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PHASE 2 REPORT
FURTHER SITE CHARACTERIZATION AND ANALYSIS

RESPONSE TO PEER REVIEW COMMENTS ON THE PRELIMINARY MODEL CALIBRATION REPORT

HUDSON RIVER PCBs REASSESSMENT RI/FS

FEBRUARY 2000

For

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

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

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

February 29, 2000

To All Interested Parties:

The U.S. Environmental Protection Agency (EPA) is pleased to release this Response to Peer Review Comments on the Hudson River PCBs Site Modeling Approach.

Consistent with national EPA policy, EPA is having the scientific analyses conducted for the Hudson River PCBs site Reassessment peer reviewed by independent scientific experts. The first of the peer reviews for the site was held on September 9 - 10, 1998 and was on the modeling approach developed by the Agency. The recommendations of the peer review panel were released in the November 1998 Report of the Hudson River PCBs Site Modeling Approach Peer Review.

This document presents EPA's responses to recommendations of the peer review panel, and outlines the changes that EPA made to its modeling approach based on the peer review comments. EPA originally intended to issue these responses prior to or concurrent with the release of the May 1999 Baseline Modeling Report (BMR). However, significant Agency resources were needed to complete the BMR, Revised Baseline Modeling Report (January 2000) (Revised BMR) and the Responsiveness Summary for the Baseline Modeling Report (February 2000), which pre-empted finalizing this response to peer review comments. Nevertheless, the peer review comments were considered by EPA and incorporated, as appropriate, in the BMR and the Revised BMR.

The results of EPA's modeling analyses, found in the Revised BMR, are currently undergoing peer review by a panel of independent scientists. The peer review meeting for the Revised BMR will be held in at the Sheraton Saratoga Springs Hotel and Conference Center on March 27 and 28, 2000. During the peer review meeting, which will be open to the public, members of the public will have an opportunity to address the peer review panelists.

If you need additional information regarding this report or the Reassessment, please contact Ann Rychlenski at 212-637-3672.

Sincerely yours,

Richard L. Caspe, Director
Emergency and Remedial Response Division

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INTRODUCTION

On September 9 - 10, 1998, the U.S. Environmental Protection Agency (USEPA) convened a panel of scientific experts to conduct a peer review of the modeling approach developed by the Agency for the Hudson River PCBs Reassessment Remedial Investigation and Feasibility Study (Reassessment RI/FS). The modeling approach for the Reassessment RI/FS was described primarily in the Preliminary Model Calibration Report (PMCR), issued in October 1996, and modified in the Revised Scope of Work for the Baseline Modeling Report (BMR SOW), issued in July 1998. In addition, the peer reviewers were provided with USEPA's responses to significant comments received during the public comment period on the PMCR. As a result of the review and panel discussions, a list of recommendations concerning the USEPA modeling effort for the Hudson River PCBs Reassessment RI/FS was compiled. These recommendations, along with the pre-meeting comments prepared by the individual scientists on the panel, were incorporated in USEPA's November 10, 1998 Report of the Hudson River PCBs Site Modeling Approach Peer Review (Modeling Approach Peer Review Report).

This document presents the USEPA's responses to recommendations of the peer review panel. Although the Baseline Modeling Report (BMR) (May 1999) was issued prior to the release of this response to the peer review recommendations, the peer review comments were considered by USEPA and incorporated, as appropriate, in the BMR. After USEPA issued the BMR, public comment on the BMR and additional modeling analyses resulted in the issuance of the Revised BMR, which supercedes the May 1999 BMR. Responses in this Response to Peer Review Comments on the Hudson River PCBs Site Modeling Approach frequently reference sections of the text, tables or figures that are in the Revised BMR. Readers are encouraged to read this report and the Revised BMR together in order to obtain a full understanding of the material presented in this responsiveness summary.

Individual comments were prepared by each of the reviewers prior to the peer review meeting. The individual comments were refined by the peer review panel into the final recommendations listed in Section 6.3 of the Peer Review Report. As a result, only the final recommendations are specifically addressed in this response to peer review comments. Nonetheless, both the final recommendations and pre-meeting comments were considered during the preparation of the BMR and the Revised BMR.

It is important to note that the Hudson River modeling analysis actually consists of several individual models, designed to address various components of the fate, transport and biological uptake of PCBs in the Hudson River. Additionally, some models represent alternative approaches to the same modeling analysis. Thus, resuspension is represented by both the fate and transport model for the Hudson (HUDTOX) and the Depth-of-Scour Model (DOSM). Similarly, biological uptake is represented by the Gobas model (FISHRAND) and the probabilistic food chain model (PFCM). Accordingly, some of the reviewers' comments were addressed by modifying one or more of the models used in the analysis. Figure 1 illustrates an outline of the modeling structure and a brief description of how each model is used.

PEER REVIEW COMMENTS AND EPA RESPONSES

Nine separate comments or recommendations were developed by the peer review panel. The peer review panel's major comments and recommendations are summarized below, with each comment/recommendation followed by USEPA's response. For a more detailed summary of the reviewers' comments, readers are encouraged to consult the Modeling Approach Peer Review Report.

1. ***The reviewers recommended that USEPA make the following improvements in the description of sediment resuspension and deposition processes in the fate and transport models: [a] address the fate of resuspended material; [b] address the role of uncovered, potentially contaminated surfaces; [c] address the issue of non-cohesive sediment resuspension; [d] assure consistency in resuspension rates between the "depth of scour" and HUDTOX models; and [e] identify the effect of flood resuspension on the rate of long-term recovery of the Hudson River. Some reviewers thought these changes could be made within the existing modeling framework (i.e., with different fate and transport models that are linked), while other reviewers thought these changes should be made by incorporating sediment transport mechanisms directly into the HUDTOX model, instead of keeping the models separate. [f] A peer reviewer added that USEPA should analyze error propagation in the linked models and place a greater emphasis on "source attribution of PCBs to fish."***

   As part of the further development of the HUDTOX model, various revisions were made to the model structure, which addressed these recommendations. Many of these revisions were already underway prior to the peer review, having been suggested earlier during the public comment period on the PMCR. Specifically, the recommendations given above were addressed as follows:

   a. Resuspension is examined in two of the models developed for the Reassessment. Specifically, both HUDTOX and the Depth-of-Scour Model (DOSM) have resuspension components. However, only the HUDTOX model deals with the long-term fate of PCBs in the Hudson and thus addresses the fate of resuspension. In the case of DOSM, the purpose of the model was to examine the potential for a major resuspension event driven by a 100- year flow event. In this instance, the ultimate fate of the resuspended

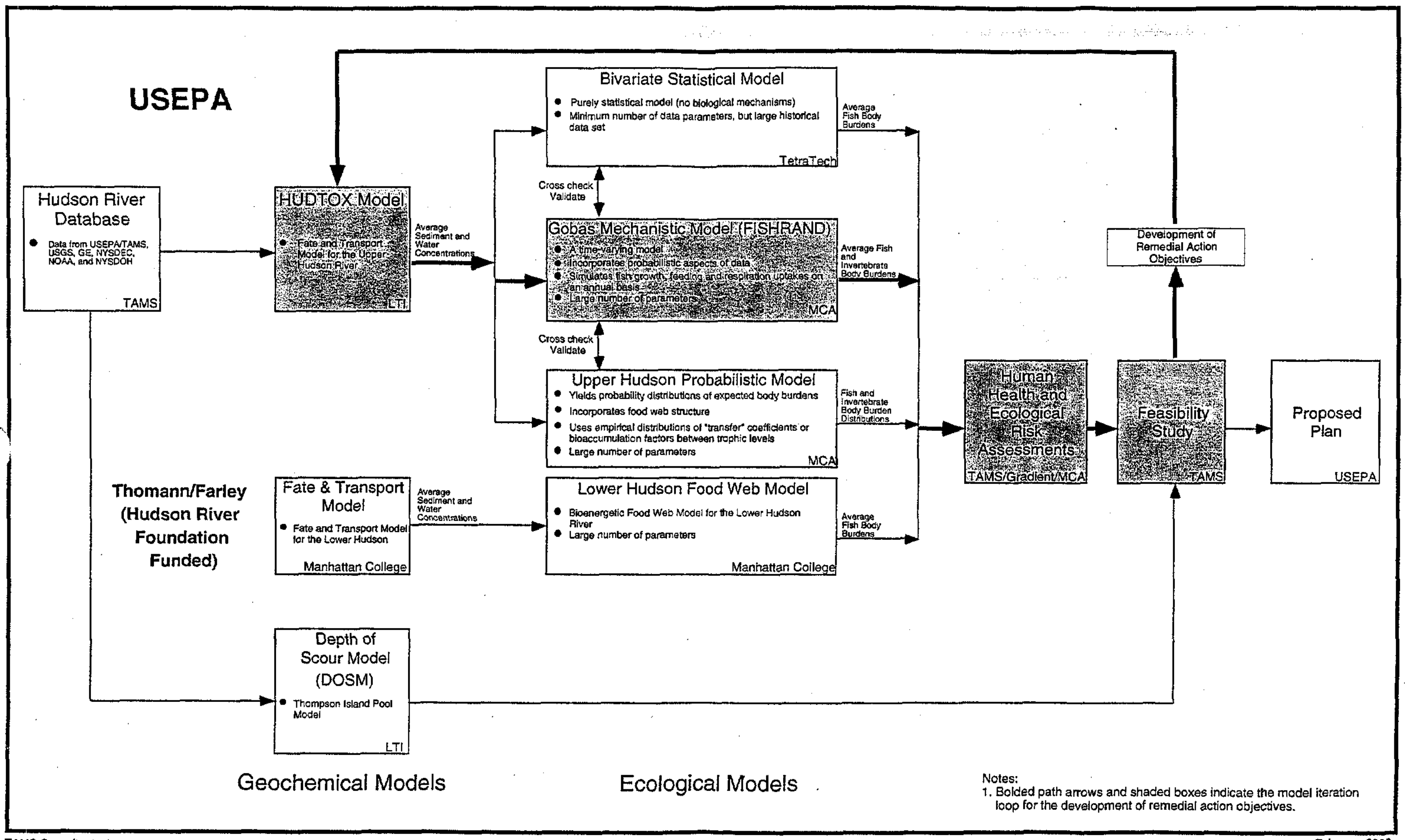

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Figure 1
Hudson River PCBs Reassessment Analysis Flowchart

material is not the focus of the analysis, because it is the mass of sediments and PCBs to be resuspended which is of concern. This is discussed in further detail in Chapter 4 of Book 1 of the Revised BMR.

In the HUDTOX transport-and-fate model, the fate of the resuspended material is of concern. In this case, both the resuspension and settling of solids are addressed. Specifically, the processes of delivery, settling and resuspension of solids are incorporated in HUDTOX. These processes represent gross rates of resuspension and settling for each model segment while also allowing for both latitudinal and longitudinal exchange among the segments.

The DOSM cohesive sediment resuspension algorithms are also used in the HUDTOX model. This assures consistency between the DOSM and HUDTOX models for representation of cohesive sediment resuspension. The DOSM non-cohesive sediment resuspension algorithms produce only upper bound results and were not used in the HUDTOX model. Resuspension values for non-cohesive sediments in the HUDTOX model were determined through model calibration. The HUDTOX calibration approach is discussed in detail in Chapter 7 of Book 1 of the Revised BMR.

b. Several additional mechanisms were added to the HUDTOX model subsequent to the issuance of the PMCR. In particular, a model mechanism was added to approximate the deposition, resuspension and re-exposure of sediments. This is discussed in detail in Section 5.4.5 of Book 1 and illustrated in Figures 5-2 and 5-3 of Book 2 of the Revised BMR. It is briefly described here. Essentially, within each model river segment, the river sediment bed is represented as a series of thin (2 cm) layers, each of which is internally well mixed. The thicknesses of the layers is held constant with the exception of the top layer. For the top layer (*i.e.,* the layer at the sediment-water interface), the layer thickness is allowed to vary dependent upon the local rate of resuspension and settling. Thus, deposition thickens this layer while resuspension thins it. As the simulation runs, this layer can thicken substantially. Once the layer reaches two times its original thickness (4 cm *vs.* 2 cm originally), the layer is split into two layers and the sediment segments are renumbered accordingly. This also serves to place the deeper layer further down in the sediment zone of the model. In this manner, the model serves to "bury" sediments. Similarly, when erosion results in a surface sediment segment being depleted, then renumbering of the segments is triggered. In this manner, the model permits scour and the re-exposure of underlying sediments. Either of these processes can continue as needed based on the model resuspension and settling rates. The sediment layers were configured based on available sediment data as part of the initial conditions and were sufficient to supply and bury sediment as needed for the period of simulation.

c. Non-cohesive sediments have been addressed in both the DOSM and HUDTOX models. In the DOSM model, an upper-bound estimate of scour from non-cohesive sediments has been incorporated into the 100-year flood scenario. The estimate, based on work by Borah (1989), describes the thickness of non-cohesive sediment that can be eroded prior to the formation of an armoring layer. The estimate is an upper bound because it assumes that the scour event will endure sufficiently such that all sediment susceptible to scour at the 100-year flow rate will be resuspended. The estimation of scour for non-cohesive sediment under the 100-year flood scenario is discussed in detail in Chapter 4.2.3 of Book 1 of the Revised BMR.

For the HUDTOX model, in the BMR, non-cohesive sediment is represented by an empirical formulation that relates the depth of scour to the bottom shear stress, the critical bottom shear stress and the time since the last event of equal or greater magnitude. Shear stress below the critical shear stress does not yield resuspension. Shear stresses above the critical shear stress yield resuspension, which is subsequently dampened by the formation of an armoring layer. Subsequent to the scouring event, this layer degrades over time, attributed to one or more processes (*e.g.*, bioturbation), thus permitting subsequent resuspension events at comparable flows and shear stresses at sufficiently later times. This is presented in Section 5.2.3 of Book 1 of the BMR.

