FINAL COMMENTS ON HOUSATONIC RIVER MODEL VALIDATION REPORT
By Marcelo H. Garcia, PhD

According to the charge for the Model Validation Report Peer Review, the goal of the modeling study is to develop a tool that will:

- **Predict future concentrations in various media (e.g., sediment, fish, and water);**
- **Assess relative performance among remedial alternatives against baseline conditions; and,**
- **Be the best estimate available of the potential magnitude of the expected reductions in exposure and, thereby, provide useful information in evaluating the performance of remedial alternatives.**

<u>Question 1</u>:

Considering the changes implemented in the Phase 2 Calibration, does the model as calibrated and validated, based on your technical judgment, reasonably account for the relevant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River to a degree consistent with achieving the goal of the modeling study?

<u>Response</u>:

While a substantial effort has gone into improving the capabilities of the Housatonic River Model since its calibration, it is clear that there is still a long way to go before the model can truly be used as a "predictive tool" to quantify future spatial and temporal distributions of PCBs (both dissolved and particulate forms) within the water column and the bed sediment.

This reviewer is of the opinion that the Housatonic River Model will need to be continuously improved until all the processes (biological and physical bed sediment mixing, streambank erosion, floodplain deposition, etc.) relevant to the transport and fate of PCBs are not only accounted for in the model but are also well represented and based on sound knowledge of sediment transport mechanics, stream biology, ecology and morphodynamics.

It is not enough to state that a given process is accounted for when the representation of the process is deficient and its implementation in the model is done with algorithms and assumptions that are not based on the physics of the process and cannot be

supported by field observations. For instance, streambank erosion has been recognized as a very important process since large amounts of PCB-laden sediments can enter the river during medium to high flows. However, fluvial erosion and mass failure of the stream banks are currently modeled simply as functions of flow discharge, a rather crude approximation, which severely limits the capabilities of the model to assess the effect of this process.

How can one determine what regions of the banks are more prone to erosion and, therefore, need protection if the model does not compute the distribution of flow velocity and bed shear stress along the banks? Could native vegetation or other bioengineering techniques be used to protect the banks of the Housatonic River against erosion or more hard-core solutions such as rip-rap are needed? Is it possible to use a combination of both? As it stands now, the model can not be used to compare the merits of such remedial alternatives, which is one of the goals of the modeling study as stated above.

Arguably the main shortcoming of the model is not the Housatonic River model itself but rather its numerical implementation which, in my opinion, has rendered the model calibration and validation unreasonably difficult. Assuming that all the processes are eventually accounted for in the model and the right algorithms are used to simulate them, the most vexing issue will continue to be the characteristics of the computational grid used to simulate the river hydrodynamics, sediment transport and associated PCB transport and fate. The computational mesh (Figure 3-6) is "hard-wired" to water stages in the floodplain associated with a flood having a recurrence time of 10 years. This results in the main river channel being modeled with the same spatial resolution (i.e. a single computational cell) regardless of the flow discharge, not just the 10 year flood.

With the current computational mesh configuration, the application of the model is computationally taxing, resulting in extremely long execution times. This has made the calibration and validation of the model a very difficult exercise and will most likely affect the analysis of remediation alternatives in the future. At the same time, the use of a course grid hinders the ability of the model to resolve the flow velocity distribution inside the main channel as well as the associated boundary shear stresses throughout its wetted perimeter. Given that erosion and sediment transport vary non-linearly with increments in flow velocity and shear stress, it is rather imperative to find a way to increase the

spatial resolution of the model so that at least three "streamtubes" are used to model flow and sediment transport in the main channel of the Housatonic River. This will in turn facilitate and make more meaningful the computation of streambank erosion as well bed sediment erosion and resuspension.

While the model capabilities have been improved since its calibration, my professional opinion is that the validation of the model is not complete at this stage. In particular the model does not capture the variability and spectrum of PCBs concentrations observed in river. There are several aspects of the model that need to be improved as stated above before validation of the model can be accomplished.

Due to the nature of the problem and the scale of the river system under consideration, it is unlikely that a full validation of the model will be possible in the near future. From a practical point of view, however, the main question in my mind would be: is the model good enough to capture most of the process responsible for the transport and fate of PCBs so that it can be used to assess the merits and drawbacks of different remediation strategies in the Housatonic River?

Right now my answer would be no but the effort by EPA and its consultants has provided a good foundation towards the goal of having a useful tool that can be used to help the Housatonic and other rivers experiencing similar problems.

<u>Question 2</u>:
Are the comparisons of the model predictions with data sufficient to evaluate the capability of the model on the spatial and temporal scales of the final calibration and validation?

<u>Response</u>:

Of particular relevance for this reviewer is the validation of flood plain deposition throughout the river system as well as sediment erosion and deposition in Woods Pond, since the record shows that this pond is a major deposit for PCB-contaminated sediments.

