**

The model does not address the potential loss of PCB-contaminated sediment to the floodplain during high flow events. Because this material is not accounted for in the model calibration, it may affect mass balance calculations resulting in an underestimation of the amount of PCBs resuspended during high flow events. In addition, this material may provide a continuing source of particulate PCBs back to the river from runoff during heavy rainfall and snow melt. Please clarify your decision to omit this term from the model. **BF-1.4**

The rationale for the selection of PCB forms should be consistent with the intended use of the HUDTOX model (i.e., p. 1-4 Modeling Goal and Objective #1: "When will PCB levels in fish populations recover..."). The BMR currently does not address the range of important PCB congeners in fish. This is currently a major shortcoming of the modeling effort, although, as per the original model plan, three additional congeners (BZ#28, BZ#101, and BZ#138) will be included. It is not sufficient to model total PCBs (i.e., Tri+)—the model should be able to reproduce the changes in composition and concentration that have been historically characteristic of PCBs in fish throughout the upper river. **BF-1.5**

The 100 year flood evaluation includes the implicit assumption that no changes in the frequency or magnitude of high flow events will take place. Is this a reasonable assumption considering the potential for future development in the watershed? The derivation of the flow scenarios used in the model forecasting and the uncertainties in the proposed scenario warrant more complete discussion. **BF-1.6**

The model results suggest that total PCB transport during low flow conditions is greater than during high flow events (>80% vs. <20%). Does this relationship hold true for Tri+ PCBs? **BF-1.7**

General Comments on Volumes 3 and 4.

Overall, the "goodness of fit" of the models indicates that bioaccumulation modeling may be useful,; however, application of the models as a predictive tool in a decision-making context should be entertained only if (a) the important uncertainties are addressed, and a field validation step is conducted to test whether the "predictive" ability of the models is retained with new data. This is especially important since HUDTOX model output is used as input to the bioaccumulation models. Because modeled results (rather than empirical data) are used for the environmental fate component, it is not clear to what extent the observed model fit is attributable to the environmental fate component versus the biologically-based food web model. **BF-1.8A**

The text in Section 3.2 provides a good description of the fundamental assumptions of the bioaccumulation modeling. In particular, the difference between a fully equilibrated system, and one in which sediment and water are internally equilibrated (but not with each other), is well described. There is good discussion of various routes of chemical intake for invertebrates (water column versus sediment), and good acknowledgment of limitations of bivariate BAF analysis (i.e., not cause-effect relationship, not useful for prediction).

Modeling of representative PCB individual congeners was not reported, although the report does indicate that these efforts are currently underway for congeners BZ#28, BZ#52, BZ#101, and BZ#138. These results are key to the validation of the Gobas models, since the composition of the PCB mixture is known to change with distance from the source. If the observed differences in PCB composition and concentration in fish can be predicted by the model, it would greatly increase the confidence in this tool for predictive purposes.

Input from the HUDTOX model to the bioaccumulation models should focus on the nearshore areas, and, to the extent that concentrations in the water column have been adjusted to more closely match mid-channel values, they should be corrected to reflect nearshore exposure. **BF-1.8B**

The models rely exclusively on summer-averaged exposure conditions. We agree that the summer period would be the most important period for food uptake of PCBs, but water-borne exposures would occur year round, and appear to be an important source of PCBs to all fish species. **BF-1.9**

The model uses growth rate determined by Gobas (1993) for lake trout for all fish species. Given the different fish species under consideration in this modeling effort, and the likely differences in food webs and temperature in the Hudson River system relative to the Great Lakes, incorporation of species-specific growth rates should be considered. **BF-1.10**

Lipid content was assigned a distribution for each species disregarding locational and temporal differences since there was no differences within a species by location or year. Pattern analysis should have also examined lipid content for a given species at a given location over time, especially in light of the importance of lipids demonstrated by the sensitivity analysis. It may be more appropriate to establish distributions for each species at each location. **BF-1.11**

The text implies that the HUDTOX model may introduce a factor or two variability in exposure concentrations to the bioaccumulation model. There is little information provided to determine whether this qualitative estimate is reasonable. Ultimately, synoptically-collected sediment, water, prey tissue, and fish tissue data would be necessary to truly validate the developed models. Ideally, this validation of the modeling would include both total PCB and congener-specific analysis. This could be done for a limited subset of the river reaches. **BF-1.12**

The results of the FISHPATH/FISHRAND modeling are not adequately addressed. There is only one half page of discussion devoted to the quality of fit for these models (page 72). This is an important omission, given that these models are the most important from a predictive standpoint, **BF-1.13** since they are mechanistically based. A more detailed discussion of where fit was good and where it was poor would help in the evaluation of the predictive ability of the models (i.e., which species and years were poorly predicted, and why?). For example, the model did not appear to have the same ability to model lipid-normalized PCBs and wet weight PCBs.

Specific Comments on Volumes 1 & 2

1 Introduction

p. 1-3 Last Para: Fractured bedrock remains a route of migration for PCBs to discharge into the Hudson River. While recovery wells have been installed to extract PCBs from bedrock and turkey basters/siphons have been used to remove observable oil droplets at known seeps, droplets of PCBs may still continue to discharge at unidentified locations. **BF-1.14**

4 Thompson Island Pool Depth of Scour Model

p. 26 Para 2: Toward the end of the paragraph it is stated that "No sediments described as "coarse" were listed for Thompson Island Pool." This is followed by "The area of non-cohesive sediments in TIP is approximately three times that of cohesive sediments." Please explain the apparent contradiction in these two sentences. **BF-1.15**

p. 28 Para 1: The median PCB concentration in cohesive surficial sediments was 32.5 mg/kg. What is considered surficial for this analysis? What was the median PCB concentration in noncohesive sediments? **BF-1.16**

"This value was used to approximate ...throughout TIP..." Why was the median used rather than the arithmetic mean, which should provide a better estimator of the "range for the mass of PCBs eroded from the sediments of TIP..."?

p. 30 'Model application to high resolution coring sites': Because these 5 high resolution cores cannot be considered representative of cohesive sediments in the Upper Hudson River, the information on potential scour of cohesive sediments gained from this comparison may be misleading.

p. 30-31: The Depth of Scour Model (DOSM) uses separate equations to describe erosion of cohesive and non-cohesive sediments. Using Monte Carlo analysis, the predicted mean depth of scour for a 100-year flood for cohesive sediments fell mainly between 0.3 and 0.4 cm (Figure 4-9). Predicted median (0.074-3.714 cm) and 95th percentile (0.356-21.789 cm) depth of scour for 5 sediment locations produced a wide range of results. For example, in Table 4-2, the greatest amount of scour was observed in the sediment core with the shallowest PCB peak. On the other hand, depth of scour was about an order of magnitude different for cores with PCB peaks at similar depths. How does the HUDTOX model incorporate these DOSM findings and does it account for such differences? The high-resolution core locations used in this analysis are highly unusual in that they represent locations with continuous undisturbed deposition according to the radionucleide analysis; most cohesive sediment areas would not show this kind of pattern (that is, they would be subject to some degree of vertical mixing). How were the results from these 5 non-representative locations interpolated over the large spatial area representing the Upper Hudson River? Could the same type of analysis be conducted considering specific hotspot locations and the results compared to those obtained from the Low-Resolution Core Report? **BF-1.17**

5 Mass Balance Model Development

p. 34: Are we to assume that most water-column PCBs are associated with dissolved organic carbon (DOC) since DOC concentration is used as a forcing function in the water column? This is in contrast to other Phase II documents. For example, the PMCR Responsiveness Summary indicates that uptake of water-column PCBs through the food chain would primarily be associated with the particulate organic carbon (OC). Direct exposure to dissolved OC would occur through water exchanges across the gill. In contrast, DEIR findings included the following: (a) water-column PCB transport occurs largely in the dissolved phase, (b) the dissolved phase represents 80% of the water column PCB inventory in the Upper Hudson during most of the year (10 to 11 months) and (c) the majority of the Upper River PCB input to the water column is introduced upstream of RM 181.3 under low-flow summer conditions. This load is transported through the Upper Hudson to Troy with minor alterations and additions. This is particularly important because the summer low-flow period coincides with the summer feeding period for fish, which is their period of maximum exposure. Given the high bioconcentration factors for PCB congeners, any water-column dissolved PCB exposure could be significant, and all species, regardless of trophic level or feeding strategy, would have comparable exposure to any dissolved PCBs. This would be in addition to any dietary input. **BF-1.1**

p. 34-35: "The mass balance for the HUDTOX model accounts for all material entering and leaving the system by external loading, advective and dispersive transport, settling and resuspension, and physical, chemical and biological transformations." The model does not account for "all material leaving and entering the system" by the mechanisms listed, since the floodplain as a source or sink for PCBs, the effects of daily fluctuating water levels resulting from hydropower generation on releases of PCBs from the sediments, resuspension from ice scour, etc. are not considered. **BF-1.1**

p. 40-42, Sediment Particle Mixing: The "improved sediment bed handling approach" appears to arbitrarily restrict the vertical mixing of the sediment. Also, the particle mixing coefficient is two orders of magnitude less at 4-8 cm than 0-4 cm. The report cites various researchers who have estimated biodiffusion coefficients but does not indicate what sediment depth the rates reported correspond to. Please explain how the mixing coefficients of 36.5 cm^2/yr for the top two sediment layers (0-2 and 2-4 cm), 3.65 cm^2/yr for the 4-6 cm and 0.365 cm^2/yr for the 6-8 cm were generated. **BF-1.2**

p. 41, Table 7-1: Why would you expect the particle mixing rate to be the same in cohesive and noncohesive sediments? The particle mixing rate is given for layers 1-2, 2-3 and 3-4, but the layer thicknesses are not defined. Does layer 1-2 represent 0-4 cm, while layers 2-3 and 3-4 correspond to the 4-6 and 6-8 cm slice? **BF-1.2**

p. 41: The sediment bed handling approach mixing does not take place until specific changes in surface layer thickness occur due to either scour or deposition. Assuming that much of the vertical mixing results from bioturbation, this mixing will occur continuously throughout the spring and summer, regardless of the changes in surface layer volume or thickness. **BF-1.2**

p. 41: Figures 5-2 & 5-3 depicts scour and burial of surficial sediments. For t_1, the legend should indicate that "Surface sediment concentrations may increase, decrease or remain the same as settling occurs". The graphic suggests a strong dilution factor. **BF-1.2**

p. 43, Bottom, Temperature dependent partitioning: What was the source of the temperature data used in the model? Was uniform temperature assumed throughout TIP, although during the summer the temperature in shallow protected areas may be higher than the temperature in mid-channel. **BF-1.2**

6 Data Development

p.52-53: The sampling difference that was reported by QEA for the west shore of TID is described as a "bias" resulting from incomplete lateral mixing, due to the presence of a nearby hotspot. It is not clear that this may more accurately reflect differences between nearshore and mid-channel areas during summertime low flow. The correction factors should only be applied to calculations of mid-channel loading and not for input to the bioaccumulation modeling, since nearshore values may be more relevant for estimating exposure concentrations in fish. **BF-1.25**

p. 53: "Monthly bias-correction factors were computed." What were these values? Is the model capable of reproducing these systematic differences in water column concentration between the channel and the nearshore?

p. 60-61: Solids load discrepancy: The estimated reach-wide average burial velocity for cohesive and noncohesive sediments was 3-15 cm and 0-3 cm respectively. Trapping efficiencies of 15% for TIP, 25% for TID-Stillwater, and 10% for Stillwater-Federal Dam were estimated. How do the large uncertainties in SS loading affect model output? Has a sensitivity analysis been performed on this parameter? **BF-1.26**

p. 61: An upward adjustment factor of 2.5 was invoked for the tributary loads between TID and Waterford relative to load estimates using unmodified rating curves. It was reported that the yields were high but within the range reported in the literature. Please provide the literature values and corresponding waterways. **BF-1.27**

Table 6-18: How is it possible that, during 1991 and 1992, more data exist for BZ#4 and BZ#52 than for Tri+? **BF-1.2**

p. 65: "An unresolved issue...stochastic pulse loads...due to...loads from flow-driven resuspension between Hudson Falls and Ft. Edward." This appears to be a critical issue, and its significance needs to be explored further to determine the potential impact on the modeling results. The planned future investigations should address the potential effect of pulse loading on the No Action model assumptions about upstream boundary conditions. Can some upper boundaries be placed on the PCB loading as part of the uncertainty analysis? **BF-1.**

7 Mass Balance Model Calibration

p. 69, Calibration Strategy: "...average properties were attributed to the congener mixture under investigation..." How were the average congener mixtures determined, and were they considered constant for all media and locations considered? **BF-1.3**

p. 71: Table 7-1 (Bk 2) summarizes the HUDTOX solids model calibration parameter values. Background solids resuspension velocity was provided for cohesive (0.2 mm/yr) and noncohesive (0.4 mm/yr) sediments based on the model calibration. How representative are the model calibrated resuspension velocities of real world conditions? Was the 3.0 mm/yr maximum potential value reported by Velleux et al. 1996 (citation absent from reference section) based on lab, field or modeling estimates? Sensitivity analysis for this parameter would be useful. **BF-1.3**

p. 72-74: Table 7-5 (Bk 2) contains HUDTOX PCB model calibration parameter values. The Kpoc and Kdoc for Tri+ was 5.821 and 4.216, respectively. The Kdoc value, set at 10% of Kpoc should read 4.821. For total PCBs, the Kpoc was 5.6 and the Kdoc was 4.6. It is our assumption that a mean Kpoc was calculated from the sum of theoretical log Koc given in Table 3-9 of the DEIR. A description of the method used to calculate the total PCB Kpoc and Tri+ Kpoc is suggested. Is it more appropriate to take the Kpoc for each congener and average those rather than **BF-1.**

use the average based on congeners represented in 16 GE peaks? A value of 10% of the Kpoc was selected for the Kdoc based on the range of values reported by other researchers for natural systems. What was the range of Kdoc reported and for what natural systems?

Table 7-5: Estimation of Kpoc for total PCBs and Tri+ was based on "apparent PCB congener distribution." How was this "apparent distribution" determined? Were these values altered by location to reflect changes in congener composition? CONTINUED

p. 72: Figure 7-2 depicts HUDTOX Spring 1994 high flow event settling and resuspension rates. There is a perceptible decline in the cohesive and non-cohesive resuspension velocity around April 15 without a drop in Ft. Edward flow or gross settling velocity. Please explain this phenomenon. **BF-1.33**

p. 72: Figure 7-4 displays monthly average water temperature by reach in the Upper Hudson River. Since temperatures were determined from the TAMS/Gradient Phase 2 Database, it is our assumption that these are mid-channel measurements may not represent or include shallow, nearshore conditions. **BF-1.34**

p. 74: Two processes - diffusion of porewater PCBs and sediment to water PCB flux from particles - are proposed as the mechanisms for exchanging PCBs between sediments and overlying water and between the upper mixed sediments without causing net solids transport. Yet these processes are attributed to bioturbation, mechanical scour and other turbulence-generating activities. Please explain why net solids transport would not be an important consequence of these phenomena. Also please explain the relative importance of each of these processes within the model. **BF-1.35**

Section 7.4: Calibration Results---what constitutes a good simulation?

p. 75, Top: Diffusive mass transfer rates varied seasonally due to dependence on temperature with slightly over a 50% rate increase in July and August. Since sediment temperatures were not recorded, temperatures were derived from applicable water column river segments for cohesive and non-cohesive sediments. Again, it is our understanding that these temperatures were from mid-channel measurements and do not include potentially higher values in nearshore shallow waters. What are the implications of higher temperatures in some areas on the diffusive mass transfer rates employed by HUDTOX and its output? **BF-1.36**

p. 75: The middle paragraph notes that the sediment-water mass transfer rate for PCBs from particulate phase was "determined by calibration to PCB observations after all other sediment-water exchange fluxes were specified." No analysis was presented as to the reasonableness of the values calculated or to alternative scenarios that could account for the observed congener patterns in the water column during low flow conditions. **BF-1.37**

p. 75: Particle-mediated transfer was included in the model to achieve the BZ#4/BZ#52 ratios in the water column. Were other mechanisms tested without successfully constraining the model? Might other mechanisms be invoked to achieve the same results? Why, mechanistically, would the mass transfer rate for particulates be much greater within the TIP than downstream of TID (see Fig. 7-6b)?

p. 76, Figures 10 a,b,c: The log-normal 1993 total suspended solids HUDTOX calibration results consistently underestimate the peaks and troughs. This is most apparent at Fort Edward but is also noticeable at West TID and to a lesser degree at Stillwater and Waterford. These figures do not appear to support the claim that the model is capable of capturing both high flow event peaks of TSS and low-flow depositional periods. **BF-1.38**

p. 77, Fig. 7-16: Displaying congener ratios on a linear scale does not allow full evaluation of the range in ratios. Ratios <1 are essentially not shown, which implies that samples where BZ#4 (or other congener) concentrations are less than BZ#52 are less important to display. The model also underestimates the ratio of water column BZ#4 to BZ#52 concentration at Stillwater and Waterford in 1991 and at the TIP in the latter part of 1993-94 and 1996. While a plausible explanation for the overestimates are provided, no discussion was provided for the underestimates. **BF-1.39**

p. 78: "additional load at Ft. Edward" Although the text suggests a couple of alternative scenarios, why was it assumed for the calibration that all of the missing load derived from above Ft. Edward and not, at least in part, from other locations above Schuylerville? **BF-1.40**

p. 79: How were the surficial sediment concentrations shown as individual data points in Fig. 7-25 derived? **BF-1.41**

p. 80, Para 1: "Accurate simulations of surface sediment" can be achieved in different ways, as described in the text. The planned future work should include different approaches to vertical mixing. **BF-1.42**

Calibration Results: Because the sediment reservoir is an important source, the model must be able to predict its behavior (i.e., the vertical distribution of PCBs). If it cannot be demonstrated that the model can predict vertical distribution as well as surface sediment concentrations, it would question the reality of the quality of the fit for other components. **BF-1.4**

p. 80: Please explain the discrepancy between TIP sediment trapping efficiencies, initially listed in Table 6-15. The TIP trapping efficiency per Figure 7-26 is 10.5% but in Table 6-15 is 15%. **BF-1.44**

Fig. 7-26: What does "dispersion" represent, and why is it only applicable to the TID to Schuylerville reach? How were the value(s) for dispersion determined? **BF-1.4**

p. 81, Figure 7-29: Please explain the significant differences in particulate PCB transfer (other than the differences in rates shown in Fig. 7-6b) within TIP and downstream of the TIP. **BF-1**

p. 81: The text discusses the contribution of BZ#4 and BZ#52 in sediments to the load gain across the TIP but Figure 7-31 depicts BZ#4 and BZ#5. It also appears that BZ#4 accounts for less than one third the net sediment release of total PCBS between 1991 and 1997, as opposed to the estimated one-half cited by the authors. **BF-1.47**

p. 81-83: The results of the Low Resolution Coring Report and the BMR should be compared to assess the ability of the model to predict measured changes in hotspot PCB content. **BF-1.48**

p. 83: "the simulation of the river's recovery trajectory depends on an accurate representation of the processes controlling sediment-water interactions of PCBs and dynamics of solids in the system.". While the HUDTOX calibration and diagnostic analysis demonstrates to varying degrees the ability of the model to characterize the Hudson River system, knowledge about "PCB partitioning (particularly in sediments), non-flow dependent sediment-water PCB fluxes (both dissolved and particulate), and sediment dechlorination and biodegradation" is incomplete. Therefore, what are the uncertainties in the output given the assumptions surrounding these processes and constraints built into the model. **BF-1.49**

8 Mass Balance Model Forecast Simulations

p. 87, Fig. 8.4: The initial condition for the TIP surficial sediment PCB concentration is about 15 ppm. Does this represent an average concentration as stated in the caption? Is this consistent with a median total PCB concentration for the cohesive sediment of 32.5 ppm reported earlier? **BF-1.50**

p. 88 (Section 8.3.2) and the accompanying figure (Figure 8-7): The text indicates that a simulated 100-year flood event only increased flux across the TID by about 59 kg, while the figure appears to indicate an increase of over 150 kg higher PCB flux. **BF-1.51**

The DOSM estimates a loss of 49-65 kg PCBs from resuspended cohesive sediments during a 100-year event (p. 31). This estimate matches closely with the predicted 59 (150?) kg PCB flux over the TID from the HUDTOX forecasting, but it doesn't account for non-cohesive sediments or redeposition of resuspended sediments. The HUDTOX and DOSM estimates are briefly discussed in terms of the differences in the approaches of the two models. A more thorough explanation should be provided. For example, is the magnitude of PCBs lost from non-cohesive sediments similar in scale to that redeposited? **BF-1.52**

The 100 year event is simulated as occurring at the beginning of the simulation period. How different would the simulation be if the 100 year peak followed a 15 year high flow event such as in January 1998 where PCB loads upstream of Rogers Island were higher than model inputs or preceded a smaller but measurable high flow event? **BF-1.53**

Specific Comments on Volumes 3 & 4

1 Introduction

p. 1 Para 3: "In August 1995, the Upper Hudson was re-opened to fishing for striped bass in the Lower Hudson River. This ban remains in effect." This sentence should be revised to read "In August 1995, the Upper Hudson was re-opened to fishing but the no consumption advisory remains in effect. The fish consumption advisory for the Hudson River was modified as of June 18, 1999. The new advisory from Federal Dam at Troy to Catskill is to eat no more than one meal per month of alewife, blueback herring, rock bass and yellow perch. The one meal per week advisory for American shad and the eat none for all other species remains in effect for this stretch of the river. Between Dobbs Ferry and Greystone a stricter advisory for American eel was also issued which now recommends no consumption (NYSDOH 1999). The commercial fishing ban for striped bass in the Lower Hudson River is being reconsidered. **BF-1.54**

3 Modeling Approach: Fish Body Burdens

p. 19, Para 4: It is stated that the main "external forcing functions" are water and sediment concentrations. Trophic structure is also a very important factor. Two different fish populations in similar water and sediment concentrations with different food webs would have different accumulation. Rasmussen et al. (1990), in a study of Ontario lakes, showed that much of the enormous between-lake variability in PCB levels in fish flesh result from differences in the length of pelagic food chains. **BF-1.55**

p. 20 (Equation 3-1): In the formula, the water column exposure component is represented by suspended solids PCB concentrations; however, the Bw parameter is for "water column **BF-1.56** concentration", not suspended solids. Since focw is apparently not available, all equation parameters should be expressed on a whole-water basis.

p. 21: The text points out that the models assume slow changes in water and surface sediments relative to uptake and depuration. Some comment needs to be made on the relative rate of seasonal change in environmental concentrations of PCBs versus rates of uptake/depuration in fish. PCBs may be readily assimilated in fish due to the hydrophobicity of the chemical and the abundance of organic carbon available in the fish; however, depuration tends to be very slow since PCBs cannot be quickly metabolized. Therefore, depending on the importance of the seasonality of PCB concentrations, it is possible that fish may reflect a historical PCB exposure that is not consistent with current data. This is particularly true for water column exposures, since PCB concentrations in water could conceivably change over the time scale of weeks to months. **BF-1.57**

p. 23, Model Structure: "Since feeding occurs primarily in the warmer months, the probabilistic model had been developed using summer averages. The fate and transport model results are averaged to provide summer water and annual sediment concentrations." While exposure may be greatest during the summer months, this does not preclude exposure throughout the year. Moreover, the monthly averaged water concentrations do not account for potentially higher PCBs in the nearshore fish habitats. These issues should be discussed here and in Sections 3.4.3 and 3.4.4, Spatial and Temporal Scales. **BF-1.58**

p. 23, Bottom: The description of the Monte Carlo modeling highlights the problem of discriminating between (a) variability in parameters estimates due to natural variation and (b) uncertainty associated with our lack of knowledge of key processes. Both of these get lumped together in the distributions. The distribution-based approach only adds value if the "uncertainty" component is small relative to the "variability" component. There are two aspects to be concerned about. First, from the perspective of the reality of the final output, using distributions rather than fixed values is helpful only if the distributions themselves are real. There are some data, e.g., the lipid concentrations, that represent both the true variability among individuals of a species (for a location and year), as well as the lab-generated uncertainty in the measurements. In this case, most likely the uncertainty is small compared to the variability, assuming the geographic and annual differences can be accounted for. However, other distributions can be created as best guesses or from literature values which may not be appropriate for the Hudson River. Second, the use of probability distributions also raises the question of why a distribution is more important than a fixed value. For example, using "maximum" values for at least some key variables (and for variables for which distributions are not well-established) might be used to generate a model that would predict a worst-case future. **BF-1.59**

p. 25: While Section 3.4.5.3 indicates that any species less than 10 cm may be consumed by a piscivorous fish, the report suggests elsewhere that only spottail shiners and pumpkinseeds are used in the model as forage fish. **BF-1.60**

p. 26, Section 3.4.5.4, Para. 2: According to Fig. 3-2, invertebrates comprise 65% of the adult yellow perch diet rather than 85%, as stated in the text. **BF-1.61**

p. 27, Top: The percent dietary component for individual fish species is inconsistent with the values presented in Fig. 3-2. For example, Fig. 3-2 indicates that yellow perch diet consists of 65% benthos and 35% epiphytes compared to the 15% forage fish, 20% benthic invertebrates and 65% water column invertebrates given in the text. For largemouth bass, the values in the figure are 85% fish, 10% benthos and 5 % epiphytes while the text has a greater contribution from fish and benthic invertebrates and no epiphytes in their diet. Which values were used? **BF-1.62**

p. 27, Section 3.4.5.5: The BSAF formula assumes a diet solely of benthic invertebrates, but Fig. 3-2 includes a 10% epiphyte component. **BF-1.6**

p. 27: Why are brown bullheads compared to both sediment and prey, for BAF/BSAF. This leads to two separate bioaccumulation values, and it is not clear which was used in the model. **BF-1.64**

p 28: Mistake in equation ("=" should be "+") **BF-1.65**

p. 31: Growth rate constants are temperature dependent but are species independent. Knowledge of species-specific growth rates should be incorporated into the model. **BF-1.66**

4 Bivariate BAF Analysis of Fish Body Burdens

p. 34: The trophic level of 5 fish species are described. A description for white perch should have been included. **BF-1.67**

p. 43, Section 4.1.2: The first sentence is misleading. Water column concentrations are predictive of fish PCB burdens only for those species which have exposure pathways dominated by overlying water. Brown bullhead concentrations would not be well predicted by water column concentrations. **BF-1.68**

p. 46, "bias correction factor": As pointed out, this "adjustment factor" is needed to be consistent with mid-channel estimates from USGS. However, the nearshore measurements may be more appropriate for evaluating exposure concentrations for fish and their food webs, which probably rely to a much greater extent on the nearshore habitat than the channel habitat. Data from mid-channel locations should be adjusted to reflect nearshore concentrations. **BF-1.69**

p. 48, Section 4.14: Fish sampling locations were subdivided into four function groupings representing RM 188 - RM 193, RM 168 - RM 176, RM 155 - RM 157, and RM 142 - RM 152. The number of functional groups should be increased to include major historical fish sampling locations in the lower freshwater Hudson, including Catskill and Poughkeepsie. **BF-1.70**

p. 50 Para 1- 3: The presented regression results compare [fish] to [water], and [fish] to [sediment] and [water] combined, but not [sediment] on its own. Why? Would it have been better to treat the analysis as a stepwise regression, to show the improvement of fit resulting from incorporation of water and sediment as explanatory variables. Also, since a regression approach was used, there is an inherent problem of intercorrelation (multicollinearity) of variables. For example, the Pearson correlation coefficient between average water column and sediment concentrations used in the Bivariate BAF analysis was 0.56. If intercorrelation is high, conclusions regarding the significance of the correlated "independent" variables are likely to be spurious. This is particularly important for evaluating the "relative importance of independent variables" as is discussed in Section 4.3.3. Interpretation of the "normalized beta coefficients" in Table 4-13 would seem to be very much complicated by this problem. It would also be interesting to see what effect the incorporation of an interaction term (between water and sediment) would have on the model. **BF-1.71**

p. 50: Table 4-10 should read 4-11 and Table 4-11 should read Table 4-12. This is important because if one refers to the tables as presently labelled, the text (i.e., R^2 values) does not match the tabulations. **BF-1.72**

p. 50 Para 3: The bivariate approach does not increase the R^2 for all species. According to Table 4-10, the R^2 for white perch and yellow perch exhibit slight decreases when sediment is added into the regression equation.

Tables 4-11 and 4-12, For Bivariate BAF analysis, the R-squared is only 80% when log-log transformations are performed - otherwise the R-squared is 67 - 76% (and goldfish value is much **BF-1.73** lower). Caution must be used when stating that the model "explains about 80% of the observed variability", since the log-log transformation could not have been predicted using the theory on bioaccumulation presented at the beginning of the document; this affects the predictive capability of the model. The R-squared could be increased further by simply adding additional parameters (e.g., suspended solids PCB concentrations, age, weight, sex, etc.), but this does not improve the model unless there is a theoretical foundation for the change in model structure.

p. 51: An estimate for the dissolved fraction total water concentration (presumably averaged May-Sept) was determined to be "about 50%" for Tri+ PCBs in the Upper Hudson based on analysis of three-phase partitioning in the DEIR for representative congeners. This appears to be inconsistent with Book 1, p. E-7 DEIR findings that water-column PCB transport occurs largely in the dissolved phase, and the dissolved phase represents 80% of the water column PCB inventory in the Upper Hudson during most of the year (10-11 months). **BF-1.74**

5 Calibration of Probabilistic Bioaccumulation Food Chain Model

p. 55: Overview of data used to derive BAFs. The analytical methods used to determine total PCBs and lipid content may not be directly comparable between studies. It appears, though not explicitly stated, that all total PCB and lipid values are treated as equivalent. **BF-1.75**

p. 56: "For the NYSDEC samples,..." The Aroclors analyzed should be consistent with the previous chapter, which was more accurate. **BF-1.76**

p. 57: The collection depth for the sediment samples should be stated, as well as the diameter of the sampling area for the samples per location. **BF-1.77**

p. 58, Section 5.2.3 Para 1: The text and Fig. 5-2 do not match. The BSAF for river mile (RM) 189 should read "3" not "6". The BSAF for RMs 100 and 189.5 should be "1.5" not "3". BSAFs for other RMs were less than or equal to 1. **BF-1.78**

p. 58, Section 5.2.3 Para 2: The BSAF for chironomids was about "2" not "4". "Gastropods" should be inserted for "Isopods" with a BSAF around"2" not "3". Remaining RMs have BSAFs of less than 2. **BF-1.79**

p. 58-59, Section 5.2.3: No explanation is provided for the trend of changing BSAF for invertebrates with location on the Hudson River. On p. 57 it is indicated that the sediment data were evaluated to determine "which river miles display significant heterogeneity and variability in concentrations." Were separate BSAF values for invertebrates used in model calculations for different reaches of the river? If so, this seems to be an arbitrary process that would improve model fit, but would not necessarily improve predictive ability of the model for future scenarios. **BF-1.80**

p. 60: The Novak (1988) citation is missing from the reference list. In this study, chironomid tissue had a PCB congener differing from the water column. Were the chironomid species identified? What feeding guild did they belong to? **BF-1.81**

p. 61: The spottail shiner collected were young-of-year—is it reasonable to assume the equal benthic/water column invertebrate diet in adult spottail would apply? Are epibenthic organisms considered to be benthic organisms for this analysis? **BF-1.8**

p. 62: Fig. 5-5 shows forage fish total PCBs at concentrations approaching 300 ug/g lipid, not wet weight. **BF-1.8**

p. 62-63, Section 5.4.3, Para 1: "The data show that the greatest variability in fish concentrations exists within the TIP..." This is not the case if the coefficient of variation is used as the measure of relative variability. The greatest variability, excluding the reference area, is in the samples collected between Hudson Falls and Rogers Island. The stations with highest variability are mostly the stations where multiple species are included in the forage fish sample (River Miles 197, 194, 189, 89, and 59). **BF-1.84**

p. 62, Bottom: "... and closest to the source of PCBs..." The sources of PCBs to fish are the water and sediment. 'closest to the Thompson Island Pool' would be more accurate, since fish between the Hudson Falls and Rogers Island showed much lower and less variable concentrations. **BF-1.85**

p. 63, Para 1: "Data show that spottail shiners consume...equal amounts of benthic and water column invertebrates." Was this derived from Appendix A, Table A-1? If so, it appears that their diet was dominated more by water column than benthic invertebrates as is suggested in Appendix A Section 1.7.1(p. A-16). **BF-1.86**

p. 63 Para 3: The oversimplified food chain used in the model creates two problems. First, there is uncertainty arising from "averaging" the dietary characteristics of each organism type. Second, the truncation of certain size classes of fish biases the results. In Section 5.5, the data for largemouth bass are excluded because they do not represent the "correct" size. This problem would be avoided if the model incorporated different age classes of fish. **BF-1.87**

p. 63: Individual largemouth bass PCB concentrations were lipid normalized while for pumpkinseed average lipid normalized PCB concentrations were used. The uncertainty in this approach should be discussed. **BF-1.88**

p. 64, Para 3: The dates 1992 and 1993 should be substituted in the phrase "...model to capture 1991 and 1992 observed concentrations for largemouth bass". **BF-1.89**

The last sentence in this paragraph seems to contradict the statement in Para 4. on p. 60 about biomagnification of PCBs in the aquatic food chain.

p. 64, Section 5.7: Section 4.1.1.3 (p. 34-35) states that PCB fish body burdens may vary with bioenergetic factors such as seasonal growth and spawning cycles. It was also noted that sex, age, weight, and length can affect PCB body burdens. These were not addressed in the BAF approach but should have been considered in the probabilistic and mechanistic models. The statement in Section 4.3.2. (p. 53 Para 1) highlights the importance of these factors and presumes that they will be included in the probabilistic and Gobas models. While the historic database may be incomplete with regard to these parameters, the models should be tested to determine if they can replicate available age, sex and weight/length data. The ability of the models to predict seasonal differences in PCB tissue concentrations can also be tested by splitting rather than lumping seasonal data. For example, May to September sampling events can be divided into spring and late summer/early fall collections rather than lumping these events together. **BF-1.90**

p. 64, Para 4: "on a lipid-normalized basis, model predictions and observed data show excellent agreement. This agreement is less robust when evaluated on a wet weight basis." This is an overstatement of the concordance of the observed to predicted results shown in Fig. 5-8 through 5-10. **BF-1.91**

6 FISHPATH and FISHRAND: Time-Varying Mechanistic Models Based on a Gobas Approach

p. 67: NOAA Phase II and NOAA 1995 fish data apparently were also used in development and validation of the models. In addition, there is no discussion of the differences in the quantification methods for total PCBs and lipid content, which make the data not directly comparable. **BF-1.92**

p. 68: Monthly average temperatures were required by FISHRAND, since growth rate is a temperature-dependent parameter. Temperature is also important to the partitioning of PCBs. An assumption of the FISHPATH and FISHRAND models was that fish spent most of their time (on average 75%) in areas with cohesive sediments and the nearshore areas were weighted more heavily in the TIP. However, the monthly averaged temperatures apparently were based on mid-channel measurements. To account for the potentially higher temperature in shallow nearshore areas, sensitivity analysis for the FISHRAND model was conducted by adjusting the temperature distributions upward by 20%. What is the basis for the 20% factor? Because the FISHRAND model uses the output from HUDTOX, simply assessing the sensitivity of the bioaccumulation model to temperature effects fails to consider the linkage between these models and does not fully address the potential temperature difference. **BF-1.93**

p. 70, Section 6.1.2.1: Lipid data were combined across years and locations to create lipid distributions for each species. It may be more appropriate to develop lipid concentration distributions per species per location. **BF-1.94**

p. 72 Para 1: Table 6-2 presents the summary of the relative percent difference between modeled and observed lipid-normalized and wet weight PCBs at four river mile locations for five fish species. There is inadequate discussion of the results. The statement "In general, the model is better at capturing lipid-normalized concentrations versus wet weight concentrations" minimizes the high bias associated with the wet weight results. Moreover, at the Science and Technical Committee meeting earlier this month, another set of tables indicated this bias was higher and more systematic than documented in the BMR. **BF-1.95**

p. 72 Para 2: "The model shows that concentrations tend to increase in the late summer, when feeding is maximized." Is there a seasonal difference in fish feeding, i.e., feed more in the late summer? **BF-1.96**

7 Initial Bioaccumulation Model Predictions

p. 73-76: Predicted fish body burdens are given under zero and constant upstream boundary conditions. Concentrations are compared to selected human health target levels such as the FDA Action Level and the Great Lakes Uniform Sportfish Advisory Task Force. Ecological target levels such as Newell et al. (1987) and IJC (1989) of 0.11 mg/kg and 0.1 mg/kg, respectively, should also be considered. **BF-1.97**

8 Discussion of Uncertainty

p. 78, Bottom: (the rationale for not including incorporation of different feeding strategies) suggests that identification of probability distributions for model parameters negates the need to revise model structure. Adding distributions is only useful if basic model processes are well-described and does not improve model predictions. This tends to blur the distinction between variability and uncertainty. **BF-1.98**

p. 79-80, Section 8.2: FISHPATH and FISHRAND utilize (a) an equilibrium partitioning approach rather than including a biomagnification mechanism via benthic invertebrate feeding preferences, and (b) a growth dilution approach rather than an age-class model for each year of the fish's life. They do not contain a pharmacokinetic model to incorporate metabolism. While these issues are discussed in Section 8.1.2.2, the document would benefit from a discussion of the uncertainty of excluding current revisions to the Gobas (1993). There is no reference to Tables 8-2 through Table 8-4 in the text. **BF-1.99**

p. 80, Section 8.2.1: It appears that the discussion of Table 8-1 actually combines results presented in Tables 8-1 through 8-4. This paragraph should be rewritten for clarity in terms of the tables discussed and the table contents, i.e., the correlations are between lipid normalized PCBs and lipid content in various media, Kow, sediment organic carbon and % diet. **BF-1.10**

9 Summary and Conclusions

p. 84: Appropriate target levels ("environmentally protective") should include values that are protective of aquatic, avian and terrestrial receptors as well as human health. **BF-1.101**

p. 86: The report states that for the Bivariate BAF model, "much of the remaining unexplained variability is due to uncertainty in historic water column concentrations"; this conclusion is not supported in the report. For example, much of this variability could be due to errors in the HUDTOX model, lack of representativeness of sediment and water column measurement to fish habitat use, etc. The remaining variability could also be "white noise"; we have no assurance that improving the water column concentrations will eliminate most of the remaining uncertainty. **BF-1.102**

Please contact me at (212) 637-3259 or Jay Field at (206) 526-6404 should you have any questions regarding these comments.

Sincerely,

Lisa Rosman

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United States Environmental Protection Agency
Emergency and Remedial Response Division
Sediment Projects/Caribbean Team
290 Broadway
New York, New York 10007

Re: Hudson River Reassessment PCBs Reassessment RI/FS
Site No.: 5-46-031

Dear Mr. Tomchuk:

Following are NYSDEC comments on the Phase 2 Report-Review Copy, Further Site Characterization and Analysis, Volume 2D-Baseline Modeling Report (Books 1 through 4), Hudson River PCBs Reassessment RI/FS prepared by Limno-Tech, Inc., Menzie-Cura & Associates, Inc. and Tetra Tech, Inc. on behalf of EPA. The Baseline Modeling Report details the construction and results of the baseline (no action) modeling work. The modeling efforts include a hydrodynamic model and a PCB fate and transport model of the upper Hudson River, a scour model of the Thompson Island Pool (TIP), and four models used to predict fish body burdens.

1. Page ES-4 Book 1, The 21-year model forecast (1997 to 2019) was run using the same flow, solids loadings, and other external forcing functions for the 1977 to 1997 time frame. The solids loadings values for this time period should be examined to determine if they are representative and appropriate for use in the models. The period of the late 1970s to early 1980s represent a period of time shortly after the Fort Edward Dam removal and during some in-river dredging activities. Applying the solids loadings measurements from this time period could misrepresent solids loading conditions occurring in the 1990s and the future since the Dam removal and dredging activities would have influenced solids loading. We recommend that EPA review the United States Geological Survey (USGS) data which dates back to the late '70's since this data shows the higher historic suspended solids loadings from shortly after the dam was removed compared to that which is observed in the 90's. **BS-1.1**

2. Page ES-5 Book 1, Second finding and Section 8; The referenced passages discuss the reactivation of deeply buried contaminated sediments following a major flood event. Specifically, the PCB flux from the 100 year flood is estimated to be 60 kilograms which are resuspended and transported from the Thompson Island Pool. Have the models been used to estimate the PCB flux below the Thompson Island Pool to Waterford and ultimately the lower river resulting from a 100-year flood? **BS-1.2**

3. Page ES-6 Book 1, Fifth Finding; The model determined that the Stillwater Pool PCB fish **BS-1.3**

concentrations would lag behind the predicted recovery levels of the Thompson Island Pool. This seems to be incorrect in comparison to what other source conditions indicate about the behavior of an established gradient in a riverine system. Since both areas of the river are undergoing some depletion of their PCB reservoirs, it is difficult to envision that the Thompson Island Pool will leapfrog ahead of the Stillwater Pool in that regard. Furthermore, it should be noted that yellow perch at Stillwater reached below 2 ppm PCB in 1997.

4. Page 19 Book 1, second paragraph It is not clear why maximum stresses are observed in the flood plain, when the velocities are lower as shown in Figure 3-3? Lower stresses would be expected. Please check this and provide some explanation of this in the report if it is correct. **BS-1.4**

5. Section 4, Book 1 The Depth of Scour Model for Thompson Island Pool (TIP) was applied to the High Resolution Core results. It is unclear how erodibility of the TIP can be applied to five cores which are only descriptive of a very small portion of conditions in the TIP. These areas by definition are not conducive to erosion and may only represent a small percentage of the surface of this reach. We assume that this parameter is highly variable and uncertain in the model and also recommend that this be indicated in the text of the report and/or the responsiveness summary. **BS-1.5**

6. Page 65, Book 1, third paragraph What is the "Future work planned to investigate the significance of these sources [sources above Rogers Island] and their potential implications for forecast simulations with the HUDTOX model."? **BS-1.6**

7. Page 79 Book 1; Figure 7-29 Book 2; Surficial sediments are defined as 0-4 centimeters (cm) in the fate and transport model. The PCB concentrations for this depth of sediment in the fate and transport model is then used as the sediment concentration available to the biota in three of the biological models. Thus, the use of the 0-4 cm depth as surface sediments may be interpreted to define the depth at which PCBs are considered to be isolated from the river. However, the depth of biological activity in sediments has been studied in other systems relevant to the upper Hudson River. These studies show that while most taxa are restricted to the upper few centimeters, there are some exceptions which are notable because of their size and numbers, which could influence the amount of bioturbation they can cause and their role in the food chain. Hexagenia mayflies typically burrow down to 8 cm (Charbonneau and Hare 1998). Chironomus midges may burrow down to 8-40 cm (in the literature review of Ford 1962) and tubificidae worms may penetrate to 200 cm (Ford 1962). Naididae worms may penetrate as deep as 20-70 cm in coarser sediments Learner et al (1978). The macroinvertebrate survey conducted in September of 1997 by Exponent (1998) indicated that all of these taxa are common in the upper Hudson River, as does the 1986 survey by Simpson et al (1986) of the freshwater portion of the lower river. **BS-1.7**

What is the reasoning for the 0-4 cm definition, and is there any actual data to document that 4 cm is the maximum depth of biological penetration and bioturbation in the upper Hudson River?