In the Revised BMR, representation of non-cohesive sediment resuspension in the HUDTOX model was simplified and no attempt was made to simulate armoring conditions in non-cohesive sediments. Resuspension in non-cohesive sediments is represented by specification of a constant high-flow resuspension velocity operative during scouring conditions. Non-cohesive sediment scour is considered insignificant below specified flow thresholds, which are spatially variable in the model. Non-cohesive resuspension rates in the model switch between zero and the specified high flow resuspension rate. These rates were determined by model calibration using measured burial rates from dated sediment cores, computed burial rates from the General Electric Company sediment transport model, PCB surface sediment concentration trends, and in-river solids and PCB mass transport at high and low flows as calibration constraints. The representation of non-cohesive sediment resuspension in the HUDTOX model is described in Section 5.4.3 of the Revised BMR and the calibration approach for the coupled solids-PCB mass balances is described in detail in Chapter 7 of the Revised BMR.

d. Consistency between the DOSM and the HUDTOX simulations needs to be viewed in the context of the different questions each model was designed to answer. The DOSM model is intended only to provide an upper bound on the resuspension that might occur during a 100-year flood event. HUDTOX has a very different purpose, in that it was intended to examine the long-term transport and fate of PCBs in the Upper Hudson and as such requires best estimates of conditions and not upper bounds. HUDTOX also needs to simulate resuspension and settling over a broad range of flow conditions, unlike the DOSM model.

Both models utilize the same formulation for cohesive sediments, although time scales and spatial segmentation differ. The expressions and coefficients for cohesive sediment resuspension were developed from several recent studies (*e.g.,* Lick *et al.,* 1995) as well as site-specific data. The formulation and parameterization for cohesive sediments are discussed in Sections 4.2, 4.3 and 5.4.2 of Book 1 of the Revised BMR.

Non-cohesive sediments, which represent about 70 percent of the surface of the river bottom in the Upper Hudson, are handled differently by the two models. In the DOSM simulation, an upper-bound estimate of the amount of scour was developed from the work by Borah (1989), as described in item 1.c., above. While this simulation is useful for the purposes of the DOSM model (*i.e.,* an upper-bound estimate of the mass of sediment resuspended by a single 100-year flood), a best estimate of the actual gross resuspension rate was needed for the long-term HUDTOX simulation. In particular, because the DOSM formulation for non-cohesive sediments does not account for armoring as a function of time, the model is not appropriate for the frequent flow variations that are a part of the long-term simulation. The formulation for non-cohesive sediments in the HUDTOX model was developed empirically and is described in item 1.c, above and in Section 5.4.3 of Book 1 of the Revised BMR.

By utilizing an upper-bound estimate for the 100-year flood simulation, the DOSM describes the maximum resuspension that might be expected in a single event. On the other hand, HUDTOX attempts to generate a "best estimate" for sediment resuspension over the long-term simulation, and synthesizes resuspension as well as the many other processes affecting sediment and PCB concentrations over a wide range of conditions. In this manner, HUDTOX describes the gradual changes in river conditions over time. Considering the very different purposes of the two models, the differences in their formulations are appropriate and consistent with their stated objectives.

e. The effect on Hudson River PCB concentrations in water and sediment resulting from a 100-year flood event was examined as part of the forecast developed with the HUDTOX model. Specifically, the HUDTOX model was run with and without a 100-year flood event. The simulation showed little net effect, with river conditions as estimated by the two models being essentially the same within about 1 year following the 100-year event. This is presented in Section 8.5 of Book 1 of the Revised BMR.

The changes suggested by the peer reviewers were made within the existing modeling framework. The revised modeling approach and the relationship among models are described in Chapter 2 of the Revised BMR. Chapter 5 of the Revised BMR describes the model details. Both the current and previous versions of the HUDTOX model represent sediment transport directly. The mechanisms have been further refined and developed for the Revised BMR. The current version includes gross settling into cohesive and non-cohesive areas as well as resuspension from these areas.

f. In the final form of the HUDTOX model, sediment transport mechanisms were incorporated directly in the model execution. Error propagation was examined as part of the refinements of the models for the Revised BMR. In many instances, however, error propagation is not straightforward because the uncertainty in many modeling parameters is not well constrained. For this reason, sensitivity analyses were completed as part of the Revised BMR to identify the major potential sources of uncertainty to the model forecast. The Revised BMR was released to the public in January 2000. A peer review for the Revised BMR is underway as of the release of this document and scheduled to be completed in March 2000.

The issue of source attribution to fish is not a simple one. An approach to address this was presented in Appendix K of EPA's Baseline Ecological Risk Assessment for the Hudson River PCBs site (USEPA, 1999b). Congener patterns in fish, sediment and water were examined via a principal components analysis. This analysis showed that the congener patterns present in Hudson River fish are related to Hudson River sources such as sediment and water but cannot be linked in a simple fashion (*i.e.*, pattern-matching or "finger printing"). The various biological processes involved in the absorption of PCBs by fish serve to substantively alter the congener pattern and render it unlike any seen in the sediment or water.

2. ***The reviewers recommended that EPA employ time and space-dependent mechanistic models that reflect the abiotic and biotic dynamics of the Hudson River system.***

To address this issue, several modifications were made to the HUDTOX model and two additional bioaccumulation models were added to the modeling analysis. As described in Chapter 5 of Book 1 of the Revised BMR, revisions to the HUDTOX model included the addition of separate mechanisms to estimate resuspension of cohesive and non-cohesive sediments. Additionally, a model construct was created to permit the tracking of sediment re-exposure as well as burial. Spatial resolution in the Thompson Island Pool was greatly enhanced with the creation of a quasi-two dimensional model segment grid designed to examine both center channel and near-shore conditions. Below the Thompson Island Dam, model segments are larger and only one-dimensional, but still are consistent with the available data. As described in Chapter 6 of Book 1 of the Revised BMR, hydraulic flows, solids loads, PCB loads, temperature, and other external forcing functions were specified on a time-variable basis at scales commensurate with the available site-specific data.

To address the bioaccumulation concerns, a mechanistic model formulation was added to the suite of ecological models. This model, FISHRAND, is based on the published works of Gobas et al. (1993 and 1995). However, FISHRAND also incorporates parameter variability via a Monte Carlo simulation, thus providing estimates of the degree of variability anticipated in future fish body burdens. During the development of FISHRAND, a deterministic version of the model was also developed, called FISHPATH. Both of these models were discussed in the BMR. However, FISHPATH was not utilized in the preparation of the Revised BMR, and therefore is not reported on in the Revised BMR. A detailed discussion of FISHRAND is provided in Book 3 of the Revised BMR.

3. ***The reviewers indicated that the models should be based on a consideration of bioavailability and sediment sequestration with respect to congener sorption/desorption kinetics, sediment particle characteristics, and biotic characteristics.***

In the development of the final model versions, the issues of bioavailability and sediment sequestration have been addressed via several modifications. As noted above in response 1b, sediment sequestration has been addressed via the incorporation of a dynamic sediment stratigraphy model that can respond to deposition and resuspension throughout the simulation period.

Bioavailability has been addressed via the use of a mechanistic model that describes the process of PCB uptake through the food chain. However, the issue of kinetic absorption and desorption, while noted in the discussions in the Revised BMR and elsewhere, is not addressed by the models. While kinetics certainly play a role in the rates of PCB exchange between sediments, water and the biota, there are little data available to describe the processes and their rate constants. Moreover, it has been demonstrated in the USEPA reports as well as elsewhere (*e.g.*, USEPA, 1997; Bergen *et al.,* 1993), that equilibria-based relationships among suspended matter, water and fish tissue provide an adequate description of the observations. Incorporation of kinetic-based transfers would add additional coefficients to the model that would be poorly constrained at best, but would amount to little more than model fit adjustment parameters and add little to the understanding of the problem. For these reasons, kinetic absorption and desorption have not been added to the models. Rather, equilibrium-based exchange is assumed between among river matrices.

As described in the DEIR, sediment-water partitioning is well described by equilibria-based calculations when temperature and organic carbon content are considered. In preparing the models, these characteristics have been incorporated in estimating exchange between sediments, water and suspended solids. Additionally, information from the geophysical investigation of the river has been incorporated in estimating sediment properties on an area basis.

With regard to biotic characteristics, both the mechanistic and probabilistic bioaccumulation models incorporate the processes of fish growth, food consumption and depuration. These processes directly affect the uptake and loss of PCBs from the fish. Additionally, feeding preferences, physical setting, and fish physiology (size, weight and lipid content) are parameterized. In this manner, fish bodyburden estimates are created by a dynamic balance of biological processes. That is, fish body burdens are the net result of uptake and depuration processes and are not calculated based on simple equilibria among fish, water and sediment. The mechanistic model explicitly evaluates both uptake and loss of PCBs based on feeding preferences, exposure concentrations (monthly for water and annual for sediment), and fish physiology. Using both the wet weight as well as the lipid-normalized PCB concentrations as constraints on the model results for existing data, the models provide credible estimates of future fish body burdens.

4. ***The reviewers recommended that EPA link, to the greatest extent possible, the spatial and temporal scales of the different fate and transport and bioaccummulation models.***

In their final renditions, the biological and geochemical models have been designed with this concern in mind, while also considering the available data to constrain the model simulations. Specifically, water column data are relatively plentiful and are available on at least a quarterly basis throughout the period 1980 to 1997. However, with the exception of 1993, these data are largely limited to the Ft. Edward-Thompson Island Pool area. By contrast, fish data are only available annually during this period, and then from only a limited number of stations. Least available are the sediment data, with only a few years of extensive coverage. Essentially, the models can be best constrained only in those locations where data are available. In many respects, the temporal availability of the data varies inversely with the ability of the matrix to integrate PCB loads over time. Thus the sediments, which can be thought of as representing decadal PCB loads, have the least data while the water column, representing daily PCB loads, has the greatest temporal resolution of data. Fish fall in between, in both the temporal extent of the data and in the ability of fish to integrate PCB exposure or loads.

Nonetheless, the models were constructed so as to match both temporal and spatial scales as best as possible in light of model purpose and data availability. HUDTOX was constructed using a grid with nodes corresponding to the Upper Hudson fish monitoring locations represented in the Reassessment database (USEPA, 1998) and used in the bioaccumulation models. Because of the absence of daily fish measurements and the tendency of fish to integrate their exposures over time, the daily estimates of water column and sediment concentrations were combined into monthly averages for the water column and annual averages for the sediments for use in the bioaccumulation models. The resuspension model, DOSM, has a much finer grid scale than that of HUDTOX, but DOSM was designed to closely examine resuspension rates and not overall mass transport over long periods of time. In fact, DOSM was designed to examine a single 100-year flood event that would last only a few days. Thus, both its temporal and spatial scales are much finer than that for HUDTOX. To maximize comparability between the two models, a 100-year event was also examined using HUDTOX. This is discussed further in Chapter 8 of Book 1 of the Revised BMR.

5. ***The reviewers recommended that EPA clearly identify in its modeling approach the risk assessment targets as related to forms and concentrations of PCBs (e.g., to what guidelines or advisories will the modeled concentrations be compared). More specifically, the reviewers thought risk assessors and managers should be involved with the development of the transport and fate and bioaccumulation models, such that the model outputs will generate the data needed for completing human health and ecological risk assessments.***

From the initiation of the modeling effort, the risk assessors and USEPA management team have been involved in directing the focus of the modeling effort. As a result of the management discussions that took place prior to the inception of the modeling program, three overall modeling objectives were defined, in the form of three principal questions. They are presented in the PMCR as well as in the BMR and Revised BMR. They were the focus of the modeling effort throughout its duration. They are repeated here for this discussion:

1. When will PCB levels in fish populations recover to levels meeting human health and ecological risk criteria under continued No Action?

2. Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels?

3. Are there contaminated sediments now buried that are likely to become reactivated following a major flood, possibly resulting in an increase in contamination of the fish population?

The main modeling effort, as described in the Revised BMR, addressed questions 1 and 3 above. Question 1 represents the concern raised by the peer reviewers and in fact has been the major focus of the modeling effort to date. Question 3 was initially addressed in the PMCR but was further evaluated in the BMR/Revised BMR. The remaining question (Question 2) will be answered as part of the Feasibility Study in which the modelers and the design engineers will coordinate their efforts and utilize the models for this purpose. On-going discussions between USEPA and the modeling team have continued throughout these efforts so as to maintain the model focus.

In a similar fashion, the risk assessors have been involved as well. Team meetings between the modelers and the human and ecological risk assessors have been an on-going part of the Reassessment RI/FS. Due to limitations in the available data as well as inherent biogeochemical limitations regarding the fate and bioaccumulation of PCBs in the environment, it was not possible to directly simulate the Aroclor mixtures (*e.g.*, Aroclor 1242, Aroclor 1254) required for the risk assessments. However, this issue was anticipated and algorithms relating the modeled PCB forms and the desired Aroclor mixtures were developed and applied, yielding concentration estimates of the desired Aroclor mixtures in the various exposure media. As further evidence of the degree of involvement of the risk assessors in the modeling effort, it should be noted that the ecological risk assessment team included several members of the bioaccumulation modeling team.

USEPA will establish Remedial Action Objectives (RAOs) for the site, including acceptable human health and ecological exposure levels for PCBs, as part of the Feasibility Study, which is Phase 3 of the Reassessment RI/FS. (An initial set of guidelines was presented in the Phase 1 Report issued in 1991.) Remediation goals (e.g., acceptable PCB levels in fish and sediment) will be developed on the basis of the Baseline Human Health and Ecological Risk Assessments for the Reassessment RI/FS (USEPA 1999b and USEPA 1999c). USEPA will not finalize the RAOs and final remediation goals until after the Feasibility Study is completed in December 2000. Moreover, it was not necessary or appropriate for the Agency to identify "risk assessment targets" in order to complete its baseline modeling approach, the BMR or RMBR, which address the fate, transport, and bioaccumulation of PCBs in the river under baseline conditions of no remedial action. After USEPA establishes the RAOs, the models will be used to back-calculate PCB concentrations in sediment and the water column that are necessary to achieve acceptable PCB levels in fish, sediment and surface water that are protective of human health and the environment. Such acceptable levels will be used to develop remedial action alternatives in the Feasibility Study.