Regarding the sedimentation of Woods Pond, the calibration/validation exercise has produced results showing rates of (*net*) sedimentation for

the period going from 1979 to 2004 (Figure 6.2-34). The results seem reasonable with predicted sedimentation rates (mm/year) that are within an order of magnitude of sedimentation rates determined from Cesium data. The model also reproduces fairly well the distribution of PCBs with depth as observed from sediment cores. However, as stated below, the model shows some bias when predicting temporal variations of surface PCB concentrations in Woods Pond.

Woods Pond is perhaps one of the few locations in the Housatonic River where the capabilities of the model to predict the spatial and temporal distribution of sediment and PCB can be extensively tested due to the large amount of observations available. This has been done to some extent but more effort should go into this since the pond could become a major source of PCBs to the downstream portion of the river during a major flood event.

Regarding floodplain sedimentation, the model has been used to predict process-based (advection, erosion, deposition, volatilization, etc) sediment and PCB fluxes (Kg/year) for the main channel and the floodplain, over the validation period (Figures 6.2-62 and 6.2-63). The analysis results in an estimate of yearly fluxes. However, it is well known that sediment erosion and transport is most prominent during flood events, which can have duration of a few hours to several days. Thus it would seem that the model should be validated for time scales that are relevant to the processes involved.

Since a large percentage of the river system consists of floodplain, it is important to ensure that the model can indeed capture the process of floodplain sediment/PCB deposition. To this end, a simple one-dimensional approach was suggested that could be used to estimate a "Floodplain Dimensionless Number" for different reaches of the Housatonic River (Garcia, 2006-technical note on floodplain sedimentation). Once such number is calibrated for each reach, it will be possible to test if indeed the model can predict floodplain depositional rates that result in similar Floodplain numbers for different flooding conditions (hydrologic event scale), thus helping in the overall validation of the model. This approach will clearly show the capabilities of the model. If there is any hope of predicting PCBs fate in the floodplain, sedimentation has to be properly simulated by the model.

As mentioned in the response to question one, the size of the computational grid makes it difficult (and meaningless) to compare model predictions for processes that take place at hydraulic and sedimentation scales determined by the flow rate and the main channel width. This is not the case for Woods Pond and the floodplains were the size of the computational grid is appropriate for the scale of the flow field.

Question 3*:*
Is there evidence of bias in the models, as indicated by the distribution of residuals of model/data comparisons?

Response*:*

As shown in MVR Figure 6.2-50, the model predictions of variation with of surface PCBs concentrations are not consistent with the field observations in Woods Pond. The model seems to underpredict the observed values in the time period from 1979-1984 and to overpredict the observations in the time period from 1995 to 2000.

There is evidence that model predictions do not match well with observed surface sediment concentrations of PCBs in reaches 5A, 5B, and 5C as displayed in Figure 6.2-49.

Model predictions in Figures 6.2-45 and 6.2-46, show that during low flow conditions the model does not capture observed longitudinal gradients in the water column. This results in the model underpredicting PCB fluxes from the sediments along Reach 5A, which in turn could lead to an under estimate of the bed sediments PCB contributions to fish in the Food Chain Model.

Question 4:
Have the sensitivities of the models to the parameterization of the significant state and process variables been adequately characterized?

Response:
Given the facts that several processes are yet to be fully characterized in the model and that a coarse computational grid has been used for the model calibration, I do not think that a full sensitivity analysis can be conducted at this time.

In the case of low flow conditions, the model predictions seem to be very sensitive to diffusion parameters, suggesting the representation of pore water diffusion as well as the thickness of the so-called "mixed layer' need to be carefully analyzed.

Question 5:
Are the uncertainties in model output(s) acknowledged and described?

Response:
While uncertainty in model inputs and outputs was recognized, the nature of the model does not allow for a conventional uncertainty analysis. Once all the processes are accounted for and well represented in the model and assuming that the EFDC code can be run more efficiently, it might be feasible to conduct an uncertainty analysis.

Question 6:
Upon review of the model projections of changes in PCB concentrations in environmental media in the example scenarios, are such projections reasonable, using your technical judgment, and are they plausible given the patterns observed in the data?

Response:
Model projections seem reasonable but I would have liked to see more potential scenarios, particularly for extreme conditions such as low flow summer-like conditions and floods.

Question 7:
Is the final model framework, as calibrated and validated, adequate to achieve the goal of the modeling study to simulate future conditions 1) in the absence of remediation and 2) for use in evaluating the effectiveness of remedial alternatives?

Response:
I do not think that the model is ready to accomplish the goals of the modeling study. If the model is to be used to simulate future conditions, first is has to adequately simulate the existing conditions throughout the river and its floodplain.

<u>Overall, this is a very challenging undertaking but the study and modeling of the Housatonic River is a worthwhile effort that will hopefully benefit future generations.</u>