A definitive way to demonstrate the depth of bioturbation is to collect field data designed to measure the depth of penetration , either by coring or photographic techniques. Lacking these data, and since there is documentation that several of the common taxa of macroinvertebrates typically penetrate and extensively mix the sediment down to 8 cm, we suggest the model be run using the same high mixing rate down to at least 8 cm to test the model's sensitivity to this parameter. The additional work mentioned on page 80 of Book 1 should be described.

8. Page 76 to 77 Book 1; Figure 7-13 to 7-15 in Book 2; page 31 Book 3; Figure 7-9 Book 4: The report discusses the seasonality of the PCB concentrations in the water column and the fluxes out of the **BS-1.8**

sediments. In the response to the GE/QEA reports (page 30, Figure 2-4), EPA describes this seasonality in the water column concentrations as " Concentration peaks after the spring high flows, then declines across the summer months." The water concentration in June may be twice that in September (Figure 2-4 response to GE/QEA reports).

This seasonal variation could raise a concern about the timing of various data collections and their interpretation. Figure 5.6 Book 4 compares the ratio of PCB concentrations in bass to that of pumpkinseed, yet largemouth bass are collected in June while pumpkinseed are collected in September. Is this comparison , which is used to derive transfer coefficients between prey and predator fish, valid if two species were collected under different PCB concentration regimes? This suggests that the differences in PCB concentrations between species may not be due to trophic position, but rather other aspects such as time of collection or life style (i.e. are exposures different seasonally, channel vs. shoreline, depth, sex and reproductive status, age)? The model should document more conclusively that these interspecies differences are trophic position dependent (i.e. do all top level predators have similar PCB level, or do PCB concentrations change dramatically when a species changes trophic status with age?). Does the FISHRAND model, which uses monthly average water column PCB concentrations (page 31 Book 3, Figures 7-8 and 7-9 Book 4), suggest a seasonal variation in the fish PCB concentrations? This should be discussed, as it bears on the validity of the Figure 5.6 comparison, and may suggest potential management /sampling issues for the future.

9. Page 40, Page 81 Book 1, and Figure 7-29 Book 2: These sections discuss the mechanisms which transfer PCBs into the water column. The terminology is not consistent. Clarify that the non-flow-sediment resuspension (text on page 40) or the combination of all PCB particulate resuspension are the same components in the report (text on page 81 and Figure 7-29). **BS-1.9**

10. Figures 3-2, 3-3, and 5-4 Book 2; Figures 3-2 and 3-3 show the area of the river for which flow is modeled and the corresponding water velocity results (RMA-2V model). These figures show that the flood plain is included in these modeling efforts. Figure 5-4 shows the area of the river modeled for PCB fate (HUDTOX model) , which does not include all of the area in Figures 3-2 and 3-3. The reason and implications for this difference should be discussed. **BS-1.10**

11. Figures 7-14 to 7-16, 7-23 Book 2, the figures are very cluttered and therefore difficult to read. The figures are presented to show how well the model simulates the data. The figures need to be revised or the figure's quality needs to be improved. **BS-1.11**

12. Page 1, Book 3 The description of the fishing bans and advisories is missing some text. Please insert the missing text. **BS-1.12**

13. Page 8, Book 3; Ankley et al (1992) indicated that ingestion of food or sediment produced higher PCB concentration in free roaming fish than in fish confined in aquaria. These data can also be interpreted to indicate other mechanisms. For example, reduced metabolism in confined fish may cause the difference in field versus laboratory values, and that ingestion may not play as major a role as is indicated. **BS-1.13**

14. Page 13, Book 3, top of page The species and the 'Characteristics' list at the top of the page needs some modification. Pumpkinseed are readily eaten by anglers and brown bullhead are commonly rather than occasionally eaten. The continual characterization of brown bullhead as a sediment dweller is misleading (also see Page 27). It is not exclusively a sediment inhabitant. White perch are also eaten but they are not as highly favored as other species. Information on eating preferences can be found in the **BS-1.14**

book “Freshwater Fishes of New York State” by Robert Werner, 1980.

15. Page 22, Book 3 Under the description of the model structure there is an either-or condition introduced regarding the type ‘a’ and type ‘b’ invertebrates. It may not be that simple as one is water influenced and the other sediment. In the more productive littoral zones, it may be nearly impossible, if not impractical, to separate the two exposure regimes. **BS-1.15**

16. Page 24, Book 3 top of page The supposition about the summer foraging area may be unfounded since most of the adult fish are collected in the spring. The modifying influence may be that there is some year-to-year overlap in events whereby sampling is not truly independent between years. In that same paragraph regarding the unlocalized nature of the white perch, this observation is perhaps over stated. In evaluating fish data over the years, almost all species can exhibit the influence of localized conditions. The variability may be such that expanded sample sizes are necessary, but it is still possible to sort out a local condition. It may be better to simply state that the white perch is mobile over large stretches of the river. **BS-1.16**

17. Page 24, Book 3 In Section 3.4.3, third paragraph, the notation of rivermile 154 being above the Federal Dam is incorrect. That rivermile is below the Federal Dam. **BS-1.17**

18. Page 31, Book 3 In Section 3.5.3, to characterize white perch as ranging throughout the river overstates their distribution. Based upon DEC sampling work, white perch are only found in any numbers about as far upstream as Lock 1 and are not sampled at Stillwater or in the TIP. Below the Federal Dam, where it is tidal, they can be in both nearshore, shallow zones and main channel areas. **BS-1.18**

19. Page 34, Book 3 The characterization of largemouth bass versus yellow perch needs to be modified because both will exhibit directed movements for spawning. The use of goldfish as a trend species is problematic since the DEC database is limited for this species. Early in the establishment of cyprinids as a useful monitoring tool, goldfish were much more prevalent. As water quality improved and clarity increased, goldfish disappeared in many areas. Carp and goldfish tended to be treated as one entity for purposes of monitoring PCBs since they can hybridize and if goldfish were not available carp usually were. Of the two, carp were definitely sampled more often and probably in the last 15 years there are no goldfish in the collections. **BS-1.19**

20. Page 35 Book 3 In Section 4.1.1.3., the point about expelling PCBs with eggs as a possible explanation for sex differences should be removed or modified because the theory of PCB depuration through expulsion of eggs is speculative at this point and requires further research. **BS-1.20**

21. Page 46, Book 3 The last sentence should be checked for consistency with the Fate and Transport model conclusions. **BS-1.21**

22. Page 48, Book 3 The collection location shifted from above the Stillwater Dam to the Coveville area in about 1994. **BS-1.22**

23. Page 52, Book 3 In the third paragraph there may have been some mixing of different age classes of pumpkinseed which may confuse some of the interpretation of results. **BS-1.23**

24. Page 55 Book 3: There appears to be a typo in section 5.1.1. The sentence “Benthic invertebrates were identified to the taxonomic group level for PCB analysis” does not make sense. **BS-1.24**

25. Page 57 and Page 58 Book 3; Figure 5-2. The Benthic Invertebrate; Sediment Accumulation Factor (BSAF) varies by river mile, with the highest values being in the Thompson Island Pool. Since the Thompson Island Pool has the highest sediment PCB concentrations, this suggests that the mechanism of exposure to the invertebrates is different in the Thompson Island Pool. The report should discuss why the BASF would be expected to change as a function of location or level of PCB contamination. **BS-1.25**

26. Page 64, Book 3 The document observes that the peaks in fish PCB concentrations in the early 1990's were not captured well. Only the water concentration showed such dramatic increases in this time frame. This suggests that the model does not represent uptake from the water column adequately. Analysis should be conducted to assess the impact of either direct uptake or accumulation through the water column food chain. **BS-1.26**

27. Page 70, Book 3 The discussion about lipid content implies this biological parameter should be constant. However, large shifts are observed between locations, species and years. The reason why lipid content is so highly variable is not understood. To address this variability, the report uses a single distribution of lipid content for each species, derived from the entire database. However, this variability will still be a source of uncertainty in the modeling which should be acknowledged in the report. **BS-1.27**

28. Page 72, Book 3 The rivermile 152 and 154 locations are confusing as presented. Both should be below the Federal Dam and both should be below the confluence with the Mohawk. If there is a mistake in the database in terms of location descriptions and coordinates, it needs to be corrected. **BS-1.28**

29. Page 73, Book 3, last line:. The text should be more explicit as to what population is being protected. **BS-1.29**

30. Chapter 8, Book 3 Given the uncertainties, would a simple regression model of the existing fish data provide another means to evaluate the fish data for future predictions? **BS-1.30**

31. Chapter 9, Book 3 In the summary and conclusions of the food web models there is no reference to goldfish and carp. **BS-1.31**

32. Page 86, Book 3 In the second bullet there is confusion over data and locations. Was this part of the model intended to capture something about the influence of the Mohawk River? **BS-1.32**

33. Page 86, Book 3 The second bullet should be checked for a typo. **BS-1.33**

34. On page 87, Book 3 The fifth bullet should be revised. Yellow perch reached below 2 ppm in 1997 at Stillwater. **BS-1.34**

35. Page 87 Book 3; The Principal Report Findings present estimates for wet weight concentrations for PCBs in fish by location and the year they are predicted to reach this level. When presenting these estimates, EPA should discuss the range of uncertainty for each of the estimates that are made by the models. **BS-1.35**

36. The EPA presentations made at the Joint Liaison Group and the Scientific and Technical Committee Meetings for the modeling results noted that additional work will be performed for the models. The scope of the additional work should be provided to the model reviewers as soon as this information is available. This should facilitate a more timely response to any additional modeling work **BS-1.36**

products.

37. The modeling work on specific congeners (BZ#28, BZ#52, BZ#101, BZ#138) should be completed and the conclusions reported. The available PCB congener fish data show a change in composition with distance from the source area. The PCB congener modeling work should be able to demonstrate these changes if the model is going to be used for predicting fish PCB congener composition into the future. **BS-1.37**

38. The responsiveness summary for the Baseline Modeling Report should include a comparison of the General Electric and EPA models at least for the key assumptions and findings. **BS-1.3**

If you have any questions please contact me at (518) 457-5637.

Sincerely,

William T. Ports

William T. Ports P.E.
Bureau of Central Remedial Action
Division of Environmental Remediation

cc: John Davis, NYSDOL
Robert Montione, NYSDOH
Jay Fields, NOAA
Lisa Rossman, NOAA
Anne Secord, USF&WD

References cited:

Charbonneau, Patrick, and Landis Hare. 1998, Burrowing Behavior and Biogenic Structures of Mud Dwelling Insects . J. N. Am. Bethol. Soc. 17(2):239-249

Exponent, 1998, Macroinvertebrate Communities and Diets of Selected Fish Species in the Upper Hudson River, Prepared for General Electric Company, Albany NY.

Ford, John B. 1962, The Vertical Distribution of Larval Chironomidae (Dipt.) In the Mud of a Stream. Hydrobiologica 19 (3)

Learner, M.A. , G. Lochhead, and B.D. Hughes. 1978. A Review of the Biology of British Naididae (Oligochaeta) with Emphasis of the Lotic Environment. Freshwater Biology 8, 357-375.

Simpson, K. , R. Bode, M. Novak, J. Fagnani, D. Denicola. 1986. The Benthic Macroinvertebrates of the Hudson River From Troy to Albany, New York. Final Report to Hudson River Foundation.

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SARATOGA COUNTY
ENVIRONMENTAL MANAGEMENT COUNCIL

PETER BALET
CHAIRMAN

GEORGE HODGSON
DIRECTOR

June 11, 1999

Douglas Tomchuk
USEPA – Region 2
290 Broadway – 19th Floor
New York, New York 10007-1866

RE: Baseline Modeling Report Comments

Dear Doug:

Enclosed you will find the Saratoga County Environmental Management Council's (SCEMC'S) comments on the Baseline Modeling Report, Volume 2D, Books 1 and 2, Fate and Transport Models. In the enclosed comments, the SCEMC recommends a procedure which the SCEMC believes is the best approach in achieving a model which is the best possible, and restore public confidence in EPA's study. If the EPA disagrees with the EMC's recommendations, the EMC will re-emphasize its previously stated position, recommending that a side-by-side peer review of EPA's model and GE's model is necessary. **BL-1A**

Both models are impressive in their detail and sophistication but there are significant differences between them. Reconciliation of the EPA and GE models will allow EPA to use the best of both models in its critical prediction of future PCB behavior in the Hudson River. The SCEMC is sure EPA agrees the decision as to whether remedial action is necessary is so important to the Hudson River ecosystem and to the affected public that the best decision possible is desired. It is for this reason the SCEMC urges EPA to deviate from its established peer review procedure.

No comments are being made at this time on the future projections as the SCEMC believes it would be premature to comment in this area before the peer review process is completed.

Sincerely,

David D Adams
ALP

David D. Adams
Member-at-Large

Enc.
cc: William McCabe, USEPA, Region 2
SCEMC Members
Darryl Decker, Chairman, Government Liaison Committee, CIP
The Honorable John Sweeney

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SARATOGA COUNTY
ENVIRONMENTAL MANAGEMENT COUNCIL

PETER BALET
CHAIRMAN

GEORGE HODGSON
DIRECTOR

COMMENTS ON THE PHASE 2 BASELINE MODELING REPORT, VOL. 2D, BOOKS 1 AND 2, FATE AND TRANSPORT MODELS

Prepared by: David D. Adams, Member, Saratoga County EMC and Government Liaison Committee

June 11, 1999

1. General

Both the EPA model report and the GE model report have been reviewed. This review indicates that both models are of a high degree of technical sophistication. While the two models, in some cases, produce similar results (e.g. behavior of the Thompson Island Pool and the effects of a 100 year flood) there are other areas of significant differences. These include methods for determining values of parameters needed as inputs to the model, methods for specifying missing data needed to satisfy time steps in the model, parameters used to calibrate the models as well as major differences in the modeling of sediment transport. The last difference cited is especially critical as both the EPA and GE reports emphasize the importance of the sediment in determining PCB fate and transport. Also, while it is premature to comment on future projections until peer review is complete, the major differences reported between the EPA model and GE model projections of future PCB levels in fish at Stillwater emphasize the need to reconcile the models and achieve a model which represents the most accurate method of predicting the future behavior of PCB's in the Hudson River. This can best be accomplished by first having the technical people hired by EPA and GE meet to discuss the models and resolve their differences to the extent possible. EPA's contractor could then present the revised model to EPA for EPA's concurrence. After EPA's agreement, the revised model and any unresolved differences remaining unresolved differences should be subjected to peer review and the model subsequently finalized. It is crucial that the best predictions possible be made regarding the future behavior of the PCB's in the River as it is these predictions that will be incorporated into the final health and ecological risk assessments to determine whether or not remedial action is necessary.

It is the SCEMC's belief that following the procedure outlined above, would offer the most feasible path to achieve the desired result of using the best model possible. The consequences of EPA's final decision on the Hudson River PCB Reassessment are so significant they demand EPA's decisions be made using the best information possible. The SCEMC hopes EPA will agree to the above procedure which should r~~re public confidence, which is now lacking, in the process EPA is following to reach its final Reassessment decision. If the differences between the EPA and GE model predictions at Stillwater cannot be resolved, it suggests the possibility that there is a flow histogram dependence in the models. This possibility should be checked by EPA reviewing GE's projected flow histogram and GE doing the same with EPA's flow histogram. If EPA decides against the above procedure, then the EMC will reiterate its previously stated recommendation that side-by-side peer review of the EPA and GE models be conducted.

2. <u>General</u>

When reviewing the EPA and GE model reports, it was apparent that the GE report provides much more detailed discussion of the rationale for the data used in the model. It would be helpful to the review if EPA did the same. It is recommended that this information be added. **BL-1.1**

3. <u>Section 3.2.1, P. 10</u>

Why aren't different values of "n" used for cohesive and non-cohesive areas? It seems unlikely they have the same roughness. **BL-1.2**

<u>Section 3.3.3, P. 13</u>

Why was the model not checked versus the entire flow regime for the data available for the 1991, 1992, 1993, 1994 and 1995 periods listed in Table 3-2? This would seem to be a better check than just checking the peak flows. **BL-1.3**

5. <u>Section 3.3.4, P. 13</u>

From this discussion, it doesn't appear that tributary flows were included. If not, why not? Also, the rating curve explicitly used for the Thompson Island area should be included in the report. **BL-1.4**

6. <u>Section 3.5.1, P. 14</u>

Model results should be given and compared to USGS data for cross-section points, not just the mid-point. **BL-1.5**

7. <u>Section 3.8, P. 19</u>

This discussion shows no attempt to calibrate or validate the flow model for the River below the Thompson Island Dam. There also seems to be no discussion of such calibration/validation in subsequent sections. Why was calibration/validation below the Thompson Island Dam not done as it would seem to be necessary? **BL-1.6**

8. Section 4.3.3, P. 29

The GE model approach to armoring of the non-cohesive bed uses d_{50} as a parameter and then calculates armoring depth. The resulting relationship compares very well to the data without the large spread of Fig. 4-3. EPA should consider using the GE approach. **BL-1.7**

9. Section 6.4.4, P. 63

More information should be provided on exactly what was used for estimating the missing PCB concentrations, (i.e. when was linear interpolation used and when were seasonal averages used?). **BL-1.8**

10. Section 7.3.1, P. 71

Are the values in Table 7-1 the final ones used in the model? If so, which of the values were changed from those at the start of calibration. Were any further adjusted as the result of PCB concentration calibration runs? Is so, which ones? These questions are important because the capability of a model to predict the future is inversely related to how many parameters needed to be adjusted to calibrate the model to existing data. **BL-1.9**

11. Section 7.3.1, P. 72

The presentation of Fig. 7-2 in the report makes it impossible to decipher which curve is which. Please provide a Fig. 7-2 which labels each curve as to what it represents. **BL-1.10**

12. Section 7.3.2, P. 72

Please explain what "adjustments" had to be made for partitioning to account for site specific data. Is this "flexibility" the "calibration flexibility" discussed starting at the bottom of P. 72? If so, this is an example of the concern expressed above in Comment #10. **BL-1.11**

Section 7.3.2, P. 75

Were the "final HUDTOX calibration values for diffusive mass transfer rates and seasonal variability" fixed at the start of calibration or changed during calibration to get the "final" values? **BL-1.12**

13. Section 7.3.2, P. 75

What is the reason(s) that sediment-water transfer rates depicted in Fig. 7-6b should be so much different for the Thompson Island Pool and regions below the Thompson Island Pool? **BL-1.13**

14. Section 7.4.1, P. 75

What parameters were adjusted during calibration to achieve the results shown in Fig. 7-7? **BL-1.14**

15. Section 7.4.3, P. 79

Fig. 7-24, discussed herein, shows an increasing high bias for the model over the data-based estimate as time goes by. This raises the concern that the model will increasingly overestimate PCB concentrations for time projections beyond 1997. **BL-1.15**

16. Section 7.5, P. 80

The statements on this page that the Hudson River is not depositional, that the burial (or net deposition) rates for cohesive sediments in the Thompson Island Pool are much greater than for non-cohesive sediments and the presence of hot spots in the Thompson Island Pool all support the conclusion that burial of PCB's is and has occurred in the cohesive sediments in the river. Where does EPA find this conclusion to be illogical? **BL-1.16**

Section 7.5, P. 81

What characteristics of the river would likely be the cause of the different dominant processes for PCB sediment to water transfer in different regions of the river cited here? **BL-1.17**

17. Comparison of HUDTOX and Low Resolution Coring Report (LRCR) Results, PP. 81, 82 and 83

The discussion in this section seems self-serving and not worthy of EPA. The principal conclusion in this section is that the model estimate of PCB loss from the Thompson Island Pool is very close to the estimated loss GE provided in 1998. Also, the use of a calculated average sediment bed elevation should not be used to draw conclusions about burial in the Thompson Island Pool. EPA, itself, cited in Section 7.5 on P. 80 the order of magnitude difference between the burial rates for cohesive and non-cohesive sediments. No one is saying burial occurs in non-cohesive areas, only in cohesive areas. Therefore, if EPA wishes to evaluate burial, it should concentrate on only the cohesive sediments and not use average values which include both cohesive and non-cohesive sediments. **BL-1.18**

BG-1

John G. Haggard, Manager
Hudson River Projects

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June 23, 1999

Douglas J. Tomchuk
USEPA Region II
Emergency & Remedial Response Division
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Re: General Electric Company Comments on EPA Baseline Modeling Report

Dear Mr. Tomchuk:

The General Electric Company (GE) is pleased to submit the enclosed comments on the EPA report entitled "Phase 2 Review Copy: Further Site Characterization – Volume 2D – Baseline Modeling Report (May 1999)."

Having commissioned our own quantitative model of the Upper Hudson using much the same data collected over much the same period, GE offers these comments in the hope that our experience, observations and recommendations will assist EPA in promptly completing the substantial work that remains to be done on its own model, correcting the significant flaws, omissions and discrepancies identified in our comments, and in improving the overall quality of science in EPA's model. In their current state, these models are inadequate for predicting future river conditions or for evaluating potential remedial options. The model limitations are clearly illustrated by their inability to replicate important data. As an example, the model consistently calculates PCB levels in fish from Stillwater that grossly exceed values actually measured by the NYSDEC. The models projections of future river conditions are also questionable since a starting point for PCB concentrations in sediments are higher than the data show. Lastly, the model below Thompson Island Pool are based upon different assumptions than those applied to the Thompson Island Pool.

As you know, GE has provided to EPA a copy of the report on its model and asked the Agency to subject both models to side-by-side peer review. We appeal to EPA to reconsider its decision to conduct a limited, unilateral peer review of its model only. It is GE's strong belief that independent scrutiny by a panel of impartial experts will serve the public interest by reconciling whatever differences may exist between the projections made by these critically important technical tools. We BG-1A
reiterate our request for simultaneous peer review in a fully open public process at which there is ample opportunity for all interested parties to exchange information and question the data and analyses. We reiterate our offer to cover the costs associated with such a simultaneous peer review. This will not result in any extension of the project schedule

When EPA Administrator Carol Browner appeared before a New York State Assembly committee in 1997, she called on GE "to work with us to provide the public with full and accurate information and help finish the job of cleaning up the Hudson River." Simultaneous peer review of the two models is the best opportunity that has existed in the nine years of EPA's Reassessment to fulfill the Administrator's challenge to provide the public with the most accurate, most credible science. GE is ready and willing to work with EPA. We await EPA's answer.

Based on our review of EPA's report and the comments of EPA's representatives at the June 16, 1999, Hudson River Science and Technical Committee (STC) meeting, we have concluded that this report and the EPA model in its current form are incomplete. Indeed, EPA itself has aptly described the model as a "work in progress." The work as documented in the EPA report is also not "transparent." The report does not discuss key assumptions in the model, explain the relationships between the various model runs (calibration, hindcast and projections), presents data-model comparisons on a compressed scale that obscures differences between the data and model, and omits a number of key data-model comparisons. BG-1.1

These are not trivial flaws. They hamper the public's ability to evaluate the report and provide meaningful comment. This defeats the opportunity to comment that is required by the Administrative Procedure Act (APA), CERCLA and the National Contingency Plan. The data and analysis employed by EPA in the development of the model must be laid out in sufficient detail so that the public can provide meaningful and germane comments. United States v. Nova Scotia Foods Products Corp., 568 F2d. 240, 252 (2d Cir. 1977) ("to suppress meaningful comment by failure to disclose the basic data relied upon is akin to rejecting comment altogether... When the basis of a proposed rule is a scientific decision, the scientific material which is believed to support the rule should be exposed to the view of interested parties for their comment"); Endangered Species Committee of the Building Industry Association of Southern California v. Babbitt, 853 F. Supp 32, 36-37 (D.D.C. 1994) ("where an agency relies upon data to come to a rule-making decision, it generally has an obligation under the APA to provide such data for public inspection."); see also Chemical Manufacturing Association v. U.S. EPA, 870 F. 2d 177 (5th Cir. 1989).

In order to respond promptly and effectively to the opportunity to comment on the Baseline Monitoring Report, GE requested, at EPA's public meeting at the time the Report was released, that EPA provide GE with the codes which are building blocks of the model. That material, essential to commenting, has not been provided. GE reiterates its request for the codes. GE further requests that EPA provide documented codes and input files for the models constructed to date and data model output files for the key comparisons described in the attached comments. We ask that EPA provide these codes and files promptly so that we can fully and fairly evaluate the model and provide additional comment to the Agency. It is GE's position that, as set out above, EPA was obligated to provide this data and analysis at the beginning of the comment period. In the event that EPA disagrees with this position, we ask that EPA treat this as a request under the Freedom of Information Act.

GE also urges EPA to withdraw this report until the model is completed, the discrepancies reconciled and the additional information provided for public review. A new report is required in order to make thorough review of the model possible and to satisfy the Agency's legal obligation to provide all relevant information for public review. In the interim, the validity of the model in its current form and the conclusions presented in this report are so suspect that they should not be used to inform EPA's human health and ecological risk reports.

GE recognizes EPA's anxiousness to complete this reassessment consistent with its publicly announced deadline. Thorough scientific investigation and analysis should not -- and need not -- be compromised in pursuit of a timely decision. GE will continue to cooperate fully with EPA to resolve the problems with its model. EPA must allow its consultants the time and resources necessary to conduct their assigned tasks in the most professional manner. At the recent Science and Technical Committee meeting, EPA consultants Menzie-Cura repeatedly sought to deflect criticisms of their work by explaining that they had done the best they could given the resource and schedule constraints imposed upon them by EPA and TAMS. Science that is not the best but "close enough" will not stand the test of public, judicial and peer scrutiny on this important project, and the one where EPA itself insisted that it was uniquely qualified to perform all of the reassessment investigation and analysis in the most objective manner.

Please place a copy of these comments in the administrative record for this site.

Yours truly,

John G. Haggard SMW

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COMMENTS OF THE GENERAL ELECTRIC COMPANY ON

Phase 2 Report – Review Copy
Further Site Characterization and Analysis
Volume 2D – Baseline Modeling Report
Hudson River PCBs Reassessment RI/FS
May 1999

June 23, 1999

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SECTION 1
INTRODUCTION

The General Electric Company ("GE") submits these comments on the Baseline Modeling Report ("BMR"), which presents EPA's models of PCB fate, transport, and bioaccumulation for the Upper Hudson River ("EPA's models"). GE has also developed a model of PCB fate, transport, and bioaccumulation for the Upper Hudson River, which has been presented to EPA.

GE's review of the BMR has raised serious concerns that the models have not been properly and fully developed and in their current states are inadequate for predicting future conditions and evaluating the efficacy of remediation in the upper Hudson River. The major findings are as follows:

- The Report's descriptions of the models lack transparency and are incomplete and insufficient to allow a comprehensive evaluation of the work.
- The equations and coefficients describing sediment transport and PCB fate in the 34 miles between the Thompson Island Dam (TID) and Troy are inconsistent with the equations and coefficients used in Thompson Island Pool (TIP) and inaccurately represent the processes critical to PCB fate in the river.
- The model over-states the low flow PCB flux from the sediments in the Thompson Island Pool and under-states the low flow PCB flux from the sediments in the reaches downstream of Thompson Island Pool.
- The model over-states the total PCB flux passing the various locations at which measurements have been routinely taken.

- The model's calculations of sediment deposition in the Thompson Island Pool over-state deposition in non-cohesive sediments and under-state deposition in cohesive sediment because the spatial patterns of sediment deposition are mischaracterized.

- The surficial sediment PCB concentrations at the start of the model's projections are inconsistent with data; they are two to three times too high in the region between Schuylerville and Troy.

- The bioaccumulation model (FISHRAND) lacks predictive ability. It is inaccurate and biased, consistently calculating concentrations substantially higher than measured values in fish from Stillwater.

EPA is developing its model to analyze future events in order to provide a quantitative and objective basis for decision-making. The model needs to predict what will happen to PCBs in the Upper Hudson River if there is no further remedial action taken and what will happen to the PCBs under a variety of remedial scenarios. This will allow a comparison of remedial alternatives so that a rational decision can be made as to whether any particular remedial course can be justified as materially accelerating the date at which PCBs in fish will reach concentrations protective of human health and the environment. Particularly in a context where more than one model is available, it is important to focus on the benchmarks by which to determine the degree of confidence, or comparative confidence, that should be placed on a model.

We have identified four benchmarks for evaluating a model:

1. Effective and comprehensive use of site-specific data in model development. The accuracy with which the model replicates the unique conditions of the Upper Hudson River is dependent on the extent to which the river and its ecosystem are characterized by measurement and the model's use of these measurements. This characterization involves the collection, analysis, interpretation and integration of site-specific data.

2. Closeness of fit between data and model calculations. The greater the number of diverse, known data points that the model's calculations are able to simulate, the greater confidence one has in the model. A key to predicting the future is replicating the past.

3. Consistency within and between models. Within the model, physical, chemical and biological processes must be consistently described without regard to the time or place where they occur. A model is internally inconsistent if it uses different equations for the same process. Failure to meet this test would deeply damage the predictive capability of the model. Where more than one model is used for analysis, there should be consistency between the models for the same reason.

4. Mechanistic formulations of the physical, chemical and biological processes that the model simulates. A calibrated, validated mechanistic description provides confidence that the model's ability to simulate known data points is more than fortuitous. Predictions beyond the historical conditions for which data exist are only possible if the mechanisms affecting PCBs are described correctly and the constraints of scientific laws are invoked.

Beyond these benchmarks, there are a number of common sense indications of modeling quality. For instance, effective calibration of general equations to a body of site-specific data increases confidence in the model. The more detailed and complete the effective analyses of the model, the greater value it has in choosing future courses of action.

GE has approached the review of the BMR with these benchmarks in mind. Unfortunately, in a great many instances, an evaluation cannot be carried out because the Report fails to accurately describe the data relied on in the models; the equations and codes from which the models are constructed; and/or the results obtained from operating the models. In other cases, the data or results are presented in a manner that prevents detailed analyses or comprehension of what is shown. For instance, no sediment mass balance during floods is presented. The model's spatial patterns of PCB concentrations and loads downstream of the TIP are not presented. The long-term concentrations of PCBs in the water column calculated by the model are compared to the data in a manner that obscures the relationship of model to data and largely prevents model evaluation. The same is true of the presentation of total suspended solids during high flow events.

The lack of transparency that pervades the BMR is not a trivial flaw. It defeats the purpose of providing the opportunity for public comment. The data and analyses employed by EPA in the development of a document must be laid out in sufficient detail so that the public can provide intelligent and germane comments. A prime example of the difficulty that flows from the failure to provide sufficient data is the inability to understand why the validation and calibration runs of EPA's model apparently result in materially different PCB concentrations in sediment. The 1991-1997 calibration and the 1977-1997 hindcast produce grossly different predictions of surface sediment PCB concentrations in 1998 in Reaches 2-7. 1998 surface sediment PCB levels generated by the 1991-1997 calibration are lower in Reaches 6-7 and higher in Reaches 2-5 than those generated by the 1977 to 1997 hindcast. The cause of this discrepancy is not clear. Without a full presentation of the model results, these results remain inexplicably inconsistent and clearly unsupported by the data.

The lack of a reasonably comprehensive guide to the model and the lack of a thorough presentation of its results is a severe handicap in commenting properly on the Report. We present here in short form some of the significant findings from our evaluation of the model against the benchmarks set out above. A more complete discussion of these and other findings is presented in subsequent sections of this document.

1. <u>Effective and comprehensive use of site-specific data in model development</u>

- Extensive site-specific data on PCB congener partitioning between particulate and dissolved phases exist for both the water column and sediments of the Upper Hudson River. Despite such data, the coefficients describing this process were adjusted during the model calibration process. While some variability exists in measured partition coefficients, there is no sound basis for adjusting these data-derived coefficients. The measured coefficients provide the best estimate and should not have been adjusted during calibration.

- EPA's development of a description of PCB flux from sediments during low flows did not take advantage of the extensive data set of matched PCB measurements at Rogers Island, Thompson Island Dam and Schuylerville. These data provide the best opportunity to develop an empirical description of the flux within and downstream of the TIP. Further, no site-specific data exist to support EPA's description of low-flow sediment resuspension. As described in EPA's model, the low-flow resuspension process is unconstrained. Moreover, the process is parameterized differently within the TIP than in downstream reaches without any site specific data to support such spatial variability.

- FISHRAND used default fish growth rates computed with two generic weight-based regressions. EPA did not analyze the extensive data set of weight and age measurements for fish from the Upper Hudson River. The growth rates used in the model appear to be considerably greater than the values measured in the Upper Hudson River. This difference is important because growth rate dilution can have a large impact on the PCB concentration in the fish. **BG-1.2**

- The lipid contents of the fish used in the model were calculated directly from the values measured by NYSDEC. For largemouth bass and brown bullhead, these values were for fillets. Whole-body lipid contents are the correct values to use and are approximately 2.5 times greater than lipid levels in fillets in several species of fish. Therefore, the lipid contents used in the largemouth bass and brown bullhead models appear to be too low. In addition, one average lipid content was used for all locations and years, even though the data indicate that the lipid contents of the fish vary considerably year-to-year and by location. Differences among populations and between fillet and whole body levels are **BG-1.3** important because the lipid content of the fish impacts the PCB excretion rate, and therefore affects the degree of bioaccumulation.

- The food web structure used in FISHRAND was based upon "professional judgement and a careful analysis of all the available data" (BMR Book 3, p. 71). The report, however, presents no analyses of the extensive gut content data and invertebrate population data collected in the Hudson River for the purpose of evaluating food web structure. The structure of the food web controls the relative importance of sediment and water column PCBs to the food web, and therefore the response of fish PCB levels to natural recovery and to remediation activities. **BG-1.4**

2. Comparison of model results to data

In this case, the central measurements of concern are the concentrations of PCBs in the water column; the concentrations of PCBs in the sediments; and the concentrations of PCBs in fish, all over an extended period of time. These broad categories require at least two refinements. First, each of these metrics should be tested both in the TIP and the reaches of the river downstream from the TIP. Second, for purposes of remedial action, it is essential to distinguish the PCB concentrations of surficial cohesive sediments from surficial non-cohesive sediments to evaluate direct sediment remediation.

EPA's model was calibrated by fitting the results to the extensive series of PCB water column readings. One would expect that the model would fit these data best. Nevertheless, at the Thompson Island Dam ("TID"), the model over-estimates PCB flux. Starting in late 1992, the model diverges from the data. From late 1992 to late 1997, the model overstates the cumulative PCB flux from the Pool by approximately 660 pounds or 0.35 pounds per day. This is 37% above the actual data-based flux from the TIP.

The 1977-97 hindcast significantly overstates the PCB flux past Schuylerville after 1982. By the end of the simulation, the model overstates the PCB flux by about 6,000 pounds or about 1.1 pounds per day (about 45% over-prediction over the 1982-97 period).

The model's performance with regard to sediment and fish is clearly weak and requires marked improvement before the model can be used in decision making. Initial sediment conditions in the reaches below the Pool, derived from the 1991-97 calibration, and used for the long-term projection, are two to three times higher than concentrations measured in 1991, the most recent extensive sediment survey. There are two possible explanations for this inconsistency. Either the model projections started with inaccurate initial conditions or the model predicts an increase in surface sediment PCB concentrations between 1991 and 1997. The latter is inconsistent with the model hindcast, which depicts a gradual decline in surface sediments from 1977 through 1997.

With regard to fish, the model results consistently over-predict the data points in the reach of the river downstream from the TIP, as presented in Book 4, Figure 6-4 of the report. Since the PCB levels in fish are ultimately derived from PCBs in sediments or water column, this suggests systematic error in fish diet, sediment, or water column calculations. **BG-1.5**

3. Consistency within and between models

The PCB fate model uses multiple descriptions of the same processes without theoretical or empirical justification.

The parameter that controls the non-cohesive bed armoring rate was set at 6.0 in the TIP and three times lower below the TIP. This results in a threefold increase in the non-cohesive resuspension rate below the TIP. No justification is given for this large increase. Gross settling speed was decreased downstream of Schuylerville. The report justifies this approach by explaining that because "the flow-velocity relationships change as one moves downstream, these parameters have been established on a reach-specific basis according to cumulative drainage area" (BMR Book 1, p. 71). The report provides no explanation or justification as to how the flow-velocity relationship changes as one moves downstream or why and how these changes should affect the settling speed relationship.

The model uses different exchange coefficients in the TIP and downstream reaches to describe low-flow sediment-water PCB exchange. Data collected from the Hudson River has not provided any sound technical basis for spatially varying the processes of sediment-water exchange.

When the formulation of physical and chemical processes is changed from place to place in the river without explanation, the credibility of the model becomes questionable.

The bioaccumulation model FISHRAND does not use the water column particulate PCB concentrations computed by the fate and transport model. Rather, water column particulate PCB concentrations are calculated from the water column dissolved PCB concentrations computed by the fate and transport model. The calculation yields concentrations much higher than those computed by the fate and transport model. **BG-1.6**

The credibility of the bioaccumulation models is diminished by the lack of consistency between the models. The relative importance of water column and benthic PCBs to the food web is a critical parameter of the models. However, the composition of fish diet differs among models. For example, the spottail shiner consumes equal amounts of benthic and water column invertebrates in the Probabilistic Food Chain Model ("PFCM"). In FISHRAND, it consumes 75% water column-associated food. In addition, 67% of the forage fish diet consists of water column invertebrates in PFCM; in FISHRAND forage fish consume 75 to 80% water column-associated food. Finally, the choice of forage fish differs among the models, all of which are designed to estimate the same thing: transfer of PCBs up the food web. Such inconsistency provides no basis for choosing a prediction of fish diet in the future. **BG-**

4. Mechanistic Explanations of Physical, Chemical, and Biological Processes

The model is inconsistent in its use of mechanistic descriptions of the processes affecting PCBs. Of particular concern is the use of non-mechanistic representations that are at variance with known mechanisms.

The model applied the same gross settling speed relationship to both cohesive and non-cohesive bed areas. Typically, cohesive bed areas are lower energy environments than non-cohesive areas because cohesive areas are more conducive to deposition. As a result, effective settling speeds are generally higher in cohesive areas, especially at high flow rates. Thus, assuming that the same gross settling relationship applies in both areas is fundamentally incorrect. This flaw has significant impact on both sediment transport and PCB fate simulations. While the model may be correctly predicting the average sedimentation rate for a particular reach, the distribution of net deposition between cohesive and non-cohesive bed areas is incorrectly predicted. Sedimentation rates will be under-predicted in the cohesive bed areas and over-predicted in the non-cohesive bed areas.

One of the goals of the PFCM was to develop a method by which the variability in fish PCB levels could be calculated. This model is entirely empirical and has no mechanistic basis. Furthermore, the model is static; the values of the parameters of the distributions will not change **BG-1.8** over time. Only the mean exposure concentrations will change. Therefore, the model does not correctly account for the sources of PCB concentration variability within fish populations. In fact, the mechanisms underlying natural variability in PCB concentrations are not well known. Because there is a large database with which to directly estimate the distributions of PCB levels among individual fish, an appropriate method of estimating variability is to use the distributions of measured fish PCB levels directly.

Finally, the Bi-variate Statistical Model ("BSM") is based upon a regression between PCB levels in fish collected in Spring (largemouth bass and brown bullhead) and PCB levels in **BG-1.9** water sampled throughout the same year. That is, most of the water samples were collected after the fish were sampled. Water column PCB concentrations have exhibited considerable year-to-year variation (BMR Book 4, Table 4-7), suggesting that this approach may have a significant impact on the results.

The comparisons of the models presented in the report to the evaluation benchmarks have revealed numerous shortcomings that show that the models are not yet appropriate tools for predicting the course of natural recovery in the upper Hudson or the ability of remedial actions to materially accelerate recovery. Severe deficiencies exist in the fate model's representation of the 34 miles between the TID and Troy and in the bioaccumulation models' representation of the relationship between PCB levels in water, sediment and biota.

Significant revisions are needed to address inconsistencies within and between models and to correct misrepresentations of physical and biological processes. Further, much more detailed and comprehensive descriptions of the models and their results are required to allow a full examination and review of the models.

SECTION 2

THE INFORMATION PRESENTED IN THE BMR IS INADEQUATE TO ASSESS MODEL VALIDITY

Scientific reports should have clear and concise descriptions and presentations of the assumptions relied upon, the methodology and data used, and the results generated. The BMR falls short in all these aspects. The BMR also lacks a clear description of many of the important analyses, assumptions, and data manipulations underlying the development of the models. It omits critical comparisons between model and data, hindering assessment of the models' accuracy. The model-data comparisons that are provided are often in a scale too coarse (*e.g.*, logarithmic instead of arithmetic scale; compressed time scales) to permit proper analysis. Together, these problems make it difficult to provide a detailed and adequate review of the models described in the BMR.

2.1 EPA'S FATE AND TRANSPORT MODEL

2.1.1 The Comparisons Between Model and Data are Inadequate to Fully Judge the Accuracy of the Model

Comparisons between model predictions and data, over various temporal and spatial scales, must be made to calibrate the sediment transport and PCB fate models applied to the Upper Hudson River. Comparison of model calculations to site data allows an assessment of model quality. While the BMR contains comparisons between site data and model predictions, a number of important comparisons are not provided. Moreover, the EPA's use of compressed time scales and logarithmic concentration scales precludes close scrutiny of the model's ability to replicate historical events and long term trends.

2.1.1.1 Sediment Transport Issues

Calibration and validation of the sediment transport components of EPA's model requires successful comparison of model results to:

- TSS concentrations during low and high flow,
- sediment mass balances during flood events, and
- sediment burial rates.