6. ***The reviewers recommended the EPA develop a mechanistic food web model based on exposure dynamics of the identified forms of PCBs relevant to risk quantifications, and that USEPA identify appropriate data needs for the fate and transport models.***

As discussed in the response to Comment No. 2 above, a mechanistic bioaccumulation model has been included in the modeling effort. Specifically, a form of the mechanistic model developed by Gobas (1993, 1995) has been added to the suite of bioaccumulation models being used in the Reassessment RI/FS (i.e., FISHRAND). FISHRAND is described in the Revised BMR, in addition to the probabilistic and bivariate models (which were also described in the PMCR.)

7. ***The reviewers recommended that EPA develop an explicit plan for model calibration and independent validation that includes criteria for validation, makes use of numerous data sets that span a long time period, and includes chemicals in addition to PCBs.***

The USEPA developed and applied an extensive calibration plan for both its fate-and-transport model (HUDTOX) and its principal bioaccumulation model (FISHRAND) as outlined below.

Fate and Transport Model Calibration The calibration strategy for the HUDTOX transport and fate model is described in detail in Chapter 7 of Book 1 of the Revised BMR. The principal model application was a long-term historical calibration to Tri+ for a 21-year period from 1977 to 1997. The historical calibration was tested through short-term hindcast applications for total PCBs and five individual congeners (BZ#4, BZ#52, BZ#28, BZ#[90+101] and BZ#138) from 1991 to 1997. Consistent with the Reassessment RI/FS questions, emphasis was placed on calibration to long-term trends in sediment and water column PCB concentrations. Many different metrics were used to demonstrate model reliability and they were used collectively in a "weight of evidence" approach.

The calibration strategy was minimal and conservative. It was minimal in the sense that external inputs and internal model parameters were determined independently to the fullest extent possible from site-specific data, and only a minimal number of parameters were determined through model calibration. It was conservative in the sense that parameters determined through model calibration were held spatially and temporally constant unless there was supporting information to the contrary.

A 21-year historical calibration was the principal development vehicle for the HUDTOX model. The calibration focused on representing long-term Tri+ trends in water and sediment. The historical calibration was conducted simultaneously for solids and Tri+. Operationally, the approach consisted of adjusting four model parameters: gross settling velocities into cohesive and non-cohesive sediment areas; resuspension rates from non-cohesive sediment areas; depth of particle mixing in the sediment bed; and magnitude of sediment particle mixing.

Solids and Tri+ dynamics in HUDTOX were calibrated to achieve long-term results consistent with the extensive available historical data. In the simultaneous solids and Tri+ calibration, primary emphasis was placed on representing long-term historical rates of decline for Tri+ in the water column and surface sediments from 1977 to 1997. The calibration sought to describe mean high and low flow solids and Tri+ dynamics in the river. Calibration to short-term dynamics was not emphasized because detailed representation of short-term event impacts was not necessary to answer the principal Reassessment RI/FS questions.

The model calibration was tested with a short-term 1991 to 1997 hindcast application for total PCBs and the five congeners listed above. The physical-chemical properties of the five congeners span a wide range of partitioning and volatilization behavior. These important differences in environmental behaviors provided an opportunity to test the rigor of the Tri+ calibration, especially sediment-water and air-water exchange processes.

Subsequent to calibration of the HUDTOX model, a validation was conducted using an independent dataset collected by General Electric Company in 1998. These data included PCB measurements of water column and sediment concentrations. The focus of the validation testing was on the water column data for 1998 at Fort Edward, Thompson Island Dam and Schuylerville.

The baseline modeling effort for the Reassessmentdid not attempt to examine the transport and fate of chemicals other than PCBs, which are the contaminants of concern for this site. There are relatively few data on other chemicals in the Upper Hudson River. Those chemicals that have been measured lack the extensive spatial and temporal coverage available for PCBs and thus are unlikely to increase the scientific and technical soundness of the HUDTOX model calibration. In the absence of useful data for other chemicals, and given the needs of the Reassessment RI/FS, emphasis was placed on the hindcast applications for total PCBs and the five congeners to test and strengthen the long-term historical calibration for the Tri+ form of PCBs.

<u>Bioaccumulation Model Calibration</u> The calibration methodology for the mechanistic bioaccumulation model (FISHRAND) is described in Chapter 3 of Book 3 of the

Revised BMR. Chapter 6 of Book 3 provides the results of the calibration. The FISHRAND model makes use of distributions instead of point estimates for model parameters. The calibration approach takes advantage of this feature by incorporating Bayes Rule. The procedure is as follows: Using the distributions specified in the initial parameter estimates, *i.e.*, Level 1 (generic model constants together with site-specific distributions of lipid content, sediment and water concentrations generated from the HUDTOX model, fish weight, K_{ow}, and dietary preferences), the model generates distributions of fish body burdens for each species, location, and year. These simulated values are compared to available NYSDEC monitoring data. The model output and the observations are reconciled using Bayes Rule to determine a posterior mass function for the model output, that is, the distribution that leads to a best fit between model output and observations. In this way, initially specified distributions ("priors") are updated using Bayes Rule to obtain revised input distributions ("posteriors") that lead to the closest agreement between predicted distributions of fish body burdens and measured fish body burdens. This is done within constraints of data using likelihood profiling.

The calibration of the bioaccumulation models (*e.g.*, FISHRAND) parallels that of the fate and transport model (HUDTOX). In this instance, there are no short-term studies but simply long-term monitoring data at stations throughout the Hudson, similar in temporal coverage and more extensive in spatial coverage than the water column data used for the HUDTOX model. Due to the strong similarity between the Tri+ sum and total PCB concentrations in fish, only one of these, Tri+, was simulated in the bioaccumulation models. As part of the on-going model refinements, concentrations of several of the congeners listed above will be simulated as well, providing an additional degree of calibration and verification to the models. These will be examined subsequent to the release of the Revised BMR.

To validate the FISHRAND model, several approaches were followed as presented in Chapter 6 of Book 3 of the Revised BMR. First, the calibrated model for one river mile was run using conditions at another river mile and predicted body burdens compared to measured body burdens at this location. Satisfactory agreement for both river miles implies model validity across locations in the Hudson River.

A second approach involves model calibration using only part of the available dataset and comparison of model predictability of the remaining portion of the dataset. A good concordance of the model prediction with observed data implies model validity within the timeframe of available measurements and therefore model usability for future predictions.

Finally, model predictions for the policy-relevant endpoints (such as concentrations at some point in the future) were compared for the model calibrated using all available experimental data and then only a portion of the data. Agreement between the model predictions using the full dataset calibration versus the partial dataset calibration indicates robustness of the model. These results are described in Chapter 6 of Book 3 of the Revised BMR.

8. ***Noting that analytical methods have improved and will continue to improve, the reviewers recommended that USEPA develop, and agree on how to use, a method for interpreting historical PCB monitoring data.***

USEPA agrees that this is a major concern to the Reassessment RI/FS. USEPA has in fact expended a large effort on the issue of interpreting historical PCB data. Data have been obtained from a multitude of sources, including NYSDEC (sediment and fish), USGS (water), USEPA (water, sediments and biota), General Electric (water, sediment and air), Lamont-Doherty Earth Observatory (sediment and water) as well as others. Results from all of these sources form a network of data to which the models are calibrated. As illustrated in Appendix E of the Low Resolution Sediment Coring Report (USEPA, 1998) and in Butcher *et al.,* 1996. USEPA has examined many of the historic data sets in detail and developed conversion algorithms to standardize the various results. In this manner, data from several sources on a single matrix can be used to calibrate the models over long periods of time.

9. ***Noting that EPA has already addressed or considered many of the recommendations listed above, the reviewers suggested that EPA hold an open workshop (involving all interested parties as well as independent reviewers) to evaluate current modeling efforts.***

USEPA agrees that it is important to meet with the various interested parties so as to consider their concerns and suggestions. USEPA has provided and continues to provide many opportunities for the various interested parties to participate in the Reassessment RI/FS process. Specific to the modeling effort, USEPA has held meetings with the Hudson River PCBs Scientific and Technical Committee (a panel of scientiststhat provides input to USEPA on scientific issues relating to the Reassessment RI/FS) to discuss the merits of each of its reports (including the PMCR and the BMR) and to receive feedback concerning better or other approaches for the investigation. USEPA also has had numerous discussions with General Electric Company and its consultants regarding modeling issues. In addition, USEPA released the Baseline Modeling Report for public comment in May 1999, and in January 2000 released the Revised BMR, which incorporates changes to USEPA's modeling approach that were made in response to public comments received on the BMR. In February 2000, USEPA issued a Responsiveness Summary that responds to all significant public comments received on the BMR and provides references to the appropriate sections of the Revised BMR where the comments were addressed. The Revised BMR and the Responsiveness Summary for the BMR are undergoing peer review, which will be completed in March 2000. Members of the public are invited to attend the peer review meeting and will be given an opportunity to address the peer reviewers at the meeting.

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REPORT OF THE HUDSON RIVER PCBs SITE MODELING APPROACH PEER REVIEW

—Final Report—

Prepared for:

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November 10, 1998

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NOTE

This report was prepared by Eastern Research Group, Inc. (ERG), an EPA contractor, as a general record of discussion for the peer review meeting. This report captures the main points of scheduled presentations and highlights discussions among the reviewers. This report does not contain a verbatim transcript of all issues discussed during the peer review. Additionally, the report does not intend to embellish, interpret, or enlarge upon matters that were incomplete or unclear. EPA will evaluate the recommendations developed by the reviewers and determine what, if any, modifications are necessary to the current modeling approach. Except as specifically noted, no statements in this report represent analyses or positions of EPA or of ERG.

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LIST OF ABBREVIATIONS

DOC	dissolved organic carbon
EMC	environmental management council
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
GE	General Electric Company
PCB	polychlorinated biphenyl
PMCR	"Preliminary Model Calibration Report"
QEA	Quantitative Environmental Analysis, LLC
TEQ	toxic equivalent
TSS	total suspended solids

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EXECUTIVE SUMMARY

Seven independent peer reviewers critiqued the October 1996 "Preliminary Model Calibration Report" (PMCR), a document prepared as part of the U.S. Environmental Protection Agency's (EPA's) reassessment of the Hudson River PCBs Superfund site. After discussing at length the scientific rigor of the proposed modeling approach, most of the reviewers commended EPA on its extensive modeling efforts, but they unanimously agreed that the modeling approach described in the PMCR was "acceptable with major revision." At the close of the peer review meeting, the reviewers developed a short list of major findings and recommendations, which are summarized below. Except as noted otherwise, all of the peer reviewers agreed with these major findings and recommendations. Specific examples of other suggested revisions and recommendations made by the peer reviewers can be found throughout this report.

- The reviewers recommended that EPA make the following improvements in the description of sediment resuspension and deposition processes in the fate and transport models: address the fate of resuspended material; address the role of uncovered, potentially contaminated surfaces; address the issue of non-cohesive sediment resuspension; assure consistency in resuspension rates between the TIP and HUDTOX models; and identify the effect of flood resuspension on the rate of long-term recovery of the Hudson River. Some reviewers indicated that these changes could be made within the existing modeling framework (i.e., with several different fate and transport models that are linked), while other reviewers thought these changes should be made by incorporating sediment transport mechanisms directly into the HUDTOX model, instead of keeping the models separate.

- The reviewers recommended that EPA employ time- and space-dependent mechanistic models that reflect the abiotic and biotic dynamics of the Hudson River system.

- The reviewers indicated that the models should consider bioavailability and sediment sequestration with respect to congener sorption/desorption and transformation kinetics, sediment particle characteristics, and biotic characteristics.

- The reviewers recommended that EPA link, to the greatest extent possible, the spatial and temporal scales of the different fate and transport and bioaccumulation models.

- The reviewers recommended that EPA clearly identify in its modeling approach the risk assessment targets as related to forms and concentrations of PCBs (e.g., to what

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guidelines or advisories will the modeled concentrations be compared). More specifically, the reviewers thought risk assessors and managers should be involved with the development of the transport and fate and bioaccumulation models to ensure that the model outputs will generate the data needed for completing human health and ecological risk assessments.

- The reviewers recommended that EPA develop a mechanistic food web model based on exposure dynamics of the identified forms of PCBs relevant to risk quantification, and that EPA identify appropriate data needs for the fate and transport models.

- The reviewers recommended that EPA develop an explicit plan for model calibration and independent validation that includes criteria for validation, makes use of numerous data sets that span a long time period, and includes chemicals in addition to PCBs.

- Noting that analytical methods have improved and will continue to improve, the reviewers recommended that EPA develop, and agree on how to use, a method for interpreting historical PCB monitoring data, including data quality factors.

- Noting that EPA has already addressed or considered many of the recommendations listed above, the reviewers suggested that EPA hold an open workshop (involving all interested parties as well as independent reviewers) to evaluate current modeling efforts.

1.0 INTRODUCTION

This report summarizes a peer review by seven experts of the site modeling approach that the U.S. Environmental Protection Agency (EPA) proposed for reassessing the Hudson River PCBs Superfund site. The peer reviewers addressed information provided in three documents:

- The October 1996 review copy of the "Preliminary Model Calibration Report" (PMCR) (Limno-Tech et al., 1996)
- The July 1998 draft copy of the revised scope of work for baseline modeling (Limno-Tech et al., 1998)
- Written responses to selected comments that stakeholders made following the initial release of the PMCR

The seven reviewers participated in the peer review meeting, which took place in Saratoga Springs, New York, on September 9–10, 1998. Eastern Research Group, Inc. (ERG), a contractor to EPA, organized the expert peer review and prepared this summary report. This introductory section provides background information on several topics relevant to this report, including a brief background of the Hudson River PCBs site, the scope of the current peer review, and the organization of this report.