Although the BMR includes comparisons of predicted and observed TSS concentrations, it lacks important comparisons of the model calculations to data-based estimates of sediment mass balances. **BG-1.1(**

The BMR compares calculated and observed TSS concentration data collected during the 1994 spring flood to demonstrate sediment transport model calibration. Comparing observed and predicted TSS concentrations is necessary for model calibration. However, this type of comparison alone is not sufficient for calibrating sediment resuspension and deposition formulations used in the model. Because sediment resuspension and deposition control long-term burial rates and, consequently, the rate of natural recovery, it is critical that these processes be appropriately calibrated. Calibration to TSS alone is problematic because predicted TSS concentrations are insensitive to changes in parameters controlling deposition and resuspension. That is, large changes in predicted net resuspension and deposition fluxes cause small changes in predicted TSS concentrations. The only way to constrain these mechanisms is to confirm that the mass of sediments entering the river from tributary and upstream areas as well as leaving the river via downstream transport is properly accounted for by the model.

To demonstrate the insensitivity of water column TSS concentrations to sediment bed dynamics, GE conducted three simulations of the 1994 spring flood in the TIP using the calibrated GE sediment transport model (QEA, 1999). These simulations included: (1) treating the entire sediment bed as hard bottom (*i.e.*, no resuspension or deposition), (2) using the GE model calibration as documented in QEA (1999), and (3) using the EPA settling speed function in the GE model. The results of these simulations (Figure 1) demonstrate the insensitivity of predicted TSS concentrations at Thompson Island Dam to vastly different sediment resuspension and deposition formulations.

Although predicted TSS concentration is insensitive, the net sediment flux from the TIP is very sensitive to changes in resuspension and deposition formulations. Using a mass balance procedure in the TIP that considers TSS loadings from tributary and upstream sources as well as main channel solids loadings, the original GE model predicted 370 MT of net erosion from the TIP. This erosion estimate compares well to the data-based estimate of 450 MT (18% error). Using the EPA settling speed function in the GE model yields a prediction of 1,720 MT of net erosion, corresponding to an error of 280%. These results demonstrate that TSS concentration data alone are insufficient to evaluate model performance and infer the correctness of resuspension and deposition formulations; additional measures, including mass balance, are needed. **BG-1.11**

Comparing predicted and data-based estimate of the mass of solids passing a given station over a specific time period (solids fluxes) along the main stem of the Upper Hudson River (*e.g.* BMR Book 2, Figures 7-8, 7-11 and 7-22), also does not constrain the model's representation of resuspension and deposition dynamics in the river. This is because flux measurements cannot distinguish among the different mechanisms from which solids are derived within a reach: upstream boundary, tributary loadings and resuspension. In the Upper Hudson River, the main stem fluxes are dominated by solids loadings input at Fort Edward and from the tributaries. Large changes in resuspension and deposition fluxes in the area upstream of a particular main stem location will have relatively minor impact on the predicted solids flux in the river. Accordingly, there is no basis for the BMR's conclusion that "The success of the model at simulating the cumulative TSS flux at TID, Stillwater and Waterford (BMR Book 2, Figure 7-11) suggests that a good closure of the solids mass balance has been attained and, therefore, an accurate estimate of net solids burial rates difference between sediment deposition and sediment resuspension in these reaches has also been achieved" (BMR Book 1, page 76). **BG-1.12**

For the calibration period under consideration, 1991-1997, it is unclear how the TSS flux comparisons were accomplished. Because no solids flux data are presented at the TI Dam (top

panel of BMR Book 2, Figure 7-11), it is impossible to make any statement concerning the accuracy of the model to predict net solids burial rates between TID and Stillwater based on the solids flux information at those locations. More importantly, the only way to determine the accuracy of the model with regard to resuspension and deposition processes on a reach-average basis is to compare data-based and model-predicted mass balances. This is different from the solids flux analysis set out in the BMR in that it includes an assessment of tributary solids loading in addition to main stem loadings. The lack of such a mass balance comparison precludes a determination of the accuracy of predicted burial rates. In addition, it is unclear how the "data- BG-1.1
based" estimates of long-term TSS fluxes were developed from the few measurements that exist at the Stillwater and Waterford stations for the period from 1991 to 1997. Presumably, these estimates are subject to considerable uncertainty associated with extrapolation of the few measurements to form what is presented as a continuous record.

Use of mass balances on specific reaches of the Upper Hudson River during a particular time period (*e.g.*, 1994 spring flood) is thus critical for evaluating the capability of a sediment transport model to simulate resuspension and deposition processes (QEA 1999). Data-based mass balances apparently were constructed for the TIP during the spring floods in 1993, 1994 and 1997 (BMR Book 1, page 61). However, model predicted mass balances are not compared to the data-based results. Such comparisons are critical for evaluating the ability of a sediment transport model to accurately and realistically simulate resuspension and deposition processes in BG-1.1
the Upper Hudson River. Sufficient data were available to construct mass balances during the 1993 and 1994 spring floods for the reaches downstream of the TIP and this information should have been used to evaluate model performance. Without such mass balance comparisons, the ability of the sediment transport model to simulate resuspension and deposition processes in the Upper Hudson River cannot be determined.

In addition, some of the TSS comparisons provided in the BMR are presented on compressed time and concentration scales that impede model-data comparisons. For example, BG-1.
logarithmic scales were used to compare predicted and observed TSS concentrations between 1977 and 1997 (BMR Book 2, Figure 7-9) and during 1993 (BMR Book 2, Figure 7-10). This type of comparison gives a false sense of model accuracy because errors during high flow events,

(*i.e.*, high TSS concentrations) are not evident on a logarithmic scale. An arithmetic scale should have been used to make these model-data comparisons because errors during high flow events can be plainly ascertained using an arithmetic scale. Another problem with the model-data comparison for the 1977-97 simulation is temporal compression on the figures, making it impossible to determine the accuracy of the model during high flow events. Similarly, using logarithmic scales for TSS concentration and compressed temporal scales for the 1993 and 1997 spring floods make it impossible to adequately determine model performance during these periods. Predicted TSS concentrations during these floods should have been plotted using the same format used to display the 1994 spring flood results (*i.e.*, on an arithmetic scale for TSS concentration and on a temporal scale that corresponds to the time scale of the flood; see BMR Book 2, Figure 7-7).

The BMR presents little information concerning net sedimentation rates predicted by the model. One figure (BMR Book 2, Figure 7-27) presents predicted sedimentation rates in the TIP for the 21-year period from 1977 through 1997. These results could have been compared to measured rates, determined from ^{137}Cs-dated high-resolution sediment cores, to evaluate model performance. The only statement concerning model accuracy is given on BMR Book 1, page 80: "... the average bed elevation change in TIP over the 21-year hindcast period is approximately 4 cm, a very reasonable estimate for a dammed river." This statement has no apparent basis in fact, EPA must provide data for the Upper Hudson River or other rivers to demonstrate that an approximately 0.2 cm/yr deposition rate is 'a reasonable estimate.' The BMR also fails to present predicted sedimentation rates for the reaches downstream of the TIP. **BG-1.16**

2.1.1.2 PCB Fate and Transport Issues

Calibration and validation of the PCB fate model requires successful comparisons of the model to observed PCB concentrations in the sediment and water. For the model to be capable of accurately predicting future PCB conditions in the river, as well as PCB levels under rare storm events, certain calibration objectives must be met. Specifically, the PCB model must be able to reproduce:

- long-term trends in sediment PCB levels,
- long-term trends in water PCB levels,
- water PCB levels during high-flow storm events, and
- seasonal variations in water PCB levels.

Additionally, the calibration results (1991-1997) and hindcast validation (1977-1997) must be compared. The BMR fails to provide such comparisons in water or sediment. The calibration and the hindcast presumably share the same parameter set. As the 1977-97 hindcast is used to demonstrate the validity of the calibration, the absence of comparisons makes it impossible to assess whether the 1977-97 hindcast is truly a model validation.

With respect to long-term sediment PCB trends, the BMR states: "...in a system for which sediment-water interactions are very important, the capacity to reproduce trends in surface sediment concentrations is crucial" (BMR Book 1, page 80). This statement is correct because the ability of the model to reproduce surficial sediment concentrations is critical to the model's prediction of sediment to water PCB fluxes as well as the exposure levels for biota. The BMR model-data sediment comparisons, however, do not demonstrate the model's capacity to reproduce surface sediment trends. The BMR does not include any comparisons between the 1991-97 calibration results and measured sediment PCB concentrations. The omission of this **BG-1.1** key calibration target precludes an assessment of the model's capability to represent river conditions accurately. In addition, comparisons between the results of the 1977-97 hindcast and sediment data (BMR Book 2, Figures 7-25a-d) do not validate the 1991-97 calibration results since the results generated from these two model calibrations may be inconsistent (see Section 4). Further, calibration of surface sediments in the TIP should be evaluated using GE's 1998 sediment survey data.

The comparisons between the hindcast and measured sediment data are also problematic. First, the model calibrations and the presentation of results should be extended to 1998. Currently, the 1998 data set is not included in the model to data comparison. The 1998 sediment coring program conducted by GE within the TIP (O'Brien & Gere, 1999) provides an additional calibration point for the surface sediments of Reach 8. This program was smaller in scale than the 1991 program, but reoccupied over 50 sediment stations sampled in 1991. In total, the 1998 program analyzed 298 sediment samples for PCBs and represents an important data set upon which to base the PCB fate calibration. Indeed, inclusion of the 1998 sediment PCB congener data in the 1991-1997 calibration to the TIP would provide a necessary constraint in the model calibration.

Second, the model-data comparison of the 0-4 cm sediment PCB concentrations includes the 1984 and 1994 data sets (BMR Book 2, Figure 7-25). The vertical resolution of these two surveys is too coarse to permit comparison to the 0-4 cm layer. For the 1984 data, only approximately 7% of the surface samples truly represent 0-5 cm; the remainder range from 0-6 to 0-51 cm. Similarly, all the 1994 surface samples represent a 0-20 or 0-23 cm (0-8 or 0-9 in) surficial sediment layer. The larger surficial sediment layers of the 1984 and 1994 surveys cannot be used to accurately represent the 0-4 cm surface layer of the model. **BG-1.1**

As with the sediment transport model, the BMR's presentation of the comparison between 1991-97 calibration and water column PCB data lacks sufficient resolution to assess model performance. BMR Book 2 Figures 7-13 to 7-15 presents results at TID, Stillwater, and Waterford on a scale that is too compressed and obscured to judge whether the model reproduces the observations without bias. Additionally, these figures include GE and EPA data, but omit USGS data collected at Stillwater and Waterford. These are important data to judge whether the model is capturing the trend in water column concentrations through the latter years of the calibration. **BG-1.19**

Another important calibration metric that is not included in the BMR is the reproduction of water column PCB levels during high-flow events. Accurate representation of sediment to water exchange processes requires reproduction of water column PCB concentrations under both low and high flow events. As the BMR states, "tradeoffs often exist between two processes that cause the same change in a given state variable" (BMR Book 1, Page 68). For the transfer of PCBs from the sediment to the water column, tradeoffs exist among resuspension, particulate PCB exchange, and pore water diffusive exchange. In this context, "tradeoffs" refers to multiple processes exhibiting the same effect on model results. That is, resuspension, pore water diffusion and particle PCB exchange all increase water column PCB concentrations. Therefore, an increase in water column PCBs may be due to any of these processes. In order to evaluate the parameterization of these processes, the model must be evaluated based on its ability to track sediment and water column PCB levels during both long-term and short-term time scales. Comparing model to measured water column TSS and PCB concentrations during high-flow events is critical to determining whether the model is accurately simulating the contribution of sediment resuspension to the overall sediment to water PCB mass transfer. The BMR acknowledges that "...the juxtaposition of PCB behavior during high and low flow periods in more recent, high-frequency data sets (1991-1997) was also important for the iterative PCB calibration." (BMR Book 1, page 70). The BMR, however, does not to provide any high-flow model-data comparisons by which to make calibration judgements. **BG-1.20**

In sum, the limited model-data comparisons presented in the BMR are inadequate and do not meet critical model calibration objectives.

2.1.2 The BMR Presents an Incomplete Description of Model Development

Detailed information on the assumptions, datasets, and procedures used during model development are essential to evaluating the conclusions of the modeling effort. The BMR should have documented the data analysis efforts that produced model initial conditions, boundary conditions, process formulation parameters and constants. It did not. The following critical omissions preclude a full evaluation of the model:

- initial sediment conditions for 1977 and 1991,
- upstream boundary conditions at Fort Edward,
- data averaging and loading calculations for data-to-model comparison,
- model parameterization, and
- model sensitivity.

Initial conditions in the sediments play an important role in the concentrations determined by a model's predictions, especially in areas where little or no sedimentation is occurring. For the BMR, initial concentrations of PCB in the sediment were necessary for the 1991-97 calibration period and the 1977-1997 hindcasting. We assume that these numbers were determined from the 1991 GE composite survey and the 1977 NYSDEC sampling program, respectively. However, the BMR does not describe the methodology or assumptions used to aggregate the average data for the purpose of generating initial concentrations. Data averaging can be approached in a number of different ways – some of which may not be accurate given the data and model characteristics. In addition, the modeling of two sediment types in EPA's model presents added complexity to the initial condition generation. For these reasons, the absence of a presentation of the methodology behind the initial conditions is a critical omission. **BG-1.21**

EPA's method to develop PCB loadings at the model boundary near Fort Edward used both seasonal averages and data interpolation ("...where sufficient data frequency existed to support interpolation" - BMR Book 1, p. 63). The procedure also described the handling of random historical "pulse loads" by abandoning the interpolation method and using "best professional judgment" to apply the apparent pulse load over a limited amount of time and filling the gaps before and after the pulse with a year-specific seasonal average. This method should have been supplemented by a statistical analysis and a more phenomenological approach to the historical dataset. For example, the loading could be viewed in three components: a base load, a resuspension load, and a pulse load as presented in QEA (1999). The base load can be determined by analyzing all the data during average flow with low TSS conditions. The resuspension load can be calculated by developing an understanding of the PCB concentration on solids during resuspension events. The occurrence of the pulse load can be quantified by statistically analyzing the data to determine magnitude and frequency of occurrence. Model sensitivities can aid in developing the magnitude and duration of the apparent pulse. Due to the limited data frequency, this approach allows the use of all the data to quantify the three load components. **BG-1.22**

Calibration of a model entails comparing the model results to available data to show that the model can accurately represent the system over time and space and adjusting model parameters within uncertainty bounds to better replicate site data. In many cases, direct comparisons to specific data points within a given area or over a certain time period, can be performed to illustrate the accuracy of the model. However, in some cases, the model resolution is coarser than the data distribution. As a result, data must be averaged to represent the area within the model construct. The BMR presents model to data comparisons for large areas often covering different sediment types, which indicates that some type of data averaging occurred (*e.g.* BMR Book 2, Figure 7-25). However, the BMR does not present the methodology behind the averaging used to produce these data points. As noted above, the assumptions and procedures involved in averaging spatial data are numerous and complex and should be presented in sufficient detail so as to allow reproduction of the calculation. **BG-1.23**

The data shown in BMR Book 2 Figure 7-24 are also questionable. The primary concern deals with the assumptions and methodology used to develop cumulative PCB flux over the 21 year period plotted in BMR Book 2 Figure 7-24. For all 3 stations shown, very limited data exist, both historically and in the 1990's. The USGS sampling effort, which occurred from 1977 to 1995 for most stations, included, on average, 25 samples per year. It is questionable whether this bi-weekly sampling effort provides enough data to determine cumulative loading over a 14 year period (on average, 8 samples per season). In addition, the 1990's sampling effort performed by GE is not continuous at any of these stations (Schuylerville, Stillwater, or Waterford). All three stations were sampled generally once per week from April 1991 to the end of 1991 and Schuylerville's sampling resumed in 1997 and continues currently. These sampling programs give a clear picture of the PCB flux, but only over a very short period of time. Chapter 6 of the BMR discusses the general method applied to obtain the PCB fluxes, however, we were unable to reproduce their results. **BG-1.24**

The basis for the parameter values used to specify the various PCB fate processes are inadequately specified. Table 7-4 of Book 1 gives particulate and dissolved organic carbon content of the water, cohesive, and non-cohesive sediments. However, the BMR does not explain how data were used to generate the values provided. Additionally, the molecular weight and Henry's Constant for total PCB are not adequately supported. Values given in Table 7-5 of Book 1 are purported to be based on PCB congener distribution, but the BMR makes no mention of how the congener distribution was developed nor the methodology used to develop these model parameters. **BG-1.25** **BG-1.26**

In addition, the BMR does not clearly explain the basis for the particulate organic carbon normalized partition coefficients given in Table 7-5. The BMR states that (page 72 of Book1): **BG-1.27**

> "Some calibration flexibility is available for setting the organic carbon normalized partition coefficients. The approach was to begin with the values arrived at by the theoretical analysis performed in the DEIR (TAMS et al., 1997). It was then recognized that some adjustment of these values could be made during calibration process..."

This statement implies that the partition coefficient is a calibration parameter, but the BMR does not explain how the final values were derived. It also should be noted that the analysis performed in the DEIR was not theoretical, but based upon site-specific data collected as part of the EPA Phase 2 Reassessment. In any event, the proper method for deriving the partition coefficients is to use values measured at the site. Two data sets exist for comparison and analysis of dissolved and particulate PCBs in the water, the EPA Phase 2 and GE water (1991-92) data. In the sediment, the GE 1991 sediment survey was available, as pore water and particulate PCB concentrations were measured.

The dissolved organic carbon normalized partition coefficients were set to 10% of the particulate organic carbon normalized coefficients with no apparent analytical or theoretical justification. The BMR only indicates on page 73, "this practice is within the range of values (1 to 10 percent) obtained for PCBs in natural systems." Again, this assumption should have been evaluated using the 1991 GE sediment data.

For parameters that have a significant degree of associated uncertainty, sensitivity analyses are required to understand what effect their uncertainty has on the overall uncertainty of model calibration. Statements made in the BMR acknowledge the importance of sensitivity analyses in the PCB fate model calibration process (BMR Book 1 page 68): **BG-1.28**

> "Even with the constraints imposed by mechanistic process descriptions, calibration of the EPA's model required scientific judgement in specifying process coefficients and many sensitivity analyses were conducted to understand state variable responses to each parameter."

Despite this recognition, the BMR fails to present any model sensitivity analyses.

Overall, the absence of detailed descriptions of model development results in many unresolved concerns. Without the methodology and assumptions behind model input and data averaging, one cannot conclude with confidence that the model accurately represents PCB dynamics of the Upper Hudson River. In addition, the absence of model sensitivity analyses reduces the credibility of the model development and calibration process, and consequently the model predictions.

2.2 EPA'S BIOACCUMULATION MODELS

2.2.1 The Comparisons Between Model and Data are Inadequate to Fully Judge the Accuracy of the Model

The FISHRAND model computes a mean and distribution of PCB concentrations in fish that was calculated on the basis of assumed distributions of parameter values. The graphical comparisons of the model and data (*i.e.*, BMR Book 4, Figure 6-4) consist of two computed values and individual data points for each year of the calibration period. The meaning of the plotted model results is not given, but the two calculated values presumably represent the mean and upper 90th percentile value of the predicted concentrations. The actual measured data are presented as individual points, *i.e.*, each of the individual sample results are presented. Because many of the data points overlap or over-plot, it is not possible to judge the mean or distribution of the data. Thus, it is impossible to assess the relationship between the model and the data. BG-1.2

A more effective and widely accepted method to graphically represent a data distribution is the box and whisker plot, an example of which is shown in Figure 2. Such a presentation is visually interpretable and provides a means to visually judge the accuracy of the distribution's computed by the model.

2.2.2 The BMR Presents an Incomplete Description of Model Development

The discussion of the bioaccumulation model development and calibration in the BMR lacks sufficient detail to perform a critical assessment of the process. For example, the basis for establishing the diets of forage and predator fish, which control the relative contributions of sediment and water column PCBs to the food web, is not described. The BMR states that the dietary composition of the fish in FISHRAND was determined based upon "professional judgement and a careful analysis of all the available data" (BMR Book 3, page 71). However, the analysis is not presented. Thus, the basis upon which spottail shiner and pumpkinseed were chosen to represent the diet of the largemouth bass in FISHRAND is not presented. Moreover, the basis for the particular combination of water column and benthic invertebrates in the diets of the pumpkinseed and spottail shiner is not provided. Finally, no results are presented for spottail shiner, so that the impacts of this assumption on PCB levels in largemouth bass prey cannot be determined. **BG-1.3(**

The realism of the FISHRAND bioaccumulation model (as developed for the Upper Hudson River) cannot be determined as a result of insufficient BMR description of the model development and calibration process. **BG-1.31**

To allow a full evaluation of the model, the EPA should provide the model-data comparisons described in Table 2-1 on scales which facilitate model-data comparison.

Table 2-1. Model-Data Comparisons Required to Evaluate EPA's Model Calibration		
Model Process	**Model-Data Comparison**	**Comments**
Hydrodynamic Model	Stage heights over a range of flows	Not provided
	Current velocity	Not provided
Sediment Transport Model	TSS during low flow	Provided
	TSS during high flow	Provided, however scales are inappropriate
	Sediment mass balance during floods	Not provided
	Sedimentation rate	Not provided
PCB Fate and Transport Model	PCB in water column	
	a. long term concentration trends	Provided, however scales are inappropriate
	b. annual loads	Provided, however data-based estimate imprecise
	c. seasonal patterns in concentration and load	Provided for TIP only
	d. short term changes in concentration during high flow	Not provided
	e. spatial patterns in concentration and load	Provided for TIP only
	PCB in sediments	
	a. cohesive and non-cohesive surface sediment trends	Results presented for hindcast only
	b. vertical profiles in cohesive sediments	Not provided
Bioaccumulation Model	Trends in PCB concentrations in biota	
	a. long term	Presentation of model results inappropriately compared to data
	b. response to short term events	No discussion/analyses of impact of elevated loadings in 1991-1993
	c. spatial gradients	Not provided

Additionally, EPA should provide all model input and output files with appropriate documentation. This will allow a thorough and complete evaluation of the EPA's model development and calibration.

SECTION 3

THE MODEL CALCULATIONS ARE OFTEN INCONSISTENT WITH THE DATA

3.1 EPA'S FATE AND TRANSPORT MODEL

3.1.1 The Model does not Predict Water Column PCB Levels Accurately

An important measure of the validity of a model is its ability to reproduce PCBs measured in the water column at various locations. EPA's model fails this test. The model overestimates the PCB flux at TID. As shown in BMR Figure 7-19, after about September 1992, the model diverges from the data, demonstrating a high bias in the model's estimate of PCB fluxes from the TIP. From September 1992 to September 1997, the model overstates cumulative PCB flux by about 300 kg. Averaged over 5 years, this represents an additional 0.16 kg/d from the pool. When compared to the average data-estimated load gain of 0.43 kg/d shown in BMR Figure 7-18, this bias is 37% above the actual load gain. No judgement can be made about the long-term performance of the model at Stillwater and Waterford because of the paucity of water column PCB data-based estimates for the 1991-97 calibration period. **BG-1.32**

Similarly, in the 1977-1997 hindcast (BMR Book 1, Figure 7-24), the model shows a high bias in the computation of in-river fluxes past Schuylerville. The model diverges from data starting in about 1981-82. By the end of simulation, the model has overstated PCB_{3+} fluxes by about 2,700 kg. This represents an over-estimate of the 1982-97 Schuylerville figures of about 45%. The average overestimate of about 0.5 kg/d also shows a large degree of error when compared to the average load gain across the TIP.

3.1.2 The Model's Predictions of PCB Levels in Sediments Downstream of the TIP are Inconsistent with Concentrations Measured in these Sediments

The 1998 surface sediment PCB concentrations (generated from the 1991-97 calibration) used at the start of the EPA's model predictions are inconsistent with available data.

As indicated by the model/data comparisons (Figure 3),[1] EPA's model performs well within the TIP. The model's calculations are close to the 1998 observed PCB levels. The model calculates a reduction in Reach 6-7 between 1991 and 1998, a trend consistent with the TIP data. However, the model grossly over-predicts surface sediment PCB_{3+} levels in Reach 5 and Reaches 2-4. The predicted 1998 reach average surface sediment PCB_{3+} levels are a factor of 2-3 higher than the observed 1991 data within these reaches. **BG-1.3**

The apparent increase in surface sediment PCB concentrations between 1991 and 1998 in Reach 5 and Reaches 2-4 of the river is inconsistent with both the observed temporal trends of the 1977-1997 hindcast as well as the observed trends in surface sediment TIP PCB data between 1991 and 1998. The hindcast depicts a gradual decline in surface sediment PCB concentrations in both cohesive and non-cohesive sediments over the 20 year period between 1977 and 1997 (BMR Book 2, Figure 7-25). If the model predicts an increase in surface sediment PCBs between 1991 and 1998, it would be inconsistent with this long-term trend, suggesting that something is wrong with the model. Moreover, analysis of data collected from the TIP in 1998 (O'Brien & Gere, 1999) indicates that average surface sediment PCB_{3+} concentrations in this reach of the river have declined from the levels observed in 1991. This confirms the trend observed in the data and indicates that the model predictions downstream of TID are incorrect. It is possible the model calibration began in 1991 with initial sediment concentrations that were incorrect (*i.e.*, too high) or the information presented in BMR Book 2, Figure 8-4 is incorrect.

3.2 EPA'S BIOACCUMULATION MODELS

3.2.1 FISHRAND does not Accurately Reproduce the Historical Fish PCB Levels

To provide a proper evaluation of the FISHRAND predictions, the predicted mean concentrations (as displayed in BMR Book 4, Figure 6-4) were compared with the mean values

1

Reach average PCB levels were calculated as an area weighted average using PCB_{3+} concentrations in cohesive and non-cohesive sediments (Table I-2) and corresponding sediment areas (BMR Table 6-2). For Reach 8 (TIP), the model results are compared to the 1998 GE data. For downstream reaches, the model results are compared to the 1991 GE data. Model results were gleaned from Book 2 Figure 8-4 of the BMR and converted to a PCB_{3+} basis based on reach specific PCB_{3+} fractions calculated from the 1991 sediment survey data (O'Brien & Gere, 1993).

of each year's measured fish PCB levels. The comparisons for largemouth bass from Thompson Island Pool and Stillwater are shown in Figure 4. These comparisons show that FISHRAND predicts average PCB levels that differ substantially from the measured levels, failing to accurately reproduce both the magnitude and the year-to-year trends of the data. The differences are most pronounced at Stillwater, where the model's predictions are two to three times higher than those measured by NYSDEC.

A further deficiency of the model is that it does not accurately portray the difference in PCB levels between the largemouth bass from Thompson Island Pool and Stillwater. This is shown in Figure 5, which shows the ratios of average PCB levels at these locations calculated from data and from the FISHRAND results. FISHRAND computes similar concentrations at the two locations, whereas the data clearly indicate that levels from Stillwater are significantly lower than levels from Thompson Island Pool.

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SECTION 4

THE MODELS ARE INTERNALLY INCONSISTENT

4.1 EPA's FATE AND TRANSPORT MODEL

4.1.1 The 1991-1997 Calibration and 1977-1997 Long Term Validation Appear to Compute Inconsistent Surface Sediment PCB Concentrations

Surface sediment PCB concentrations produced by the 1991-1997 calibration and the 1977-1997 hindcast appear to produce grossly different predictions of surface sediment PCB concentrations in 1998 for Reaches 2 through 7. Surface sediment PCB levels are lower at the start of projections in Reach 6-7 and higher at the start of projections in Reaches 2 through 5 than at the end of the 1977 to 1997 hindcast. This discrepancy renders the model unusable for projecting future PCB levels in water and sediment. **BG-1.34**

EPA's long-term hindcasts (1977-1997) were performed to evaluate the calibration achieved over the 1991 to 1997 period by checking model consistency with long term trends in the water column and sediment data. This two step approach to model calibration yielded two estimates of PCB levels in 1998 including that produced by:

- the 1991-1997 model calibration, and
- the 1977-1997 hindcast.

If the model accurately accounts for the various PCB fate and transport processes, these two projections of surface sediment PCB concentrations should be consistent. The results of the model hindcast and model calibration, however, reveal a large discrepancy in the two 1998 estimates of surface sediment PCB levels below the TIP.

A comparison of surface sediment PCB_{3+} predicted by the hindcast and that predicted by the 1991-97 calibration was developed from the data presented in the BMR. The hindcast estimates of 1998 surface sediment PCB concentrations were developed from BMR Book 2

Figure 7-25. To compare to the calibration's 1998 average TIP PCB concentrations presented in BMR Book 2 Figure 8-4, the six TIP subreaches designated by the EPA were combined into a single TIP area weighted average PCB_{3+} concentration using the cohesive and non-cohesive areas presented in BMR Book 2 Table 6-2. A similar process was followed for Reaches 2 through 7.

For comparison to the long-term hindcast, the 1998 surface sediment PCB_{3+} concentrations calculated by the calibration were converted from a total PCB to a PCB_{3+} basis. This was accomplished by subtracting the mono- and di-chloro fractions from the total PCB estimate based upon PCB homolog data collected in 1991. This process reasonably assumes that the fraction of mono- and dichlorinated PCBs did not change between 1991 and 1998.

The two estimates of 1998 surface sediment PCB_{3+} concentrations are presented in Figure 6. While the two estimates of PCB_{3+} are consistent within the TIP, there are gross differences in the downstream reaches. The surface sediment PCB_{3+} concentration in Reaches 6-7 in the initial conditions of the 21 year forecast as generated from the 1991-97 calibration is 50% lower than at the end of the model hindcast. In contrast, the surface sediment PCB_{3+} initial conditions for the forecast are 200-300% higher in reaches 5 and 2-4 than the ending conditions predicted by the hindcast.

This discontinuity in surface sediment PCB_{3+} is graphically presented in Figure 7. The gradual decline predicted by the hindcast over the period 1977 to 1997 is interrupted by the drastic decrease (Reaches 6-7) and increase (Reaches 5 and 2-4) that occurs in 1998. This discontinuity shows an inconsistency between the calibration and the hindcast. This basic error renders the model's predictions unreliable and calls into question the 1991-1997 calibration, whose results were used to set the initial conditions for the forecasts. Whatever the explanation of the inconsistency, it must be identified and resolved prior to using the model for prediction purposes.

4.1.2 Computed DOC Partitioning Within the Sediment is Inconsistent with Reported Parameter Values

Another apparent model inconsistency arises from the 1991-97 total PCB mass balance (BMR Book 1, Figure 7-29). In the TIP, the sediment-water mass transfer of dissolved PCB accounts for 62 kg while PCB sorbed to DOC accounts for 389 kg. This difference between dissolved and DOC-bound sediment water PCB flux is inconsistent with the PCB partitioning parameters presented in the BMR.

Using parameters presented in this report (BMR Book 2, Tables 7-1, 7-4 and 7-5), the calculated fraction of total PCBs that is DOC-bound in the TIP is a factor of 1.5-2.0 higher than the dissolved fraction. Because the same temperature slope factor for PCB partitioning affects both phases equally and the sediment-water transfer rate is the same for both phases, the sediment-water mass transfer associated with the two phases should only differ by a factor 1.5-2.0. This is not consistent with the greater than 6-fold difference presented in BMR Book 2, Figure 7-29. **BG-1.35**

4.2 EPA'S BIOACCUMULATION MODELS

4.2.1 The Bioaccumulation Models are not Developed in a Consistent Fashion

The BMR states that the bioaccumulation models "provide complementary views of PCB uptake" (BMR Book 3, page 11). To provide a valid basis for comparison among models, one must use a consistent set of assumptions. The most significant inconsistency among the models is the relative contribution of sediment and water column PCBs to fish. The BSM model indicates "a significant sediment food chain contribution to body burden" (BMR Book 3, page 50) for brown bullhead, goldfish and largemouth bass. Yet, FISHRAND has a minimal sediment contribution for the largemouth bass (Page 75 of BMR Book 3 (indicating that largemouth bass derive much of their body burden from water column sources)). **BG-1.36**

In addition, the composition of the fish diet differs among the models. For example, the PFCM assumes that the spottail shiner consumes equal amounts of benthic and water column invertebrates (BMR Book 3, Section 5.4). In contrast, in FISHRAND it is assumed to consume 75% water column invertebrates (BMR Book 4, Figure 3-2). In addition, 67% of the forage fish diet consists of water column invertebrates in PFCM (BMR Book 3, page 26), while the value for FISHRAND is 75 to 80% (BMR Book 4, Figure 3-2). **BG-1.37** **BG-1.38**

The composition of the forage fish community was also developed in an inconsistent fashion. The PFCM forage fish diet accumulation factor (FFBAF) was developed using all small fish (<10 cm) in the EPA Phase II data set. The piscivorous fish diet bioaccumulation factor (PFBAF) was developed using the relationship between PCB concentrations in largemouth bass and pumpkinseed reported in the NYSDEC data set. On the other hand, in FISHRAND largemouth bass diet consists of a combination of spottail shiner and pumpkinseed. All of these analyses are intended to estimate the same thing, namely transfer of PCBs from invertebrates to forage fish to predators. The BMR does not explain the basis for the different compositions of the forage fish community used in the models, but this discrepancy renders the models and their results incompatible. **BG-1.39**

Finally, the distributions of feeding preferences are uniform in PFCM and triangular in FISHRAND (p.18). This inconsistency raises questions about the validity of the bioaccumulation models. **BG-1.40**

4.2.2 The Multiple Bioaccumulation Models Yield Inconsistent Results

Although the BMR states that agreement among the models provides a check on the various approaches, agreement is not sufficiently demonstrated. To the contrary, the BSM, the PFCM and FISHRAND give significantly different predictions and indicate different relationships among PCB levels in fish, water and sediment (Figure 8). For example, during the calibration period, concentrations in largemouth bass computed at Stillwater by FISHRAND are always greater than concentrations computed by PFCM. **BG-1.41**

4.2.3 The Water and Sediment PCB Concentrations used in the Predictions of Future Fish PCB Concentrations Appear to be Inconsistent with the Values Presented in the Fate and Transport Section of the BMR

The bioaccumulation models use two sets of water and sediment PCB concentrations. **BG-1.42**
The PFCM used the first set, shown in BMR Book 4 Figures 7-1 and 7-2 and FISHRAND used the second set, shown in BMR Book 4 Figures 7-9 and 7-10.

The water column PCB concentrations purported to be from the fate and transport model for TID (BMR Book 2, Figure 8-2) begin at about 55 and 45 ng/L in 1998 for the two Fort Edward boundary concentration scenarios. A declining trend is shown from 1998 to 2000. In contrast, the concentrations presented for the PFCM (BMR Book 4, Figures 7-1 and 7-2) begin at about 27 ng/L for both scenarios and decline for only one year. Rather than decrease between 1999 and 2000, the concentrations increase. Other differences exist through the entire projection period.

Water column concentrations presented for FISHRAND (BMR Book 4, Figures 7-9 and 7-10) are not directly comparable to the concentrations presented in BMR Book 2 Figure 8-2 because different averaging periods are used and whole water concentrations are presented in one case and dissolved concentrations in the other. However, significant differences are evident. BMR Book 4 Figures 7-9 and 7-10 show monthly average dissolved PCB concentrations at River Mile 189 peaking in the summer at about 22 ng/L in 1998, 20 ng/L in 1999 and 17 ng/L in 2000. Given that dissolved PCBs constitute most of the water column PCBs at the lower river flows characteristic of the summer period, these peak levels are much lower than expected based on the levels shown in BMR Book 2 Figure 8-2. Also, the apparent lack of concentration differences between the upstream source scenarios (compare BMR Book 4, Figures 7-9 and 7-10) is inconsistent with BMR Figure 8-2. Finally, PCB concentration differences between River Mile 189 and River Mile 168 on BMR Figures 7-9 and 7-10 are inconsistent with the spatial patterns apparently generated by the fate and transport model. The mass balance graphic from the fate and transport model (BMR Book 2, Figure 7-29) indicates that the PCB mass fluxes passing River Miles 189 and 168 are approximately equal. Given that river flow and TSS are higher at

River Mile 168 than at River Mile 189, the equal mass flux predictions imply that the dissolved PCB concentrations are lower at River Mile 168 (despite a higher assumed TSS organic content at River Mile 189). In fact, BMR Book 4 Figures 7-9 and 7-10 indicate that the dissolved PCB concentrations at River Mile 168 are approximately twice the concentrations at River Mile 189.

The BMR states that sediment concentrations predicted by the fate and transport model are relatively insensitive to the Fort Edward boundary concentration (see BMR Book 4, Figure 8-4). In apparent contradiction to this statement, a comparison of BMR Book 4 Figures 7-1 and 7-2 indicates that assumptions about PCB concentrations in water at the Fort Edward boundary concentration have a large impact on the sediment concentrations. However, the impacts implied by these graphics are illogical. For example, the 1998 concentrations differ between the figures even though they should represent the same starting point. Furthermore, the two sets of graphics inconsistently present the relative differences in sediment concentrations among the various reaches of the river. **BG-1.43**

4.2.4 FISHRAND Predictions of Fish PCB Levels at Stillwater are not Supported by the Water and Sediment PCB Levels on which they are Based

BMR Book 4 Figure 7-13 shows that largemouth bass, yellow perch and pumpkinseed PCB levels are predicted to decline from 1998 to 1999 and then increase from 1999 through 2001 (pumpkinseed and yellow perch) and 2002 (largemouth bass). Over this period, the increases are a factor of two for largemouth bass (ca., 450 to 900 ppm lipid) and yellow perch (ca., 150 to 300 ppm lipid) and almost a factor of three for pumpkinseed (ca., 100 to 290 ppm lipid). These increases imply exposure concentration increases of a factor of three or more. However, the graphics displaying the water and sediment exposure concentrations (BMR Book 4, Figures 7-9 and 7-10) show no increases of this magnitude. In fact, the sediment PCB concentrations monotonically decrease. The water PCB concentrations decrease from 1998 through 2000 and have no annual trend through 2002. **BG-1.44**

4.2.5 The Calibration and Projection Simulations are Inconsistent

While FISHRAND concentrations are always greater than PFCM during the calibration period, concentrations predicted by the two models after 2000 are very similar, as shown in Figure 8. The BMR does not explain the reason for this change in relationship.

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SECTION 5

EPA'S MODEL DEVELOPMENT IS INCONSISTENT WITH ESTABLISHED THEORY AND SITE-SPECIFIC DATA

5.1 EPA'S FATE AND TRANSPORT MODEL

5.1.1 Solids Deposition is not Properly Modeled

Realistic and accurate modeling of sedimentation in the Upper Hudson River is important because deposition processes control long-term trends in surficial bed PCB concentrations and, hence, PCB levels in biota. A sediment transport model applied to the Upper Hudson River must be able to accurately predict pool-average sedimentation rates and be able to properly simulate differences between deposition processes in cohesive and non-cohesive bed areas. Without the ability to simulate deposition processes accurately and realistically in both cohesive and non-cohesive bed areas, a sediment transport model will not accurately predict long-term sediment bed changes and the associated PCB fate model projections will be highly uncertain.

The gross settling relationship used in the sediment transport model (BMR Book 2, Figure 7-1) is flow dependent, with a relatively low settling speed (1 m/day) at low flows and a higher settling speed (8 m/day) at high flow rates. The BMR incorrectly claims that "the gross settling mechanism in EPA's model is similar to the empirical relationship used to model particle settling in other river systems (Gailani et al., 1991; Gailani et al., 1996; Ziegler and Nisbet, **BG-1.45**
1996)" (BMR Book 1, page 37). The referenced papers all involve application of various versions of SEDZL, which is the sediment transport model that GE updated and applied to the Upper Hudson River (QEA 1999). SEDZL uses mechanistic formulations that were developed from laboratory data to simulate cohesive and non-cohesive sediment deposition processes. In contrast, the gross settling relationship used in the EPA model is not data-based; it is an unconstrained function that was arbitrarily adjusted during model calibration. This relationship is not similar, or of equal scientific credibility, to the formulations used in SEDZL.

The EPA model incorrectly uses the same gross settling speed relationship in both cohesive and non-cohesive bed areas, ignoring the significant differences between the depositional environments of these two bed types. Typically, cohesive bed areas are lower energy environments than non-cohesive areas, making cohesive areas more conducive to deposition. Because of this difference, effective settling speeds are generally higher in cohesive areas than in non-cohesive areas, especially at high flow rates. Thus, assuming that the same gross settling relationship applies in both areas is fundamentally incorrect. **BG-1.46**

This flaw has a significant impact on both sediment transport and PCB fate simulations. It leads to under-predicted sedimentation rates in the cohesive bed areas and over-predicted rates in the non-cohesive bed areas. To illustrate this point, consider that although the EPA and GE sediment transport models predict approximately the same average sedimentation rate for the TIP (*i.e.*, 0.16 and 0.20 cm/yr, respectively), the rates for cohesive and non-cohesive sediments are very different. The GE model predicts average TIP deposition rates in the cohesive and non-cohesive bed areas of 0.81 and 0.03 cm/yr, respectively (QEA 1999). The EPA model predicts average rates of about 0.4 and 0.09 cm/yr in cohesive and non-cohesive bed areas, respectively (estimated from BMR Book 2, Figure 7-27).

Probability of deposition also is important and needs to be included in cohesive and non-cohesive deposition formulations (QEA 1999). As sediment particles or flocs settle in the water column, the probability that a particle or floc that hits the sediment bed becomes permanently attached decreases from a value of one for a quiescent flow to approximately zero for high flow rates. Because EPA's model does not incorporate probability of deposition, these effects on deposition processes are not accurately or realistically simulated.

Neglecting probability of deposition on settling causes the model to simultaneously simulate high deposition and resuspension fluxes during high flow events (see BMR Book 2, Figure 7-2). This is inconsistent with accepted sediment transport theory, for both cohesive and non-cohesive beds. At a particular cohesive bed location, a transition will occur as bottom shear stress (flow rate) increases from net deposition (high gross deposition and low/zero gross resuspension) to net erosion (low/zero gross deposition and high gross resuspension) until bed **BG-1.47** armoring occurs. This transition is caused by decreasing probability of deposition (which approaches zero at higher shear stresses) and increasing erosion rate (until bed armoring occurs) as bottom shear stress increases. High gross deposition and resuspension do not occur simultaneously in cohesive bed areas. Similarly, non-cohesive suspended load transport theory, based on a large body of experimental and theoretical research, shows that simultaneous resuspension and deposition does not occur in non-cohesive bed areas. Thus, the formulations will not correctly simulate resuspension and deposition processes during high flow events, with significant impacts on PCB fate simulations.

5.1.2 Erosion of Non-Cohesive Sediments is not Properly Modeled

Suspended load transport of non-cohesive sediments in rivers has been studied extensively during the last 50 years. Various formulations and models have been developed, based upon laboratory and field data, and successfully applied to a large number of riverine systems. EPA ignores this information in the development of its sediment transport model and instead develops a new model that ignores all previous research concerning non-cohesive suspended load transport. Indeed, no references or experimental data were cited to support the validity of Equations (5-6) and (5-9) and examination of these equations reveals significant problems.

The resuspension velocity, BMR Book 1 Equation (5-6), was assumed to be a linear function of bottom shear stress with no experimental or theoretical basis. This assumption is not even qualitatively correct because non-cohesive resuspension processes are known to be non-linear functions of bottom shear stress, (*e.g.*, van Rijn 1984). Temporally varying the critical bottom shear stress using BMR Book 1 Equation (5-9) will cause the resuspension velocity to approach zero as time increases, which is functionally correct but has no theoretical or experimental basis. Thus, it is unclear whether this formulation is even qualitatively correct and should be used for modeling bed armoring.

This model contains four free parameters that were adjusted during model calibration: β_3, β_5, β_6 and t_{rec}. These four parameters are 'knobs' that can be turned in the model without physical basis or constraints. The BMR does not justify the recovery period, t_{rec}, and provides no explanation of how this value was determined. In fact, this value was not even reported. The purpose of the recovery period is to account for changes in the composition of the surficial layer of the non-cohesive bed after a flood due to deposition of relatively fine-grained sediments. The armored layer becomes 'de-armored' during low to moderate flow periods. This de-armoring process is highly variable in the Upper Hudson River, both temporally and spatially, and attempting to simulate this complex process as EPA has done is dubious.

The values of β_3, β_5 and β_6 were determined during model calibration (BMR Book 2, Table 7-3). All model segments in the TIP use the same values. Similarly, spatially constant parameters, with values different from the TIP, were specified downstream of the TIP. Significant spatial variation in non-cohesive bed properties occurs in the TIP and the reaches downstream of the TIP. Using constant parameter values in a reach is unrealistic.

Overall, the non-cohesive suspended load transport formulations are not scientifically credible. Previous comments by GE and the EPA modeling peer reviewers emphasized the need to include a viable non-cohesive sediment transport sub-model in the EPA modeling framework for the Upper Hudson River. In addition, GE provided to EPA a detailed presentation of a non-cohesive suspended load transport model, developed from the peer-reviewed literature. EPA did not rely on this information, instead using new formulations, (BMR Book 1 Equations 5-6 and 5-9, that are speculative and not based on laboratory or field data. Parameterization of the model is poorly constrained and use of spatially constant parameter values is dubious. Therefore, EPA's model simulation of non-cohesive suspended load transport is invalid. **BG-1.4**

5.1.3 There is No Basis for the Significant Differences in the Descriptions of the Dominant Fate and Transport Processes in the Thompson Island Pool and the Rest of the River

5.1.3.1 Hydrodynamics and Sediment Transport

Although EPA developed a hydrodynamic model for the TIP, it did not develop or apply a hydrodynamic model downstream of the TIP. Thus, bottom shear stresses cannot be estimated with any confidence in these reaches. Instead, the model uses a single relationship for bottom shear stress and flow rate for all segments downstream of the TIP, the derivation of which the BMR does not explain (BMR Book 2, Table 7-3). Use of this single relationship downstream of the TIP is invalid because it is inconsistent with the significant variability demonstrated by EPA's model within the TIP. **BG-1.49**

The β_5 parameter controls the non-cohesive bed armoring rate. In BMR Book 1 Equation (5-9), different values were used in the TIP (6.0) and downstream of the TIP (2.0). Decreasing β_5 by a factor of three causes a three-fold increase in non-cohesive resuspension rate in the downstream reaches for the same bottom shear stress as in the TIP. The BMR fails to explain this large increase in non-cohesive resuspension. In addition, the seven reaches between TID and Troy were assumed to have the same non-cohesive resuspension properties, as represented by one set of parameter values, which is an obvious gross over-simplification of non-cohesive sediment dynamics in those reaches (as evidenced by the parameter variation used within the TIP). **BG-1.50**

The model also represents cohesive resuspension properties downstream of the TIP by a single set of parameters with no description of parameter determination. Significant variation (up to five-fold) in cohesive resuspension properties exists between the seven reaches located downstream of the TID (QEA 1999), which makes use of spatially constant parameters a poor approximation. **BG-1.51**

EPA decreased gross settling speed downstream of Schuylerville (RMI 181.4) because "the flow-velocity relationships change as one moves downstream, these parameters have been established on a reach-specific basis according to cumulative drainage area (BMR Book 1, page 71). The BMR does not explain or justify how the flow-velocity relationship changes as one moves downstream or why and how these changes should affect the settling speed relationship. **BG-1.52** Table 7-2 of Book 2 also appears to contain errors in the areas downstream of the Hoosic River because the drainage area increases and flow rates are inconsistent with upstream values. The **BG-1.53** drainage area increase for Segments 40-41 and 47 is only 0.16, which is considerably lower than the increases for Segments 29-39 (all greater than 1). Transition flow rates in Segments 40-41 and 47 are also much lower than transition flow rates in Segments 1-39. In addition, BMR Book 2 Table 7-2 provides no information for segments 42-46.

The BMR also contains an inaccurate statement about the critical shear stress for cohesive sediment resuspension (page 40 of Book 1): **BG-1.54**

> Using results from laboratory flume experiments, HydroQual (1995) concluded that the critical shear stress parameter in Equation 4-1 for cohesive sediments in TIP was 1.0 dynes/cm^2. This value was used as the critical shear stress for cohesive sediment resuspension in both DOSM and EPA's model. Recent experimental results by Zreik et al. (1998) claim to achieve better accuracy of critical shear measurements at very low flows and suggest that critical shear stress for cohesive sediment resuspension might actually be closer to 0.1 dynes/cm^2. Consequently, the non-flow-dependent background resuspension in EPA's model may be considered to represent resuspension that occurs under low flow conditions that generate bottom shear stresses between 0.1 and 1.0 dynes/cm^2.

The statement on shear stress units is incorrect. In Zreik et al. (1998), flume tests were conducted for shear stresses ranging from 0.1 to 1.0 Pa. (Note that Pa stands for Pascals and 1 Pa = 1 N/m^2 = 10 dynes/cm^2.) Thus, the range of the Zreik experiments was 1 to 10 dynes/cm^2, which is a factor of 10 higher than stated in the BMR. In addition, even if the bottom shear stress exceeds the critical shear stress, resuspension will not necessarily occur because of bed armoring processes. Bed armoring depends on temporal variations in the vertical distribution of bed properties at a particular location.

In sum, sediment transport model results downstream of the TIP are not constrained because no hydrodynamic model was used in those reaches to develop relationships between bottom shear stress and flow rate, as was done in the TIP. Without the ability to predict bottom shear stress accurately, one cannot simulate with confidence cohesive or non-cohesive resuspension. In addition, significant variations in bed properties occur among the seven reaches downstream of the TIP, and neglecting this spatial variation adds further uncertainty and inaccuracy to the model.

5.1.3.2 Low-Flow PCB Flux between Sediment and Water

The description of low-flow sediment-water PCB exchange in EPA's model is unjustifiable in three regards:

1. mass transfer coefficients differ in the TIP and downstream reaches,
2. mass transfer coefficients differ in cohesive and non-cohesive sediments, and
3. the flux is largely controlled by EPA's hypothesized process of low flow resuspension for which there is no technical basis.

EPA's assumption that sediment-water exchange processes occur at a greater rate in TIP than in the downstream reaches is inconsistent with measured water column PCB concentrations. Low-flow sediment PCB loading were calculated using EPA's model mass transfer and partitioning parameters and 1991 sediment PCB data. Results are plotted for TIP in Figure 9. The average monthly TIP total PCB loading calculated in this analysis is approximately 1.3 lb/d, which is consistent with low-flow water column data from the 1990's. The seasonality in the EPA's model mechanisms is very strong, as evidenced by the approximately five-fold increase in loading between January and June. The plots on Figure 9 also indicate that the low-flow resuspension portion of the TIP load in EPA's model accounts for a large portion (more than 70%, on average) of the total load. Therefore, the major low-flow sediment-water exchange process represented in EPA's model is a mechanism whose existence cannot be directly supported by data. A similar analysis was performed for the reach from TID to the Northumberland Dam (TID-ND), plots are shown in Figure 10.

Available data show that sediment-water PCB exchange mechanisms are similar in TIP and TID-ND, which is contrary to the representation in EPA's model. The TID-ND loading **BG-1.55** exhibits seasonality similar in magnitude to that of the TIP load (Figure 12). EPA's mean monthly loading (as calculated with EPA's model parameters) from TID-ND sediments is approximately 0.3 lb/d, as shown on Figure 10. In contrast, 1997-99 water column data collected from the Schuylerville station (just downstream of the Northumberland Dam) indicate that water column loads measured at Schuylerville are consistently greater than those measured at TID (Figure 11). In fact, the incremental loading from TID-ND is approximately 0.6 lb/d (Figure 12). The EPA's model calibration period (1991-97) had very little water column PCB data collected downstream of TID, and therefore, the model has not reproduced sediment PCB loadings in these reaches. EPA should refine the its model calibration to include the 1997-1998 water column PCB data collected from Schuylerville.

The BMR's pore water mass PCB transfer coefficient (k_f) differs in cohesive and non-cohesive sediments (BMR Book 2, Figure 7-6a). EPA's justification for assigning a different k_f to cohesive and non-cohesive sediments is purely speculative, as there are no site-specific data to support this hypothesis. Specifying a higher mass transfer coefficient in cohesive sediments results in poor estimates of sediment–water exchange. In addition, this hypothesis increases uncertainty in model results because it necessitates the use of an additional unconstrained parameter. Moreover, in the absence of supporting data, specification of spatially variable parameters is inappropriate. **BG-1.56**

In addition to EPA's use of a spatially varying pore water PCB mass transfer coefficient, there are three fundamental problems with EPA's particulate sediment-water PCB exchange mechanism:

1. There are no data to support simulation of this mechanism. Particulate mass transfer cannot be differentiated from pore water exchange, leaving the process (and model) inappropriately constrained. **BG-1.57**

2. There are no data to support different particulate phase mass transfer coefficients in different reaches of the river. The mass transfer rate used in the model is approximately 5 times greater in TIP than in the reach from TID to Northumberland Dam (BMR Book 2, Figure 7-6b). The mixing mechanisms represented by this process occur throughout the Upper Hudson River, and not just in TIP, and EPA's assumption that greater transfer occurs in TIP is purely speculative. This leads to an

inappropriate focus on the TIP sediments as potential PCB sources and leads to an inconsistency between the model and data downstream of TID. **BG-1.57**

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3. The mass transfer coefficient is uncertain because of uncertainty in the conditions under which partitioning occurs. The net PCB loading from this mechanism depends on the fraction of particulate phase PCBs that settles back to the sediments after partitioning to the water column. This fraction depends on the concentration of solids during partitioning, which, depending on the depth over which this exchange occurs, will vary greatly (the solids concentration in the bed is on the order of 1 kg/L, while that in the water column at low flows is typically less than 10 mg/L) (Figure 13). The assumed solids concentration under which this partitioning occurs can result in significant differences in how much particulate phase PCBs are transferred to the water column. The high sensitivity of the mass loading from the EPA's model particulate transfer mechanism adds significant uncertainty. The mass transfer coefficient that was calibrated in EPA's model depends on the assumed depth over which this exchange occurs. In this regard, the process is not well constrained. Therefore, the application of this mechanism in EPA's model and the mass transfer coefficients calibrated have little physical relevance and are best represented as a bulk process in conjunction within pore water exchange.

A mechanistic representation of each of the processes controlling sediment-water exchange with Hudson River-specific parameterization is optimal when data are available to appropriately constrain the model. In the absence of data to represent these mechanisms, it is appropriate to model their combined effect empirically using a global sediment-water exchange coefficient that is calibrated to seasonal sediment PCB loadings under low flow conditions. This limits the uncertainty associated with simulating multiple processes that each have uncertain parameters. To simulate sediment-water exchange, this single process should be applied consistently across all reaches of the river and all sediment types, unless data to differentiate between processes and sediment bed types are available. Since all of the processes that potentially contribute to low flow sediment-water PCB exchange result in the net transfer of particulate phase PCBs to the overlying water column, they can be simulated as a single, empirical relationship applied to the dissolved plus DOC phases.

5.2 EPA'S BIOACCUMULATION MODELS

5.2.1 The Development Of The Gobas Model does not Include a Full and Accurate Evaluation of the Site-Specific Data and is at Variance with Many of these Data

The lipid contents used in the Gobas model were calculated directly from the values measured by NYSDEC. For largemouth bass and brown bullhead, these values were for fillets. On average, whole-body lipid contents are approximately 2.5 times fillet levels in several species of fish. Therefore, the lipid content used in the largemouth bass model appear to be too low. **BG-1.58**

In the BMR, the water column component of the spottail shiner diet is considered to be smaller than the water column component of the pumpkinseed (PFCM) or similar to the water column component of pumpkinseed (FISHRAND). This contrasts with several lines of evidence that suggest that spottail shiner consumes a somewhat greater proportion of water column-based invertebrates than pumpkinseed. For example, the EPA Phase II data set shows that the average number of chlorines per biphenyl is greater in spottail shiner, consistent with a less dechlorinated PCB source than pumpkinseed. In addition, the Exponent gut content study shows that the spottail shiner gut contents include a greater proportion of invertebrate prey items that are unique to the water column. Finally, Cladocera were relatively common in the guts of spottail shiner, while tubificids were relatively uncommon, suggesting a water column preference. **BG-1**

EPA's use of default growth rates with the availability of the extensive data set of Hudson River fish is unwarranted. These default growth rates appear to be considerably greater than the values measured in the Hudson River. EPA should use the available site specific data or fish growth rates. **BG-1.60**

5.2.2 The Contribution of Water Column PCBs to the Largemouth Bass Food Web in FISHRAND is Grossly Overestimated

To properly estimate the relative importance of water column and sediment PCBs to the food web, the concentration of PCBs on particulate matter must be calculated correctly. Because the particulate matter forms the base of the food chain. The concentration of PCBs on sediment particulate matter to which the food web is exposed in FISHRAND is computed by EPA's fate and transport model. In contrast, the concentration of PCBs on water column particulate matter is calculated by multiplying the dissolved PCB concentration computed by EPA's model by a partition coefficient. The partition coefficients used in EPA's fate and transport model (Log K_{POC}=5.82) and FISHRAND (Log K_{POC}=6.6) differ by a factor of six (Figure 14). Thus, the concentration of PCBs on water column particulate matter to which the food web is exposed is overestimated by a factor of six. This incorrectly increases the degree of bioaccumulation and therefore the relative importance of water column PCBs. **BG-1.61**

5.2.3 The Contribution of Water Column PCBs to the Largemouth Bass Food Web in PFCM is Grossly Overestimated

The average diet (C_{diet} in Book 3, Equation 3-4) appears to be calculated as the weighted average of lipid-based concentrations. Although not presented, the equation for this parameter appears to be: **BG-1.62**

$$C_{diet,l} = C_{wci,l}\, p_{wci} + C_{bi,l}\, p_{bi} \qquad (1)$$

where:

- $C_{diet,l}$ = concentration of PCBs in the diet of the forage fish (µg/g lipid diet)
- $C_{wci,l}$ = concentration of PCBs in water column invertebrates on a lipid basis (µg/g lipid wci)
- $C_{bi,l}$ = concentration of PCBs in benthic invertebrates on a lipid basis (µg/g lipid bi)
- p_{wci} = proportion of water column invertebrates in the diet (g wet wci/g wet diet)
- p_{bi} = proportion of benthic invertebrates in the diet (g wet bi/g wet diet)

The weights (p_{wci},p_{bi}) are based upon the analysis of dietary information (67% water column 33% benthic, BMR Book 3, page 26), and therefore are based presumably upon an estimate of the relative biomass of each prey type consumed. This means that the calculation of the weights and concentrations are inconsistent because the units in Equation 1 do not cancel:

$$\frac{\mu g}{glipid, diet} \neq \left(\frac{\mu g}{glipid, wci}\right)\left(\frac{gwet, wci}{gwet, diet}\right) + \left(\frac{\mu g}{glipid, bi}\right)\left(\frac{gwet, bi}{gwet, diet}\right) \qquad (2)$$

To correct the equation, the lipid contents of the water column invertebrates and benthic invertebrates must be included in the calculation. One way to do this is to compute the average wet weight-based concentration of PCBs in the diet of the forage fish (μg/g wet diet) and the average lipid content in the diet (g lipid/g wet diet). Then, simply divide one by the other to calculate the average lipid-based concentration of the diet (μg/g lipid). The average wet weight-based concentration of PCBs in the diet is given by:

$$C_{diet,w} = C_{wci,w} p_{wci} + C_{bi,w} p_{bi} \qquad (3)$$

where:

$C_{diet,w}$ = average dietary PCB concentration on a wet weight basis (μg/g wet diet)

$C_{wci,w}$ = concentration of PCBs in water column invertebrates on a wet weight basis (μg/g wet wci)

$C_{bi,w}$ = concentration of PCBs in benthic invertebrates on a wet weight basis (μg/g wet bi)

Similarly, the average lipid content of the diet is given by:

$$f_{lip,diet} = f_{lip,wci} p_{wci} + f_{lip,bi} p_{bi} \qquad (4)$$

where:

$f_{lip,diet}$ = lipid content of the diet (g lipid/g wet diet)

$f_{lip,wci}$ = lipid content of the water column invertebrates (g lipid/g wet wci)

$f_{lip,bi}$ = lipid content of the benthic column invertebrates (g lipid/g wet wci)

Then, the average lipid-based PCB concentration in the diet is:

$$C_{diet,l} = \frac{C_{diet,w}}{f_{lip,diet}} \tag{5}$$

The average lipid-based dietary concentration can be calculated by combining Equations 3, 4 and 5. Substituting $C_{wci,l} \cdot f_{lip,wci}$ for $C_{wci,w}$ in Equation 3, make a similar substitution for benthic invertebrates, and using the following values from the BMR:

p_{wci} = 0.67 (BMR Book 3, page 26)

p_{bi} = 0.33 (BMR Book 3, page 26)

$f_{lip,wci}$ = 0.0021 (BMR Book 4, Table 6-1)

$f_{lip,bi}$ = 0.022 (BMR Book 4, Table 6-1)

to yield:

$$C_{diet,l} = \frac{C_{wci,l}(0.0021)(0.67) + C_{bi,l}(0.022)(0.33)}{(0.0021)(0.67) + (0.022)(0.33)} = (0.16)C_{wci,l} + (0.84)C_{bi,l} \tag{6}$$

Thus, by incorrectly using Equation 2 with weights equal to 0.67 (water column) and 0.33 (benthos), EPA's model greatly overestimates the contribution of water column PCBs to the fish. The true weights for the lipid-based concentrations should be 0.16 and 0.84, respectively. This is because the benthic invertebrates have a much higher lipid content than water column invertebrates, which means that for the same consumed biomass, benthic invertebrates contribute more PCBs.

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FIGURES

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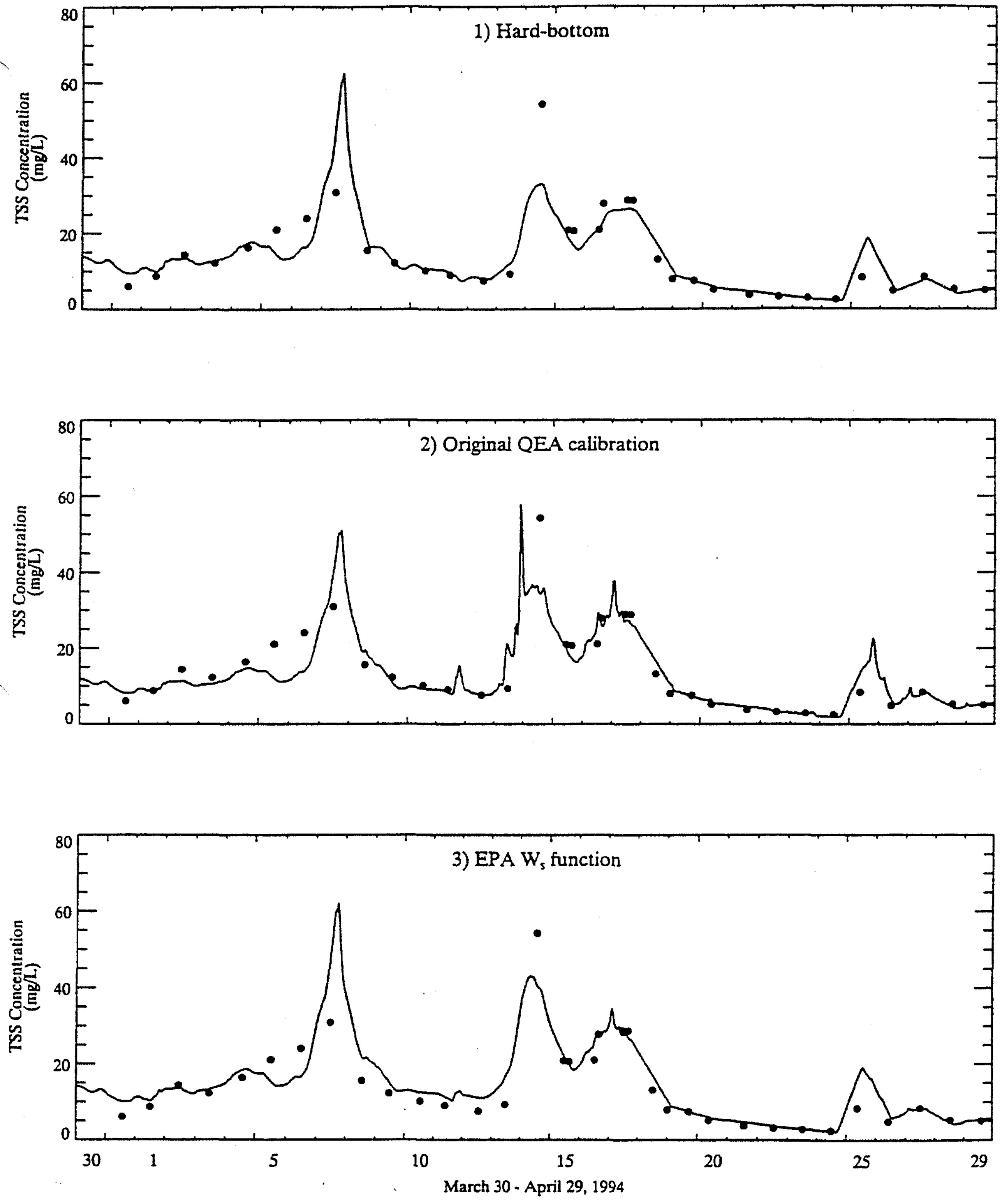

Figure 1. Comparison of TID TSS concentrations for three different scenarios:
1) original QEA calibration; 2) hard-bottom (no depostition/resuspension);
3) using EPA W_s function.

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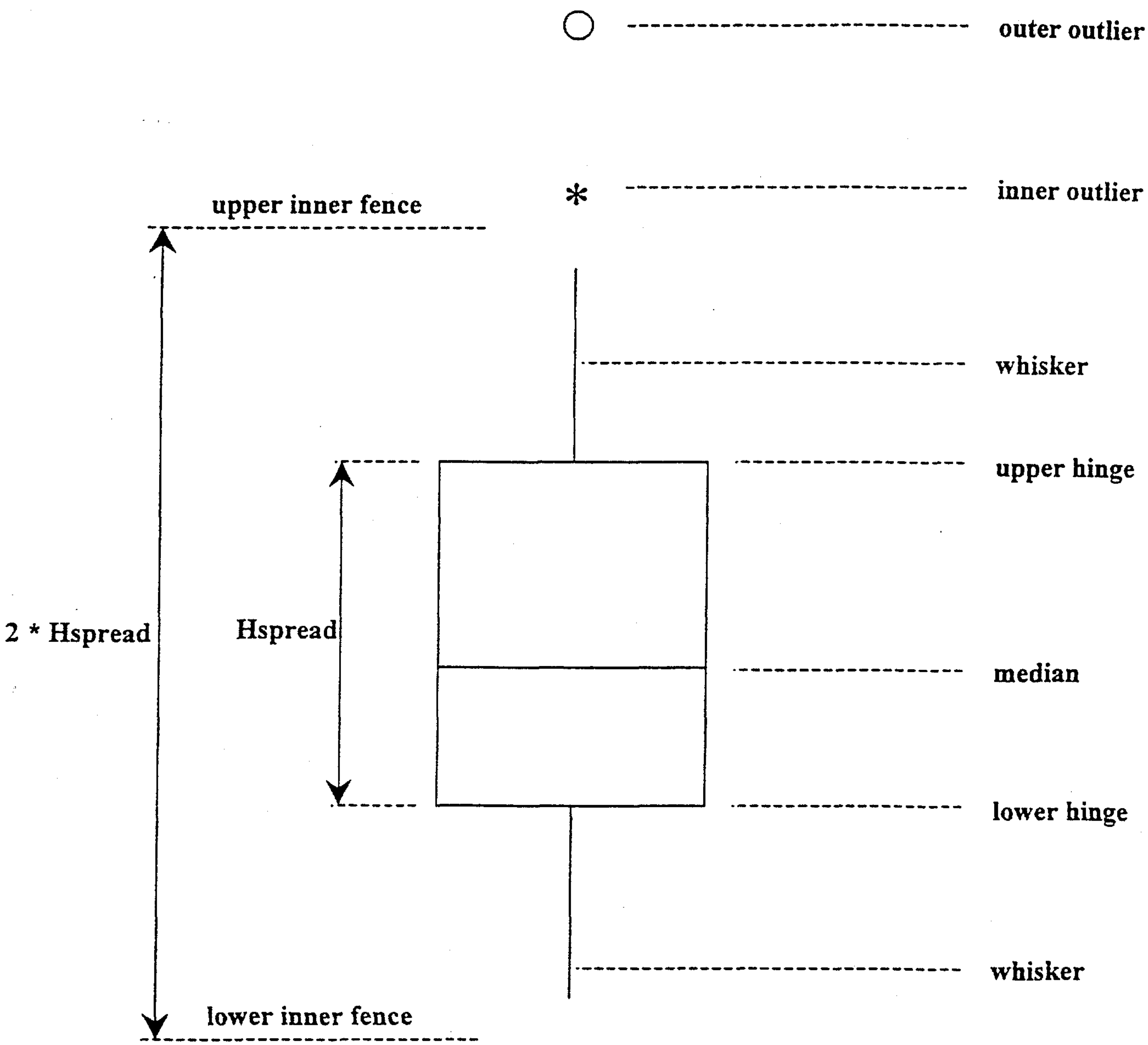

Figure 2. Example box and whisker plot.

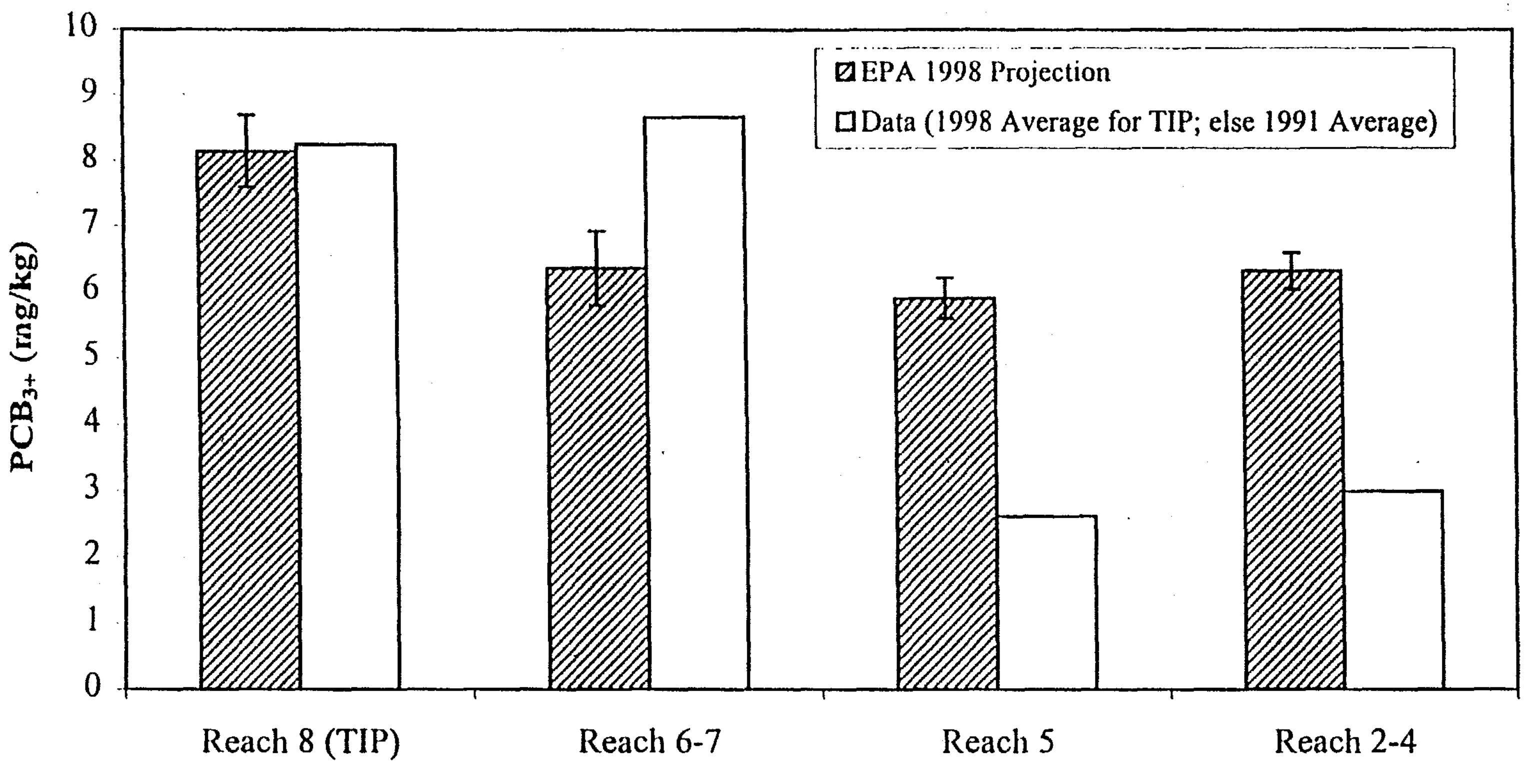

Figure 3.

Comparison of surface sediment PCB_{3+} concentrations at the beginning of EPA's model projection with averages from data.

Note: Error bars represent 2 standard errors about the mean for the mono and di fraction used to calculate PCB_{3+}

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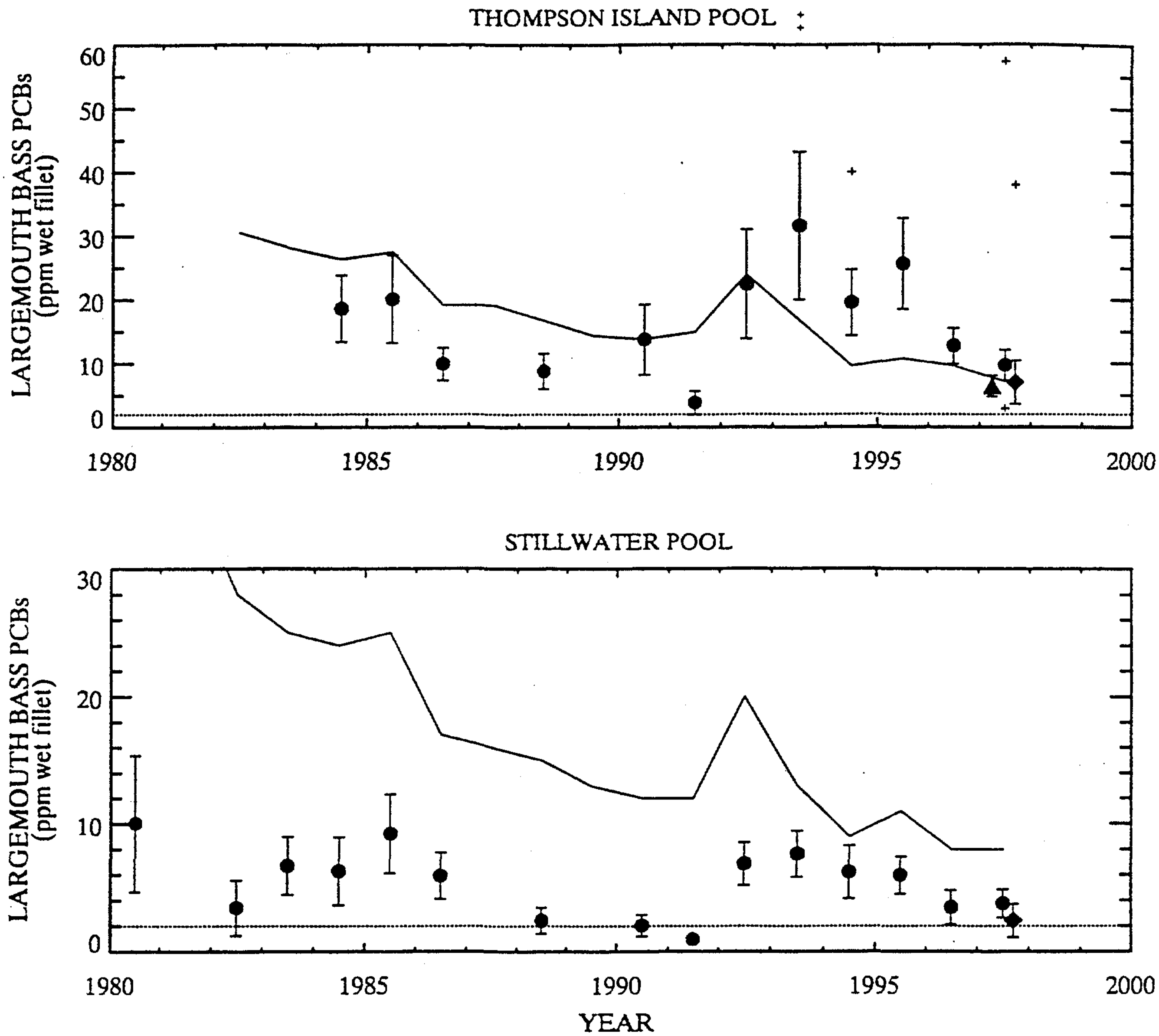

Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Solid line = FISHRAND model results.

Figure 4. Comparison of predicted PCB_{3+} concentrations in TIP and Stillwater Pool largemouth bass using FISHRAND to those measured in samples collected by NYSDEC.

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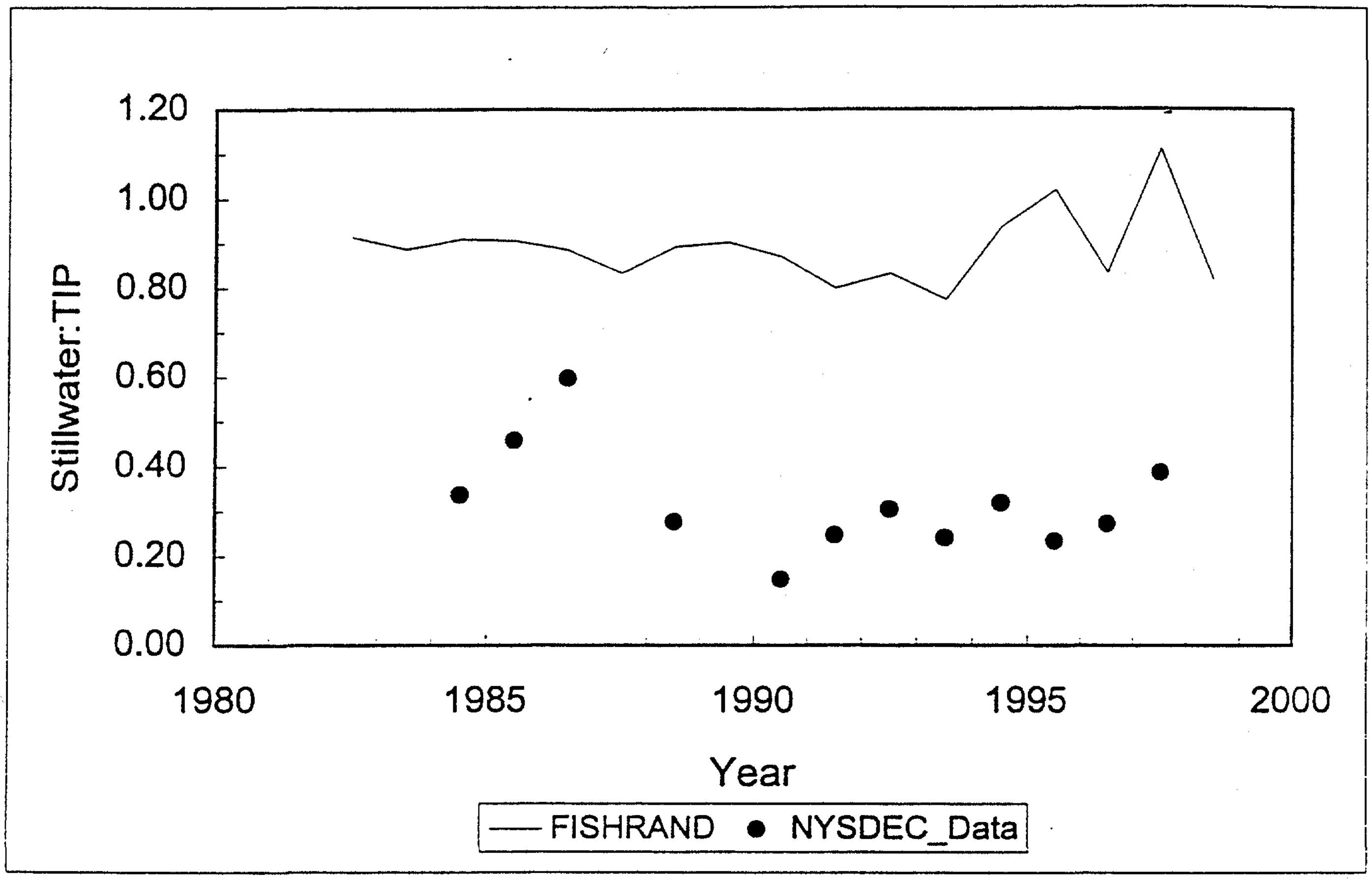

Figure 5. Comparison of FISHRAND ratios of PCB levels in largemouth bass to ratios developed from NYSDEC data (Stillwater:Thompson Island Pool).

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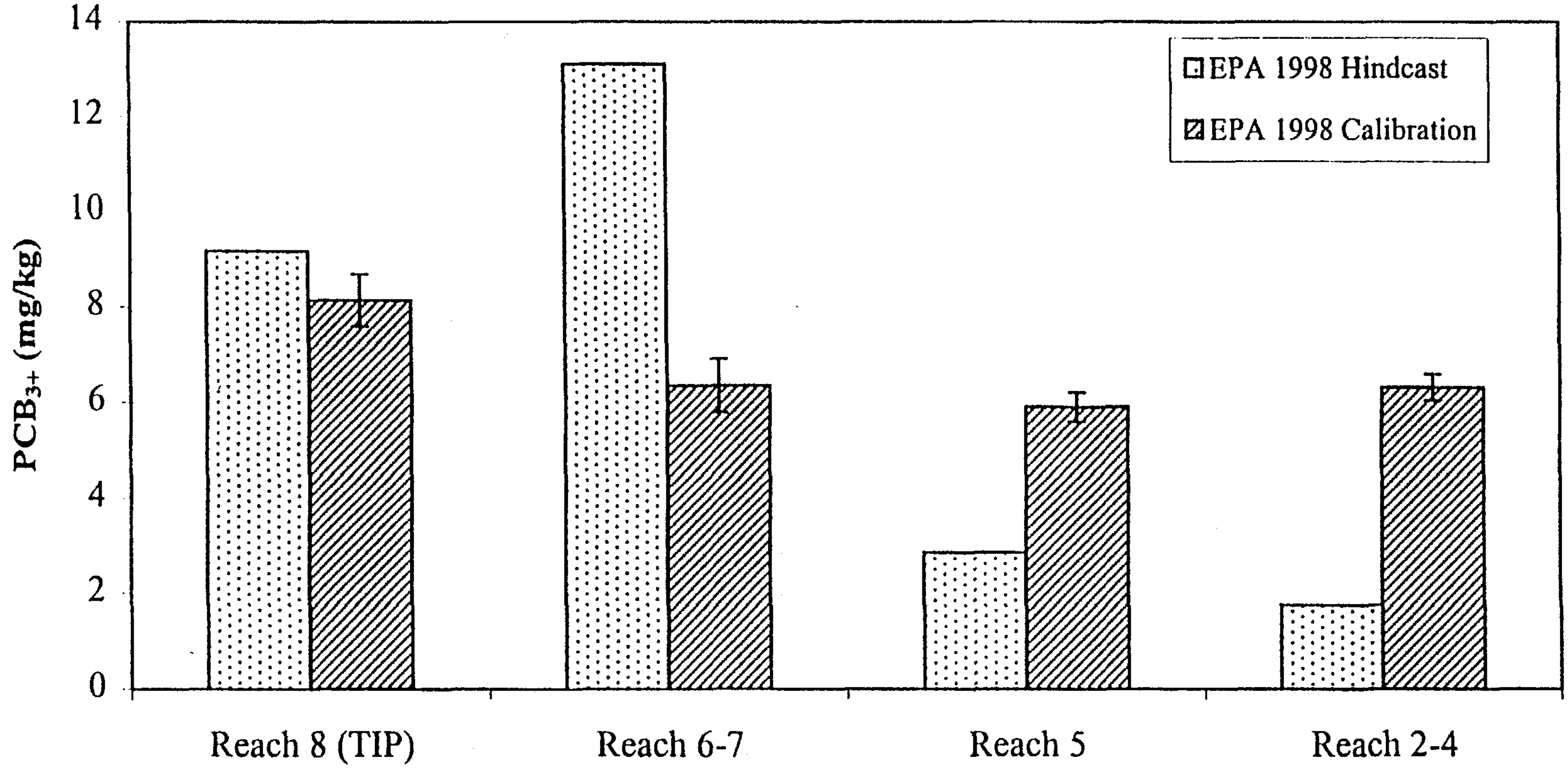

Figure 6.
Comparison of 1998 surface sediment PCB_{3+} concentrations derived from the end of EPA's model calibration and the end of EPA's model hindcast.