1.1 Background

In 1983, EPA classified approximately 200 miles of the Hudson River in the state of New York as a Superfund site, due to elevated concentrations of polychlorinated biphenyls (PCBs) in sediments. The sediments are believed to have been contaminated by discharges of PCBs over approximately 30 years from two General Electric (GE) capacitor manufacturing plants, one in Hudson Falls and the other in Fort Edward. The Superfund site runs from Hudson Falls to the Battery in New York City. After an initial site assessment, EPA issued an "interim No Action decision" in 1984 for the contaminated sediments at the Hudson River PCBs site.

Since 1990, EPA has been reassessing its "interim No Action decision" to determine whether the PCB contamination in the Hudson River necessitates a different course of action. EPA proposed to complete this reassessment by compiling and analyzing existing data ("Phase I"), collecting additional data and using models to conduct human health and ecological risk assessments ("Phase II"), and performing a feasibility study of selected remedial alternatives ("Phase III"). As part of "Phase II" of the site reassessment, EPA's contractors completed the PMCR, which is the subject of the current peer review. The purpose of the PMCR was to describe models that EPA will use to characterize the fate and transport of PCBs in sediments, water, and biota in the Hudson River. More specifically, the PMCR was prepared "to provide interested parties with information about the data and assumptions that are being used in the models, prior to completion of the actual modeling work" (Limno-Tech et al., 1996). Several parties provided comments on the PMCR during the report's public comment period in 1996.

To ensure that the assumptions and preliminary findings presented in the PMCR are based on sound scientific principles, EPA decided as per policy to obtain an expert peer review of the document. The remainder of this report describes the scope and findings of the peer review of the PMCR.

1.2 Scope of the Peer Review

To organize a thorough review of the PMCR, ERG selected seven independent peer reviewers who are engineers or senior scientists with demonstrated expertise in any combination of the following areas:

- Transport and fate models for sediments and the water column
- Fish body burden models
- Calibration and validation of models
- Sensitivity analysis of models
- Familiarity with PCBs or other compounds that bioaccumulate

To ensure the peer review's independence, ERG considered only individuals who could provide an objective and fair critique of EPA's work. ERG did not consider in the reviewer selection process individuals who were associated in any way with preparing the PMCR or individuals affiliated with GE or any other specifically identified stakeholder.

Appendix A lists the seven reviewers ERG selected for the peer review meeting. Brief summaries of each reviewer's area of expertise can be found in Appendix C. Recognizing that few individuals specialize in every topic area listed above, ERG ensured that the collective expertise of the selected peer reviewers covers the topic areas listed above (i.e., at least one reviewer has expertise in transport and fate models, at least one reviewer has expertise in fish body burden models, and so on).

To focus peer reviewer comments, ERG worked with EPA to develop written guidelines for the technical review. These guidelines (commonly called a "charge") asked reviewers to address at least the following topics: if the proposed models could be used to make scientifically credible decisions; whether EPA's proposed models, datasets, and assumptions could answer the principal study questions of the PMCR; and if the modeling approach had any serious flaws that would invalidate its conclusions. A copy of the charge, which includes many additional topics and questions, is included in this report as Appendix B.

Several weeks before the meeting, ERG distributed copies of the PMCR, the revised scope of work for baseline modeling, and the responses to selected stakeholder comments to the reviewers and asked them to prepare written responses to the charge questions, based on their initial reviews of the documents. ERG compiled these "premeeting comments," distributed them to the reviewers, and made copies available to observers during the peer review meeting. These initial comments are included in this report, without modification, as Appendix C. It should be noted that the premeeting comments are preliminary in nature and some reviewers' technical findings may have changed based on discussions during the meeting. The premeeting comments should not be considered as the reviewers' final opinions.

It should also be noted that the reviewers were asked to base their reviews on the written materials distributed by ERG: the PMCR, the revised scope of work, and the responses to public comments. Even though EPA has currently completed several "Phase II" reports in addition to the PMCR, the reviewers were not asked to consider these additional reports, which will be (or already have been) subject to public comment and separate peer reviews. Though not required for this peer review, some reviewers may also have researched site-specific reports they obtained from other sources.

1.3 Meeting Organization and Agenda

The peer review meeting, which was held at the Sheraton Saratoga Springs Hotel and Conference Center in Saratoga Springs, New York, on September 9–10, 1998, was attended by the seven expert reviewers and at least 29 observers. Appendix D lists the observers who confirmed their attendance at the meeting registration desk. The schedule of the peer review meeting generally followed the agenda, presented here as Appendix E. As the agenda indicates, the meeting began with introductory comments both by the designated facilitator and by the designated chair of the peer review meeting. (Section 1.4 of this report summarizes these and other introductory comments.) The rest of the meeting consisted of discussions that focused on responding to the questions in the charge. During the technical discussions, the reviewers provided many comments, observations, and recommendations. The agenda included two time slots for observer comments, which are summarized in Appendix F of this report. An ERG writer attended the meeting and prepared this summary report.

1.4 Summary of Opening Remarks at the Meeting

On the first day of the meeting, Jan Connery of ERG—the designated facilitator of the review—welcomed the seven reviewers and the observers to the 2-day meeting. In her opening remarks, Ms. Connery introduced Dr. Al Maki (a peer reviewer and the technical chair of the meeting), stated the purpose of the peer review meeting, and identified the documents under review. To ensure that the peer review remained independent, Ms. Connery asked reviewers to discuss technical issues among themselves during the meeting and to consult EPA only for necessary clarifications. Ms. Connery explained the procedure observers should follow to make comments. Finally, she reviewed the meeting agenda, which appears in this document as Appendix E.

Following Ms. Connery's opening remarks, the peer reviewers introduced themselves, noted their affiliations, identified their areas of expertise, and stated that they had no conflicts of interest in conducting the peer review. Selected representatives from EPA and from EPA's contractors then introduced themselves and identified their roles in the site reassessment. To orient the peer reviewers to EPA's ongoing site reassessment efforts, Mr. Doug Tomchuk (EPA) then gave a presentation describing the history, current status, and planned future activities for the Hudson River PCBs site. Mr. Tomchuk explained how the PMCR relates to EPA's overall site reassessment, though he did not interpret, or expand on, the assumptions and findings documented in the report.

As a transition into technical discussions, Dr. Maki reviewed the 11 questions in the charge and identified several common themes among the peer reviewers' premeeting comments. For the remainder of the meeting, the peer reviewers discussed the questions in the charge, following the agenda. This report summarizes the peer reviewers' discussions and documents their major findings and recommendations.

1.5 Report Organization

The structure of this report reflects the order of questions in the charge to the reviewers: Section 2 of this report summarizes the reviewers' discussions on Question A in the charge, Section 3 summarizes the discussions on Question B, and so on. Section 7 of this report lists all references cited in the text.

As mentioned earlier, the appendices to this report include a list of the peer reviewers (Appendix A), the charge to the reviewers (Appendix B), the premeeting comments organized by author (Appendix C), a list of the observers present at the meeting (Appendix D), the meeting agenda (Appendix E), and summaries of the observer comments (Appendix F).

2.0 DISCUSSION ON QUESTION A: On the Appropriateness of Using the Models, Datasets, and Assumptions to Make Scientifically Credible Decisions

The peer reviewers opened their technical discussions by addressing the first question in the charge: "Is EPA using appropriate models, datasets and assumptions on which to base a scientifically credible decision?" To answer this question, each reviewer presented his or her initial thoughts and comments, which the reviewers as a group then further discussed. Summarizing the discussions, the technical chair suggested that the reviewers thought some of the selected models were appropriate, but that the reviewers also thought EPA could achieve its ultimate goals only after making major revisions. A general record of the peer reviewers' discussion on this question, organized by topic, follows (but, it should be noted, that Sections 6.2 and 6.3 present the reviewers' final list of major recommendations):

- *Limitations posed by the question.* When responding to Question A, several peer reviewers commented that their responses may have been limited by ambiguities in the question. For example, finding the question too broad, three reviewers indicated that they would present only general comments in response to this question but would provide detailed comments in response to other questions in the charge. Further, several reviewers thought the question could be interpreted in many ways: What kinds of scientific decisions will EPA make? What makes a decision "good enough" to be considered scientifically credible? Will the decisions be used in legal proceedings or regulatory determinations? To clarify the intent of the question, representatives from EPA explained that they were particularly interested in whether the reviewers thought the models could answer the three "principal study questions" of the PMCR. Recognizing that Question B of the charge addresses the principal study questions (see Section 3.0), several reviewers again indicated that they would provide their detailed comments in response to Question B and other questions that focus on more specific topics.

- *The proposed bioaccumulation models.* Three reviewers recommended (and all of the reviewers later agreed) that EPA should use predictive or dynamic models to address bioaccumulation, instead of using the descriptive models proposed in the PMCR. More specifically, the reviewers suggested that EPA use a more complex model based on a mechanistic understanding of bioaccumulation, rather than use a simpler model based on empirical relationships. The reviewers indicated that they would provide more detailed comments on the bioaccumulation models when responding to other questions in the charge.

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- *The proposed transport and fate models.* The two reviewers who commented on the proposed transport and fate models (in response to Question A) found them to be generally appropriate. One reviewer provided detailed comments, noting that he approved of the proposed grid sizes, model calibration, and selected steady-state assumptions. Regarding improvements to the models, this reviewer recommended that the "depth of scour" model for the Thompson Island Pool consider erosion of non-cohesive sediments, that the models consider how turbulent flows affect erosion, and that EPA reconsider the assumption that bed shear stresses reach their maximum values instantaneously.

- *Involvement of risk assessors.* Several reviewers emphasized the importance of ensuring that EPA's proposed modeling approach can meet the data needs of the human health and ecological risk assessments planned for the Hudson River PCBs site. As an example, one reviewer indicated that the modelers should know whether the risk assessors intend to evaluate exposures to total PCBs, to a subset of Aroclors, or to individual congeners. To demonstrate a clear link between the PMCR and the risk assessments, the reviewer suggests the modeling reports should describe "acceptable risk levels" and other concepts relevant to the planned risk assessments. Another reviewer wondered if the risk assessors might evaluate environmental contaminants other than PCBs, thus necessitating modeling for a greater number of contaminants.

- *Consideration of bioavailability.* One peer reviewer indicated that the models should more prominently acknowledge the issue of bioavailability, including kinetics of adsorption and desorption, though the reviewers reserved specific comments on this topic for later in the peer review meeting.

- *Links between the proposed models.* Several reviewers did not think the PMCR adequately addressed how EPA plans to interface the different transport and fate models and bioaccumulation models. A reviewer noted that the modeling effort could face future problems if the temporal and spatial scales of the various sub-models are not linked.

- *Consideration of other relevant data sources.* A peer reviewer gave two examples of how the modeling approach in the PMCR can be strengthened by considering data from other relevant sources. First, the reviewer was surprised that the PMCR did not compare any of the monitoring data or preliminary model predictions to data and predictions from PCB modeling efforts in other river systems. Second, the reviewer thought EPA should make use of data sets for pollutants other than PCBs. As an example, the reviewer indicated that monitoring data for other chemicals (e.g., inorganics) could illustrate fate and transport in the Hudson River over the long term. The reviewer acknowledged that the relative importance of various fate and transport processes differ from one chemical to the next, but noted that the same processes result in the transport of all chemicals. Thus, the rigor of the model testing and validation could be greatly improved by considering other chemicals.

- *Use of historical monitoring data.* Several reviewers were concerned about the appropriate use of historical monitoring data for the Hudson River. For instance, one reviewer stressed that historical monitoring data for PCBs are particularly difficult to interpret because analytical methods and sensitivities have changed significantly in the last 20 years—an issue the reviewer intended to describe in greater detail during later discussions. According to another reviewer, the fact that many different agencies and parties have collected Hudson River samples for different purposes may also complicate efforts to understand historical data. This reviewer wondered whether some unique trends in the historical data (e.g., relatively high concentrations of BZ4 in the distribution of PCBs) reflect actual levels of environmental contamination or indicate evolving analytical techniques.

- *Links between the aquatic, terrestrial, and atmospheric systems.* One reviewer was concerned because the proposed modeling approach apparently ignores possible physical or biological links between the aquatic, atmospheric, and terrestrial systems. Two reviewers cited examples of other systems in which they thought such links have been addressed. The examples were PCB transport between the atmospheric and aquatic systems for the Great Lakes and PCB transport between the aquatic and terrestrial systems for the St. Lawrence River. The reviewers did not provide specific references for these examples during the meeting.

- *Impact of uncertainty.* One reviewer wondered if there might be enough uncertainty in the proposed models to limit their use in making scientifically credible decisions. This reviewer stressed that the uncertainty in the models' predictions does not necessarily imply that the selected models, datasets, or assumptions are inappropriate or invalid. Rather, he indicated that current "quantitative understanding" of the transport and fate and bioaccumulation of PCBs in river systems may be too limited for models to predict future river conditions with "sufficient certainty."

- *Inability to verify references to the "gray literature."* One reviewer found references in the PMCR to the "gray literature" troubling in two regards. First, the reviewer thought EPA should cite peer-reviewed literature to the greatest extent possible. Second, the reviewer was frustrated that the public generally cannot access much of the "gray literature" that was cited. As a result, the reviewer suggested that EPA encourage wider dissemination of the "gray literature," in cases where reference to such sources is truly necessary. Another reviewer was frustrated that details of the Thomann model—a major feature of the overall modeling effort—were not readily accessible and possibly not complete.

- *Incomplete information on the available data.* Several reviewers commented on different topics related to the monitoring data available for the Hudson River. For example, some reviewers were unsure of exactly how much monitoring data are available for the site and exactly what subset of these data EPA plans to consider in its modeling analysis. As a result, one reviewer said he did not have enough information to determine whether EPA was using appropriate data sets. Two reviewers thought that, to address concerns regarding the use of available data, the PMCR should not only list the available data sources but should also state the criteria used to include and exclude these sources from the modeling analysis. On a related topic, one reviewer thought the extent to which EPA considered data outliers was unclear; the reviewer recommended that outliers be considered in the modeling analysis, because they may provide clues to unique trends and patterns in the river system. Finally, one reviewer thought giving reviewers access to the monitoring data might have helped the reviewers evaluate the PMCR more comprehensively.