Note: Error bars represent 2 standard errors about the mean for the mono and di fraction used to calculate PCB_{3+}

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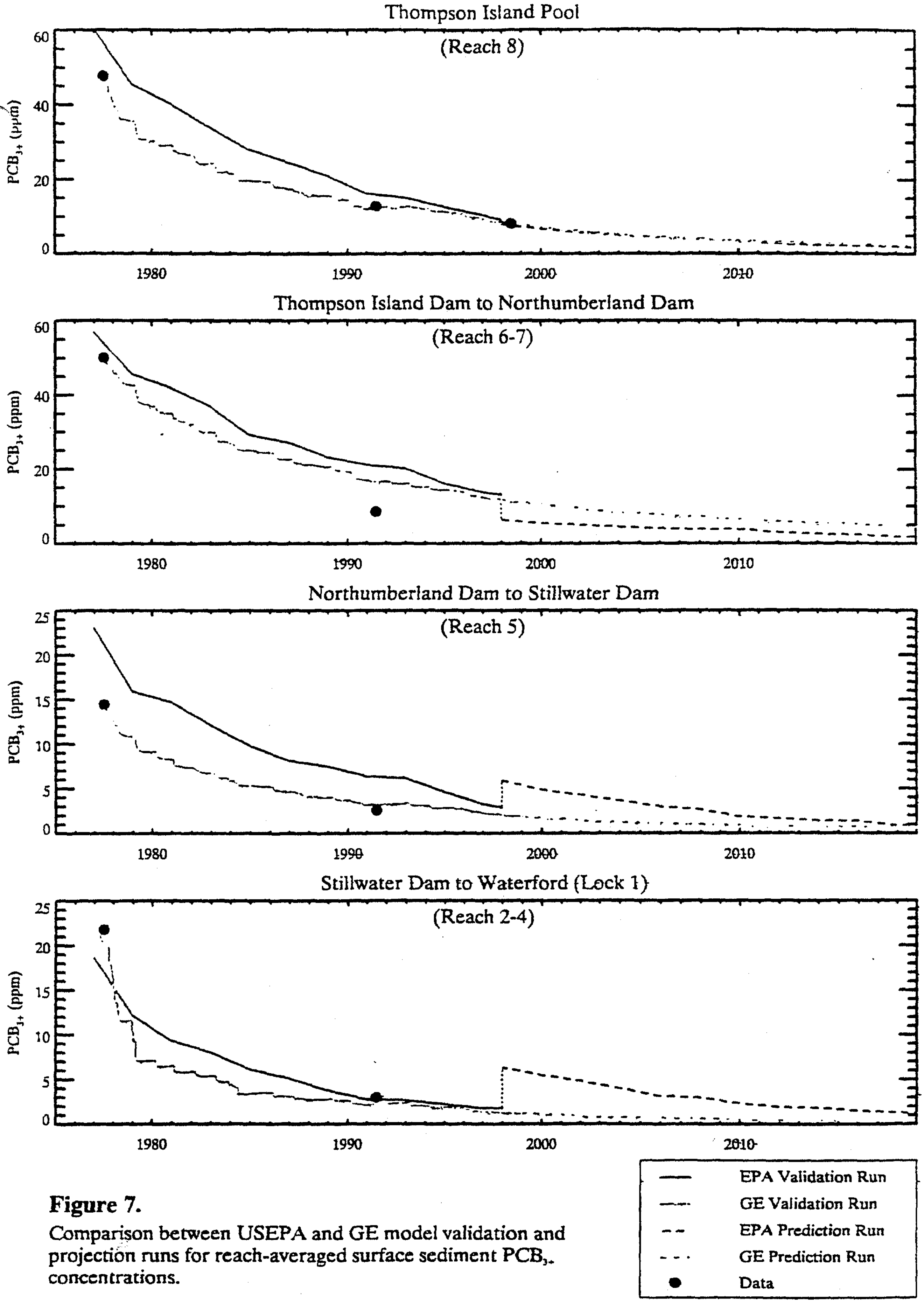

Figure 7.
Comparison between USEPA and GE model validation and projection runs for reach-averaged surface sediment PCB_{3+} concentrations.

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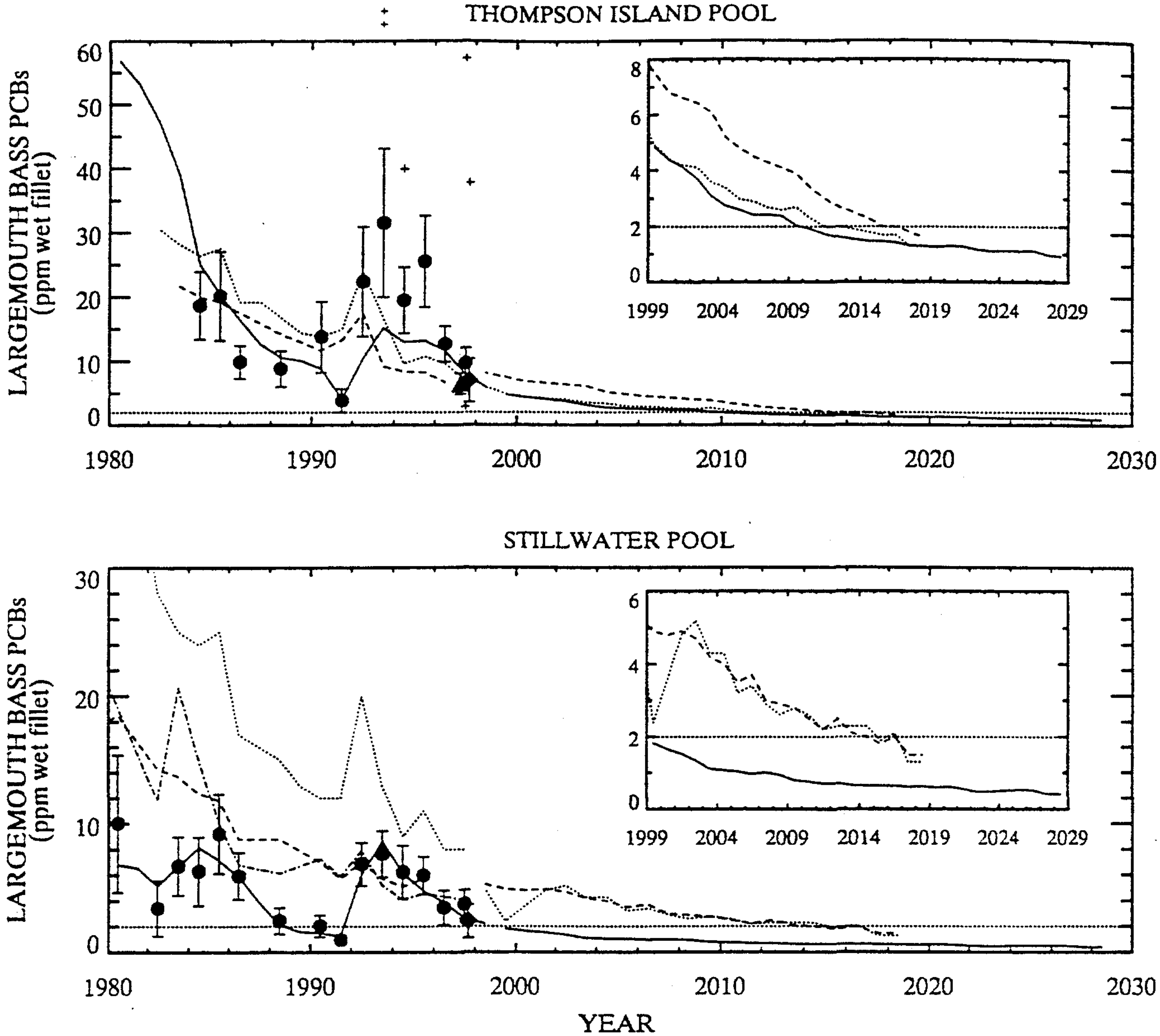
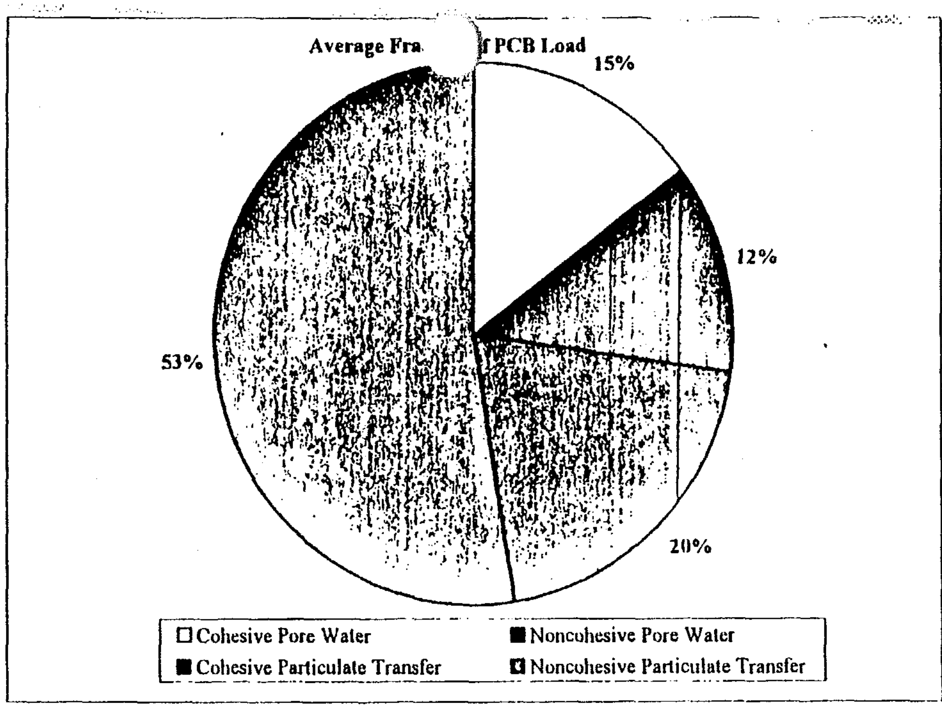


Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Solid line = QEA model
Dotted line = FISHRAND model
Dashed line = PFCM model
Dashed-Dotted line = BSM model (Stillwater only; no projections provided by EPA)

Figure 8. Predicted PCB_{3+} concentrations in TIP and Stillwater Pool largemouth bass over the time period from 1980 to 2029 under natural recovery (constant upstream loading).



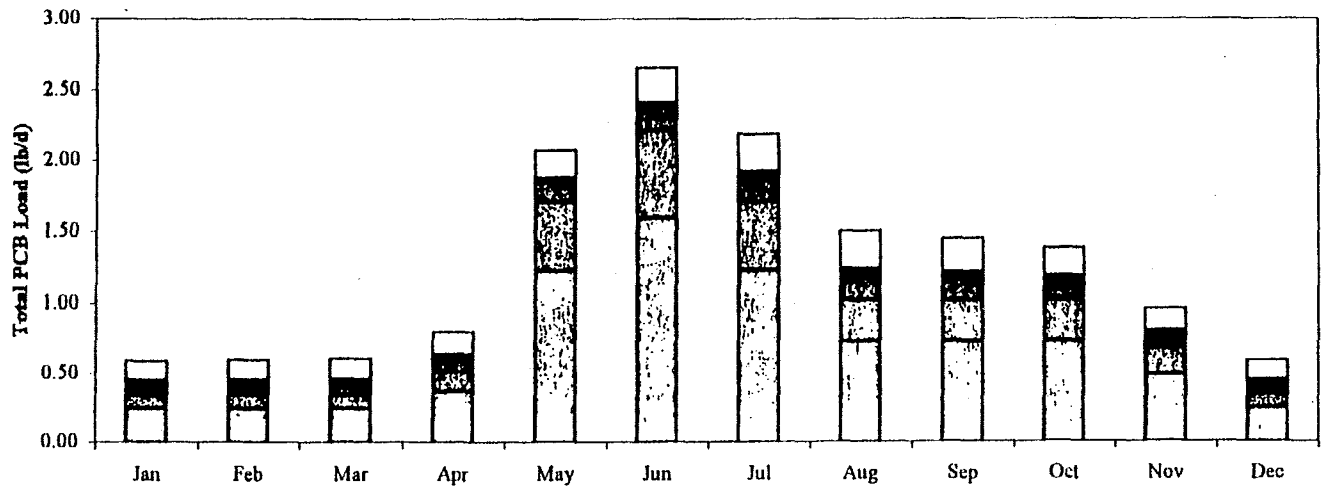


Figure 9. Calculated PCB loading from Thompson Island Pool sediments based upon sediment-water exchange processes and parameters from EPA's model and average 1991 surface sediment PCB concentrations.

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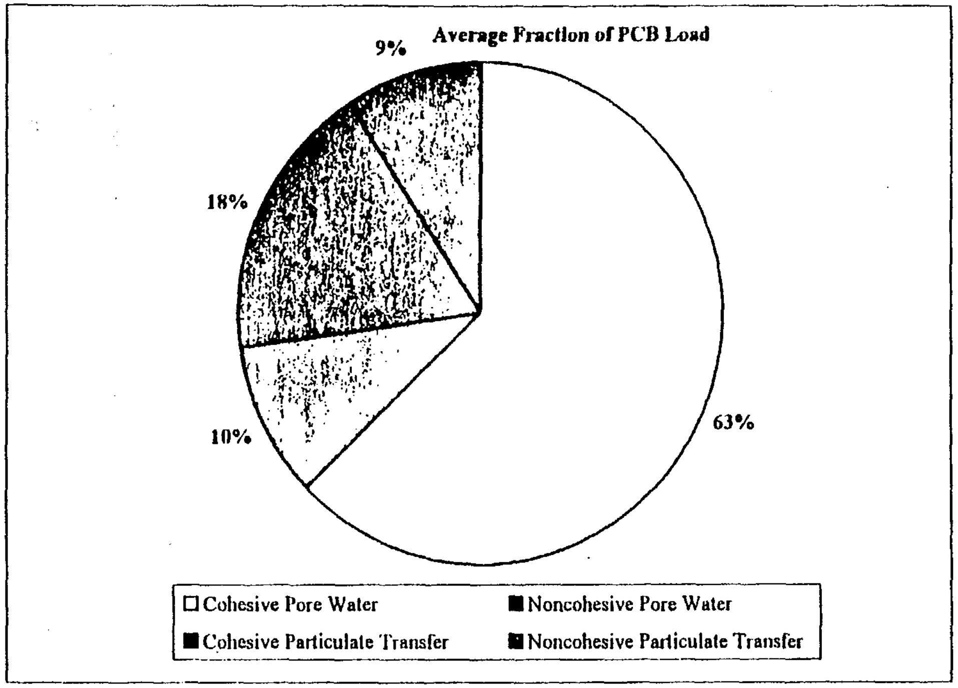

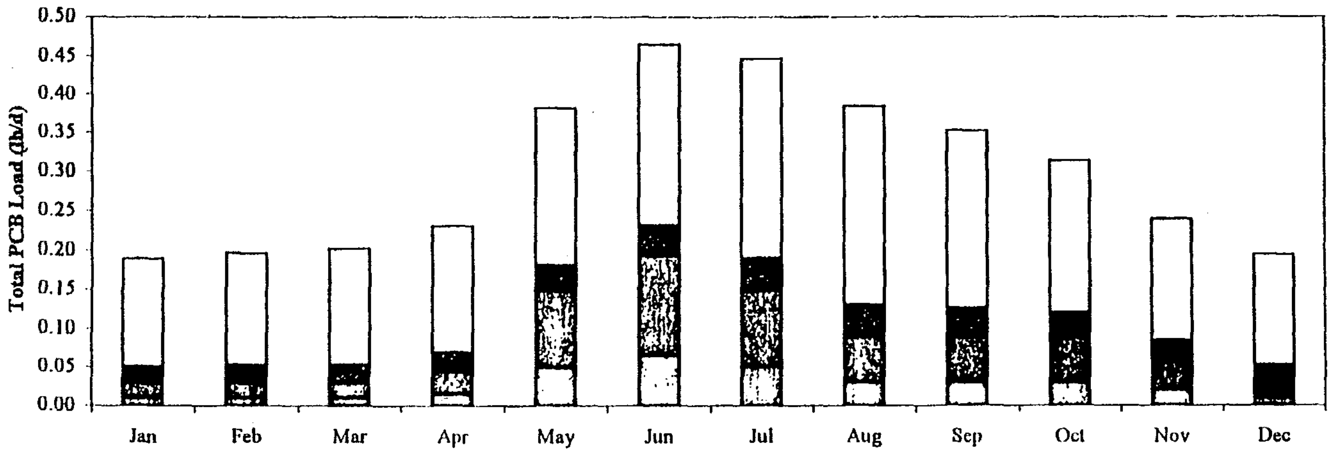

Figure 10. Calculated PCB loading from Thompson Island Dam to Northumberland Dam sediments based upon sediment-water exchange processes and parameters from EPA's model and average 1991 surface sediment PCB concentrations.

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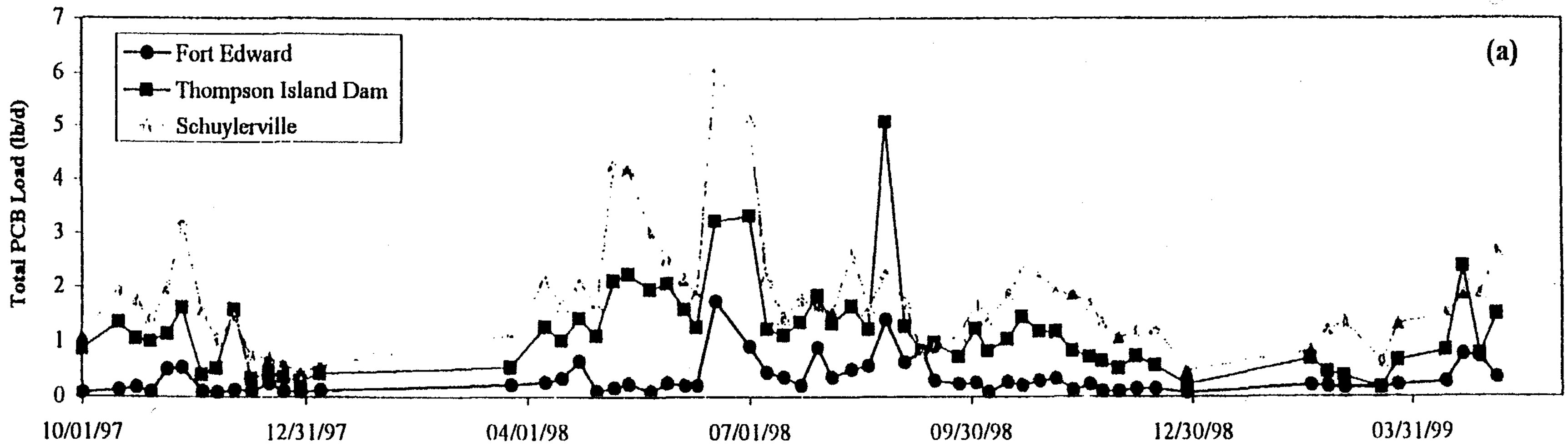

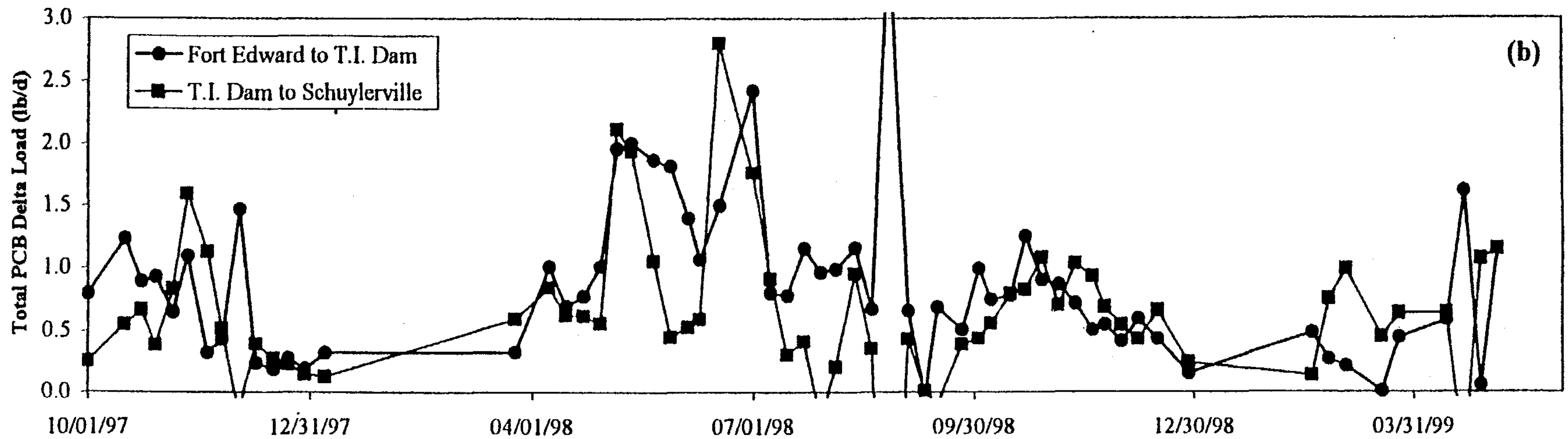

322215

Figure 11. Temporal profile of total PCB (a) loadings and (b) delta loadings (load between Fort Edward and T.I Dam or between T.I. Dam and Schuylerville) from 10/1/97 to present.

Notes: Low flow data only. Thompson Island Dam data is from unbiased PRW2 station.

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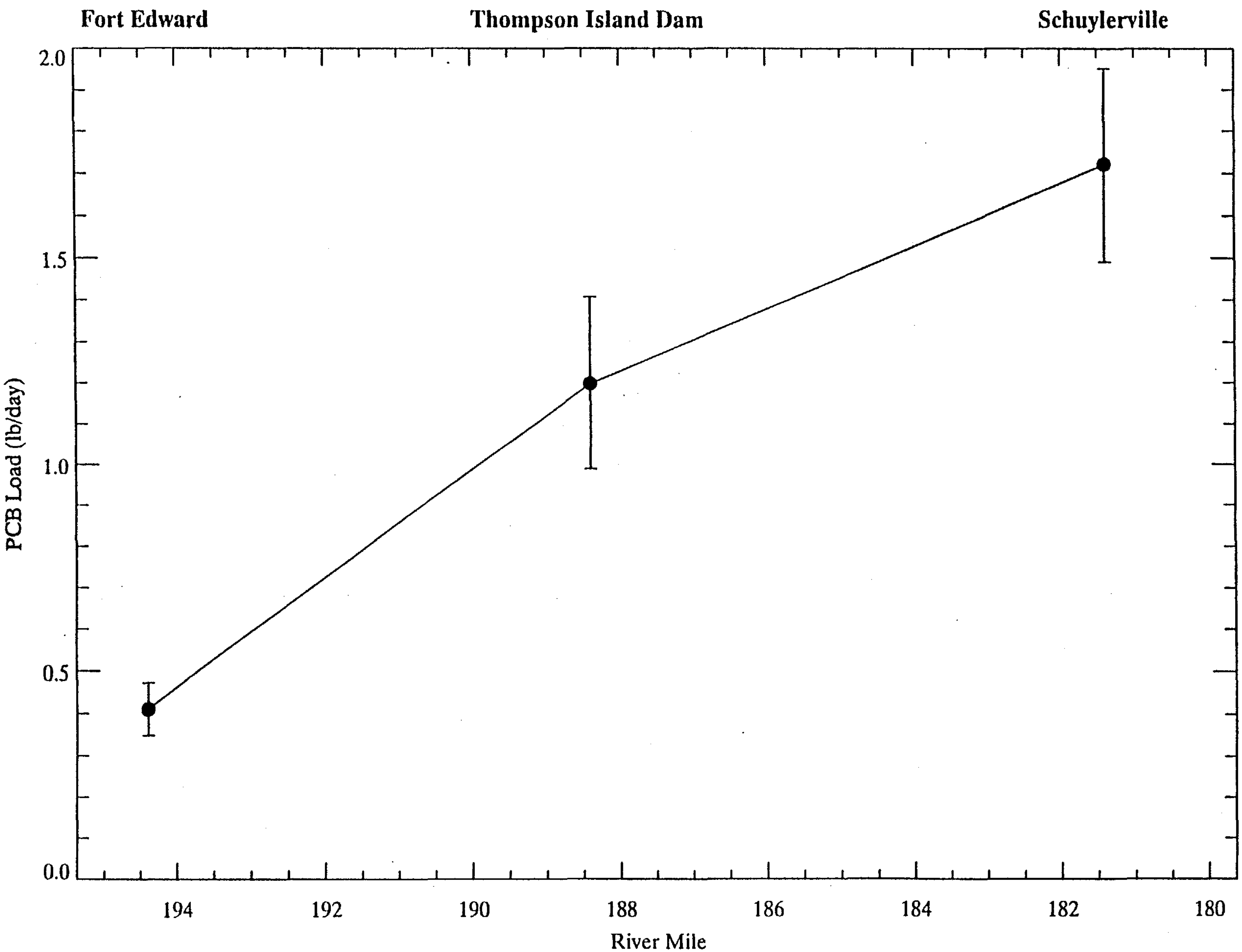

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Figure 12. Spatial profile of average PCB loading from Fort Edward to Schuylerville for low flow data (<10,000 cfs) collected after 10/01/97.

Notes: Flow at TID and Schuylerville prorated using flow balance proration factors from EPA's model.

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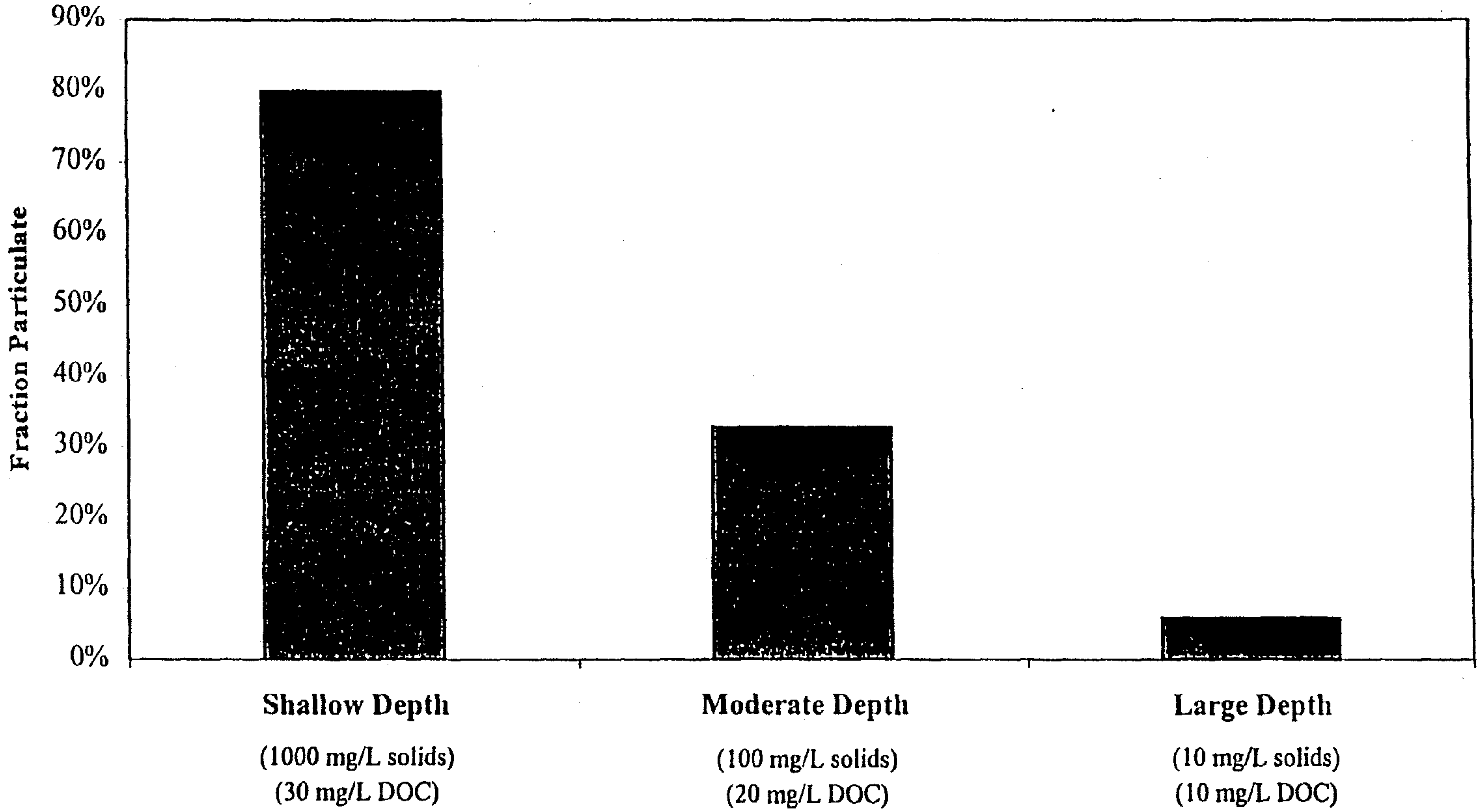

Figure 13. Sensitivity of the particulate PCB fraction to the solids and DOC concentrations within the "mixing zone" (i.e. the depth over which exchange *via* resuspension, partitioning, and settling occurs).

Note: Fractions calculated with EPA's model partition coefficients.

322217

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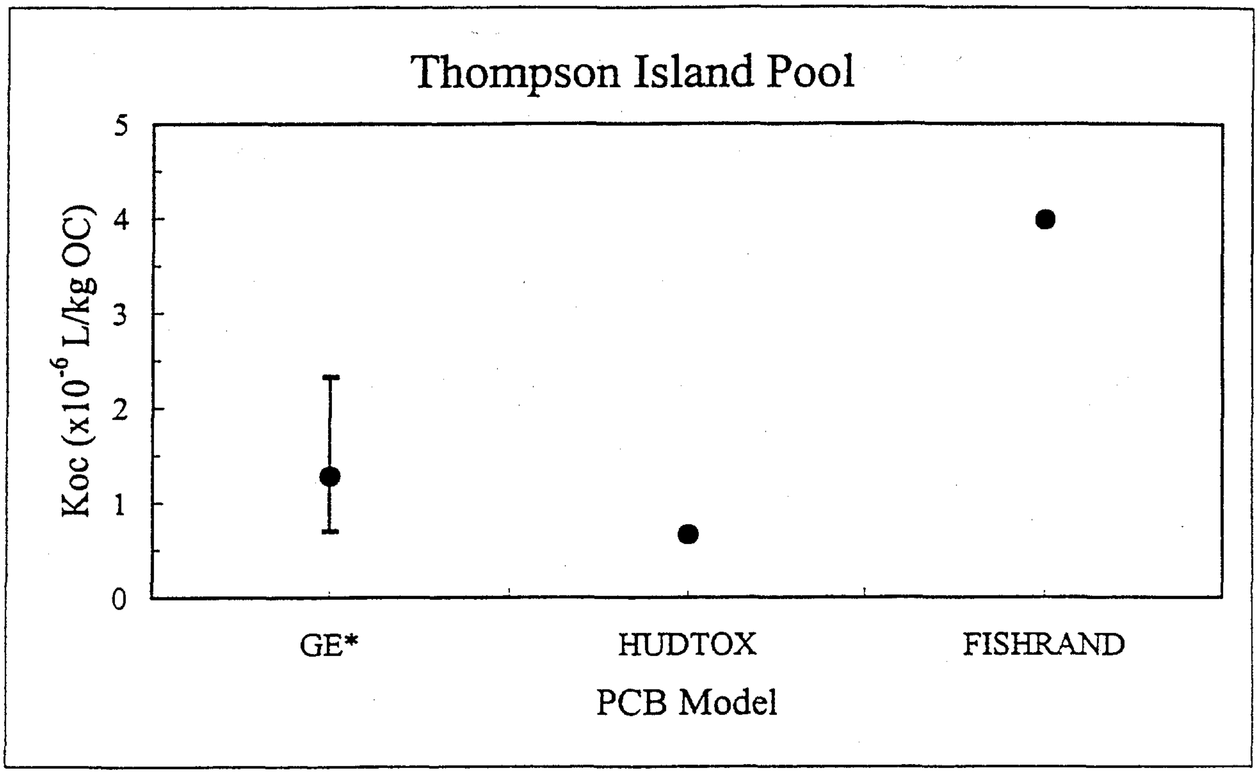

* Values presented as arithmetic mean and range.

Figure 14. Comparison of partition coefficients at the base of the food web used in the GE and EPA PCB models.

JimQ - D:\GENhud\FDCHN\Plots\Projections\USEPAcomp\tipkoc_comp.xls
6/25/99 11:36 AM

Community

BC-1

Merrilyn Pulver
Councilwoman, Town of Fort Edward
2842 County Route 46
Fort Edward, N.Y. 12828
518-747-4985

June 18, 1999

Mr. Douglas Tomchuk
U.S. Environmental Protection Agency
290 Broadway 20th Floor
New York, New York 10007

Dear Doug:

I am writing as co-chairman of the Agricultural Liaison Committee of EPA's Hudson River PCB Superfund Reassessment and as a member of the Fort Edward Town Board. My comments today are in regard to the most recent Baseline Modeling Report.

Having come away from the May 18, 1999, EPA joint liaison group meeting feeling frustrated with the established peer review procedure being thrust us upon by EPA, I felt compelled to draft a resolution in hopes that it might be an effective tool that the Town of Fort Edward as well as the Washington County Board of Supervisors may use to help convince EPA to have full side-by-side peer review of EPA's model and GE's model.

On Monday, June 14, 1999, the Fort Edward Town Board adopted Resolution No. 39 of 1999, **URGING EPA TO SUBMIT BOTH ITS AND GE's MODELS TO SIMULTANEOUS, INDEPENDENT PEER REVIEW.** On June 18, 1999, the Washington County Board of Supervisors adopted Resolution No. 180 Title: **URGING EPA TO SUBMIT BOTH ITS AND GE's MODELS TO SIMULTANEOUS, INDEPENDENT PEER REVIEW.** Please find enclosed both resolutions.

The future of the Hudson River and the communities that reside on its banks will rest on the data that this modeling effort will predict. There is no room for anything less that full cooperation from all parties. Both reports predict future recovery of the river without any dredging action. The reports do differ in the time the recovery will take. Obviously, this factor will be imperative to determining the future outcome of this reassessment. Certainly EPA must be aware of the lack of credibility it will demonstrate to all concerned if it does not deviate from its established procedure. One would have to wonder if EPA lacked confidence in its model otherwise! Let's resolve the fact that this side-by-side peer review will only make the science better.

Sincerely,

Merrilyn Pulver

Merrilyn Pulver

322220

RESOLUTION NO. 39

Urging EPA to submit both its and GE's models To simultaneous, independent peer review

WHEREAS, citizens, the community and the agricultural, tourism and recreational resources of the Town of Fort Edward are directly affected by the U.S. Environmental Protection Agency's reassessment of PCBs in the Hudson River, and

WHEREAS, The Town of Fort Edward has closely monitored EPA's performance and, in view of the potentially grave consequences of its decision, has urged EPA to rely on the soundest scientific principles and the most valid data analyses, and

WHEREAS, the EPA and the General Electric Co. each have recently developed computerized models to simulate river dynamics and forecast future progress in the river's recovery, and

WHEREAS, these computer models are likely to be the best available quantitative tools on which to base future policy decisions about the river, and

WHEREAS, the models both predict future recovery for the river but differ as to the time that recovery will take, and

WHEREAS, the inadvertent use of inaccurate, outdated or misinterpreted data could lead EPA to order an unnecessary and destructive dredging and dumping project with serious, long-term environmental, social and economic damage to Town of Fort Edward and neighboring communities, and

WHEREAS, an open public process designed to narrow and reconcile the technical differences between the two models can reduce the risk of error and help foster a higher level of public confidence in EPA's ability to make the correct decision, and

WHEREAS, Congressman John Sweeney has announced his intention to send both models for thorough review by an independent panel of scientists convened by the General Accounting Office, and

WHEREAS, EPA has refused repeated requests to agree to a simultaneous scientific peer review of both its model and the GE model by qualified, independent experts, and

322221

WHEREAS, EPA nevertheless plans to use the projections from its model in the development of ecological and human health reports even before its model has been examined by independent scientists, now, therefore,

BE IT RESOLVED, that the Town Board of the Town of Fort Edward, hereby endorses Congressman Sweeney's plan and commends his leadership on the issue, and, be it further

RESOLVED, that the Town Board of the Town of Fort Edward, urges EPA to reverse its opposition and promptly submit both its model and the GE model to independent peer review simultaneously before any model projections are used as the basis for any other Hudson River reports, and, be it further

RESOLVED, that the simultaneous peer review be conducted at an open public meeting with full opportunity for public comment and discussion by the citizens and elected officials of Town of Fort Edward and all other interested parties, and, be it further

RESOLVED, that copies of this resolution be sent to U.S. EPA Administrator Carol Browner, Regional EPA Administrator Jeanne Fox, U.S. Sens. Moynihan and Schumer, Gov. Pataki, Congressman Sweeney, our state legislators, and the chief elected officials of all municipalities in Warren, Washington, Saratoga and Rensselaer counties with a request for their support of this resolution

RESOLUTION NO.180 June 18, 1999

By Supervisors Ferguson, Booth, Wilbur, Brown, Aspland, Cosey

TITLE: URGING EPA TO SUBMIT BOTH ITS AND GE's MODELS TO SIMULTANEOUS, INDEPENDENT PEER REVIEW

WHEREAS, the citizens, communities and prized agricultural, tourism and recreational resources of Washington County are directly affected by the U.S. Environmental Protection Agency's reassessment of PCBs in the Hudson River, and

WHEREAS, Washington County has closely monitored EPA's performance and, in view of the potentially grave consequences of its decision, has urged EPA to rely on the soundest scientific principles and the most valid data analyses, and

WHEREAS, the EPA and the General Electric Co. each have recently developed computerized models to simulate river dynamics and forecast future progress in the river's recovery, and

WHEREAS, these computer models are likely to be the best available quantitative tools on which to base future policy decisions about the river, and

WHEREAS, the models both predict future recovery for the river but differ as to the time that recovery will take, and

WHEREAS, the inadvertent use of inaccurate, outdated or misinterpreted data could lead EPA to order an unnecessary and destructive dredging and dumping project with serious, long-term environmental, social and economic damage to Washington County and neighboring counties, and

WHEREAS, an open public process designed to narrow and reconcile the technical differences between the two models can reduce the risk of error and help foster a higher level of public confidence in EPA's ability to make the correct decision, and

WHEREAS, Congressman John Sweeney has announced his desire to have both models reviewed by an independent panel of scientists convened by the General Accounting Office, and

WHEREAS, EPA has refused repeated requests to agree to a simultaneous scientific peer review of both its model and the GE model by qualified, independent experts, and

WHEREAS, EPA nevertheless plans to use the projections from its model in the development of ecological and human health reports even before its model has been examined by independent scientists, now, therefore be it

RESOLVED, that the Washington County Board of Supervisors hereby endorses Congressman Sweeney's plan and commends his leadership on the issue, and, be it further

322223

RESOLVED, that the Board of Supervisors urges EPA to reverse its opposition and promptly submit both its model and the GE model to independent peer review simultaneously before any model projections are used as the basis for any other Hudson River reports, and, be it further

RESOLVED, that the simultaneous peer review be conducted at an open public meeting with full opportunity for public comment and discussion by the citizens and elected officials of Washington County and all other interested parties, and, be it further

RESOLVED, that copies of this resolution be sent to U.S. EPA Administrator Carol Browner, Regional EPA Administrator Jeanne Fox, U.S. Sens. Moynihan and Schumer, Gov. Pataki, Congressman Sweeney, our state legislators, and the chief elected officials of all municipalities in Warren, Washington, Saratoga and Rensselaer counties with a request for their support of this resolution.

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SCENIC HUDSON

YEARS

Protecting the Valley's Environment, Town by Town

June 23, 1999

Mr. Doug Tomchuk
U.S. Environmental Protection Agency
The Federal Building – Region II
290 Broadway
New York, NY 10007-1866

Dear Mr. Tomchuk:

RE: Baseline Modeling Report

Scenic Hudson has received the Baseline Modeling Report (BMR) and has reviewed it in-house. The BMR was not forwarded to our Technical Advisor for review under our Technical Assistance Grant. As stated in the TAG, we will be using TAG funds to review both the Human Health and the Ecological Risk Assessment.

Need for Cleanup Indicated

BC-2.1

As with previous EPA Reassessment documents, the findings of the BMR, indicate the need for remediation of PCBs in the Upper Hudson River. Such remediation is necessary to accelerate recovery of the River so as to protect human health and the environment. All of the EPA's findings to date indicate that remediation is necessary.

EPA Target Levels

BC-2.2

Health officials in the State of Connecticut recently adopted 0.1 parts per million (ppm) for determining fish advisories. This human health advisory information that was recently put forth by Connecticut health officials should factor heavily into any modeling updates of the Upper Hudson. We would encourage EPA to disregard the use of the Food and Drug Administration's 2ppm target level. It is becoming increasingly clear that the FDA level is not appropriate for a site-specific case such as the Hudson. It is also increasingly clear that the 2ppm level of PCBs in fish is not adequately protective of human health and the environment. We suggest that the EPA also use a level of 0.1 ppm.

SCENIC HUDSON, INC.
9 Vassar Street
Poughkeepsie, NY 12601-3006
Phone 914.473.4440
Fax 914.473.2648
www.scenichudson.org

Peer Review

To date, the EPA has indicated that the BMR will not be subject to a side-by-side peer review as suggested by the General Electric Company. We strongly support EPA's position on this. For one thing, EPA is already conducting peer review. Secondly, the process cannot afford any further delays that might be caused by such additional review. Finally, this is simply not how peer review is conducted. **BC-2.3**

In addition, we encourage the EPA to instruct members of the Peer Review committee to disregard any and all information submitted to them by the General Electric Company. **BC-2.4**

Public Participation

Due to the fact that 200 miles of the Hudson River are considered a federal Superfund site and the health of individuals and the ecosystem along all portions of the Hudson are affected by PCB contamination of the Hudson, we again encourage EPA to provide members of the Mid and Lower Hudson Valley the opportunity to take part in this process by holding meetings in these respective areas.

Respectfully submitted,

Cara Lee

Cara Lee
Environmental Director

/cdc

BC-3

June 22, 1999

TO: Ann Rychlenski - EPA

FROM: Judy Schmidt-Dean - Chair, Citizen LAison Group

RE: Comments - EPA BASELINE MODELING REPORT

Two computer models, each describing the transport and fate of PCB's in the Hudson River, one by EPA and one by GE, have been presented to the public. The two models differ in their conclusions and the obvious question is - which one is right???

The answer is not an easy one and there is only one way to answer it. An independent peer review of both models must take place.

On May 13, 1999, The Saratogian newspaper ran this editorial-- " For years, the General Electric Co., government, environmental groups and others have debated what to do about cancer-causing PCBs in the Hudson river running along and near Saratoga County.

GE has long maintained that the best way to deal with the PCBs it had legally dumped into the river is to leave well enough alone. This week, GE presented what it considers scientific proof positive that PCB levels in fish are dropping, and that within a year, they could be within government safety standards.

But the case on whether to dredge PCBs our of the Hudson is not closed.

Next week, the federal EPA is expected to present its version of projected PCB levels, which may or may not show the reiver is getting as clean as GE claims.

Computer models are being used by both GE and the EPA to advance the discussion on whether to dredge PCBs. They have been tracking changes in the river over the last nine years.

GE is the big guy, but not necessarily the bad guy. Over the years, persuasive arguments on both sides of the dredging issue leave one to conclude that there is not one right answer. If that remains the case, why not leave the PCBs alone?

The next question will be how to resolve the presumable differences between the findings of the EPA and GE computer models.

GE is repeating a refrain that has previously fallen on deaf ears: to have both computer models evaluated by an open peer review process. Scientists without vested interests in the outcome would critique all aspects of the models and the conclusions drawn from them.

The public would be well-served by that kind of public review by outside experts, to get away from the "he-said, she-said" claims about the safety of this stretch of the Hudson".

The headline on this editorial is "Outside Review Essential To Settle Hudson PCB Debate". It is esential and the public is now demanding that it be done.

If the EPA is truly and agency that repsonds to the public, then it will conduct this review.

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BC-4

Dept. of Earth &Atmospheric
Sciences ES 351
State University of New York
Albany, NY 12207

Mr. Douglas Tomchuk
USEPA - REgion 2
290 Broadway
New York, NY 10007

Dear Mr. Tomchuk:

I have attended the June 16 EPA presentation of the Baseline Modeling Report and submit the following comment. My main concern with the HUDTOX model centers on the conceptual approach, calibration, and assumptions used in obtaining mass balances in the Thompson Island Pool (TIP). This matter is critical to model validity, and also fundamental to an understanding of overall Hudson River processes and dynamics, not just the TIP.

In reviewing the data and debate to date, I think there is general agreement that PCB and sediment loading observations at the TI dam can be representative; and that PCB loading of the water column generally increases during transit of the TIP. However, to adequately constrain TIP mass balance of both PCB and sediment, observations of equal quality for input loading are necessary at Ft. Edward/Rogers Is., and there are two problems that I still see as adding to model uncertainty, if not conceptual error. BC-4.

The first is representative water column sampling, as I have noted before. If the EPA accepts the GE "routine composite sample" procedure developed for this site (as implied, Responsiveness Summary 1·4·2, book 1, p DEIR 9,10), then use the GE results and use all of them for consistency. Second is the problem of estimating total mass flux in high discharge events. Again, GE data is probably the best obtainable, but considerable variance, especially for PCB loading, will be present (e.g. see the USGS study of the 1981(?) event at the Stillwater station by C.Barnes, and note the variability in PCB loading at this sample frequency). As a result, estimates of total PCB mass input to the TIP are poorly constrained, and a simple relationship of PCB concentration (or TSS for that matter) to discharge does not exist. Other than that both PCB concentration and TSS qualitatively tend to increase during high discharge events, there is little or no correlation of the two at any observation station (I have presented a review of this data at a prior STC meeting).

Under these circumstances, the incorporation of the LRC results into the model calibration then becomes a forcing function that is likely to distort the TIP conceptual model and model output because short term PCB and sediment mass balance, and long term mass conservation, is insufficiently constrained. As HUDTOX stands, an assumption of a net PCB loss of 43% from the 0-10cm sediment zone (what calibration period?) then translates to an implied TSS resuspension component, and the unknown mechanism of low flow PCB transfer to the water column (assumed resuspension) may be an artifact of this assumption. An assertion that the values of model variables appear to 'fit' together, or are internally consistent, is then circular reasoning and not a test of validity. BC-4

If the EPA feels that changes in PCB congener pattern and PCB loading imply sediment resuspension (Waterford, March 1993, Responsiveness Summary book 1,3·2·4,p.DEIR 25), what were the results at BC-4 the TI dam? Given the HydroQual analysis of sediment sources and loading in the TIP, how do you know that resuspended sediment can be distinguished from tributary and upstream sediment flush?

The Hudson hydrodynamic model is being used to estimate high discharge event scour effects. The 1975-76, 1983, and 1998 events potentially would produce distinct sediment layer truncation boundaries where scour has occurred (that for '75-'76 was described by Tofflemire and Quinn; DEC, 1979, using ^{137}Cs chronology). Have these been looked for in appropriate cores and locations as a check against model predictions? BC-4.4

Again, I recommend that the matter of incorporating the LRC results into HUDTOX be submitted to peer review. My comments regarding the Human Health and Ecological Risk Assessment SOWs will be submitted in a separate letter. BC-4.5

Very truly yours,

George W. Putman

George W. Putman, PhD
Emeritus Faculty

322232

USEPA Commentary on
PCBs in the Upper Hudson River (QEA, 1999)

USEPA Commentary on
PCBs in the Upper Hudson River (QEA, 1999)

In May 1999, Quantitative Environmental Analysis, LLC (QEA) prepared a report for General Electric Company entitled *PCBs in the Upper Hudson River*. The report consists of an executive summary and three volumes, and presents GE's comprehensive modeling approach to PCBs in the Upper Hudson River. A volume of Errata was submitted in July 1999. The GE modeling effort (also referred to within as the QEA model) has many aspects in common with the modeling effort conducted by US EPA. There are also key differences, which may lead to different conclusions. Interestingly, the significant differences are predominantly in the interpretation of data, rather than in the modeling approach and implementation.

This critique reviews QEA's effort, and identifies those areas where (1) QEA's interpretation of data is not consistent with USEPA's interpretation, (2) inferences and interpretations do not appear to be supported by the data, and (3) there are apparent shortcomings in the theoretical approach to modeling. The critique generally follows the organization of volumes and sections submitted by QEA.

Summary

EPA has considered the GE modeling report, *PCBs in the Upper Hudson River* (QEA, 1999) ("the QEA report"), as part of the public comment on EPA's Baseline Modeling Report (BMR). As a result of its review of the QEA report and other comments provided by the public, EPA has incorporated appropriate changes to the Agency's models. Such changes are reflected in the Revised BMR. This commentary provides a critique of certain aspects of the QEA report, highlighting aspects that are inconsistent with EPA's understanding of the observed data, and focusing on a number of apparent shortcomings in the theoretical approach used in the QEA report.

The fate and transport model in the QEA report is more notable for similarities than for differences from the HUDTOX model in the Revised BMR and indeed both modeling efforts share some of the same limitations due to constraints posed by the existing database. This is not surprising, as EPA's and GE's modeling teams have compared and debated approaches on numerous occasions, and each team has recognized and adopted ideas from the other team.

Differences in results between the QEA and EPA fate and transport model applications are primarily due to differences in data interpretation. Some of the data-based differences have potentially large impacts on the predicted response of the system. The most notable differences in the models due to data interpretation are:

- It is likely that the QEA model overestimates current and future rates of PCB burial in cohesive sediments based, in part, on the failure of the QEA model to account for a decline in solids loading observed in data collected at Ft. Edward after 1990. This leads to overly optimistic predictions of natural recovery rates.

- The QEA model fails to account for all PCBs stored in non-cohesive sediment at depths below 5 cm, despite the likelihood that some of these PCBs would be uncovered by future erosion.

- While the sediment transport model in the QEA report is more complex than that of the Revised BMR, and provides some useful insights, the available solids data are not sufficient to support the additional complexity. In addition, the lack of simultaneous constraint of solids and PCBs in the

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calibration of the QEA model is a considerable weakness that outweighs most benefits gained by the increased complexity of the model.

The bioaccumulation model in the QEA report has weaknesses relating to data interpretation and handling during model calibration. The most significant of these are:

- The bioaccumulation model in the QEA report was calibrated to data reported as PCB Aroclor sums in fish without proper adjustments to account for known changes in analytical methods over time. Additional uncertainty is added by the use of Aroclor sums because they are not directly comparable to PCB_{3+}, which is the PCB form that the QEA fate and transport model predicts.

- An adjustment was necessary to the output of the PCB fate model to improve the apparent fit of the bioaccumulation model to the fish data: PCB_{3+} concentrations computed by the fate model at both Thompson Island Dam and Stillwater from 1984 to 1989 were divided by two. This suggests serious deficiencies in either the PCB fate or bioaccumulation model calibrations, or both.

As a result of these issues, the bioaccumulation model in the QEA report is not appropriately calibrated.

There are also some significant differences in the theoretical approach used by QEA for bioaccumulation modeling relative to those used in the Revised BMR. The QEA bioenergetic model is again seemingly more "sophisticated" than the FISHRAND model in the Revised BMR, in the sense that a greater variety of mechanisms and more temporal effects are included in the model formulation. However, the available data for the Upper Hudson River are insufficient to support this higher level of complexity. Due to the data limitation, the actual calibration of the QEA bioaccumulation model relies on empirical fitting at a level that is comparable to FISHRAND. Furthermore, the predictive ability of the QEA bioaccumulation model is limited because lipid content is assumed to remain constant based on the last year of calibration data.

Overall, claims that the more complex approach used in the QEA report is inherently superior to the Revised BMR are not substantiated by a comparison of the two modeling reports. The QEA models provide a reasonable interpretation of observed PCB data in the Hudson River (i.e., hindcast), although a number of criticisms have been raised regarding specific points of data interpretation and calibration strategy. However, the ability of QEA models (as well as the Revised BMR) to predict beyond current conditions (i.e., forecast) and predict the time it takes to reach acceptable fish tissue concentrations is subject to uncertainty. Such uncertainty should be considered in the evaluation of protective remedial alternatives for the Hudson River PCBs Reassessment.

1. PCBs in the Upper Hudson River, Executive Summary

While QEA's modeling effort is sophisticated and generally credible, the Executive Summary overstates the certainty and accuracy of the model. Because there remain considerable shortcomings in theoretical aspects of the modeling, interpretation of data, and status of model calibration, the statement that "There are no other means to perform such [remedial action] assessments at a comparable level of confidence" (Vol ES, p. 1-2) is unwarranted.

The presentation of key findings in the ES (pp. 1-2 - 1-3) implies that dredging would do little "to accelerate the recovery of the river". This finding is dependent on interpretation of the data and assumptions regarding future conditions that control PCB cycling in the river. For instance, predictions of rapid natural recovery over the next decades are largely driven by high rates of burial of PCBs in Hudson River sediment, which depend strongly on assumptions regarding future solids loading to the system. As discussed below (Section 5.3, 8.2), it appears that QEA over-estimates future clean solids loads, and thus over-estimates rates of natural recovery. In addition, comparison of natural recovery versus remediation options is based on analysis of time required to reach the FDA action level of 2 ppm PCBs in fish tissue. Recent fish concentrations are quite near this level already, so intervention appears to make little impact on the time required to reach the target. Although EPA has not yet selected an appropriate risk-based target for PCBs in fish tissue in the Hudson, it does not appear that the 2 ppm FDA level is protective under the exposure scenarios evaluated in EPA's baseline Human Health Risk Assessments for the Upper and Mid-Hudson River. Analysis of lower, more realistic risk-based targets in fish may show a considerable difference in time to target between natural recovery and remediation. For example, to reach a target of 0.5 ppm wet weight, the difference in time to target between natural recovery and remediation in the QEA model appears to be on the order of 30 years (see Figures 4-2 and 4-3 in QEA's July 1999 Errata).

The presentation of the mathematical models (ES, p. 3-1) states that these "are equations developed from the basic scientific principles of conservation of mass, energy, and momentum... The equations are general and can be applied to any river system." While generally true, this statement neglects the fact that the models contain empirical, non-mechanistic components that cannot be derived from first principles and may be site-specific in nature. Most notably, the PCB model requires use of an empirical, non-mechanistic sediment-water PCB transfer rate coefficient to approximate observations during the summer period which drives fish body burden. Similarly, the bioaccumulation model is presented as mechanistic, yet actually relies on empirical fitting parameters to achieve calibration.

The Executive Summary (pp. 3-1, 3-4) also implies that all the sub-models have been validated, implying a rigorous test of model ability against observations independent of the calibration data. This is not true, as no validation is presented for the bioaccumulation model.

2. Historical Perspective (Volume 1)

QEA states (Vol 1, Sec. 2.4.3) that "Net sedimentation, at various rates, occurs in nearly all of the cohesive sediment deposits of the Upper Hudson River." While cohesive sediments are generally expected to be depositional, the evidence assembled by QEA is less than convincing. The evidence cited takes three forms: presence of ^{7}Be within surface sediments; ^{137}Cs profiles within finely segmented sediment cores; and data analysis and mathematical modeling of solids loading and transport. ^{7}Be is a marker of recent deposition. QEA notes that ^{7}Be was detected in the surface layer in only 70% of the 1994 US EPA Low Resolution cores and 54% of 1998 GE cores, but then speculates that "lack of ^{7}Be at those locations simply indicates that deposition rate was insufficient to yield detectable ^{7}Be concentrations within the surficial sediment core sections." This is possible; however, it is also possible that the locations without ^{7}Be were non-depositional, or even erosional. The second line of evidence cited is deposition rates calculated from ^{137}Cs profiles in US EPA High Resolution cores. This represents circular reasoning in regard to inferring consistent deposition across all cohesive sediments, as cores have dateable ^{137}Cs profiles only if they come from consistently depositional locations. Indeed, US EPA also obtained a number of cores from cohesive sediment areas which did not have interpretable ^{137}Cs profiles, and thus are not shown to be consistently depositional. The final line of evidence comes from sediment mass balance analysis. This mass balance, however, is based on assumptions regarding tributary solids loads. Furthermore, assumed trapping efficiencies used to estimate tributary solids loads (given as 8.5 percent for all reaches on Vol. 2, p. 3-20) appear to be inconsistent with long-term estimates of solids trapping efficiency from the sediment transport model, which were less than 2.5 percent in five of the eight reaches simulated (Vol. 2, Table 3-4).

The discussion of PCB trends in fish (Vol 1, Sec. 5.1.3) is marred by the fact that QEA has used NYSDEC-reported total PCBs, which do not constitute a consistent analytical quantity over time. As demonstrated in the BMR (and the Revised BMR), changes over time in analytical methodologies and laboratories have a substantial impact on the reported total PCB concentration in fish; however, most of the different results can be converted to a consistent basis, as explained in Volume 3 of the BMR. Judging from its Volume 2, QEA has converted results prior to 1989 to a consistent Aroclor basis, but has not correctly interpreted the subsequent data. For instance, they note (Vol 1, p. 5-7) that the 1990 to 1993 concentration data for largemouth bass in TIP are not consistent with measurements of PCB exposure. This is the period for which fish analyses were performed at the Hale Creek laboratory using a capillary-column approach that differed significantly from the packed column analyses performed by NYSDEC's contractors prior to 1990 and after 1992.

Estimates of the annual flux of tri- through decachlorobiphenyls (termed PCB_{3+} by QEA) from the Upper Hudson River to the Lower Hudson River (Vol 1, Figure 6-5) are based on the PCB fate and transport model, and reflect all the assumptions of that model. Estimates over the same period may also be obtained through analysis of the USGS monitoring data at Waterford, with results that differ somewhat from the QEA model. Estimation of load from the available flow and concentration data is discussed in the DEIR; however, those results did not take into account potential biases in the USGS results for the period after 1987[1], nor did they include the most recent PCB data. Revised estimates of PCB_{3+} load past Waterford are provided in the following table. For the period 1978 through 1997, the ratio estimate from USGS data amounts to 13,500 kg, or about 30,000 pounds. This data-based estimate is 25 percent larger than the amount estimated by QEA for the period 1978 through 1998.

[1] Rhea, J. and M. Werth. 1999. Technical Memorandum Re: Phase 2 Evaluation of Analytical Bias in the USGS Water Column Database. Report to John Haggard, GE Corporate Environmental Programs, March 22, 1999. Quantitative Environmental Analysis, LLC.

PCB_{3+} Loads past Waterford from USGS Data, kg/year

Combined Ratio Estimate (4 Strata)						Averaging Estimate
Year	Ratio Estimate	Variance	Standard Deviation	Lower Confidence Limit	Upper Confidence Limit	
1977	2439	55297	235	1978	2900	3371
1978	2260	43262	208	1853	2668	2217
1979	2963	48008	219	2534	3393	3953
1980	1007	14749	121	769	1245	892
1981	1299	290763	539	242	2356	1392
1982	818	11465	107	608	1028	966
1983	1191	13582	117	963	1420	1308
1984	702	19402	139	429	975	625
1985	414	1175	34	347	481	437
1986	366	598	24	318	414	375
1987	242	2876	54	137	347	278
1988	87	140	12	64	110	87
1989	128	231	15	98	158	196
1990	497	13950	118	266	729	475
1991	231	7051	84	67	396	235
1992	342	4402	66	212	472	281
1993	302	748	27	249	356	315
1994	155	280	17	122	187	133
1995	110	124	11	88	132	68
1996	184	405	20	144	223	197
1997	188	61	8	173	203	

3. General Approach to Model Formulation and Calibration (Volume 2)

3.1 Linkage of Model Components

QEA gives the impression that its modeling suite is a seamlessly linked whole, in which a hydrodynamic component drives a sediment transport component, which drives the PCB component. In fact, QEA does temporal and spatial collapsing of the output from its hydrodynamic and sediment models to drive the fate and transport models at a daily time step:

> *...simulations of the Upper Hudson River were realized through coupling the sediment transport and PCB fate models. Coupling the models means that sediment transport model results were aggregated to determine total suspended sediment concentration..., deposition flux..., and resuspension flux...in each grid cell of the PCB fate model. Thus, solids transport was not simulated within the PCB fate model. All sediment transport information...was...input to the PCB fate model, using output from the sediment transport model.*

The QEA models are thus not truly coupled, but rather applied sequentially with offline processing. In addition, there is a mismatch between the state variables addressed in the sediment and

PCB models: QEA's sediment model represents dynamics of both cohesive and non-cohesive sediment beds in the entire Upper Hudson. The sediment model is driven by the hydrodynamic modeling. Sediment model results are aggregated to provide spatially and temporally averaged daily vertical fluxes of sediment for use in the PCB fate and transport model. Two classes of sediment (cohesive and non-cohesive) are tracked in the water column for the sediment model. Settling of cohesive flocs depends on concentration and water column shear stress, while settling of non-cohesive sediment depends on effective particle diameter. However, in transmitting information forward to the PCB model, the cohesive and non-cohesive sediment fluxes were aggregated into total sediment flux. Finally, the form of PCBs addressed in the fate and transport model (the sum of trichlorobiphenyls through decachlorobiphenyls, or "PCB_{3+}") is not consistent with the sum of reported Aroclor concentrations in fish used in the bioaccumulation model.

3.2. Calibration Strategy

QEA has calibrated the solids and PCB models sequentially, with no documented feedback. EPA, on the other hand, has used an iterative approach which is equivalent to joint calibration of the sediment and PCB models. The EPA approach makes sense, because it is clear that the sediment model is under-determined by the available data. That is, calibration to total suspended solids (TSS) observations does not allow a unique determination of parameter values in the sediment transport model. Most importantly, the calibration to solids data only tends to resolve *net* resuspension, but not the gross rates of resuspension and settling. PCB is a marker for the movement of sediment in the Upper Hudson, and simultaneous consideration of both sediment and PCBs in the calibration as done for USEPA model provides more rigorous constraints on the sediment model calibration (USEPA, 2000).

4. Hydrodynamic Models (Volume 2, Section 2)

4.1 Model Specification

QEA employed two hydrodynamic models: a one-dimensional model that was "coupled" to the PCB fate and transport model, and a two-dimensional model that was coupled to the sediment transport model. The model specification generally appears to be correct. It should be noted, however, that Volume 2, Figure 2-3 shows a TIP flood plain grid, although the flood plain is not included in the hydrodynamic model used for calibration and forecast purposes. This figure can easily be misconstrued by the reader, because the corresponding text discussing the hydrodynamic model does not mention that the flood plain is not included. That information is only found in volume 2, section 3, page 63 of the QEA Report where QEA states that "...numerical grids assume that the flow is confined to the main channel of the river and overbank flow is not simulated during a major flood". Flood plain inundation with use of the flood plain grid was apparently included only in sensitivity analyses presented in Section 3.5.4.

4.2 Model Calibration

For the one-dimensional model, the text (Vol 2, p.2-13) indicates that the "coupling output was flow balanced to ensure mass conservation", but it is unclear as to whether the flow balancing was implemented on a daily basis or a long-term average basis. Further clarification of what was actually done regarding the flow balancing between river reaches should be provided.

In the two-dimensional model (Vol 2, p.2-16) discrimination between cohesive and non-cohesive bottom friction coefficients may not be warranted. Figure 2-6 in the GE Executive Summary Report shows extensive submerged aquatic vegetation associated with fine (i.e., cohesive) sediment areas in the

TIP, however no evaluation of these conditions on bottom friction coefficients is provided in the hydrodynamic calibration discussion.

It is also important to point out that Reach 7 hydrodynamics are not calibrated (Vol 2, p.2-14). This reach is just downstream of the TIP and contains relatively high levels of PCB contamination in the sediments. Since GE collected velocity data in the TIP during 1997 to assist in validating the TIP hydrodynamic model, it would have been prudent to collect similar data within Reach 7, even given the uncertainty in the downstream boundary surface water elevation forcing condition.

4.3 Sensitivity Analyses

The sensitivity analyses presented by QEA are not sufficient to fully establish the reliability of the hydrodynamic models. For instance, no sensitivity analyses are presented showing the effect of inclusion of the flood plain on the hydrodynamic model predictions. The two-dimensional hydrodynamic model sensitivity only assesses the effect of changing the effective bottom roughness, z_0, in the non-cohesive bed. Since the minimum bottom friction factor in Equation (2-6), $C_{f,min}$ may be in effect most of the time in many of the non-cohesive grid elements, the sensitivity to z_0 is somewhat misleading and the sensitivity of the model predictions to $C_{f,min}$ should also be presented. Additionally, no justification is provided as to why this sensitivity assessment was not also applied to the cohesive sediment bed. In effect, the analysis presented for sensitivity to z_0 shows minimal sensitivity in the model predictions because this parameter is not typically controlling the predictions and because the effect of changing it was only assessed for a fraction of the total TIP sediment bed.

5. Sediment Transport Models (Volume 2, Section 3)

5.1 Sediment Model Specification

The QEA SEDZL model contains a sophisticated theoretical approach to representation of sediment transport and settling in the water column. Unfortunately, very little data are available on particle size distributions in the water column, and the sediment transport model was calibrated and validated to total suspended solids data (Section 3.3.2). Further, calibration and application of the QEA model require assumptions about the size class of tributary loads, for which data are lacking. The sediment models are thus not well-constrained by available data. Even so, it was difficult to achieve a reasonable calibration: To make the model fit, QEA was forced to make what appear to be unrealistic assumptions, e.g. "The sand content of sediment loads from Moses Kill and direct drainage was assumed to be zero. Initial model testing showed that unrealistic amounts of sediment were predicted to be deposited at the mouth of Moses Kill whenever sand was included in the sediment loading for that tributary..." (Vol 2, p. 3-23). Finally, only total sediment concentrations and fluxes are carried forward into the PCB model. While the QEA approach to transport and settling appears sophisticated, the data are not available to make use of the sophistication of the model. Therefore, the complexity of the SEDZL model may not add predictive capability over alternative, less sophisticated approaches, which make full use of available data.

In general, the complexity of the sediment transport model and the stated success of the calibration are not justified by the available data. Large uncertainties in loadings and sediment transport model parameters result in a somewhat arbitrary calibration. Considering that the rates of sediment deposition and resuspension are not constrained, and only the net effect is, the sediment transport model is under-determined and was not subjected to simultaneous constraint by the PCB model. In the PCB model calibration, an undue level of confidence is placed on the sediment transport model results considering the limitations of the available data and the calibration approach.

The mismatch between model theory and data also applies to the simulation of non-cohesive resuspension, which is driven by a hydrodynamic model combined with representation of active layer thickness and bed armoring. As with settling, the data do not appear to be sufficient to ensure that the more complex representation yields a more accurate result. Indeed, QEA states (Vol 2, p. 3-10):

> *None of these active layer thickness formulations were developed from laboratory or field data. The relationship between bed properties and/or bottom shear stress in each equation was hypothesized and supported by qualitative, mechanistic arguments, with no data used to support the proposed [active thickness] equations.. Hence, active layer thickness formulations used in non-cohesive bed armoring algorithms must be considered to be mathematical constructs that approximate a complicated, and poorly understood, physical process.*

In addition, QEA neglects bed load transport of non-cohesive sediment. While, as stated by QEA (Vol 2, p. 3-11), "these coarse sediments do not directly affect water column transport of particle-sorbed PCBs", bed load transport is likely to have an important effect on active layer thickness and armoring of non-cohesive sediments. The statement also fails to acknowledge the potentially significant effect that bed load dynamics may have on sediment-water PCB transfer.

QEA contends (Vol 2, p. 3-26) that "without implementation of mechanistic formulations to predict non-cohesive resuspension and bed armoring, as has been done in this study, empirical relationships cannot be developed that accurately predict non-cohesive resuspension rate as a function of flow..." Earlier in the development of the model, the non-cohesive active layer thickness behavior is presented as being poorly understood with no experimental data to support proposed modeling formulations. The calibration of the model relies on a controlling parameter in the active layer thickness equation along with the effective particle diameter of class 2 particles. In addition, important parameters with much uncertainty were specified as constants. Therefore, the resulting model can be considered, to a large degree, empirical in that it uses unbounded parameters to attempt to describe observed shapes in the TSS concentration time series used in the calibration. Thus, the statement regarding the necessity of mechanistic modeling of non-cohesive sediment armoring processes is inappropriate.

5.2 Sediment Model Forcing Functions

It should be emphasized that sediment model calibration for the Hudson appears to be more sensitive to the specification of external forcing functions than to exact details of the sediment transport model formulation. Because solids concentrations are not monitored continuously at Fort Edward, the upstream boundary of the modeling domain, QEA uses a sediment rating curve approach to estimate a continuous upstream solids boundary condition. The data periods and sources used to develop the Fort Edward solids loads by QEA are not explicitly stated. The inference from the report text is that only data from 1977-1992 were used to develop the rating curve for solids loading at Fort Edward. There are extensive TSS data collected at Fort Edward available beyond 1992, largely collected by USGS and GE, in addition to the USEPA 1993 Phase 2 sampling. The report provides no indication of whether or how these data were used in developing the Fort Edward solids load rating curve.

In EPA's Revised Baseline Modeling Report (Revised BMR), LimnoTech Incorporated (LTI) notes that upstream sediment concentrations in the Hudson River at Fort Edward appear to be consistently lower after 1990 than in the pre-1990 period. Changes over time may reflect both changes in watershed land use patterns and stabilization of sediment deposits within the river. Clearly, sediment loads were likely highest in the period immediately after removal of the Fort Edward Dam. While changes may be gradual over time, LTI selected a 1990 boundary for time stratification based on trends observed in the data and the fact that stabilization activities were completed by GE in the remnant deposit area in the fall of 1990. Both parametric and non-parametric statistical tests show a significant difference in the relationship between flow and TSS before and after 1990. Solids load for a given flow is less after 1990 than before 1990. This finding implies that a single sediment-rating curve across all time periods (as used by QEA) is not appropriate to establish upstream boundary loads, and leads to an incorrect calibration of the model. If a lower sediment rating curve is present in the future this also has important implications for slowing the rate of natural recovery of the system, as the predicted rate of burial will be decreased. Determination of solids loads from unmonitored, or infrequently monitored tributaries, is also a challenging problem which is not fully resolved. Given that solids predictions are strongly driven by external forcing, the EPA approach of simultaneous calibration to solids and PCBs seems preferable to the sequential approach of QEA.

For tributary solids loads, QEA acknowledges the lack of sufficient tributary monitoring data and uses an approach that compares solids loads past Fort Edward, Stillwater, and Waterford to yield net tributary loads. Artificial sediment rating curves were then adjusted to yield the observed gain in mainstem loads. This procedure, however, rests on the assumption that initial model simulation predictions of a trapping efficiency of 8.5% for the TIP are correct and are extrapolatable to reaches 1 through 7. In fact, trapping efficiency clearly varies by reach. QEA states (Vol 2, p. 3-21) that their results are consistent with sediment yield predicted by Phillips and Hanchar (1996) with the assumption that "roughly 50% of a tributary drainage basin in the Upper Hudson River is forested", citing 1974 data. However, this assumption is not supported by comparison to actual forest cover of individual drainage basins.

QEA's assumption (Vol 2, p. 3-23) that Moses Kill solids loads to the Hudson River mainstem have zero sand content *may* be reasonable. However, the need to make this assumption could also indicate that the total load estimated for Moses Kill should have been reduced if the tributary data collected do not represent the composition of the solids load that actually progresses beyond the mouth of Moses Kill and into the mainstem of the Hudson River. This should also be acknowledged as a calibration parameter if the basis for the adjustment was feedback from the PCB model predictions. For example, was this parameter adjusted to improve surface sediment PCB_{3+} concentration trajectory comparisons with data in the mainstem segments (11 and 12) which may be affected by the solids loading from Moses Kill?

The summary statement that sand content for external solids loads was set based upon available data and not adjusted during simulations (Vol 2, p. 3-27) is misleading. It is evident that specification of the sand content for Moses Kill solids loads was based upon an iterative process of model simulation followed by an adjustment of model input assumptions. As such, these inputs should be acknowledged as model calibration parameters and not simply termed data-based constructs.

5.3 Sediment Model Calibration

While QEA claims a high level of success in their sediment model calibration (ES, Section 3.2.2), the information presented in the report suggests significant discrepancies that call into question the quality of the calibration. A key piece of evidence presented for the claim of an accurate calibration is replication of temporal variations in flux to sediments, M_{bed} (Vol 2, p. 3-32). This does not constitute a true calibration however, as the "data" on M_{bed} is actually an inference from a highly uncertain mass balance for TSS across the TIP – and the model may thus be forced to fit an inaccurate target. Evaluation of mass balances for the 1993 spring flood showed 9,600 MT of deposition between Fort Edward and Stillwater, while the model predicted net erosion of 5,100 MT (Vol 2, p. 3-38). Further, the model systematically under-predicts sand content at all stations between Schuylerville and Waterford in the long-term simulation (Vol 2, p. 3-43). Finally, comparison is made to observed and predicted rates of deposition at dated sediment cores in Table 3-6 (Vol 2, p.3-44). While a reasonable fit is claimed, it actually appears that there is essentially no correlation between model predictions and observed sedimentation rates. Most notably, the highest predicted rate of sedimentation was for a core (HR-16) with an observed sedimentation rate below the average across all cores. It is, in any case, unclear that the dated sediment cores, which provide point estimates of sedimentation in known depositional areas, can be used to constrain average rates of sedimentation across a model grid segment. (The SEDZL model uses the same grid as the hydrodynamic model, which is stated to have an average grid size of 140 x 25 meters in the Thompson Island Pool).

Global statements regarding the relationship between flow rate and settling are made based on output from a single model cell (Vol 2, p. 3-25), and may reflect merely an artifact of the model. Volume 2, Figures 3-18 through 3-25 show relationships for effective settling speeds and resuspension rates versus flow at a location that may be influenced by a tributary (Snook Kill). It would be informative to see how these relationships vary at other locations. For example, it is unclear whether the subsequent conclusion that there is no correlation between resuspension rates and flow in non-cohesive sediment areas is completely accurate, since no statement is made regarding generalization of the Snook Kill relationships shown in the report to other areas of the river.

The sediment model calibration is described as requiring adjustment of only two parameters (Vol 2, p. 3-28): the effective particle diameter of class 2 sediment, d_2, and the constant, B, in the non-cohesive active layer thickness formulation. Factors other than d_2 and B should be acknowledged as adjusted sediment transport model calibration parameters including: particle distributions for tributary solids loads, and lateral eddy diffusivities.

The probability of deposition parameter for cohesive sediments, $\tau_{b,min}$ is specified as 0.1 dyne/cm^2 without justification (Vol 2, p. 3-28). The effect of this specification on the model predictions is unknown, since sensitivity analyses were not conducted for this parameter.

QEA's calibration involved an iterative procedure in which the model was used to estimate change in total suspended sediment mass across the TIP, ΔM_{wc}, which was in turn entered back into a "data based" mass balance for TIP to estimate net solids flux to the sediment bed (M_{bed}). The resulting estimates of M_{bed} are then used as a calibration parameter (Vol 2, p. 3-31). The effect of using a model-based value of ΔM_{wc} to generate the time series of M_{bed} fluxes should have been assessed in more detail. The effect on the cumulative flux over an event may be small, but the possible effect on the time series comparison between the "data-based" versus model predicted M_{bed} should be clarified. It is also not certain that realistic "data-based" hourly estimates of M_{bed} can be generated given the frequency of TSS data collection during the Spring 1994 high flow event and the lack of actual flow measurements in TIP tributaries corresponding to instantaneous Fort Edward flow measurements. It would seem to be appropriate to say the "data-based" estimates of M_{bed} are partly dependent upon the construct of interpolated and extrapolated external forcing conditions applied to the model.

The average cohesive sediment deposition rate of 3.8 cm/year simulated for Reach 4 (Vol 2, p. 3-40) seems unrealistic. The only available dated high-resolution sediment core (HR-16) in this reach shows an observed deposition rate of 0.9 cm/year. It is difficult to believe that the average deposition rate in cohesive sediments for this entire reach could be more than 4 times greater than the rate for a sediment core that was specifically located to minimize disruption of the core chronology and maximize the possibility that the core represents a high rate of deposition.

The sediment transport model predictions at flows above 25,000 cfs in TIP (Vol 2, p. 3-37) are suspect due to the exclusion of flow within the flood plain. For example, no assessment is made of including flood plain effects for the spring 1994 flood calibration (27,700 cfs maximum daily flow; instantaneous peak flow must be even higher), or the spring 1993 flood validation (29,000 cfs maximum flow at Fort Edward). The effect of including the flood plain in the TIP model should have been evaluated for these events, as well as for the long-term simulation, since the spatial distribution pattern of sediment deposition and erosion may be affected significantly by periodic large flood events. The fact that the sediment transport/hydrodynamic model base calibration does not represent flood plain effects results in an estimate by QEA that scour in TIP is significantly over-predicted for the 100 year flood event (55% too much net scour in cohesive and 85% too much net scour in non-cohesive sediments). The effect on the sediment transport model calibration due to the lack of flood plain inclusion is unknown and was not evaluated by QEA. Because the calibration is based on replicating estimated changes in suspended solids mass across the TIP, omission of the flood plain, which is a major location of deposition during inundation could result in over-estimating sediment deposition rates within the channel. The only assessment done by QEA was to examine sensitivity of the sediment model to flood plain inundation within the TIP for just the 100-year flood. Any flow greater than approximately 25,000 cfs (perhaps lower) through the TIP results in significant flood plain interaction. Since this represents about a once-in-2-year flow, it suggests that the QEA sediment transport model calibration may need to be revised to incorporate flood plain effects.

Exclusion of a flood plain effect in the TIP brings into question the value of the results presented regarding simulation of a 100 year flood event (Vol 2, Sec. 3.5). The flood plain sensitivity evaluation clearly indicates a significant effect on predicted scour during higher flow conditions. The effect of flood plain exclusion on calibration to short-term events and the long-term historical predictions was not examined. Therefore, we cannot concur with the conclusion that exclusion of the flood plain produces "conservative results". Instead, it would be more appropriate to state that exclusion of the flood plain produces conservative results, relative to its inclusion, for high flow events as a result of the present model calibration parameterization.

Sensitivity analyses of the sediment transport model are presented only for the TIP (Vol 2, Sec. 3.4). The analysis fails to address the issue of large uncertainties in tributary solids loading estimates downstream of the TIP, resulting in an overly optimistic estimate of the level of uncertainty in the model as a tool for predicting sediment and PCB dynamics throughout the Upper Hudson.

6. PCB Fate and Transport Model (Volume 2, Section 4)

6.1 Model Specification

QEA has developed a two-dimensional model of PCB fate and transport in the water column. In addition to process-based descriptions of transfer between the sediment and water column, QEA required an empirical sediment-water transfer coefficient to achieve calibration during low flow conditions. The empirical transfer coefficient approach is examined in more detail under heading 6.5 below.

Within the sediments, the QEA model represents only the top 5 cm in non-cohesive areas (Vol 2, p. 4-19), thus imposing an arbitrary assumption that the PCB mass present at depths greater than 5 cm cannot now or in future interact with the water column. This use of a 5 cm deep model grid in non-cohesive sediments is questionable. The 1977 sediment grab samples are described as representing approximately the top 5 inches (13 cm) of the sediment depth. The sediment data mapping onto the model grid by QEA presents these data as representing at least 13 cm of sediment. The modeling "presumption" that these data only represent the top 5 cm of sediment is unsupported and likely causes the PCB model to misrepresent non-cohesive sediment PCB mass inventory for the 1977 initial conditions. Non-cohesive sediment conditions in the TIP during 1977 likely still reflected the effects of solids and PCB mass loadings caused by removal of the Fort Edward Dam in 1973, so there is no basis for presuming that only 5 cm of non-cohesive sediments were contaminated with PCBs in 1977.

QEA contends that the sediment transport model shows non-cohesive sediments to be non-depositional and that these sediments are not likely to have accumulated PCBs at significant depths. The modeling presumption that non-cohesive sediments are not likely to have accumulated PCB below 5 cm is at odds with the available sediment data, which, according to the sediment classification scheme presented in Tables 4-4 and 4-5, show significant PCB inventories below 5 cm. If some of these non-cohesive areas are indeed slowly eroding, as predicted by the GE sediment transport model, then the use of the best available information regarding the depth of contamination in non-cohesive sediments (i.e., up to at least 13 cm) should be made, else future PCB loads from both resuspension and non-resuspension flux from sediments may be underestimated. The omission of PCB inventories in the model below 5 cm in non-cohesive sediments thus has important implications to the future trajectory of the system due to the possibility that PCB inventories below 5 cm may be remobilized over long time periods due to continuing scour in these areas. This suggests that the GE model cannot accurately describe the effect of contamination below 5 cm on the future trajectory of PCBs in the majority of the Upper Hudson River sediments over long time scales. The ability of small amounts of erosion to expose PCB concentrations in non-cohesive sediments over time was demonstrated in EPA's modeling effort in the Revised BMR.

6.2 Quality of Model Fit and Calibration Strategy

QEA's PCB model appears to provide a reasonable fit, on a visual basis, to observed water column PCB_{3+} data from 1991 on, although no concise statistical summary of the quality of fit is provided. For the older USGS PCB data, the QEA model appears to yield a severe under-prediction of the data for the period from 1977 to 1983, while over-predicting the data from 1984 to 1989. Indeed, the water column PCB predictions for the late 1980's are so poor that the discussion of the bioaccumulation model rejects use of the fate and transport model results (Vol 2, p. 5-42): "To correct this inaccuracy, PCB_{3+} concentrations computed by the fate model at both Thompson Island Pool and Stillwater from 1984 through 1989 were divided by two." This admission that the QEA PCB fate model is not well enough constrained to support accurate bioaccumulation modeling suggests that the model is also not sufficiently well calibrated to provide a reliable tool for analysis of remedial options.

The calibration shows fits to event data on compressed time and concentration scales, making evaluation of the actual fit between model and data difficult for the three events shown in Vol 2, Figure 4-53 (i.e., 1982, 1983, and 1993). Close inspection of these results suggest that the model significantly under-predicts peak PCB concentrations at all locations for the 1983 event. For the 1993 event, the model under-predicts peak concentrations at Stillwater and Waterford and the usefulness of this particular event for model-data comparison is compromised by the uncertainty in the estimate for the Fort Edward PCB load. The fits to event data are probably acceptable considering the uncertainties in PCB and solids loadings, but should not be referenced as verification of the sediment transport model. Scatter plots of PCB model to data comparisons in the water column for various locations should have been generated and provided in the report.

QEA has made selective use of the available data for calibration within the TIP, focusing mainly on the limited number of TIP center channel observations. We do not concur with the statement that TI Dam west shoreline data cannot be used for model calibration (Vol 2, p. 4-62). These data are valid observations, but reflect lateral gradients in PCB concentrations under certain flow and upstream loading regimes. Excluding these data completely from model comparisons produces a significant temporal gap (1993 through 1996) for assessing the PCB model predictions through the TIP during the period of most intensive water column data collection by a number of entities (GE, USGS, and US EPA) between 1977 and 1998.

In general, the QEA calibration/validation strategy (Vol 2, pp. 4-39 - 4-40) attributes an inappropriate level of certainty to the parameterization of the model and implies that the model is more tightly constrained that the available data allow. The depth and extent of particle mixing are presented as the only significant parameters whose values are not tightly constrained. This ignores important and seemingly inappropriate assumptions about the depth of contamination in non-cohesive sediments, and also attributes an unjustified level of accuracy to the sediment transport model calibration. Based on the lack of system-specific data to constrain settling and resuspension processes throughout the Upper Hudson River, and the lack of feedback from the PCB fate and transport model to the sediment transport calculations, the gross rates of settling and resuspension computed by the sediment transport model are unconstrained. For example, an alternate calibration parameter set for the sediment transport model may well have resulted in equally acceptable matches to in-river TSS concentrations, but could have produced different calibration values for particle mixed depth and mixing rate. Considering the important influence of these parameters on long-term PCB fate in the system, the specific calibration of the sediment transport model, which is to a degree arbitrary, led to the choice of particle mixing rates and depths. Thus, the statement that these parameters were the only ones not tightly constrained in the model is inaccurate.

The calibration of the model also involved adjustments to the estimated PCB load at Fort Edward in order to fit the surface sediment trajectory in TIP (Vol 2, p. 4-40). No details are provided in the report allowing an assessment of the degree to which PCB loading was used as a calibration variable.