- *Assumptions in the modeling approach.* One reviewer noted that the modeling approach documented in the PMCR essentially assumes "ecological steady state" for the Hudson River. The reviewer presented several scenarios (e.g., development of wetlands in the area, invasion of the Hudson River by foreign species, and so on) that could invalidate this assumption. When reviewing these discussions at the end of the peer review meeting, however, the group of peer reviewers unanimously agreed that the modeling assumption of "ecological steady state" was neither a "major" or a "minor" flaw in the proposed modeling approach.

- *Location of the upstream modeling boundary.* In response to Question A, two reviewers recommended that EPA consider moving the upstream boundary of its models to a location upstream from Hudson Falls. The reviewers thought this change would not only allow the models to provide a more complete mass balance of PCBs in the Hudson River but would also allow the models to characterize "background" levels of PCBs at locations upstream from the major sources. As Sections 5 and 6 describe, the peer reviewers' recommendations on this topic changed during the meeting, and they eventually decided that moving the upstream boundary may not be necessary.

- *Insufficient time for the peer review.* Noting that, in the time prior to the peer review meeting, the reviewers had to (1) become familiar with the Hudson River system and (2) research and critique the proposed models, one reviewer thought EPA should have given the group of reviewers more time and more background information earlier in the peer review process to critically evaluate the PMCR.

3.0 DISCUSSION ON QUESTION B: On the Ability of the Models to Answer the Principal Study Questions of the Preliminary Model Calibration Report

The peer reviewers continued their technical discussions by addressing Question B in the charge: "Will the models, with the associated datasets and assumptions, be able to answer the following principal study questions as stated in the PMCR:

1. When will PCB levels in the fish population recover to levels meeting human health and ecological risk criteria under No Action?

2. Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels?

3. Are there contaminated sediments now buried and effectively sequestered from the food chain which are likely to become 'reactivated' following a major flood, resulting in an increase in contamination of the fish population?"

At the beginning of the discussions, the meeting facilitator (Jan Connery, ERG) emphasized that Question B does not ask the reviewers to answer the three principal study questions, but rather asks the reviewers whether the models will be able to answer the three principal study questions. The following subsections summarize the reviewers' discussion on Question B. Their comments are organized by the principal study question under discussion. It should be noted, however, that Sections 6.2 and 6.3 present the reviewers' final list of major recommendations.

3.1 Predicting Future Levels of PCBs in Fish

The reviewers made the following comments, observations, and recommendations regarding Question B.1 of the charge:

- *Comments on the question.* One reviewer noted that some aspects of Question B.1 overlap with aspects of Questions B.2 and B.3. For example, the reviewer thought the ability of the models to predict sediment resuspension during floods (Question B.3) significantly affects the ability of the models to predict levels of PCBs in fish (Question B.1). As a result, the reviewers occasionally indicated when their specific responses applied to more than one question. As described later in this subsection, another reviewer wondered exactly what "human health and ecological risk criteria" EPA will consider in its risk assessments.

- *Improvements to the bioaccumulation models.* Much of the reviewers' discussion focused on the bioaccumulation models' inadequacy to predict future levels of PCBs in fish. Consistent with the responses to Question A, several reviewers reiterated the importance of using dynamic and mechanistic bioaccumulation models, instead of using empirical models that have no predictive capacity. Elaborating on the inadequacies of the models, one reviewer explained that the bivariate and probabilistic models provide only "pairwise comparisons" of concentrations of PCBs in different media, without mechanistically linking the different media. For instance, the proposed models assume that if the concentrations of PCBs in the sediment and in the water column decrease by a factor of two, then the concentrations of PCBs in the biota will also decrease by a factor of two. The reviewer cited examples from Lake Ontario where such simple "pairwise comparisons" are not observed in the food web. In short, the reviewer noted that concentrations of PCBs in the different media—biota, sediment, and water—will change at different rates, a scenario that the proposed bioaccumulation models cannot consider.

  To improve the bioaccumulation models, the reviewers offered several recommendations. First, several reviewers recommended that EPA use a bioaccumulation model, such as one of the Gobas models, with mechanisms for predicting how concentrations of PCBs in biota will respond to changing levels of PCBs in the river system. The reviewers indicated that such mechanistic models can explore different pathways of exposure and uptake. Second, another reviewer recommended that the bioaccumulation models link with the temporal scales of the HUDTOX model and that these temporal scales be short enough to address key life cycle stages in biota. Third, another reviewer thought the bioaccumulation models should consider, to the extent possible, congener-specific rates for PCB metabolism, uptake, and excretion. Finally, yet another reviewer recommended holding a separate workshop to review the available bioaccumulation models before selecting the most appropriate model for the Hudson River PCBs site.

- *Modeling the appropriate compounds for the risk assessment.* One reviewer was concerned that the PMCR did not specify the form of PCBs that will be considered in the human health and ecological risk assessments. To illustrate his concern, the reviewer wondered whether the risk assessments will consider total PCBs, a subset of Aroclors, individual PCB congeners, or possibly a toxic equivalency (TEQ) analysis. Asserting that the modeling outputs will eventually be critical inputs to the risk assessments, the reviewer recommended that EPA ensure that the fate and transport and bioaccumulation models evaluate the same forms of PCBs that the risk assessments will consider.

- *Models' consideration of bioavailability.* Several reviewers suggested that the fate and transport models should place a greater emphasis on bioavailability (in contrast to simple chemical detectability). As an example, one reviewer thought the models should not only predict the amounts of sediments that are resuspended, but also should consider the sorption and desorption kinetics of PCBs in these resuspended sediments (i.e., how much is desorbed or becomes bioavailable as a result of resuspension). The reviewer recommended using available congener-specific sorption and desorption kinetics, or estimates of these parameters if they are not available, in the fate and transport models, especially because some PCB congeners (higher-chlorinated PCBs) tend to bioaccumulate in fish more than lower chlorinated PCB congeners. A reviewer also noted that those congeners that sorb most to sediments also tend to bioaccumulate. Therefore, the models need to address the bioavailability of PCBs sorbed to resuspended sediments.

- *Long-term validation of models.* One reviewer acknowledged that long-term PCB fate and transport modeling is a difficult, and often unsuccessful, endeavor. As a result, the reviewer recommended that EPA perform long-term validation studies on levels of PCBs in the fish and in the river, and possibly even on levels of other chemicals for which data are available. The reviewer thought the results of such long-term validation studies might best indicate whether the models will be able to answer the first principal study question of the PMCR.

- *Benefits of conducting uncertainty and sensitivity analyses.* One reviewer thought it would be useful for EPA to develop a plan for conducting uncertainty analyses and sensitivity analyses on the transport and fate and bioaccumulation models. The reviewer suggested that these analyses may help EPA identify which variables and parameters have the greatest impact on future river conditions.

- *Inconsistently predicted sediment resuspension rates.* Citing a significant inconsistency between the sediment resuspension rates predicted for flood events by HUDTOX and the rates for flood events predicted by the "depth of scour" model, one reviewer wondered if the models can characterize sediment transport during flood events accurately. The reviewer further noted that an inability to characterize this sediment transport would ultimately compromise the models' ability to forecast concentrations of PCBs in fish. As a result, the reviewer recommended that EPA explain why the HUDTOX and "depth of scour" models seem to predict extremely different sediment resuspension rates during floods.

- *Location of the upstream modeling boundary.* One reviewer thought the ability of the models to forecast future levels of PCBs in fish is limited by the primary source of PCB loadings to the Hudson River being upstream of the modeling domain. More specifically, the reviewer indicated that if EPA cannot predict how the source of PCBs in the Upper Hudson River will change in the future, then the models certainly would not be able to predict future river conditions. Upon request for clarification, EPA explained that remedial actions at the GE Hudson Falls plant have greatly reduced the upstream loading of PCBs into the HUDTOX modeling domain since 1993. Further, EPA noted that monitoring upstream of the Hudson Falls plant consistently fails to detect PCBs in the water column (with a detection limit of 11 parts per trillion). As Sections 5 and 6 describe, the peer reviewers' recommendations on the placement of the upstream boundary for modeling changed during the meeting, and they eventually decided that moving the boundary may not be necessary.

3.2 Evaluating Remedies Other Than "No Action"

The reviewers made the following comments, observations, and recommendations regarding Question B.2 of the charge:

- *Comments on the question.* Because neither the PMCR nor the charge to the reviewers specify what remedial options EPA is considering for the contaminated sediments, several reviewers found it difficult to comment on whether the models can determine if remedies other than "No Action" could accelerate the rate at which environmental concentrations of PCBs might reach "acceptable risk levels." In addition, one reviewer was uncomfortable answering the question without knowing exactly what the "acceptable risk levels" are and how EPA derived them (e.g., are the acceptable levels expressed for total PCBs, selected Aroclors, or individual congeners?). Further, a reviewer said it was difficult to comment on whether remedial actions other than "No Action" could shorten the time for PCB contamination in the river to reach "acceptable risk levels," without first knowing how soon such levels would be reached under a "No Action" scenario. This reviewer also found the question difficult to answer because specific remedial actions, such as dredging sediments, can affect the ecological balance of the river system, regardless of how the actions change levels of PCBs in the river.

- *Significance of higher concentrations of PCBs in the Thompson Island Pool.* Citing the models' inability to identify the mechanisms causing the increase of PCB loading across the Thompson Island Pool, several reviewers wondered if the models would have the predictive capacity to conduct longer (e.g., 20-year) simulations, such as evaluating outcomes of different remedial actions. Elaborating on this point, a reviewer noted the calibration described in the PMCR failed to explain the significant increase of PCB concentrations over a relatively short calibration period within a relatively short section of the Hudson River. Until the models can characterize the unique observations during the model calibration period, some reviewers feared the models might not be able to answer the second principal study question. For this same reason, one reviewer thought the models may not be able to answer the first principal study question either.

- *Emphasis on source attribution.* Related to the previous topic, a reviewer thought the modeling should place a greater emphasis on source attribution. As an example, another reviewer suggested that the models should be able to determine whether PCB loads originate from recent discharges or from historical sediment sources. Referring to page 4-2 of the PMCR, this reviewer noted that the models currently might not be able to differentiate between these sources of PCBs. These reviewers indicated that understanding the sources of PCBs during different flow conditions is critical to evaluating different remedial options.

- *Need for long-term model validation.* Reiterating a concern raised in response to Question B.1, a reviewer thought EPA should conduct long-term validation studies on the proposed models under different flow conditions. The reviewer recommended that EPA conduct these validation studies both for PCBs and for other chemicals with sufficient historical data. Successful validation, according to the reviewer, could ultimately increase confidence in the models' predictive capacity.

- *Better hydrogeological characterization of the Thompson Island Pool area.* Noting that the PMCR hypothesizes that groundwater advection might explain the observed increased PCB loads across the Thompson Island Pool, one reviewer suggested that greater hydrogeological characterization in this section of the Hudson River is needed to verify this hypothesis. Subsequent discussions following the observer comment period suggested that this may not be necessary as the apparent increase across the pools may be an artifact of bias in a downstream monitoring location, as an observer suggested.

- *Consideration of two-stage partitioning models.* On several occasions, one reviewer recommended the possibility of using simple, two-stage partitioning models instead of the more elaborate fate and transport and bioaccumulation models described in the PMCR. The other reviewers commented on this proposition during their discussions on Question D and E (see Section 5).

3.3 Characterizing the Fate of "Reactivated" Sediments Following Major Floods

The following discussion summarizes the reviewers' comments, observations, and recommendations regarding Question B.3 of the charge:

- *Characterization of sediment erosion.* One reviewer listed three areas in which the models could better characterize sediment erosion. First, the reviewer recommended that the models account separately for how cohesive and non-cohesive sediments erode, instead of considering erosion of only cohesive sediments. Second, noting that turbulent flow can enhance sediment erosion, even during periods of "average" river flows, the reviewer suggested that EPA consider incorporating the role of turbulence in its models. Third, noting that sediments can erode during "average" flows as well as during flood events, the reviewer wondered whether the cumulative amounts of sediment eroded during "average" flows might be of greater concern than the large amounts of sediment eroded during 100-year floods. Other reviewers agreed with these findings, and one reviewer thought the relative significance of "average" flow and 100-year flood events was particularly important for EPA's modeling efforts (as is discussed in greater detail in the following bulleted items).

- *Significance of a 100-year flood event.* The reviewers had difficulty reconciling the models' predictions of sediment resuspension during a 100-year flood event in the Hudson River and observed sediment resuspension during major flood events in other rivers. For example, one reviewer noted that the "depth of scour" model predicts that 55 pounds of PCBs would be eroded from the Thompson Island Pool during a 100-year flood event in the Hudson River. The reviewer noted further that 55 pounds of PCBs is several orders of magnitude less than the amount of PCBs believed to be originally discharged to the river. Based on these observations, the reviewer suggested that a 100-year flood event in the Hudson River may not cause significant erosion of sediments. On the other hand, two reviewers provided quite different accounts of sediment erosion during major floods in other river systems: one reviewer said tropical storm Charlie caused floods that almost "completely scoured" the sediments in parts of the Rio Grande, and another reviewer mentioned that rains from hurricane Agnes diluted the entire salt-water content of the Chesapeake Bay. By these accounts, the reviewers implied that 100-year flood events could quite effectively remove contaminants in sediments from rivers. To make sense of these very different outcomes, a reviewer asked EPA to describe what conditions are expected during a 100-year flood in the Hudson River. In response, one of EPA's contractors indicated that, due in part to the fact that the Upper Hudson River has several "controls" (e.g., locks and dams), water levels during a 100-year flood event for the Upper Hudson River would not be significantly higher than those during a typical spring high-flow event. The EPA contractor further noted that PCBs remain in the Hudson River even though several notable high-flow events have occurred over the past 20 years. The following three bulleted items list the reviewers' recommendations that evolved from this discussion of 100-year floods.