The interpretations of the PCB model calibration results (Vol 2, pp. 4-57, 4-70 - 4-72) state that the PCB fate model was tightly constrained by the solids fluxes provided by the sediment transport model. As mentioned above, the level of constraint provided by the sediment transport model is compromised by a lack of simultaneous calibration to PCB, large uncertainties in solids loads and in a number of the sediment transport model parameters. Also, the calibration strategy states that PCB loadings were adjusted in the model calibration. Thus, it is misleading to say that the PCB model is tightly constrained and calibration error was attributed to sediment mixing processes.

The calibration approach assumed that initial errors in predicting the rate of non-cohesive sediment concentration declines were due to the specification of mixed depth or mixing rate (Vol 2, pp. 4-57 - 4-61). QEA contends that these parameters could not be responsible for calibration errors and thus the depth of non-cohesive sediment contamination was reduced. The calibration discussion fails to consider other possible explanations and instead contradicts existing observations in order to force the model to describe sediment trajectories. Other explanations include errors in the sediment-water transfer rates of PCBs from non-cohesive sediment and/or errors in sediment settling and resuspension rates. In effect, the model arbitrarily reduces the flux of PCB from sediment to the water column without providing an appropriate scientific rationale. This arbitrary adjustment detracts from the level of assurance in the model calibration and reduces the suitability of the model for use in forecasting.

6.3 Specification of Upstream Boundary Condition

A significant portion of the PCB mass observed over time in the Upper Hudson originated above Fort Edward, which is the upstream simulation boundary for the QEA model. During the earlier period, some of this load was attributable to erosion of the remnant deposits, but during the 1990's the predominant upstream source was oil seepage at the Hudson Falls facility. This source was highly variable, only partially correlated with flow, and not always associated with elevated suspended solids. Sampling frequency has not been high enough to accurately characterize loading from this erratic source, especially prior to the start of regular GE sampling in 1991. This presents a problem for the model, even if the upstream source is turned off for future projections, as model calibration must, of necessity, be based on periods of record when the upstream source was active.

It should be noted that this problem is particularly acute for a model that is calibrated only to PCB_{3+}, as is presented by QEA. Because there is a difference in congener signal from sediment sources in the TIP, a calibration which also examines individual congeners or homologous will be much better constrained – as was being done in EPA's Revised BMR.

QEA separates the upstream load (up to 1991) into three components:

- A base load component which varies annually and seasonally;
- A resuspension load component, the concentration of which is a function of TSS, based on a log-linear interpolation of high flow data from 1977 to 1991 after excluding outliers and applied to the sediment rating curve at Fort Edward; and
- A pulse load, representing (presumably) transport of PCB oils at flows greater than 15,000 cfs, estimated (through calibration) to represent 100 lb/d for 3 days per year, supposedly equal to the median pulse loading per year observed in 1977-1991 data.

It is not clear exactly how the pulse load was entered into the model. Presumably, the time series was first matched up with any observed pulse loads. Any inferred, but unobserved pulses should then have been assigned to days with flow greater than 15,000 cfs. In two years (1988, 1991) there were no flows greater than 15,000 cfs, but QEA's graphs suggest pulse loads were apparently assigned anyhow. This approach was applied up to April 1991, at which time GE weekly monitoring began and linear interpolation of observed concentrations were used from April 1991 onward.

6.4 Other External Forcing Functions for PCB Model

Uncertainties in the sediment transport model propagate directly into uncertainties in the PCB transport model. As stated previously, simultaneous validation of the sediment and PCB models is needed to confirm model performance. The significance of an assumed zero sand content in the Moses Kill solids loading (in the sediment transport model) on the predicted decline in surface sediment PCB_{3+} concentrations at this location from 240 ppm in 1977 to about 5 ppm in 1998 (Vol 2, p. 4-59) should be presented. Was an initially under-predicted PCB_{3+} sediment trajectory used as the basis for adjusting the sand content of the Moses Kill solids loads to zero? In addition, the solids loading sensitivity simulations for the PCB model (Vol 2, p. 4-75) do not address the large uncertainty in estimated external solids loads downstream of the TIP.

GE temperature data for TI Dam were applied to the entire Upper Hudson River model domain, including both water and sediment (Vol 2, p. 4-17). Temperature data in the EPA Phase 2 database suggest that there are longitudinal differences in water column temperatures moving downstream from the TIP. A spatially invariant temperature forcing condition obviously does not take this into account. Justification for this assumption should have been provided, since additional water column temperature data were available to construct temperature time series for different reaches of the river..

6.5 Empirical Sediment-Water Transfer Coefficient

To obtain a reasonable fit to the water column concentration data, QEA found it necessary to introduce an empirical transfer coefficient representing "mass transport at the sediment-water interface by mechanisms other than hydrodynamic resuspension." The necessity of including such an empirical factor means that QEA's application is not a truly mechanistic approach. The report states (Vol 2, p. 4-23):

> *While the processes controlling sediment-water exchange are generally understood, a mechanistic representation of each of these processes with appropriate Hudson River-specific parameterization is not feasible because data do not exist to support such representations in the model. Therefore, the combined effect of these sediment-water*

exchange processes was modeled empirically by a lumped sediment-water exchange coefficient that is calibrated to seasonal sediment PCB loadings under low flow conditions...

The equation used by QEA to specify the mass transfer coefficient (Vol 2, Equation 4-28) is based on surface sediment porewater concentrations only, implying that transfer is mediated by the dissolved phase. However, an analysis of congener patterns in the low-flow PCB gain across the Thompson Island Pool suggests that the mass transfer is driven by a combination of porewater and particulate-based transfer[2].

QEA apparently recognizes the mixed nature of the sediment source, as the text states (Vol 2, p. 4-24) "the source of the TIP PCB load is surface sediments as expressed through desorption and transport mechanisms. These could include a direct porewater exchange process...and/or surface sediment resuspension and subsequent PCB desorption...." Calculating the transfer coefficient, k_f, as a function of porewater concentration only and based on a single series of PCB_{3+} observations has two significant limitations: it will not correctly reproduce the congener signal of the load contribution from the sediments, and it may not be extrapolatable to other segments of the river in which physical characteristics controlling sediment–porewater partitioning (organic carbon fraction of sediment, dissolved organic carbon concentration in porewater) differ.

QEA also implies that only the surface sediments (as represented by the 0-2 cm layer) act as a source of PCBs to the water column, independent of underlying sediments (Vol 2, p. 4-24). This is misleading. Deeper sediments act as a source of PCBs to the surface sediment through the various mechanisms that the GE model includes, such as porewater diffusion and particle mixing.

QEA developed the empirical mass transport coefficient based on input/output data for the Thompson Island Pool. The same transfer coefficient is also applied to downstream reaches. The exact processes creating the transfer coefficient are poorly understood, therefore, it is unknown whether the estimated rate applies outside the reach for which it was calibrated. For example, if the transfer coefficient is related to bioturbation, which is greater in cohesive sediment areas, the transfer coefficient may vary with reach-to-reach changes in the ratio of cohesive/non-cohesive sediment areas. The data do not directly support specification of sediment-water mass transfer rates by reach. Thus, while QEA's assumption of a constant rate throughout the system is not inconsistent with the data, alternative assumptions are also possible.

6.6 Sediment Mixing Depth

A sediment mixed depth of 3 cm was specified for non-cohesive sediments, "on the basis of model calibration" (Vol 2, p. 4-28). This represents a very shallow mixed depth compared to those typically reported in the literature. Establishment of the non-cohesive sediment mixed depth through model calibration is likely affected by the incorrect specification of non-cohesive sediment initial conditions and the limitation of non-cohesive sediment depth in the model to only 5 cm.

[2] Butcher, J.B. and E.A. Garvey. 1999. Congener pattern matching to evaluate sediment PCB source in the Upper Hudson River. Poster presentation at SETAC 20th Annual Meeting, Philadelphia, PA, November 18, 1999.

6.7 PCB Partitioning

PCBs are hydrophobic compounds, which tend to leave the dissolved form and sorb to organic matter. Partitioning of PCBs in the environment is best described as a three-phase process, accounting for a fraction sorbed to particulate material, the truly-dissolved fraction, and a third fraction sorbed to dissolved or non-settling organic matter, such as organic colloids, as described in US EPA's Data Evaluation and Interpretation Report. When samples are mechanically separated by filtration, both the truly-dissolved fraction and the fraction sorbed to dissolved organic matter (DOM) appear as part of the "apparent" dissolved phase. The influence of the DOM-sorbed fraction appears to be most important for the less-chlorinated congeners.

In their PCB model, QEA has assumed that a two-phase representation of partitioning is adequate. QEA discusses the role of sorption to dissolved organic matter, but then concludes that it is not of sufficient importance to model. The following argument is given (Vol 2, pp. 4-29 – 4-30):

> *Measured apparent organic carbon partition coefficients for each congener were evaluated in relation to octanol-water partition coefficients (K_{OW})... It is notable that in all samples the relationship between K_{OC} and K_{OW} is approximately linear. A linear relationship indicates that sorption was not appreciably impacted by the presence of DOM. If a significant fraction of the PCBs in the filtered water samples had been sorbed to DOM, the K_{OC} – K_{OW} relationship would deviate from linearity in the manner illustrated in Figure 4-21. ...the partitioning to particulate organic matter apparently is much greater than the partitioning to DOM. For this reason, competitive sorption to DOM was not considered in the model.*

These arguments are partially valid for PCB_{3+}, although in fact some of the K_{OC} versus K_{OW} plots presented by QEA could be interpreted as showing non-linearity consistent with DOM sorption. An analysis of EPA Phase 2 PCB_{3+} congener sums in the particulate and (apparent) dissolved phases yields an estimate that less than 5 percent of the PCB_{3+} mass in the water column is sorbed to DOM under typical upper Hudson conditions. Conclusions regarding PCB_{3+} or total PCBs are not, however, applicable to all individual congeners. The analysis summarized in Table 4-8 in the DEIR suggests that as much as 50 percent of the apparent dissolved water column concentration of BZ#4 and BZ#8 may be present sorbed to DOM. The two-phase partitioning approach used in the QEA model may thus be satisfactory for representing PCB_{3+} in the water column, but is likely to introduce significant errors in replicating the ratios of congeners or homologue groups – and thus cannot be used for calibration to congener ratios. For this reason, the three-phase approach to representing PCB partitioning behavior appears clearly superior and should have been used by QEA.

QEA has also used a two-phase representation of PCB partitioning in the sediment (Vol 2, p. 4-31): "Partitioning to the sediment porewater dissolved organic matter was not modeled because the data indicated that it did not have a significant affect on PCB distribution in the sediment." This conclusion is based on an analysis of PCB_{3+} from GE sediment and porewater data via the following line of reasoning:

- Data that diverge from the expected relationship between sediment and porewater concentrations may be arbitrarily rejected as representing resistant (non-equilibrium) sorption.
- The remaining data show an approximately linear relationship between porewater and sediment concentrations and represent reversible sorption.
- The slope of the linear relationship yields a K_{OC} value of $10^{5.6}$, which is approximately equal to the K_{OC} estimated for the water column (from TID to Waterford).
- Therefore, there is no evidence of a significant effect of DOM on partitioning in sediment porewater.

This argument contains a number of questionable assumptions. First, the noise in the plot of sediment versus porewater concentrations is more likely attributable to inappropriate sample handling and compositing procedures used by GE's contractor (as discussed in the DEIR) than to resistant sorption. Second, even after rejecting nearly a third of the data as outliers, the remaining points still show only a weakly linear relationship, not strong enough to conclude "equality between water column and sediment K_{OC} with no evident influence of dissolved organic matter." By contrast, in New Bedford harbor porewater total PCBs were found to be dominated by PCBs sorbed to colloidal material[1].

QEA has also assumed that different partition coefficients for PCB_{3+} apply above and below Fort Edward. It is true that apparent partition coefficients in individual samples were often observed to be higher at and above Fort Edward than downstream during Phase 2 sampling. The interpretation used in the DEIR is that this represents a kinetic effect resulting from certain samples (e.g., Transect 4) representing non-equilibrated conditions. One of the assumptions of the mass balance modeling approach used by QEA is that equilibrium partitioning applies. The most consistent approach should then be to apply the same partition coefficients at all stations, but discount the comparison to observed concentrations where samples appear to represent non-equilibrium conditions. Partition coefficient estimates by US EPA are corrected for the possible presence of non-equilibrium samples by use of the median of individual estimates to describe the central tendency of observations.

In contrast, QEA has assigned a separate, higher partition coefficient for PCB_{3+} at Fort Edward, with a linear interpolation across the TIP between this value and the value obtained at stations from TID to Waterford. This approach compensates for the discrepancy in observations, but is hard to justify on a process basis unless an argument can be made that the quality of sorbent or the congener composition of PCB_{3+} differs systematically between Fort Edward and Thompson Island Dam. There does not seem to be any strong evidence for variation in sorbent quality. The character of PCB_{3+} is likely to change somewhat across the TIP during low flow due to the accumulation of lower-chlorinated homologues from TIP sediment, which could lead to a reduction in the apparent partition coefficient. But, elevated partition coefficients at Fort Edward are also seen for individual congeners in 1993. The effect is also not a consistent one, as the apparent partition coefficient for PCB_{3+} at Fort Edward was lower than the apparent partition coefficient at downstream stations during Transect 6. These lines of evidence suggests that the anomalously-high apparent partition coefficients observed upstream during other transects may have primarily been a temporary phenomenon of incomplete equilibrium related to the presence of high DNAPL loads from the Bakers Falls source during 1993. If so, QEA's approach of assigning a higher partition coefficient at Fort Edward is likely to be inappropriate for current and future conditions in which the Bakers Falls source has been largely controlled.

[1] Burgess, R.M., R.A. McKinney and W.A. Brown. 1996. Enrichment of marine sediment colloids with polychlorinated biphenyls: Trends resulting from PCB solubility and chlorination. *Environ. Sci. Technol.*, 30: 2566-2566.

7. Bioaccumulation Model (Volume 2, Section 5)

7.1 Model Formulation

QEA presents a complex bioenergetic simulation of bioaccumulation of PCBs in the Hudson River. While this model is elegant in structure and claims to be a mechanistic formulation, there are serious questions as to whether sufficient data are available to support such a complex model. Despite the complex theoretical formulation, the QEA model is, in essence, a description of the relationship between the external forcing functions of water and sediment PCB concentrations and the tissue concentrations of PCB in fish. The fact that the inner workings of the model are more complex and "mechanistic" than other approaches does not necessarily mean that it is a better predictive tool. There are two important considerations here: (1) Are data available to provide an advantage of more realistic constraints on the more mechanistic formulation?; and (2) Is the additional complexity relevant to management decisions? It appears that both questions can be answered in the negative.

At numerous points in the QEA model application simplifying assumptions are required that relax the underlying theoretical construct. For the model bioenergetic and toxicokinetic components, it is admitted that "There is insufficient information to develop a full multi-compartment model and to estimate values for all of the necessary rate constants and partition coefficients" (Vol 2, p. 5-10). In addition, relationships between age and weight are based on data from a single year, which are not necessarily representative of long term trends. Exposure concentrations are also not known at a scale commensurate with the detail of the model. Sediment exposure is estimated based on (uncertain) PCB concentrations in cohesive sediment (only) predicted by the fate model, and "inaccuracy in the fate model calibration affects the bioaccumulation model calibration" (Vol 2, p. 5-42). Further, the spatial extent over which average exposure is unknown, because "The extent to which fish move within each dammed reach is not known" (Vol 2, p. 5-41). Finally, the calibration of the model involves adjusting the empirical resistance coefficient, which is an arbitrary fitting factor on bioenergetic response, and the relative contributions of benthic and pelagic food pathways in fish diet, for which observed gut content data are available. This calibration approach suggests that available data are not sufficient to support either the bioenergetic or food chain exposure components of the model.

In terms of management decisions, the most important model predictions are annual average concentrations in fish species at specific locations. A full bioenergetic approach would be needed to simulate the time course of concentration changes within a year and the individual-to-individual differences in tissue concentrations—but will improve the quality of long-term average predictions only to the extent that the bioenergetic components of the model are properly calibrated and validated. The model is not calibrated to intra-year or inter-individual variability in concentrations. This suggests that the additional complexity of the bioenergetic approach will not yield additional assurance in predicting future responses to remedial alternatives.

7.2 Representation of PCB Forms

It is important to note that the QEA PCB bioaccumulation model is not calibrated to total PCBs or PCB_{3+}. As a calibration target, QEA has chosen instead the total PCB measure traditionally reported by NYSDEC, which is a sum of selected Aroclor quantitations. As discussed in the BMR (Book 3, Chapter 4) these Aroclor sums are (1) not a consistent quantity over time and changing analytical methods, and (2) not equivalent to either total PCBs or PCB_{3+}. QEA has partially recognized the impact of changing analytical methods, and notes that "The data from the later 1970s and early 1980s were corrected following Butcher *et al* (1997)." This paper[1] discusses approaches to convert NYSDEC Aroclor

[1] Butcher, J.B., T.D. Gauthier, and E.A. Garvey. 1997. Use of historical PCB Aroclor measurements: Hudson River fish data. *Environ. Toxicol. Chem.*, 16(8): 1618-1623.

1016 and 1254 quantitations for 1977 through 1982 to Aroclor quantitations consistent with the analytical methods used for NYSDEC in the 1983 to 1990 time period. QEA has apparently not recognized that later analytical methods used by Hale Creek (1990-1993) and by Hazleton/EnChem (1992-1997) yield results that are not consistent with the 1983-1990 results. Further, none of these methods are exactly equivalent to PCB_{3+}, which is the quantity simulated in the PCB fate model. QEA dismisses this problem by stating (Vol 2, p. 5-40):

> *Total PCB concentrations measured in fish on an Aroclor basis...were compared with model results that were computed based upon PCB_{3+} exposure concentrations... This leads to a bias of less than 5% in model results, because mono- and dichlorobiphenyl comprise less than 5% of total PCBs in fish from the Upper Hudson River.*

The reasoning here is incorrect, as it is based on the assumption that the Aroclor sums are equivalent to total PCBs. For instance, the BMR (Book 3, p. 43) shows that the 1983-method Aroclor sum underestimates PCB_{3+} by a factor of about 1.3, while the method in use in 1992-1997 appears to over-estimate PCB_{3+}. U.S. EPA, NOAA, and GE capillary column analyses which provide direct estimates of PCB_{3+} or total PCB concentrations in fish are *not* directly comparable to the Aroclor sums.

As a result of these data issues, the QEA bioaccumulation model is not properly calibrated. Instead, it has been calibrated to an artificial quantity which is not equivalent to PCB_{3+}, is likely to underestimate true fish body burdens, and which changes its relationship to PCB_{3+} over time.

7.3 Representation of Fish Lipid Content

PCBs accumulate primarily in fish lipids, but lipid content is found to vary widely with the individual, species, location, and year. Conversion of concentrations to a lipid basis also can introduce error, as there is analytical variability in lipid quantitation both within and between laboratories. QEA agrees that "the evaluation of long-term trends is best performed on a lipid basis", although cautioning that "excretion rate cannot track sudden large changes in lipid content" (Vol 2, p. 5-43). QEA has specified their model using fish lipid concentrations that vary by species, location, and time. The description of the computer code (Vol 2, p. 5-13) claims that lipid content varies on a daily basis; however, lipid content is not shown to be simulated by the model, and was actually specified on a constant annual basis by location from NYSDEC sampling results (Vol 2, p. 5-37). QEA does not explain how lipid values were determined for species-locations-years where NYSDEC sampling is not available. Lipid content is an important factor in controlling PCB transfer at the gills, as well as within the animal, and is likely to vary on a seasonal basis in response to temperature and prey availability. Formulation of the model with a dynamic simulation of weight and energy usage but annually fixed lipid content based on summer observations would seem to be a mismatch that could lead to incorrect results.

The input of lipid concentrations that vary by location and time also limits the ability of the model to function in the forecast mode, as discussed in Section 8.4.

7.4 Kinetic and Bioenergetic Parameters

QEA proposes a multi-compartment bioenergetic model of PCBs in biota, but admits "There is insufficient information to develop a full multi-compartment model and to estimate values for all of the necessary rate constants and partition coefficients" (Vol 2, p. 5-10). The shortage of data to support the model formulation means that the model is more empirical, and less mechanistic than it appears. For instance, accumulation across the gill is presented as a function of diffusive exchange across the gill and exchange between the lipid and blood fractions. But, because the rate constants between compartments are not known, the final equation for gill uptake is determined by a purely empirical "resistance" factor which is used as a calibration parameter.

QEA presents a lengthy discussion of feeding preferences for each component of the food web (Vol 2, Sec. 5.2.1), but is unable to derive consistent relationships. For instance, for pumpkinseed "the best overall relationship between computed and observed diets was observed for a mix of sediment- and water column-based invertebrates ranging between 25 and 75% of each" (Vol 2, p. 5-23). In the end, the feeding preferences were apparently used as a calibration parameter.

The QEA model also requires species-specific relationships between age and weight to evaluate growth dilution. These relationships were calculated based on a single set of samples collected in November 1990. No evaluation is provided as to the representativeness of this year and this season. Samples from other years and seasons could well show significantly different age:weight relationships.

7.5 Bioaccumulation Model Calibration

The model was calibrated using exposure concentrations as PCB_{3+} from the PCB fate and transport model and sums of Aroclors reported from fish samples from 1977 through 1998. As noted above, the mismatch between PCB forms between exposure and tissue concentrations results in an inappropriate calibration. Calibration is presented primarily on a visual basis. No separate validation tests of model fit are presented.

Interestingly, QEA found it necessary to introduce some *ad hoc* modifications to the PCB model output during calibration of the bioaccumulation model. Most notably, "PCB_{3+} concentrations computed by the fate model at both Thompson Island Pool and Stillwater from 1984 through 1989 were divided by two" (Vol 2, p. 5-42). This adjustment appears to be an entirely arbitrary choice, designed to improve the *apparent* fit of the bioaccumulation model. The necessity of including such an arbitrary modification suggests that there are serious deficiencies in either the PCB or bioaccumulation model calibrations.

Use in the model of observed lipid concentrations that vary by year and location also improves the apparent fit of the bioaccumulation model relative to what would be obtained from a truly mechanistic formulation. While this approach improves the fit to historical data, it compromises the usefulness of the model for predicting future conditions, for which lipid content has not yet been observed, and is difficult to predict.

As noted above, the calibration of the QEA bioaccumulation model consists of adjusting the empirical elimination resistance coefficient (an arbitrary fitting factor on bioenergetic response) and the relative contributions of benthic and pelagic food pathways in fish diet. Despite the availability of data on fish gut contents, QEA states (Vol 2, p. 5-54): "...for the purpose of predicting PCB levels in fish, the most important uncertainty associated with the bioaccumulation model is...the proportion of dose received by the food web from surface sediments and from the water column." In practice, treating both fish diet and bioenergetic response as fitting parameters results in a calibrated model that expresses an empirical (rather than truly mechanistic) relationship between water and sediment exposure concentrations and average fish tissue concentrations. A more defensible approach would be to use the available data on fish diet either directly or as the basis for a stochastic simulation, rather than taking dietary composition as a fitting parameter.

8. Predictive Applications (Volume 3)

Results of the predictive applications presented in Volume 3 are strongly dependent on assumptions regarding future flows, solids loading, and PCB fluxes, as well as the types of remediation methods evaluated. The net effect of these assumptions appears to be to predict a natural recovery that is faster than is justified by the data, thus reducing the apparent efficacy of remedial intervention.

8.1 Prediction of Future Hydrologic Conditions

To generate a future series of flows, QEA uses a synthetic hydrograph which includes a Markov model of annual flow rates with disaggregation to daily flows based on the nearest match among the 65 years of available flow records at Fort Edward (Vol 3, Section 3.1). The QEA projection appears to have a potential low bias, as the historical record used to generate the prediction contains five years in which annual mean flow rates are greater than any generated for the synthetic hydrograph Omission of the higher flow years could create a corresponding low bias in the projection of PCB loads. Sensitivity of model predictions to alternate formulations of the prediction hydrograph should have been investigated, but is not reported by QEA.

8.2 Future Solids Loading and Transport

For projection of future conditions, QEA applied a sediment rating curve to the projected flow series at Fort Edward to generate a sediment load series. The QEA projections result in average annual solids loads at Fort Edward that are 7% lower than those observed during the hindcast model calibration period, reflecting the fact that all of the annual mean flows used in the projection are several thousand cfs less than the observed flows of 1990 and 1995 included in the hindcast calibration. Despite average annual solids loads that are somewhat lower than those observed in the hindcast, the QEA projections show a 14% increase in average sedimentation rate within the TIP relative to historic observations, increasing from 0.81 to 0.92 cm/yr (Volume 3, p. 3-4). The increase in sedimentation rates relative to observed conditions suggests that the model forecast may tend to exaggerate the rate of burial of contaminated sediments within the Thompson Island Pool. Further, the combination of lower upstream solids loads and increased sedimentation within the TIP are likely to result in a low bias in estimates of transport of particle-associated PCBs from the TIP to downstream reaches.

8.3 Remediation Methods

QEA has considered only a limited number of remediation options. Dredging is restricted to consideration of removal of TIP hot spots and/or removal of cohesive sediments (only) from Rogers Island to Northumberland Dam. Neither capping nor removal of non-cohesive sediments were considered. Failure to evaluate a full range of potential remediation options means that global statements regarding the possible efficacy of remediation are at best premature.

8.4 Prediction of Future PCB Fate, Transport, and Bioaccumulation

QEA presents predicted concentrations in largemouth bass and PCB flux to the lower river under conditions of natural recovery and various remedial options. For the fish, the focus is on relative time to reach a 2 ppm wet weight tissue concentration. Because tissue concentrations in some reaches and species are already approaching this value, changes in the rate of approach translate to relatively small differences in time to target. It is likely, however, that a final risk-based tissue concentration level will be much smaller than 2 ppm. As shown in the corrected figures (Errata, Figures 6-4, 7-2, 8-2) the predicted time lag for achieving a target value may differ by decades or more between natural recovery and remediation for target concentrations less than 1 ppm, even using QEA's optimistic assumptions for natural recovery.

The QEA predictions of natural recovery are believed to be overly optimistic for two reasons. First, it is believed that the model likely over predicts burial rates for PCBs in the system. Second, the model does not represent PCBs stored below 5 cm depth in non-cohesive sediments. As some non-cohesive areas are predicted to be erosional, the model does not properly account for future releases to the system from deeper non-cohesive sediments.

QEA also states (Vol 2, p. 4-70) that the impact of upstream PCB pulse loading "will not propagate into future predictions", and therefore does not need to be assessed in forecasts. This is misleading in light of observed pulse loads that have occurred in recent years (e.g., 1998 and 1999). In fact, as residual surface sediment PCB contamination declines, the significance of PCB loads across the upstream boundary of the model is likely to increase. The approach taken by QEA to represent the upstream boundary in the forecasts was to assign a constant load boundary condition of 0.2 lb/d. A constant load boundary condition implies that concentrations will be least during spring high flows, and greatest during summer low flows. This is the opposite of the historic observations of pulse loading associated with high flows. Further, the use of a constant load boundary condition will over-estimate the importance of the upstream boundary during low flow conditions, which will have the effect of diminishing the apparent importance of contributions of PCBs from historically contaminated sediments during the summer growing season when bioaccumulation in fish is greatest. This causes the QEA model forecasts to underestimate the potential benefits associated with remediation of contaminated sediments as the fish body burdens will be controlled by high upstream concentrations. A more realistic approach would be to use a constant concentration boundary condition, resulting in a positive correlation between loads and flows consistent with the historical record. In addition, the forecast scenarios should be presented across a range of assumptions regarding upstream boundary concentrations (not daily average loads) to address the potential for continued pulse loading from the upstream source.

The QEA approach to fish lipid also has an impact on prediction of future conditions. Here, QEA has chosen to retain fixed differences between stations (Vol. 3, p.2-1): "The lipid content of each species of fish at each location was assumed to remain constant and was set equal to the values used in the last year of calibration." This decision is difficult to justify. For instance, the last-year-of-observation values used by QEA (see Vol. 2, Figures 5-18 and 5-19) have lipid concentrations that are higher than most of the historic record for largemouth bass and bullhead in TIP and pumpkinseed at Stillwater. Lipid concentrations assigned are about equal between TIP and Stillwater for pumpkinseed and bullhead, even though bullhead have generally had lower lipid in TIP, while a higher lipid content is assigned to largemouth bass in TIP than in Stillwater. Use of median values from historic observations (or better, use of a statistical description of the distribution of lipid content) would provide a better basis for future projections.

Appendix

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Appendix

Appendix

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Butcher, J. B, 2000a. Flood Frequency Analysis, Ft. Edward at Rogers Island Gage, Hudson River. Memorandum to E. Garvey, V. Bierman, S. Verhoff and D. Merrill. January 15, 2000.

Butcher, J. B, 2000b. 1976-78 Sediment Data Conversions. Memorandum to E. Garvey, A. DiBernardo, V. Bierman, M. Erickson and D. Tomchuk. January 18, 2000.

Butcher, J.B. and E.A. Garvey. 1999. Congener pattern matching to evaluate sediment PCB source in the Upper Hudson River. Poster presentation at SETAC 20th Annual Meeting, Philadelphia, PA, November 18, 1999.

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MEMORANDUM

To:	E. Garvey (TAMS/NJ) V. Bierman, S, Verhoff (LTI) D. Merrill (Gradient)	**Date:** January 15, 2000
From:	J. B. Butcher	**Project:** Hudson PCBs
Subject:	Flood Frequency Analysis, Fort Edward at Rogers Island Gage, Hudson River	**Pjn:** 1985-03

This memo formally transmits and documents the results of analyses conducted in June 1993.

Flood Frequency Analysis, Fort Edward at Rogers Island Gage, Hudson River

In the Phase I report we provided a preliminary analysis of peak flood flows at the USGS gage Hudson River at Fort Edward at Rogers Island (#01327750). This represents the upstream end of the Thompson Island Pool; accurate determination of flood peaks here is important to analysis for the potential for scour of contaminated sediments contained in that area. The Phase I analyses were based on data through water year 1990. Complete 1991 data are now available as well (at the time_of this analysis Fort Edward gage data had been incorporated into WATSTORE through June 1992 only, so water year 1992 was not complete.) More importantly, we determined that it was appropriate to revisit certain assumptions involved in the translation of peak flow estimates from the Hudson River at Hadley to Fort Edward. Finally, the Phase I estimates did not include confidence bounds; these are now included.

To obtain a statistical estimate of flood recurrence interval it is necessary to form the annual series of the flood peak values. This series is the set of annual maxima (largest flood event in each year of record). Flow records at Fort Edward commence in December 1976 (water year 1977); there are thus 15 years of record available. Empirical estimates of return frequency were presented in the Phase I report. However, due to the short period of record, these cannot provide a reasonable estimate of the probability of extreme events. Instead, these must be estimated using a statistical model. The method for accomplishing this recommended by the U.S. Water Resources Council (1967) is to use the log-Pearson Type III distribution to model the annual maxima series. Methods for implementing this analysis have been extensively developed by the USGS (1982). In essence, the method yields an expression for the flood Q_T (cfs) associated with any given recurrence interval, T (years), as

$$\log_{10} Q_T = \bar{X} + S * K_T$$

in which $\bar{X}$ is the mean of the distribution of base-10 logarithms of flow, S is the standard deviation of the base-10 logarithms, and K_T is the "frequency factor" for recurrence interval T, given by

$$K_T = \frac{2}{C_S}\left\{\left[\left(U_T - \frac{C_S}{6}\right)\frac{C_S}{6}+1\right]^3 - 1\right\}$$

where U_T is the standard normal deviate corresponding to recurrence interval T and C_s, is a stabilized estimate of skew, formed as a weighted average of the sample skew and generalized regional skew using the method of Wallis et al. (1974).

The first step in the current analysis was to apply USGS program J407 to the observed peak flowsat the Hudson River at Fort Edward at Rogers Island gage. Estimated historical peak floods of 43,900 cfs (1900) and 89,100 cfs (1913) were reported. However, these were not included in the analysis because they occurred before the substantial upstream flood regulation was provided by the Great Sacandaga Lake Reservoir. Based on the 1977-1991 peaks, the following estimates are obtained (Table 1):

Table 1: Log Pearson Type III Annual Flood Frequency, Fort Edward Gage, 1977-1991

Recurrence Interval (T)	T Year Flood	Upper 95% Conf. Limit	Lower 95% Conf. Limit
5	30184.5	34780.5	27288.3
10	33481.1	39896.4	29925.6
25	37451.6	46512.4	32897.8
50	40297.6	51508.1	34936.8
100	43066.3	56548.7	36866.5
200	45788.3	61664.3	38721.1
500	49348.5	68580.9	41094.1

Unfortunately, the short period of record available at Fort Edward does not enable a very reliable prediction of large magnitude flows of most interest to us. We therefore, as in Phase I, attempted to extend the annual maxima series at Fort Edward by translating peaks downstream from the confluence of the Hudson River and Sacandaga River· Unfortunately, while gaging is available on both rivers just upstream of the confluence (Hudson River at Hadley, NY, #01318500); Sacandaga River at Stewart's Bridge near Hadley, NY, #01325000), USGS does not measure peak flows for the Hudson below the confluence with Sacandaga River, although daily average flows are reported as a "dummy" gage. Further, because the Sacandaga River flow is strongly controlled, peaks on the two rivers are unlikely to coincide. Therefore a method must be developed to estimate peak flow at Fort Edward from peak flow data for the Hudson River at Hadley and data for the Sacandaga River at Stewart's Bridge near Hadley. There are two issues here: (1) an estimate of the peaks below the Hudson-Sacandaga confluence must be formed, and (2) the peak estimate must be muted downstream to Fort Edward. In an early report (Malcolm Pirnie, 1975), it was estimated that the 100-year peak flow flood at Fort Edward was 41,400 cfs. However, this estimate was obtained using a *direct* translation of the 100 year flood at Hadley downstream, without proration for drainage area and further assuming that the flow in the Sacandaga would be zero during flooding in the Hudson. Examination of flow records in the Sacandaga shows that the zero flow assumption is not always valid. The method advocated by FEMA (1980 and 1984) for estimating flood recurrence at Fort Edward based on peaks at Hadley, was to assume that the Great Sacandaga Lake reservoir would contribute 8,000 cfs of flow to the Hudson River during extreme flood events. This is the discharge which results from the opening of one control valve, which may be done during major storms to prevent topping of the dam. At the time of the FEMA reports only a short period of record was available for the gage at Fort Edward. Thus, a Log Pearson III distribution was fit by FEMA to the period of record for the Hudson at Hadley and used to predict values at Fort Edward via:

$$Q_T(FE) = [Q_T(H) + 8000] \times \left(\frac{2817}{2719}\right)^{0.75} \qquad \text{(FEMA)}$$

where

$Q_T(FE)$ =	flood (cfs) for a given recurrence interval T (years) at Fort Edward
QT (H) =	flood (cfs) for the corresponding recurrence interval at Hadley

The term (2,817/2,719) is the ratio of drainage areas (in square miles) between the Hudson just below the confluence with the Sacandaga River and the Hudson River at Fort Edward at Rogers Island. The exponent (here 0.75) is based on the USGS index-flood methodology which relates mean annual flood in a region to a fractional exponent of contributing drainage area. Given the assumption of a log-linear dependence of T year flood on mean annual flood, this means that the ratio of log peak floods at gages with differing drainage areas is equal to the ratio of the areas raised to this fractional power.

The FEMA approach of assuming a constant flood discharge from Great Sacandaga Lake is likely to overestimate the magnitude of floods (and is thus conservative for a flood insurance study). That is, examination of the record shows that on the days of peak flow in the Hudson at Hadley daily average flow in the Sacandaga at Stewart's Bridge was often near zero, and exceeded 8,000 cfs only twice between 1930 and 1976.

For the present study a modified approach was undertaken, which has been refined somewhat from Phase I. Prior to the period of record at Fort Edward, annual peaks were estimated from data from the Hudson River at Hadley gage and the Sacandaga River at Stewart's Bridge gage. Data from 1930 on only were used, as the Sacandaga River flow has been regulated by Conklingville dam since 27 March 1930. The starting point for our analysis was the set of reported peak flows in the Hudson River at Hadley (we started with the partial duration series, which contains all peaks above a specified reference level, as the maximum for Hudson plus Sacandaga did not necessarily occur with the largest magnitude peak in the Hudson alone). To these, we needed to add an estimate of the coincident peak in the Sacandaga. When peaks in the Hudson at Hadley and Sacandaga were reported on the same day, the two peak values were simply summed. However, when a peak in the Sacandaga did not coincide with a peak in the Hudson, we added the daily average flow in the Sacandaga to the peak in the Hudson at Hadley (this is probably not a bad assumption, as control in the Sacandaga tends to reduce fluctuations around the daily average). This gave us an artificial partial duration series of flood peaks for the Hudson below the confluence with the Sacandaga River, from which we selected an annual maxima series. Finally, we went back and checked this series against the sum of daily average flows in the Hudson at Hadley and Sacandaga at Stewart's Bridge. In seven instances (1932, 1951, 1955, 1959, 1969, 1971 and 1974) there was a value of the sum of daily averages which was greater than the synthetic peak, in which case the daily average maximum value was substituted into the annual maxima series. (These instances occurred during years in which the observed peaks in the Hudson were relatively small. The procedure necessarily underestimates some unmonitored flood peaks in the Hudson below Sacandaga, but is not thought to have a major impact on estimated recurrence

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frequency of extreme events.) The calculated annual maxima at Hudson below Sacandaga and the measured annual maxima at the Fort Edward gage are displayed in Figure 1.

Next, the annual maxima series had to be translated downstream to the Fort Edward gage. We assumed, as in the FEMA studies, that a relationship should exist based on the ratio of drainage areas raised to a fractional power, *p*, but did not assume the value of *p a priori*. Instead, using the data from the years 1978-1990[1] we regressed the observed Ft. Edward annual maxima on the estimated maxima for the Hudson below confluence with the Sacandaga. No intercept was included in the model. This yielded an estimate of p as 0.815, which fits well with the "typical" value of 0.75.

For the calculation of the Log Pearson Type 11I flood distribution, we used the values

$$\text{Ft. Edward} = \left(\frac{2817}{2719}\right)^{0.815} - (\text{Hadley} + \text{Sacandaga})$$

for the period of water years 1930-1976, combined with annual maxima directly measured at Fort Edward for water years 1977 to 1991. The results arc shown in Table 2, and displayed graphically, with 95% confidence limits, in Figure 2.

Table 2: Log Pearson Type III Annual Flood Frequency, Fort Edward, 1930-1991

Recurrence Interval (T)	T Year Flood	Upper 95% Conf. Limit	Lower 95% Conf. Limit
5	30126.0	33519.4	27571.8
10	34561.2	39218.7	31292.5
25	39882.6	46347.7	35590.9
50	43671.3	51581.3	38571.1
100	47330.0	56743.3	41399.3
200	50897.2	61868.9	44116.6
500	55514.0	68626.8	47582.8

Table 3 compares the estimates obtained by the different methods used here as well as those discussed in the Phase I Report.

[1] 1977 was omitted as anomalous, as the peak upstream was significantly larger than the reported peak at Fort Edward and did not fit the pattern shown by later observations.

Table 3. Comparison of Annual Flood Frequency Estimates at Fort Edward

Recurrence Interval (T)	1930-1991 Data (cfs)	1977-1991 Fort Edward Gage	Phase I Estimate (Table B.4-1)	FEMA (1984) Estimate
5	30126	30184	30090	--
10	34561	33481	34526	38800
25	39883	37452	39848	--
50	43671	40298	43636	48300
100	47330	43066	47293	52400
200	50897	45788	--	--
500	55514	49348	55471	62200

The current estimates from the 1930-1991 data are highly consistent with the estimates reported in Phase I. Both are somewhat higher than the estimate obtained from the 1977-1991 Fort Edward gage data alone, but within the large confidence bounds for those estimates (Table 1). Use of the 1977-1991 data alone is thought to result in a downward bias because of the relative paucity of large flood peaks observed during most of the 1980's. On the other hand, it appears clear that the FEMA estimates are too high. Similarly the estimates used by Zimmie (1985) in his assessment of erodibility in the Thompson Island Pool, which included a 100 year flood estimate in the Thompson Island Pool above Moses Kill of 63700 cfs, appear much too high. (As noted in the Phase I report, these estimates are apparently based on a misreading of the FEMA studies).

In sum, we recommend use of the Log Pearson Type III annual flood frequency analysis based on the 1930-1991 data, and summarized in Table 2. Appendix 1 provides a listing of the Pearson Type HI parameters, as well as a more detailed frequency tabulation.

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Appendix 1. Detailed Results of Log Pearson Type III Flood Frequency Analysis for Fort Edward, 1930-1991

Parameters

$\bar{X}$ 4.3578

S 0.1429

C_s -0.146 (regional skew = 0.345; sample skew = 0.3148)

Detailed Recurrence Interval Table

Recurrence Interval (T)	T Year Flood	Upper 95% Conf. Limit	Lower 95% Conf. Limit
5	29847.39	34022.46	26856.46
10	34561.20	39218.71	31292.48
20	38625.99	44639.32	34588.97
25	40685.65	49153.36	35485.91
30	40894.71	47733.89	36392.76
40	42468.16	49906.38	37630.90
50	43671.27	51581.26	38571.12
60	44644.34	52944.28	39327.72
70	45460.75	54093.47	39959.97
80	46163.63	55086.88	40502.50
90	46780.51	55961.73	40977.33
100	47329.98	56743.33	41399.26
150	49425.95	59744.33	43000.31
200	50897.20	61868.88	44116.61
250	52030.50	63515.20	44972.49
300	52951.87	64859.78	45665.84
350	53727.89	65996.44	46248.14
400	54398.05	66981.06	46749.81
450	54987.68	67849.66	47190.30
500	55513.98	68626.78	47582.78

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MEMORANDUM

To:	Ed Garvey, Al DiBernardo (TAMS/NJ) Vic Bierman, Mike Erickson (LTI) Doug Tomchuk (U.S. EPA, Region 2)	**Date:** January 18, 2000
From:	J. B. Butcher	**Project:** Hudson PCBs
Subject:	1976-78 Sediment PCB Data Conversions	**Pjn:** 1985-08

This memorandum formally transmits work originally reported on June 9, 1998.