- *Emphasis on modeling 100-year floods.* Assuming that sediment erosion occurs during "average" flows (see the first bulleted item under Section 3.3) and that erosion during 100-year flood events resuspends only a small fraction of the "sequestered" PCBs (see the previous bulleted item), one reviewer wondered if EPA should place less emphasis on evaluating the effects of a 100-year flood event and more emphasis on modeling the daily "average" flows. Another reviewer cautioned that this suggestion assumes that 100-year flood events do not erode significant quantities of sediments—a finding that is based on only preliminary modeling results.

- *Role of freshly uncovered sediments.* Two reviewers were concerned that the PMCR focuses on modeling the amounts of resuspended sediments and not on characterizing freshly exposed, and possibly highly contaminated, surfaces following flood events. Unsure whether these freshly uncovered sediments are a more significant source of PCBs to fish than the resuspended sediments, the reviewers recommended that EPA examine the significance of uncovered sediments in greater detail.

- *Role of resuspended sediments.* One reviewer raised the possibility that resuspended, PCB-contaminated sediments during flood events may act as a "source" (e.g., the sediments that were previously sequestered from the environment may become bioavailable) or they may act as a "sink" (e.g., flood waters may flush some contaminated sediments from the Hudson River altogether). The reviewer recommended that EPA clarify which scenario is most likely.

- *Links between the proposed models.* One reviewer noted that the mass balance in the HUDTOX model would not be complete if the model does not consider the amounts of sediments resuspended during a 100-year flood. Thinking the ultimate fate of resuspended sediments is just as important as the amount of the sediments that are resuspended, the reviewer recommended that EPA link the HUDTOX and the "depth of scour" models in a time-dependent fashion to ensure that HUDTOX models the transport and fate of sediments that are resuspended during flood events.

- *Influence of other factors on PCB loadings.* One reviewer indicated that factors other than 100-year flood events can significantly increase PCB loadings in the Hudson River. As examples, the reviewer suggested that bioturbation, "propeller backwash" from ships and boats, and even earthquakes (which might damage or destroy containment systems) all can affect sediment erosion, possibly significantly. The reviewer thought that EPA should acknowledge these factors in its modeling efforts.

- *Better characterization of suspended solids.* Citing information documented in other reviewers' pre-meeting comments, one reviewer recommended that the models incorporate a better physical characterization of resuspended sediments (e.g., particle size and fraction of organic carbon).

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4.0 DISCUSSION ON QUESTION C: Specific Questions Regarding the Models

The peer reviewers continued their discussions by answering the five specific questions listed in Question C of the charge. For these five questions, the following subsections restate a specific question in the charge and summarize the reviewers' relevant discussions. When answering the five specific questions, some reviewers referred to their comments from Questions A and B. The following subsections note these references, where appropriate. It should be noted, however, that Sections 6.2 and 6.3 present the reviewers' final list of major recommendations.

4.1 Developing Quantitative Relationships Between Forcing Functions and PCB Concentrations

Question C.1 of the charge asked the peer reviewers:

> "Are the modeling approaches suitable for developing quantitative relationships between external forcing functions (e.g., hydraulic flows, solids and PCB loads, sediment initial conditions, etc.) and PCB concentrations in the water column, sediments and fish? Are the models adequate for discriminating between water-related and sediment-related sources of PCBs?"

The following bulleted items summarize the reviewers' comments, observations, and recommendations regarding this question:

- *Evolution of analytical methods for PCBs.* Because laboratories, over the last 20 years, have used different methods with different sensitivities to measure levels of PCBs, one reviewer recommended that EPA make the issue of resolving historical differences in analytical chemistry a priority for the ongoing modeling efforts. As an example, noting peculiar trends in the distribution of congeners in selected sediment samples (e.g., relatively high levels of BZ4 in comparison to levels of other congeners), another reviewer wondered if such peculiarities accurately reflect actual levels of environmental contamination or possibly result from EPA misinterpreting historical monitoring data.

- *Improvements to the bioaccumulation models.* Two reviewers thought, and all of the reviewers later agreed, that only a mechanistic bioaccumulation model can discriminate between "water-related and sediment-related sources of PCBs." Noting that the statistical and probabilistic models proposed in the PMCR do not address mechanisms of bioaccumulation, one reviewer recommended that EPA use mechanistic models that, to

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the greatest extent possible, address congener-specific rates of uptake, metabolism, excretion, and storage of PCBs in biota.

- *Inputs from the watershed.* One reviewer thought PCB inputs from the watershed might be a relevant forcing function for the models, especially for long-term forecasting, but the reviewer indicated that the PMCR currently assumes such inputs are negligible. The reviewer acknowledged that current understanding of PCB inputs from watersheds may be too limited to incorporate in EPA's modeling approach. Nonetheless, another reviewer thought the PMCR should at least compare PCB inputs from the Hudson River watershed to other PCB loads in the system. This reviewer indicated that EPA may be able to characterize watershed loadings by moving the boundary of the modeling domain to locations upstream of Hudson Falls—a recommendation which the next bulleted item describes in greater detail.

- *Location of the upstream modeling boundary.* As the reviewers noted when discussing Questions A and B, the proposed location of the upstream modeling boundary may limit the models' ability to relate external forcing functions to concentrations of PCBs in the Hudson River. One reviewer indicated that moving the modeling boundary upstream of Hudson Falls will allow EPA to characterize the background levels of PCBs that enter the modeling domain. (As Sections 5 and 6 describe, the peer reviewers' recommendations on the placement of the upstream boundary for modeling changed during the meeting, and they eventually decided that moving the boundary may not be necessary.)

- *Consideration of "apparent" dissolved phase PCBs.* One reviewer thought that PCB measurements that do not distinguish "truly dissolved PCBs" from PCBs that are bound to dissolved organic carbon (DOC), such as the "Phase 2" measurements made in the Upper Hudson River, can be a major problem for the modeling results. The reviewer recommended that EPA make a better distinction between these two forms of PCBs. Further, another reviewer thought the PMCR should better characterize the DOC typically found in the Hudson River.

- *Bias in modeling results.* Based on a comparison of the modeling results during low-flow and high-flow events, one reviewer thought the predicted concentrations of PCBs and concentrations of total suspended solids (TSS) may have been biased. The reviewer recommended that EPA closely examine the relationship between flow, total suspended solids, and PCBs, and explain any peculiar trends; rather than dismiss outliers, as was done.

4.2 Adequacy of Spatial and Temporal Scales

Question C.2 of the charge asked the peer reviewers:

> "Are the spatial and temporal scales of the modeling approaches adequate to answer the principal study questions? If not, what levels of spatial and temporal resolution are required to answer these questions? What supporting data are required for calibration/validation of these spatial and temporal scales?"

The following discussion summarizes the reviewers' comments, observations, and recommendations regarding this question:

- *Spatial resolution of the HUDTOX and "depth of scour" models.* The reviewers agreed that the HUDTOX and "depth of scour" models have adequate spatial resolution for modeling flows in the Hudson River. Further, one reviewer thought that use of finer resolution in these models will significantly increase the time needed for computation, without providing much greater insight into fate and transport of PCBs in the Hudson River.

- *Links between the models.* Reiterating comments they made when discussing Questions A and B, several peer reviewers recommended that EPA link the spatial scales and temporal scales of every proposed model (e.g., the HUDTOX model, "depth of scour" model, Thomann model, and bioaccumulation models). The reviewers thought these links were important for modeling the Hudson River over the long term.

- *Boundaries of the models.* The reviewers commented on two aspects of the boundaries of the proposed models. First, two reviewers wondered if EPA could use a single model to characterize PCBs in the entire Hudson River, instead of using the Thomann model for the Lower Hudson River and the HUDTOX model for the Upper Hudson River. In the event that EPA continues to use separate models, these reviewers thought the models should at least be properly linked (see previous bulleted item). Second, consistent with comments made on Questions A and B, several reviewers again noted that the models currently neglect segments of the Hudson River upstream from Hudson Falls. (However, as Sections 5 and 6 describe, the peer reviewers' thinking on the placement of the upstream boundary for modeling changed during the meeting, and they eventually decided that moving this boundary may not be necessary.)

- *Temporal scale of the bioaccumulation models.* Several reviewers noted that the proposed bioaccumulation models have no temporal component, thus preventing them from predicting how changing levels of PCBs in the Hudson River will affect levels of PCBs in fish. One reviewer explained that the proposed models do not account for temporal changes in fish feeding patterns, which are known to vary daily and seasonally, or sensitive life stages. Citing these temporal changes, another reviewer thought time-dependent concentrations of PCBs in the water column may be important for characterizing PCB uptake by fish. This reviewer recommended that EPA use a "bioenergetically-based food chain model" with adequate temporal components. A different reviewer noted that EPA may have already started using such a food chain model.

- *Temporal scale of the "depth of scour" model.* One reviewer thought the temporal scale in the "depth of scour" model was generally adequate, but he disagreed with the model's assumption that bed shear stresses reach their maximum values instantaneously. However, the reviewer did not recommend alternative assumptions for addressing temporal variations in bed shear stresses.

- *Model calibration issues.* The reviewers made several comments regarding how EPA proposes to calibrate its models. For example, noting that calibration data were available for only 6 of the 13 river segments in the HUDTOX model, one reviewer thought EPA should reconcile the number of modeling segments with the available data before conducting the final model calibration. Regarding the model calibration period, another reviewer was discouraged by the statement in the PMCR that "it is not yet clear whether the PCB dynamics operative during this simulation period are fully representative of historical PCB dynamics, or whether they will be representative of PCB dynamics under future conditions" (Limno-Tech et al., 1996). Yet another reviewer recommended that EPA calibrate only a certain set of parameters in the models, rather than calibrating "the entire process."

- *Data validation issues.* Several reviewers discussed the importance of data validation, particularly with respect to levels of PCBs in fish. One reviewer suggested that data validation should consider concentrations of PCBs in sediment, the water column, and fish, but two reviewers stressed that EPA should place much greater emphasis on validating fish body burdens (e.g., average concentrations of PCBs and standard deviations of the concentrations). One of these reviewers thought using the models to estimate fish concentrations back to 1977 is also important, but only after EPA resolves historical differences in PCB analytical methods. This reviewer further recommended that validation not only consider PCBs, but also other chemicals with sufficient data. Finally, one reviewer emphasized that EPA should develop specific validation criteria (e.g., ranges of concentrations of PCBs in fish that would be considered "acceptable") before it actually performs the data validation.

4.3 Use of Several Bioaccumulation Models

Question C.3 of the charge asked the peer reviewers:

> "It is contemplated that PCB concentrations in fish will be estimated using several modeling approaches: an empirical probabilistic model derived from Hudson River data, a steady state model that takes into account mechanisms of bioaccumulation body burdens, and a time-varying mechanistic model (not included in the PMCR).

A bi-variate statistical model may also be used to provide insight into accumulations. This multi-model approach is being contemplated because of the uncertainties associated with any individual model. Is this a reasonable approach or should predictions be made using a single 'best' model?"

The following bulleted items summarize the reviewers' comments, observations, and recommendations regarding this question:

- *Use of multiple bioaccumulation models.* After lengthy discussions on the topic, the peer reviewers agreed that EPA's proposed use of multiple bioaccumulation models to estimate concentrations of PCBs in fish is advisable, even though the reviewers thought the best option ultimately will be to use a time-dependent, mechanistic model. One reviewer noted that comparing predictions from multiple models has been a productive exercise for other modeling endeavors, even when predictions from the individual models differ. Another reviewer urged EPA to review the assumptions of the candidate models and to develop expectations of what the different models will predict, before comparing results from the different models. This reviewer also suggested that EPA consider the quality of each model's input data as a factor when selecting which model is most appropriate.

- *Input from risk assessors.* Recognizing that risk assessors will ultimately use the outputs from the bioaccumulation models as inputs for risk modeling, two reviewers stressed the importance of early and frequent involvement of risk assessors in the transport and fate and bioaccumulation modeling, including the selection of appropriate models.

- *Use of experimental data.* To provide greater insight into bioaccumulation of PCBs in the Hudson River system, one reviewer thought, EPA should consider conducting simple laboratory studies designed to mimic the Hudson River. Although another reviewer agreed that additional laboratory studies might help EPA parameterize its models better, two other reviewers were not convinced that additional experimental studies should precede EPA's modeling efforts: one of these reviewers noted that models can be used to identify where experimentation is needed, and the other reviewer indicated that laboratory experiments probably would not provide useful information in the short term, due to the long time scales needed to observe bioaccumulation of PCBs in fish.

4.4 Adequacy of the Models' "Level of Process Resolution"

Question C.4 of the charge asked the peer reviewers:

"Is the level of process resolution in the models adequate to answer the principal study questions? If not, what processes and what levels of resolution are required to answer these questions? What supporting data (such as data to support specifications of a mixed depth layer, solids and scour dynamics, groundwater inflow, etc.) are required for these processes and levels of resolution?"

As Appendix C shows, the charge explains that " 'level of process resolution' refers to the theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport . . ." The following discussion summarizes the reviewers' comments, observations, and recommendations regarding this question:

- *Enhanced consideration of several processes.* The peer reviewers identified several areas that might require higher levels of process resolution, such as sorption and desorption kinetics, pore water advection, and bioavailability. Because the reviewers discussed these topics when responding to Questions A and B, they decided not to discuss them in detail when responding to Question C.4. One reviewer suggested reference to the premeeting comments for a list of other areas that, according to the reviewers, could require higher or lower levels of resolution.

- *Relevance of lipid contents to modeling bioaccumulation.* One reviewer noted that the extent to which PCBs bioaccumulate in fish strongly depends on lipid content. The reviewer explained that lipid contents in fish and other biota are known to change with time, but the reviewer noted that the bioaccumulation models described in the PMCR currently assume constant lipid values. Although the reviewer thought it was important for bioenergetic bioaccumulation models to consider variations in lipid content, she acknowledged that it is "very common" for modelers to assume constant lipid values.