1976-78 OB&G Data

For the 1976-78 sediment data, OB&G provided analyses for Aroclors 1221, 1016, and 1254. Aroclor 1221 was analyzed via a single packed column peak[1]. Aroclor 1016 was analyzed via three peaks (the same used for Aroclor 1242 in 1984), while Aroclor 1254 was analyzed via eight peaks, including some used for 1260 in 1984. No separate analysis was provided for Aroclor 1260. OB&G used an averaging method (Gauthier Method 2), in which the Aroclor is quantitated from each packed column peak, and the results averaged. This type of approach can introduce significant errors when a limited number of peaks are used, as the spectrum of congeners in the environment is typically altered relative to the Aroclor standard.

Aroclor 1221 contains lighter congeners, and may help to get a handle on the mono and dichlorobiphenyl content of sediments. However, the single peak used contains BZ#5 and 8, and was suspected to provide a poor representation of dechlorination products dominated by BZ#1 and 4.

Our evaluation of the 1976-78 data were carried out in a manner similar to that done previously for the 1984 sediment data (summarized in Appendix E of the Low Resolution Sediment Coring Report, USEPA, 1998), by calculating "what if" results on the congener data contained in high resolution core results from the freshwater mainstem portion of the Hudson. Predicting Total PCBs from the sum of Aroclor 1221+1016+1254 gives poor results, as shown in Figure 1. There is a high degree of scatter, particularly at high concentrations. This scatter results almost entirely from the fact that the single-peak Aroclor 1221 estimate provides a poor estimate of the mono and dichlorobiphenyl fraction.

Much better results are obtained by predicting ΣTri+ (tri and higher sum) from Aroclor 1016+1254. As shown in Figure 2, a good linear relationship without much scatter results. Aroclor 1016+1254 does, however, tend to slightly under-predict the ΣTri+. This effect is apparently due to use of 1016, rather than 1242, as a standard and was predicted in my earlier memo.

---

[1] Brown, M.P., M.B. Werner, C.R. Carusone, and M. Klein. 1988. Distribution of PCBs in the Thompson Island Pool of the Hudson River. Final Report of the Hudson River PCB Reclamation Demonstration Project Sediment Survey. NYSDEC, Albany, NY.

For total PCBs (in μg/kg), the regression line relating totals to the sum of Aroclors is:

$$\text{Total PCBs [1976/78]} = 41{,}455 + 0.644 \text{ [Aroclor 1221+1016+1254]}$$

The adjusted R^2 of this regression is 62.6% and the standard error is 215,330. The two coefficients are significantly different from 0 and 1, respectively.

For ΣTri+ (in μg/kg), the regression line is:

$$\Sigma\text{Tri+[1976/78]} = -1{,}091 + 1.135 \text{ [Aroclor 1016+1254]}$$

The adjusted R^2 of this regression is 98.5 and the standard error is 12,832. The slope coefficient is significantly greater than 1, but the intercept is not significantly different from zero. Therefore, a zero-intercept model can be used, as follows:

$$\Sigma\text{Tri+[1976/78]} = 1.131 \text{ [Aroclor 1016+1254]}$$

This conversion yields a consistent basis to evaluate the 1976-78 sediment data as ΣTri+, with which comparison can be made to 1984 data converted to ΣTri+, as well as later congener results. The 1984 data cannot be used to estimate Total PCBs, while estimation of Total PCBs from the 1976/78 data appears unsatisfactory. Therefore, work with historic sediment data should concentrate on ΣTri+ as a state variable.

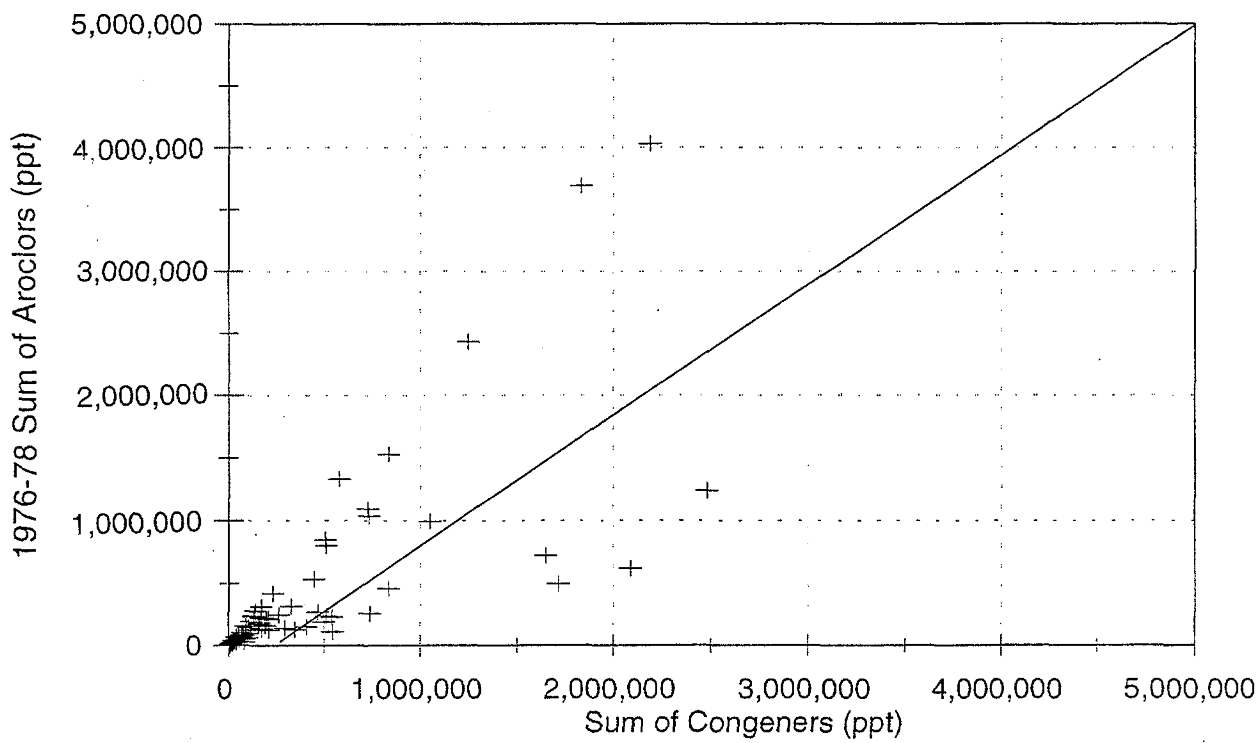

Figure 1. Prediction of Total PCBs from 1976/78 Sediment Data

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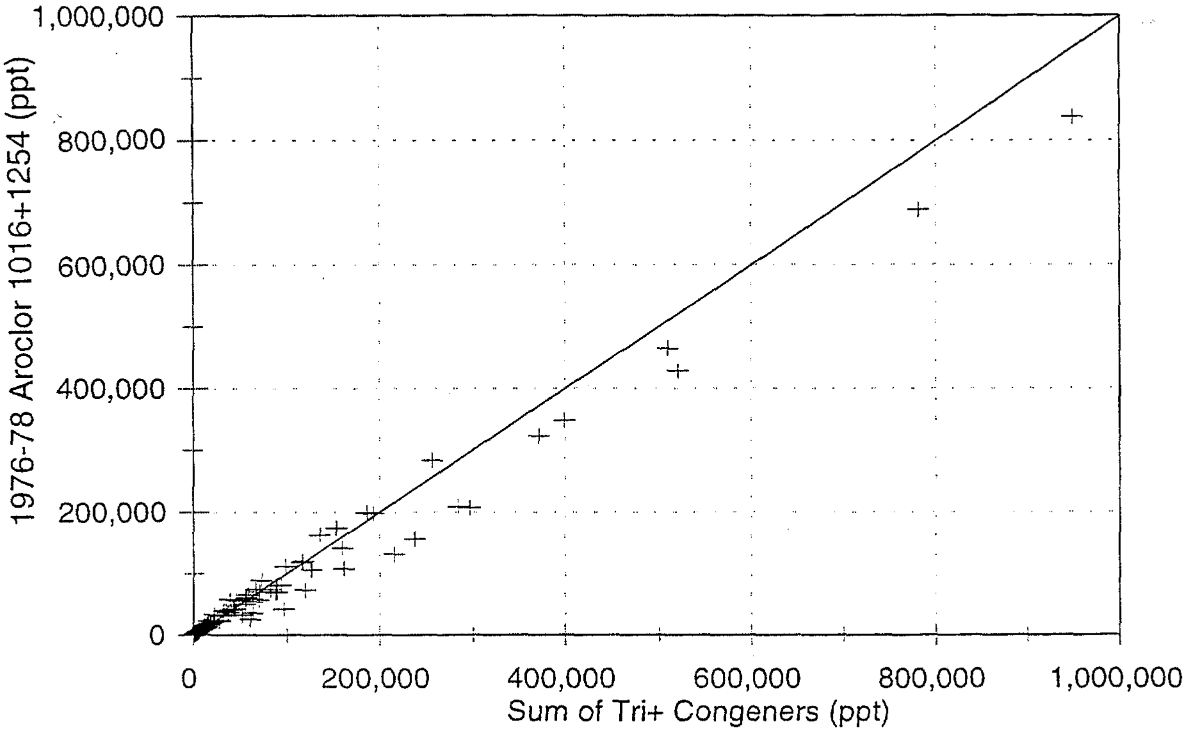

Figure 2. Prediction of ΣTri+ from 1976/78 Sediment Data

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CONGENER PATTERN MATCHING TO EVALUATE SEDIMENT PCB SOURCE IN THE UPPER HUDSON RIVER

Jonathan B. Butcher, Tetra Tech, Inc.
Edward A. Garvey, TAMS Consultants

Poster Presentation
SETAC 20th Annual Meeting
Philadelphia, PA 11/18/1999

ABSTRACT

Sediments of the Thompson Island Pool (TIP) of the Hudson River (NY) contain a large reservoir of PCBs from historic discharges. Congener composition of PCBs in these sediments has been extensively altered from the original Aroclors by anaerobic dechlorination and preferential desorption. Water flowing across the TIP experiences a gain in PCB concentration, particularly in monochlorobiphenyls and dichlorobiphenyls, which is most evident during low flow conditions, and has been attributed to pore water flux. Evaluation of load gain from TIP sediments is, however, complicated by the presence of a source of undegraded Aroclor 1242 upstream. A three-phase partitioning model was used to compute equilibrium congener patterns for in situ pore water and for surface water equilibrated with resuspended TIP sediment, which are compared with the pattern in net PCB load gain across the TIP. The congener signature of the TIP load gain is consistent with a weathered, partially-dechlorinated sediment PCB source. Assumption that pore water flux is the only summer loading pathway appears to be incorrect. Instead, congener pattern matching suggests this load is a mixture of pore water flux and water column exchange of PCBs from temporarily resuspended fine sediment, perhaps driven by bioturbation.

INTRODUCTION

- *Large quantities of PCBs were released into the Upper* Hudson River (NY) from manufacturing operations at Hudson Falls and Fort Edward through 1993 (Figure 1).

- PCB releases consisted primarily of Aroclor 1242, although Aroclor 1254 was also used prior to 1954.

- Removal of a dam in 1973 resulted in extensive movement of contaminated sediment downstream, particularly into the pool located behind Thompson Island Dam.

- High levels of sediment contamination remain within the Thompson Island Pool. Significant anaerobic dechlorination has occurred within buried sediments in the pool, resulting in a shift in the original congener pattern.

- Additional loads of unaltered Aroclor 1242 occur from bedrock seeps at Hudson Falls, upstream of the Thompson Island Pool.

- During low flow conditions, a large increase in PCB concentration occurs across the Thompson Pool, from Rt. 197 at Fort Edward to Thompson Island Dam (see Figure 2).

- *In addition to an increase in concentration, there is a shift in* homolog composition across the Pool. The upstream load is dominated by di- through tetrachlorobiphenyls, while the downstream load is dominated by mono- through trichlorobiphenyls.

Figure 1.

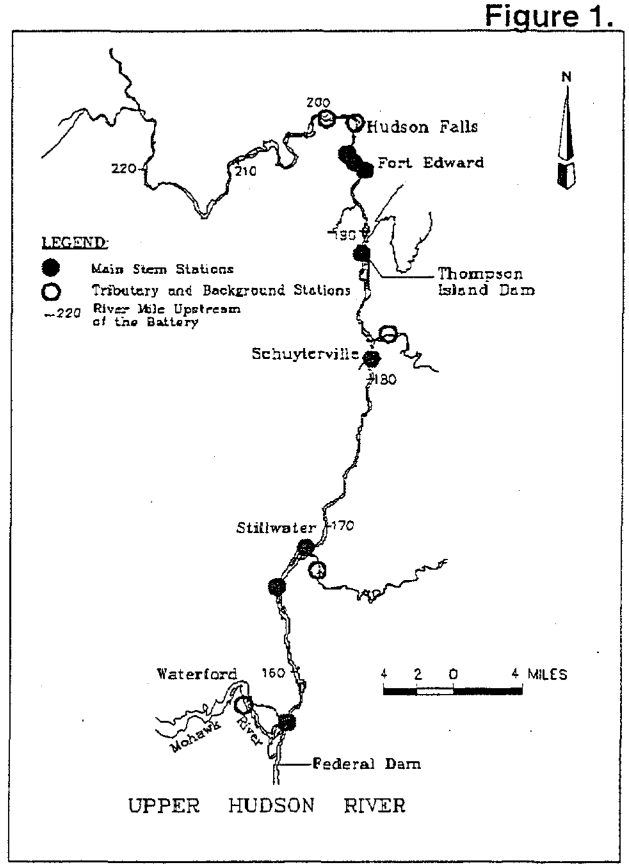
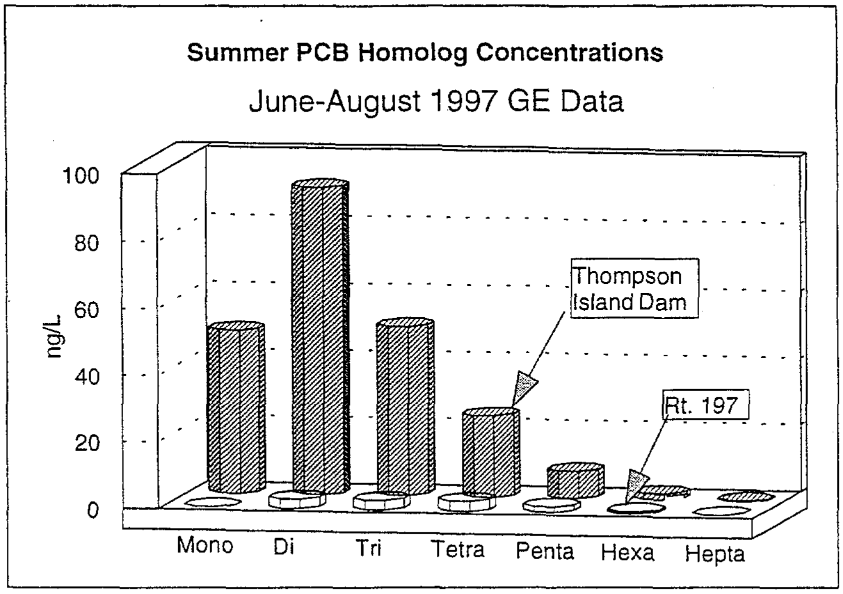


Figure 2.



The purpose of this research is to investigate potential sources of the Thompson Island Pool PCB load under non-scouring flows. Load increase associated with non-scouring flows is not accompanied by an increase in solids load. The shift in homolog pattern suggests dechlorinated sediment as a source. The pattern of individual congeners within the load gain does not, however, match that observed in porewater in the Thompson Island Pool.

MATERIALS AND METHODS

The general approach used in this study is to examine the congener pattern in the Thompson Island Pool load gain, and examine the implications for particulate versus porewater sediment sources. Accomplishing this requires information on:

- Congener concentrations and loads in the water column at both the upstream and downstream ends of the Thompson Island Pool.
- Congener concentrations within sediment on both particulate matter and in porewater.
- Information on partitioning between particulate and dissolved phases in the water column.

Water Column Data

High resolution, capillary column GC analyses of PCB congener concentrations in water at both the upstream (Rt. 197) and downstream (Thompson Island Dam) ends of the Thompson Island Pool are available from two sources: GE and US EPA.

- Contractors for General Electric Company have sampled water column concentrations and conducted capillary column analyses for PCB congeners on a regular basis since 1991. These grab samples are generally collected once every two weeks. They provide a significant long-term record of PCB concentrations entering and exiting the Pool, but do not necessarily always measure the same "parcel" of water entering and exiting the Pool.

- During 1993 only, TAMS Consultants for US EPA collected intensive data from the Thompson Island Pool and other locations in the Upper and Lower Hudson in conjunction with the Reassessment RI/FS for the Hudson River PCBs NPL site. Samples at Rt. 197 and Thompson Island Dam include both "Transect" grab samples, timed to approximate the same parcel of water at the upstream and downstream ends of the Pool, and Flow-Averaged samples, in which samples were composited on a flow-weighted basis over a two-week period.

Both US EPA and GE have primarily collected water column data from the lower end of the pool at a station the west shore above the dam, in an area of cohesive sediments with high PCB concentrations. Investigations for GE in 1997-1998 indicated that concentrations at this station may be biased high relative to flows exiting the Thompson Island Pool, at least under conditions of low flows and low upstream concentrations. This bias presumably reflects localized loading from contaminated sediments under conditions of low lateral mixing, and must be recognized in the analysis.

Sediment PCB Data

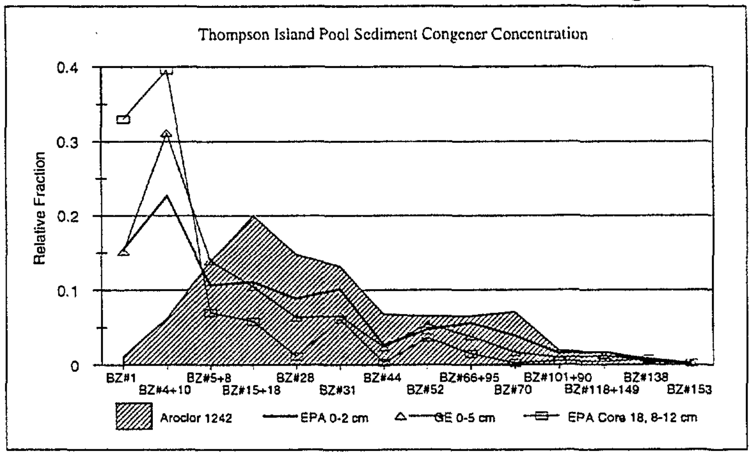
Sediment PCB data from the Thompson Island Pool are also available from both GE and US EPA.

- In 1991, GE's contractors collected sediment samples throughout the Thompson Island Pool. These samples were vertically separated into 5-cm segments, then composited across sub-areas of the Pool. Particulate and porewater fractions were analyzed separately; however, some re-equilibration between these fractions may have occurred during handling.

- In fall 1992, TAMS Consultants for US EPA collected three cohesive sediment cores from stable depositional areas of the pool. These cores were sectioned in 2 cm layers and cesium dated.

Loading to the water column is presumably most closely related to surface sediment. Figure 3 compares the relative fraction of a selected subset of congeners in the sediment. The GE and US EPA results for surface sediment are generally similar. A sample from the 8 to 12 cm layer in EPA Core 18 shows strong evidence of dechlorination, and a corresponding shift to lighter congeners. Note that all the sediment samples appear to be significantly dechlorinated relative to unweathered Aroclor 1242.

Figure 3.



Partitioning

Equilibrium partitioning of PCB congeners in the water column was estimated from US EPA 1993 data. Results are reported in Butcher et al. (1998). Partitioning between sediment and porewater was estimated from GE 1991 data. Both sets of partition coefficients represent site-specific conditions for the freshwater Hudson River.

Analysis Approach

Does the gain in PCB load during summer low flow reflect discharge of porewater, non-scour resuspension, or some combination of the two?

- Examine only summer data at non-scouring flows.
- Do not use results from 1992, when a strong upstream source was active.
- Analyze selected subset of congeners which are frequently detected and represent a range of partitioning behaviors (Table 1). Group results by co-elutants in GE data so both GE and USEPA data may be used.
- Porewater source should reflect the typical distribution of congeners found in porewater (dissolved and DOC-sorbed).
- Non-scouring sediment resuspension source should reflect the congener distribution sorbed to surface particulate matter and adjusted to reflect repartitioning in the water column and resettling of the solids.
- Begin analysis with 1997 GE results, which allow examination of the effects of nearshore sampling bias.
- Apply analysis to 1991and 1993-1996 results and check for consistency.

Table 1. PCB Congeners Analyzed

	Surface Porewater (ng/L)	Surface Sedt. (µg/kg)	Dissolved Fraction in Water Col.
BZ#1	4115	4326	0.72
BZ#4+10	4551	8557	0.91
BZ#5+8	119	2175	0.8
BZ#15+18	85	1364	0.78
BZ#28	26	667	0.52
BZ#31	35	944	0.56
BZ#44	28	234	0.52
BZ#52	44	871	0.54
BZ#66+95	33	438	0.34
BZ#70	14	156	0.38
BZ#101+90	11	137	0.36
BZ#118+149	15	143	0.22
BZ#138	9	85	0.27
BZ#153	7	43	0.31

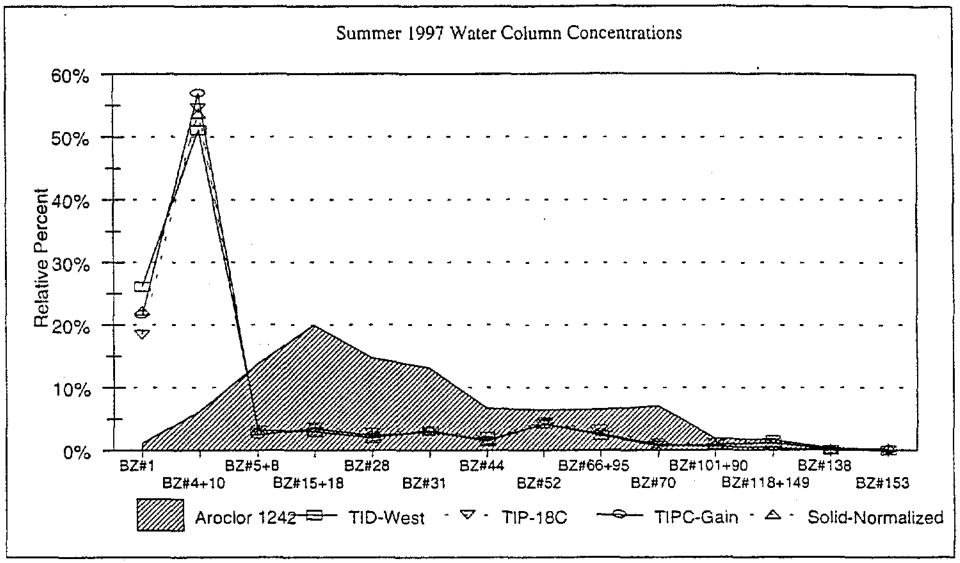
RESULTS AND DISCUSSION

Lateral Bias

Concentrations tend to be lower in the center channel than at the regular nearshore Thompson Island Dam station (TID-West). GE 1997 samples allow investigation of this issue. When examined on a relative percent basis (fraction of analyzed congeners), the congener patterns are nearly identical (Figure 4). Gain from Fort Edward to Thompson Island Dam is also nearly identical in pattern to downstream loads, as upstream load is very low in this period - but the pattern is very different from unaltered Aroclor 1242.

TID-West: Nearshore concentration
TIP-18C: Center channel concentration
TIP C-Gain: Gain (center channel)
Solid-Normalized: Gain at TID-West normalized to solids concentration.

Figure 4.



Porewater Source

- Test the hypothesis that the summer gain is due entirely to flux of porewater.
- Particulate concentration in sediment can be predicted from porewater concentration via equilibrium partitioning assumptions:

$$C_P = \frac{f_{OC}\,K_{OC}\,C_{PW,a}}{\theta(1 + m_{DOC}\,K_{DOC})}$$

Where f_{OC} is the fraction of organic carbon in the solid phase; K_{OC} is the partition coefficient to organic carbon; θ is the saturated porosity, or volume of water per volume of wet sediment, m_{DOC} is the mass of DOC per volume of pore water; K_{DOC} is the partition coefficient to DOC; C_P is the particulate concentration, and $C_{PW,a}$ is the apparent dissolved concentration (dissolved plus DOC-sorbed).

Application of this equation using estimated sediment partition coefficients and average physical characteristics for Thompson Island Pool surface sediment yields a derived sediment congener pattern which would support the hypothesized porewater flux (Figure 5). Results are similar whether the analysis is based on nearshore or center channel gain. The computed sediment pattern, however, appears quite different from that seen in the 0-2 cm layer of USEPA cohesive sediment cores (Figure 6), and the difference is even greater when compared to the 0-5 cm layer of GE cores. BZ#28 and #52 are elevated in the calculated source relative to observed surface sediment, while BZ#1, 4, and 10 are depressed. The pattern also does not match raw Aroclor 1242.

Figure 5.

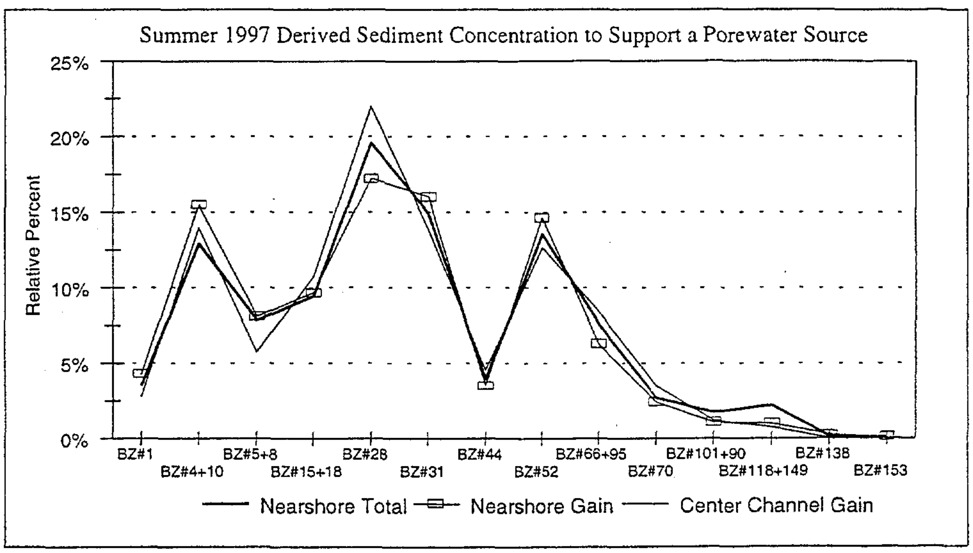
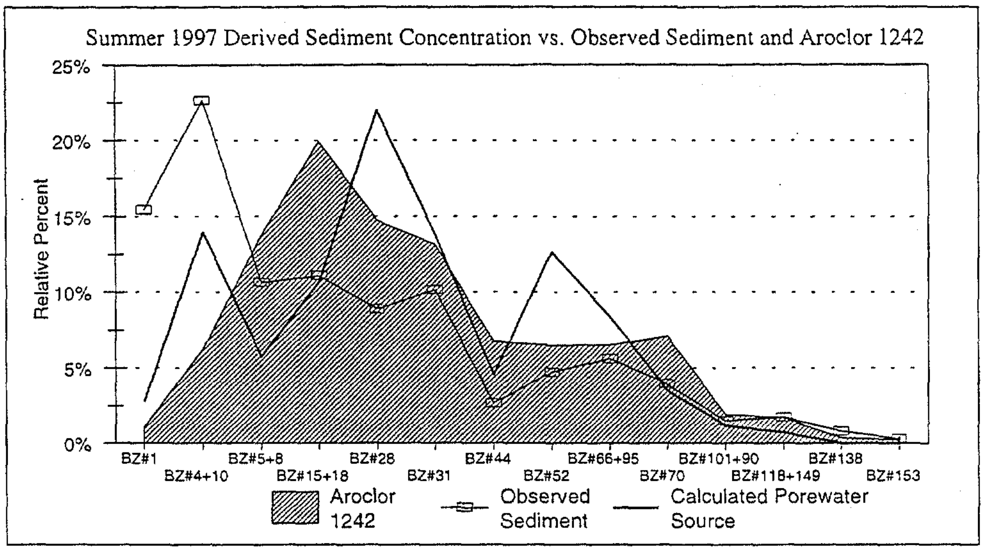


Figure 6.



Sediment Source

The congener pattern of concentration gain in the Thompson Island Pool does not resemble the congener pattern in surface sediments, suggesting that direct resuspension of unaltered sediment particulate material is not a major part of the summer flux. But, there is an alternative to porewater flux for transferring sediment particle-sorbed PCBs into the water column. This involves exchange of PCBs from bulk sediment into the water column, followed by re-equilibration in this lower-concentration environment and settling out of the residual sorbed material. In addition to apparent differences in partition coefficients between the water column and sediment, the concentrations of particulate and dissolved organic carbon are much lower in the water column than in the sediment. If sediment is mixed to the sediment surface or suspended into the water column long enough to re-equilibrate, the resulting dissolved and DOC-sorbed fractions will remain in suspension, while the remaining particle-sorbed component may settle back out. Because sediment particulate matter is much more contaminated than particulate matter in the water column, equilibrium desorption would approximate the fractionation predicted from equilibrium partitioning in the water column. This fractionation process (at equilibrium) would result in 91% of sediment BZ#4 remaining in the water column, but only 22% of BZ#118 at typical summer conditions in the Thompson Island Pool. Average apparent dissolved concentrations in the water column calculated from the partition coefficient analysis are shown in Table 2.

Possible mechanisms for mixing of bulk sediment to the sediment-water interface or into the water column in the absence of hydrodynamic scour include: bioturbation by benthic organisms, bioturbation by demersal fish, scour by propwash, mechanical scour by boats and floating debris in nearshore areas, and uprooting of macrophytes.

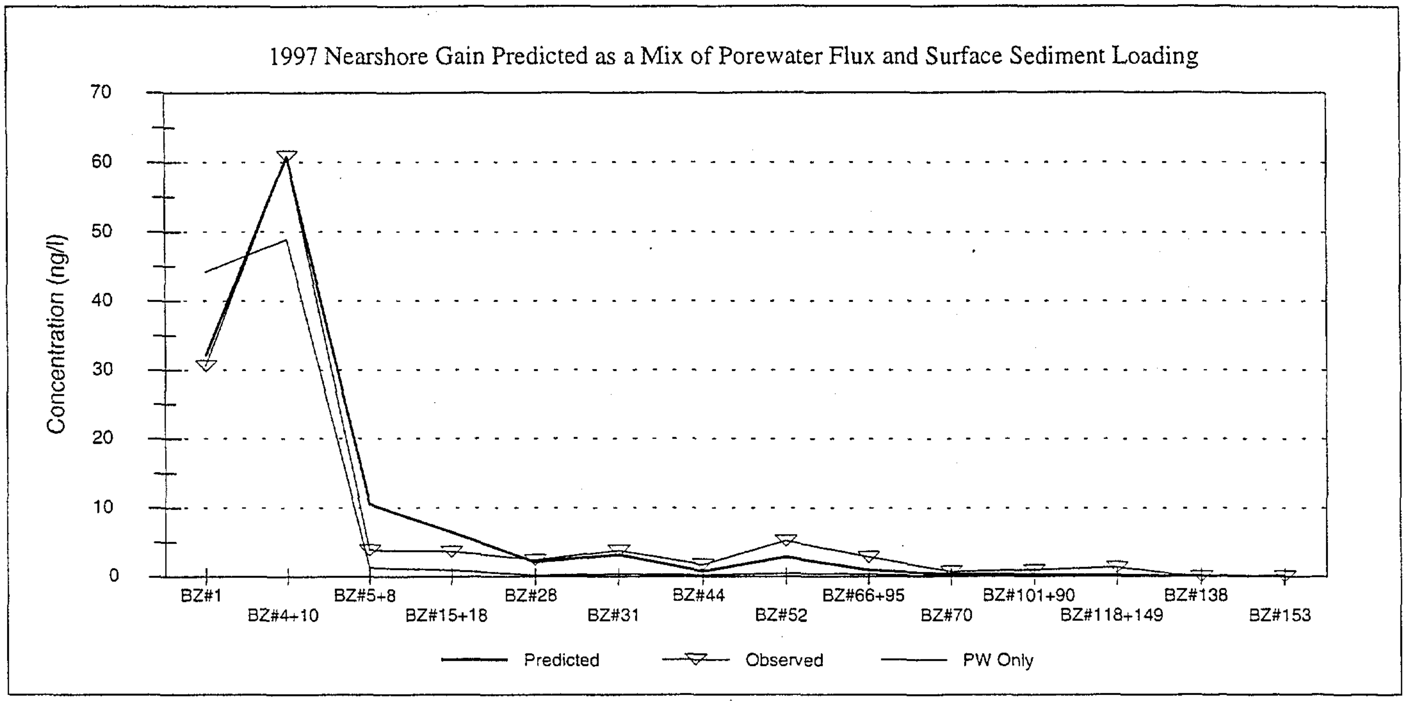
Table 2

	Apparent Dissolved Fraction
BZ#1	0.72
BZ#4+10	-0.91
BZ#5+8	0.80
BZ#15+18	0.78
BZ#28	0.52
BZ#31	0.56
BZ#44	0.52
BZ#52	0.54
BZ#66+95	0.34
BZ#70	0.38
BZ#101+90	0.36
BZ#118+149	0.22
BZ#138	0.27
BZ#153	0.31

Mixed Sediment - Porewater Source

A source consisting only of water column desorption of sediment particulate PCBs also does not replicate the observed congener signature of the gain, particularly the ratios between BZ#1, 4+10, and 5+8. In any case, some porewater flux is expected. It therefore makes sense to consider a mixed sediment and porewater source. When a mixed source of this type is considered (Figure 7), the congener pattern in the 1997 Thompson Island Pool concentration gain can be predicted quite closely by optimizing the ratio between the sediment and porewater sources. Most notably, the mixed source accurately reproduces the observed ratio between BZ#1 and BZ#4+10, whereas the best fit based on a porewater only source cannot.

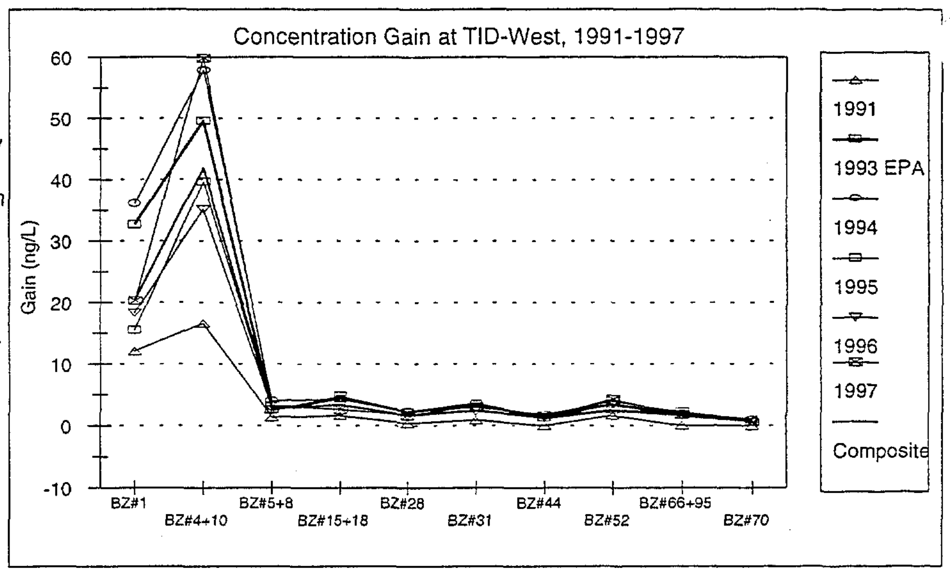
Figure 7.



Application to 1991 - 1997 Observations

- Previous section suggests a mixed sediment-porewater source is appropriate to 1997 data.
- Concentration gain pattern at TID-West is similar to Center Channel.
- Do the same results apply to other years?
- Summer concentration gain differs widely by year (Figure 8), reflecting variations in hydrology and other conditions.
- Relative percent concentration of congeners in summer gain shows high similarity from year to year (Figure 9).
- Remaining variability is within the range of analytical and sampling variability.
- Therefore, the multi-year series can be fit on a normalized (percent) basis.
- Optimized fit to a mixed porewater-sediment source provides a very close match to the composite congener fractions observed in the Thompson Island Pool gain from 1991-1997 (Figure 10).

Figure 8.



Mass Transfer Rates

Assuming concentrations in sediment are much greater than concentrations in the water column, the concentration gain for a given congener may be written in terms of mass transfer rates as

$$\Delta C = \frac{A_s}{Q}\left[k_{PW}\,\theta\, C_{PW} + d_f\, k_S\,(1-\theta)\,\rho\, C_S\right]$$

where ΔC = concentration gain (M/L^3); A_S = sediment source area (L^2); Q = flow (L^3/T); k_{PW} = mass transfer rate for porewater (L/T); θ = porosity (dimensionless); C_{PW} = concentration in porewater (M/L^3); d_f = fraction desorbing in the water column *(dimensionless), assumed equal to the equilibrium partitioning estimate of the dissolved and DOC-sorbed fraction of the* congener in the water column; k_S = mass transfer rate for particulate PCB (L/T); ρ = solid particle density (M/L^3); and C_S = concentration on sediment (M/M).

Figure 9.

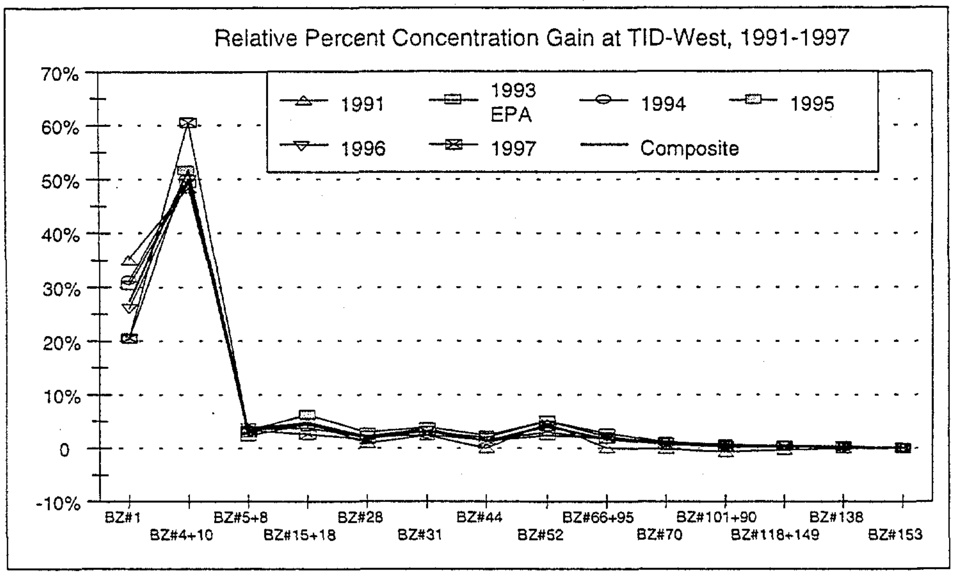
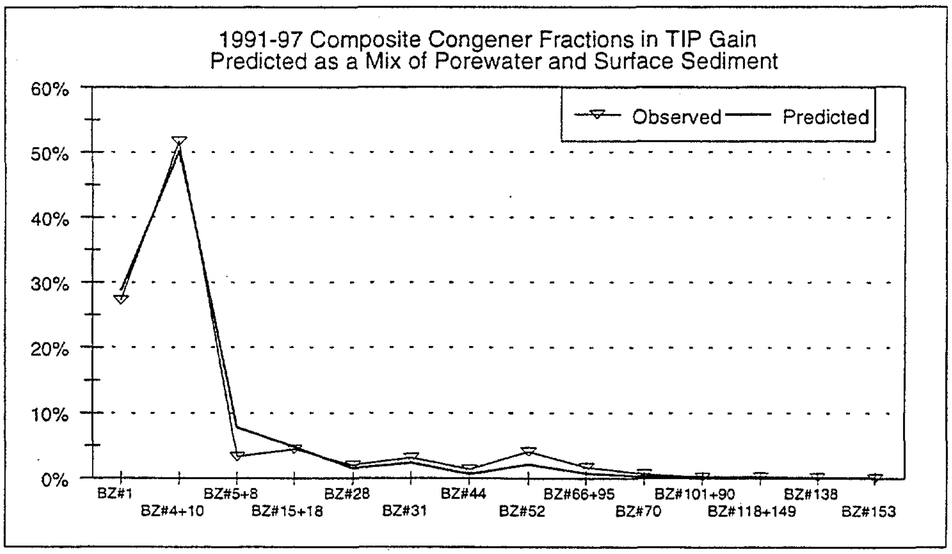


Figure 10.



QEA (1999) and LTI (1999) have both estimated a composite mass transfer coefficient, k_f, for tri- and higher-chlorinated congeners ("Tri+") based on porewater concentration only. These are in the range of 15 cm/day, which is consistent with the work of Valsaraj et al. (1997) on TCDD. To convert to a sediment volume basis, this coefficient must be multiplied by porosity, yielding a value of approximately 6 cm/day. Estimated load gain using this transfer rate may be set equivalent to the load rate from the mixed porewater-sediment transfer rate model to estimate values of k_{PW} and k_S.

In the congener pattern matching, the ratio of k_{PW}/k_S ranges from 0.6 to 6.0 by year with an overall value of 1.9, while the ratio C_S to C_{PW} is in the 10 to 20 range for the congeners making up Tri+. Solution in terms of the estimated value of k_f suggests that the value of k_S is around 0.6 cm/day, with little year-to-year variability, while the value of k_{PW} is around 1.2 cm/day, with an observed range of 0.4 to 3.3 cm/day. The sum of these coefficients is less than k_f because higher concentrations are present on solids than in porewater for Tri+.

CONCLUSIONS

Analysis of congener patterns suggests that PCB concentration gain observed across the Thompson Island Pool of the Hudson River (NY) under summer low flow conditions in the 1990's represents a mixture of porewater discharge and direct exchange from bulk sediment into the water column. Biological mixing is the most likely driver for direct exchange. Results are, however, dependent on the analysis of phase distribution of individual congeners in both the water column and sediment, both of which are subject to considerable uncertainty. The current analysis also neglects changes in surface sediment concentrations over time. Incorporating the concepts presented here into a parametric, physically-based model of PCB fate and transport is likely to improve our understanding of the processes contributing to PCB load gain within the Thompson Island Pool.

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