- *Consideration of PCB degradation.* Two reviewers discussed the significance of PCB degradation in the Hudson River system. One reviewer thought the HUDTOX model should account for how PCBs degrade in the sediments, since degradation in sediments would ultimately affect the profile of PCBs that are bioavailable. Another reviewer thought the bioaccumulation models, to the greatest extent possible, should consider PCB degradation in biota, since degradation in fish and other biota determines the profile of PCBs expected to bioaccumulate in fish. The reviewers thought PCB degradation would be particularly important to consider in the proposed long-term simulations of river conditions.

- *Balance between details and generalizations.* Regarding the six different fish species selected for bioaccumulation modeling, two reviewers debated the balance between modeling general scenarios and modeling detailed scenarios. For example, one reviewer argued that EPA could run its bioaccumulation models for only two of the six species, without losing process resolution. However, noting that EPA considered many criteria (e.g., endangered species and importance for fishing) when selecting fish species for modeling, another reviewer thought the six selected species were adequate and suggested that modeling fewer species might lower process resolution.

- *Level of resolution needed for final decisions.* One reviewer found the question difficult to answer without knowing what level of process resolution EPA requires to make its decisions on remedial actions. As an example, the reviewer explained that the level of process resolution for the models would have to be extremely high if EPA needed to predict concentrations of PCBs in fish with very tight error bounds; lower levels of process resolution might be adequate if broader error bounds in the predicted concentrations of PCBs in fish are acceptable.

4.5 Usefulness of Modeling Results for Risk Assessment

Question C.5 of the charge asked the peer reviewers:

> "The results of the modeling effort will be used, in part, to support human and ecological risk assessments. In your judgment, will the models provide estimates adequate for this purpose?"

The following discussion summarizes the reviewers' comments, observations, and recommendations regarding this question:

- *Involvement of risk assessors.* Consistent with comments made to Questions A and B and C.3, two reviewers emphasized the importance of early and frequent involvement of risk assessors in EPA's ongoing modeling efforts. The reviewers explained that this involvement should help ensure that outputs from the fate and transport and bioaccumulation models will coincide with the desired inputs for the risk assessments.

- *Relevant forms of PCBs.* Also consistent with comments raised earlier in the peer review meeting, one reviewer was not convinced that the proposed models and the risk assessments will consider the same forms of PCBs. As a result, the reviewer suggested that the models described in the PMCR might need to characterize concentrations of only total PCBs, instead of characterizing levels of individual PCB congeners, selected PCB homologues, or selected Aroclors. Noting that some health outcomes are linked to specific PCB exposures (e.g., exposure to lower homologues of PCBs may be a more likely cause of neurotoxic developmental effects in children than exposure to higher homologues of PCBs), another reviewer did not agree that modeling only total PCBs was advisable. These reviewers agreed, however, that EPA should model fate and transport and bioaccumulation of at least those forms of PCBs that the human health and ecological risk assessments will consider.

- *Adequacy of the proposed bioaccumulation models.* Again reiterating a topic from earlier discussions, one reviewer emphasized that the proposed bioaccumulation models may not generate data adequate for the risk assessment. The reviewer recommended that EPA use a dynamic, mechanistic bioaccumulation model instead of the bivariate and probabilistic models.

- *Specifics for the ecological risk assessment.* Two peer reviewers suggested that the ecological risk assessment should consider mink, and possibly snapping turtles, as sentinel species, since, once revised as suggested, the models described in the PMCR would provide estimates adequate for assessing risks to these species and their consumers or others (e.g., otter). (The reviewers agreed that the models should provide data from which exposures relevant to the ecological risk assessment can be estimated.)

5.0 DISCUSSION ON QUESTION D AND E: Recommended Changes to, and Serious Flaws in, the Proposed Modeling Approach

The peer reviewers continued their technical discussions by answering Questions D and E in the charge:

> "D. Are there any changes to the work effort outlined in the revised work plan that would significantly improve the outcome?
>
> E. In terms of evaluating the overall and specific effects and behavior of PCBs in the Hudson River, are there any serious flaws in the modeling approach (theory, structure, physical parameters, etc.) that would limit or invalidate any conclusions or further work based upon the results of these models?"

The peer reviewers decided to address these questions at the same time, because they thought serious flaws in the modeling approach (i.e., responses to Question E) would imply the need for revising the modeling work plan (i.e., responses to Question D). Before answering these questions, however, some peer reviewers indicated that they were uncomfortable commenting on improvements EPA has made since the PMCR was published. Other peer reviewers noted that their responses to Questions D and E would be quite similar, if not identical, to their responses to Questions A, B, and C.

The reviewers made the following comments, observations, and recommendations regarding Questions D and E of the charge (but, it should be noted that Sections 6.2 and 6.3 present the reviewers' final list of major recommendations):

- *Improved characterization of sediment transport.* Several peer reviewers' responses to Questions D and E focused on issues related to sediment transport. For instance, consistent with responses to Question B.3, one peer reviewer thought the proposed models could be enhanced by considering how non-cohesive sediments erode and how turbulence affects sediment resuspension. The reviewer noted that these factors have been considered in other recent modeling efforts (Cao, 1997). Further, this reviewer emphasized that sediment erosion can occur during low-flow conditions, thus potentially causing the cumulative effects of sediment erosion during "average" flows to be just as significant as effects of sediment erosion during floods. Building on these findings, another peer reviewer suggested that EPA can better characterize sediment transport by: (1) providing some justification for assuming that the "active layer" of sediments is 5 centimeters thick; (2) accounting for the ultimate fate of resuspended sediments; (3) considering the significance of freshly uncovered, potentially contaminated sediments; and (4) incorporating semi-empirical sediment resuspension algorithms in HUDTOX, rather than characterizing sediment resuspension rates by model calibration.

Although the reviewers generally agreed on how the models should characterize sediment transport, the reviewers did not agree on an approach EPA should take to revise its models. One reviewer recommended that EPA incorporate the "depth of scour" model directly into the HUDTOX model, rather than leaving the models decoupled. This reviewer thought the use of a single, comprehensive model is needed to track the fate of resuspended sediments. Another reviewer disagreed, however, thinking EPA can improve its characterization of sediment transport while still using two different models. More specifically, noting that the HUDTOX and "depth of scour" models were developed to address two different principal study questions, this reviewer thought it may be appropriate to keep the models separate. In any case, this reviewer thought, it was sufficient for the peer reviewers simply to identify the shortcomings in the proposed modeling approach and to let EPA decide how to improve its models.

- *Statistical analysis of the modeling results.* Two reviewers thought the use of Student's t-tests to evaluate the performance of the HUDTOX model (e.g., see page 4-20 of the PMCR) was statistically invalid. Both reviewers agreed that these invalid analyses may have biased conclusions in the PMCR regarding performance of the models. The two reviewers suggested that EPA instead use regression analyses or simple plots of modeling results against observed values.

- *Link between the Thomann and HUDTOX models.* One reviewer thought the use of two models with different assumptions to address PCB transport in two different regions of the Hudson River could be a "serious flaw." The reviewer suggested that there should be more agreement between how HUDTOX characterizes PCB transport in the Upper Hudson River and how the Thomann model characterizes PCB transport in the Lower Hudson River.

- *Use of congener-specific data.* Citing an example of how Henry's Law constants may differ for individual congeners within a PCB homologue, one reviewer recommended that EPA consider, to the greatest extent possible, congener-specific data for Henry's Law constants, fish uptake and metabolic rates, degradation rates, and other relevant physical, chemical, and biological mechanisms.

- *Use of predictive bioaccumulation models.* Consistent with comments made on Questions A through C, two reviewers emphasized the importance of using predictive, mechanistic bioaccumulation models instead of (or possibly in addition to) using either the probabilistic or bivariate models described in the PMCR.

- *Location of the upstream modeling boundary.* Revisiting a recommendation they made when responding to Questions A through C, two reviewers decided that it was not important to recommend that EPA move the modeling boundary to include regions upstream of Hudson Falls. These reviewers decided this recommendation was not necessary because (1) the upstream loadings during the 1993 calibration period may not have been representative of the general river conditions (i.e., conditions may still have been affected by the Allen Mill event) and (2) the PCB loadings in the Hudson Falls area may be impossible to quantify. As Section 6 notes, other peer reviewers also agreed to retract their earlier recommendation of moving the upstream boundary of the modeling domain.

- *Issue of PCBs in the Thompson Island Pool.* One peer reviewer emphasized the need to understand the mechanisms causing the apparent increase of PCBs in the Thompson Island Pool. This reviewer recommended that EPA investigate the possibility that biased sampling results from a downstream monitoring location might have caused the apparent increase, as was suggested during the observer comments.

- *Use of simpler models.* One reviewer suggested that simple, two-stage partitioning models may be sufficient for characterizing PCB transport and fate and bioaccumulation in the Hudson River; however, three reviewers disagreed with this suggestion. These three reviewers indicated that simple partitioning models are inappropriate for this application, mainly because they have no predictive capabilities. More specifically, the reviewers thought simple partitioning models could not forecast how levels of PCBs in the sediment, river, and fish would change following different remedial actions or flood events (i.e., simple partitioning models could not answer the principal study questions of the PMCR). These reviewers agreed that mechanistic models could serve this purpose.

- *Miscellaneous comments.* When discussing Questions D and E, several peer reviewers offered miscellaneous comments about the proposed modeling approach. For example, noting that over 90 percent of the PCBs originally discharged to the Hudson River may have moved downstream from the Thompson Island Pool, one peer reviewer wondered why modeling was necessary if only a small fraction of the PCBs that were discharged still remain in that area. Several other peer reviewers explained that the amount of PCBs suspected of being in the Thompson Island Pool, though a small fraction of the PCBs that were originally discharged, might contaminate fish for many years to come. Another reviewer thought the current modeling effort might not be applicable to other river systems if it becomes too specific to the Hudson River. However, several other reviewers were confident that an understanding of the mechanisms of sediment transport and bioaccumulation would be quite useful for future modeling endeavors, regardless of the river of concern.

- *Topics discussed earlier in the meeting.* At the end of their discussions on Questions D and E, the peer reviewers mentioned that they could have addressed several additional topics from their earlier discussions on Questions A through C. These additional topics include, but are not limited to, incorporating the risk assessment paradigm, involving risk assessors early and often, validating the model, addressing factors that affect bioavailability, and resolving analytical chemistry issues. Rather than repeat their discussions on these topics, however, the peer reviewers instead decided to classify their findings into "major recommendations" and "minor recommendations," as described in Section 6.

6.0 REVIEWERS' OVERALL RECOMMENDATIONS

After completing their technical discussions on Questions A through E, the reviewers spent the final hours of the peer review meeting identifying their major findings and recommendations for the proposed PCB modeling approach. The peer reviewers generally separated initial findings from their earlier discussions into three categories: major recommendations, minor recommendations (or suggested revisions), and findings they no longer considered important. This section summarizes the reviewers' discussions that led to identifying major recommendations (Section 6.1), then lists the reviewers' major recommendations (Section 6.2), and finally documents the peer reviewers' closing statements to EPA (Section 6.3).

6.1 Discussions That Led to Identifying Major Recommendations

As the first step in identifying their major recommendations, the peer reviewers engaged in a detailed discussion on the relative importance of the many recommendations presented earlier in the peer review meeting. During these discussions, the peer reviewers noted that their understanding of the modeling approach had evolved significantly since the time when they prepared their premeeting comments (see Appendix C), and even had evolved since the first day of the peer review meeting. The peer reviewers also consistently acknowledged that the issues they brought up may have already been addressed, since 2 years have passed since the PMCR was published.

When trying to identify their most important findings for the proposed PCB modeling approach, the reviewers made the following comments, observations, and recommendations. It should be noted, however, that Sections 6.2 and 6.3 present the reviewers' final list of major recommendations.

- *Importance of involving risk assessors.* The peer reviewers discussed at length the importance of involving risk assessors early and often in EPA's ongoing modeling efforts. For example, several reviewers emphasized as a "key message" of the peer review that the transport and fate and bioaccumulation modelers must be aware, if they are not already so, of the different exposure endpoints and forms of PCBs that the risk assessors will consider. These reviewers thought the modeling approach would be "fatally flawed" if the modelers were unaware of the ultimate risk assessment targets. These reviewers were concerned that even scientifically rigorous transport and fate and bioaccumulation models will be rendered useless if their outputs do not interface with the inputs for risk assessment. To enhance risk assessor involvement, one reviewer suggested, EPA should hold a workshop or series of workshops to identify bioaccumulation models that provide data sufficient for conducting the planned human health and ecological risk assessments.

When discussing this topic, one reviewer was uncomfortable making a strong recommendation to EPA without knowing the extent to which EPA has involved, and continues to involve, risk assessors in the modeling efforts. Responding to this concern, several other reviewers indicated that the PMCR shows no evidence that risk assessors provided input to the modeling approach. These reviewers listed several specific questions that risk assessors should have answered at the onset of EPA's modeling efforts: What forms of PCBs (e.g., congeners, Aroclors, homologues, total PCBs) will the risk assessors consider? Will the risk assessors conduct a TEQ analysis? What exposure pathways will be considered? What species will be considered in the ecological risk assessment? What durations of exposure will the risk assessments consider? Without finding any indication in the PMCR that these issues have been resolved, most of the reviewers assumed that risk assessors have had limited involvement in EPA's ongoing modeling efforts.

Due to limitations in the transport and fate and bioaccumulation models, one reviewer thought a compromise may eventually be necessary between what the risk assessors would ideally like to consider and what the modelers can actually provide. More specifically, this reviewer noted that insufficient data may be available to calibrate the transport and fate models for every PCB congener, possibly even for congeners selected for analysis in the risk assessment. Another reviewer disagreed, noting that modelers can consider chemically similar PCB congeners to evaluate transport and fate and bioaccumulation of congeners that cannot be validated or tested directly. In any case, all of the reviewers agreed that the modeling efforts will be most useful if risk assessors specify at least (1) the types of species the bioaccumulation models should consider, (2) the forms of PCBs that need to be quantified, and (3) the durations of exposure that will be evaluated (i.e., acute or chronic).

- *Improvements to the sediment transport algorithms.* Noting that sediment transport can play a critical role in the bioaccumulation of PCBs in fish, the peer reviewers listed several areas in which EPA could improve its characterization of sediment transport. For instance, one peer reviewer thought the HUDTOX and "depth of scour" models should address how non-cohesive sediments erode, but he acknowledged that EPA may have considered this issue since the PMCR was published. This reviewer did not identify any "fatal flaws" with the HUDTOX and "depth of scour" models from a purely scientific basis, but the reviewer indicated there may be problems with how EPA intends to use them (e.g., how EPA will calibrate and link the models). Another reviewer echoed this concern by indicating that the models will be only as good as the data against which they are calibrated. As an example, this reviewer indicated that the apparent increased loadings of PCBs in the Thompson Island Pool may have resulted from a sampling bias at a downstream monitoring location as suggested during the observer comment period (see Appendix F. To prevent biased monitoring data from invalidating the modeling results, this reviewer recommended, EPA should carefully verify the accuracy of all data used for calibration. Yet another reviewer commented on sediment transport by recommending that HUDTOX include a more mechanistic treatment of sediment resuspension and track the fate of resuspended sediments.

- *Use of mechanistic bioaccumulation models.* Several peer reviewers agreed that use of only the bivariate and probabilistic food chain models (i.e., the models described in the PMCR) would be a "fatal flaw" in EPA's effort to evaluate bioaccumulation of PCBs. These reviewers thought use of a mechanistic, predictive bioaccumulation model would be necessary to answer the principal study questions listed in the PMCR. These reviewers also acknowledged that EPA currently plans to include a mechanistic bioaccumulation model in its future work.

- *Links between individual models.* One reviewer thought EPA's proposed modeling approach may ultimately be rejected if the HUDTOX and Thomann models are not linked "in a seamless manner" and if these models do not share common assumptions. This reviewer thought the links were necessary (1) because PCBs will eventually flow from the Upper Hudson River (the domain of HUDTOX) to the Lower Hudson River (the domain of the Thomann model) and (2) because EPA will eventually assess human health and ecological risks to receptors throughout the entire Hudson River valley.

- *More sophisticated consideration of bioavailability.* Citing comments raised in responses to Questions A through C, the peer reviewers recommended that the modelers consider bioavailability in greater detail, possibly by developing chemical fate parameters (e.g., sorption and desorption kinetics) and biological fate parameters (e.g., uptake and metabolic rates), and incorporating these parameters into a bioaccumulation model—an approach that is not currently proposed in the PMCR.

- *Involvement of stakeholders.* One reviewer suggested that EPA's ongoing modeling efforts would benefit from the involvement of multiple stakeholders. This reviewer thought such involvement would ensure not only the scientific rigor of modeling results, but also the appropriateness of selected remediation options. The reviewer noted that this suggestion was related more to EPA's site reassessment process than to the technical validity of the models described in the PMCR. During this discussion, EPA explained that stakeholder involvement (including community interaction programs) has been a critical element of the site reassessment process, even though the PMCR did not describe this involvement.

- *Comprehensive evaluation of different remedial options.* Noting that the models described in the PMCR can only predict the effects of remedial options on concentrations of PCBs in the Hudson River and in fish, one reviewer recommended that EPA should also focus its resources on conducting a "life-cycle type of assessment" in order to evaluate the overall environmental burden of the different remedial options. This reviewer acknowledged that EPA already uses several criteria to evaluate the feasibility of different remedial options. (Another reviewer clarified that a "life-cycle type of assessment" considers several technical, economic, and political criteria for making decisions.)

6.2 Peer Reviewers' Major Recommendations

The peer reviewers briefly discussed selected responses to Questions A through E before identifying their major recommendations for the modeling effort. During this discussion, the reviewers agreed that they no longer considered moving the boundary of the modeling domain to a location upstream of Hudson Falls as an important issue, and they identified selected key findings, such as ensuring that the individual models will be linked, incorporating the modeling approach into the risk assessment paradigm, and considering bioavailability in greater detail.

To prepare a final list of their overall recommendations to EPA, the peer reviewers decided to have each peer reviewer list his or her major recommendations and then to characterize the extent to which the peer reviewers agreed or disagreed with each individual's recommendations. The comprehensive list of the reviewers' major findings and recommendations is provided below, as well as in the Executive Summary. Unless noted otherwise, all of the peer reviewers agreed with these major recommendations.

- The reviewers recommended that EPA make the following improvements in the description of sediment resuspension and deposition processes in the fate and transport models: address the fate of resuspended material; address the role of uncovered, potentially contaminated surfaces; address the issue of non-cohesive sediment resuspension; assure consistency in resuspension rates between the "depth of scour" and HUDTOX models; and identify the effect of flood resuspension on the rate of long-term recovery of the Hudson River. Some reviewers indicated that these changes could be made within the existing modeling framework (i.e., with different fate and transport models that are linked), while other reviewers thought these changes should be made by incorporating sediment transport mechanisms directly into the HUDTOX model, instead of keeping the models separate. A reviewer added that EPA should analyze error propagation in the linked models and place a greater emphasis on "source attribution of PCBs to fish."

- The reviewers recommended that EPA employ time- and space-dependent mechanistic models that reflect the abiotic and biotic dynamics of the Hudson River system.
- The reviewers indicated that the models should be based on a consideration of bioavailability and sediment sequestration with respect to congener sorption/desorption kinetics, sediment particle characteristics, and biotic characteristics.
- The reviewers recommended that EPA link, to the greatest extent possible, the spatial and temporal scales of the different fate and transport and bioaccumulation models.
- The reviewers recommended that EPA clearly identify in its modeling approach the risk assessment targets as related to forms and concentrations of PCBs (e.g., to what guidelines or advisories will the modeled concentrations be compared). More specifically, the reviewers thought risk assessors and managers should be involved with the development of the transport and fate and bioaccumulation models, such that the model outputs will generate the data needed for completing human health and ecological risk assessments.
- The reviewers recommended that EPA develop a mechanistic food web model based on exposure dynamics of the identified forms of PCBs relevant to risk quantification, and that EPA identify appropriate data needs for the fate and transport models.
- The reviewers recommended that EPA develop an explicit plan for model calibration and independent validation that includes criteria for validation, makes use of numerous data sets that span a long time period, and includes chemicals in addition to PCBs.
- Noting that analytical methods have improved and will continue to improve, the reviewers recommended that EPA develop, and agree on how to use, a method for interpreting historical PCB monitoring data.
- Noting that EPA has already addressed or considered many of the recommendations listed above, the reviewers suggested that EPA hold an open workshop (involving all interested parties as well as independent reviewers) to evaluate current modeling efforts.

6.3 Peer Reviewers' Final Statements

The peer review meeting concluded with each peer reviewer providing closing statements on the proposed modeling approach, including an "overall recommendation" in response to the final question in the charge: "Based on your reading and analysis of the information provided, please identify and submit an explanation of your overall recommendation for the modeling effort for the Hudson River PCB Reassessment RI/FS:

1. Acceptable as is
2. Acceptable with minor revision (as indicated)
3. Acceptable with major revision (as outlined)
4. Not acceptable (under any circumstance)"

During their final statements, several peer reviewers commended EPA on its ongoing efforts to model PCBs in the Hudson River, and some reviewers applauded EPA for using peer review to test the scientific rigor of the site reassessment process. Every reviewer found the overall modeling approach, as described in the PMCR, to be "acceptable with major revision"; however, one reviewer found the HUDTOX and "depth of scour" models to be "acceptable with minor revision." Noting that this classification is based primarily on the information documented in the PMCR, several reviewers acknowledged that EPA may have already addressed several of the major recommendations in the past 2 years.

7.0 REFERENCES

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Limno-Tech et al., 1996. Preliminary Model Calibration Report. Prepared by Limno-Tech, Inc., Menzie Cura & Associates, Inc., and The CADMUS Group, Inc. Prepared for U.S. Environmental Protection Agency Region II.

Limno-Tech et al., 1998. Preliminary Model Calibration Report, Revised Appendix B. Prepared by Limno-Tech, Inc., Menzie Cura & Associates, Inc., and The CADMUS Group, Inc. Prepared for TAMS Consultants, Inc.

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APPENDIX A

LIST OF EXPERT PEER REVIEWERS

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EPA United States
Environmental Protection Agency
Region 2

Hudson River PCBs Site Modeling Approach Peer Review

Sheraton Saratoga Springs Hotel and Conference Center
Saratoga Springs, NY
September 9-10, 1998

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APPENDIX B

CHARGE TO EXPERT PEER REVIEWERS

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United States
Environmental Protection Agency
Region 2

Hudson River PCBs Site Modeling Approach Peer Review

Sheraton Saratoga Springs Hotel and Conference Center
Saratoga Springs, NY
September 9-10, 1998

REVISED CHARGE TO REVIEWERS

Members of this peer review will be tasked to determine whether the models being used to support the decision-making process for the Reassessment, and the assumptions therein, are appropriate. The peer reviewers will base their assessment on the review the Preliminary Model Calibration Report (PMCR), an updated Technical Scope of Work for the Baseline Modeling Report (Appendix B of the PMCR) and the responses to selected comments received from stakeholders during the public comment period on the PMCR.

In October 1996, EPA released the Preliminary Model Calibration Report (PMCR), which described the models, datasets and assumptions being used as part of the Hudson River PCB Reassessment RI/FS. The PMCR represents the status of the preliminary PCB modeling effort as of Fall 1995. Datasets, database corrections and other pertinent information which became available after October 1995 were not incorporated within the fate and transport modeling presented in the PMCR. The PMCR was an interim document prepared to describe work in progress and was not intended to be a conclusive report. In particular the HUDTOX model presented in the PMCR was not intended to be used as a predictive tool to assess remedial action scenarios. In addition, while time-varying mechanistic models of bioaccumulation will be used along with other models to predict fish body burdens, these models are not described in the PMCR.

The PMCR was not formally peer reviewed at the time of publication, but was distributed to interested parties who were invited to submit comments and questions. Written responses were made to all of these comments and questions. In addition, the work plan contained in Appendix B of the PMCR has been revised to reflect the ongoing work being conducted as part of the Baseline Modeling effort. Results from this effort will be presented in a Baseline Modeling Report that will be formally peer reviewed.

The peer reviewers are requested to determine whether the models being used to support the decision-making process for the Reassessment RI/FS, and the assumptions therein, are appropriate. The peer reviewers are not being asked whether they would conduct the work ı the same manner, only whether the work being conducted will yield scientifically credible conclusions.

It is suggested that the reviewer first read the PMCR. The Responses to Comments provides information on the context of the PMCR within the overall modeling effort and additional details beyond the PMCR results. The current work plan as revised in June 1998 reflects the ongoing Baseline Modeling effort and revisions to some of the original modeling tasks proposed in Appendix B of the PMCR. In addition, the USEPA/TAMS Phase 2 database has been considerably revised. New datasets have been added and some earlier datasets have been extensively revised.

The peer reviewers are asked to comment on the following:

A. Is EPA using appropriate models, datasets and assumptions on which to base a scientifically credible decision?

B. Will the models, with the associated datasets and assumptions, be able to answer the following principal study questions as stated in the PMCR:

1. When will PCB levels in the fish population recover to levels meeting human health and ecological risk criteria under No Action?

2. Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels?

3. Are there contaminated sediments now buried and effectively sequestered from the food chain which are likely to become "reactivated" following a major flood, resulting in an increase in contamination of the fish population?

C. Specific questions:

1. Are the modeling approaches suitable for developing quantitative relationships between external forcing functions (e.g., hydraulic flows, solids and PCB loads, sediment initial conditions, etc.) and PCB concentrations in the water column, sediments and fish? Are the models adequate for discriminating between water-related and sediment-related sources of PCBs?

2. Are the spatial and temporal scales of the modeling approaches adequate to answer the principal study questions? If not, what levels of spatial and temporal resolution are required to answer these questions? What supporting data are required for calibration/ validation of these spatial and temporal scales?

3. It is contemplated that PCB concentrations in fish will be estimated using several modeling approaches: an empirical probabilistic model derived from Hudson River data, a steady state model that takes into account mechanisms of bioaccumulation body burdens, and a time-varying mechanistic model (not included in the PMCR). A bi-variate statistical model may also be used to provide insight into accumulations. This multi-model approach is being contemplated because of the uncertainties associated with any individual model. Is this a reasonable approach or should predictions be made using a single "best" model?

4. Is the level of process resolution[1] in the models adequate to answer the principal study questions? If not, what processes and what levels of resolution are required to answer these questions? What supporting data (such as data to support specifications of a mixed depth layer, solids and scour dynamics, groundwater inflow, etc.) are required for these processes and levels of resolution?

5. The results of the modeling effort will be used, in part, to support human and ecological risk assessments. In your judgment, will the models provide estimates adequate for this purpose?

D. Are there any changes to the work effort outlined in the revised work plan that would significantly improve the outcome?

E. In terms of evaluating the overall and specific effects and behavior of PCBs in the Hudson River, are there any serious flaws in the modeling approach (theory, structure, physical parameters, etc.) that would limit or invalidate any conclusions or further work based upon the results of these models?

Recommendations

Based on your reading and analysis of the information provided, please identify and submit an explanation of your overall recommendation for the modeling effort for the Hudson River PCB Reassessment RI/FS:

1. Acceptable as is
2. Acceptable with minor revision (as indicated)
3. Acceptable with major revision (as outlined)
4. Not acceptable (under any circumstance)

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1. The "level of process resolution" refers to the theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport such as: settling, resuspension, volatilization, biological activity, partitioning, etc. An example of low process resolution is use of a constant value for the solids resuspension rate. A higher level of process resolution is use of a complex mathematical description of the physics involved in remobilizing bedded sediment particles (such as cohesive forces, bed shear stresses, etc.)