HOUSATONIC RIVER

General Electric Company's Comments on EPA's Model Validation Report

MVR Peer Review Meeting

June 28, 2006

GE is Required to Apply the Model under the Site CD

- **GE will apply the EPA models to evaluate potential remedial alternatives during the Corrective Measures Study (CMS)**
  - Part of GE's work to perform the CMS for Rest of River

- **GE's comments on the Model Validation Report (MVR) presented herein focus on the topics that are most important to GE's use of the model to simulate potential remedial alternatives**

Overview of GE's Concerns

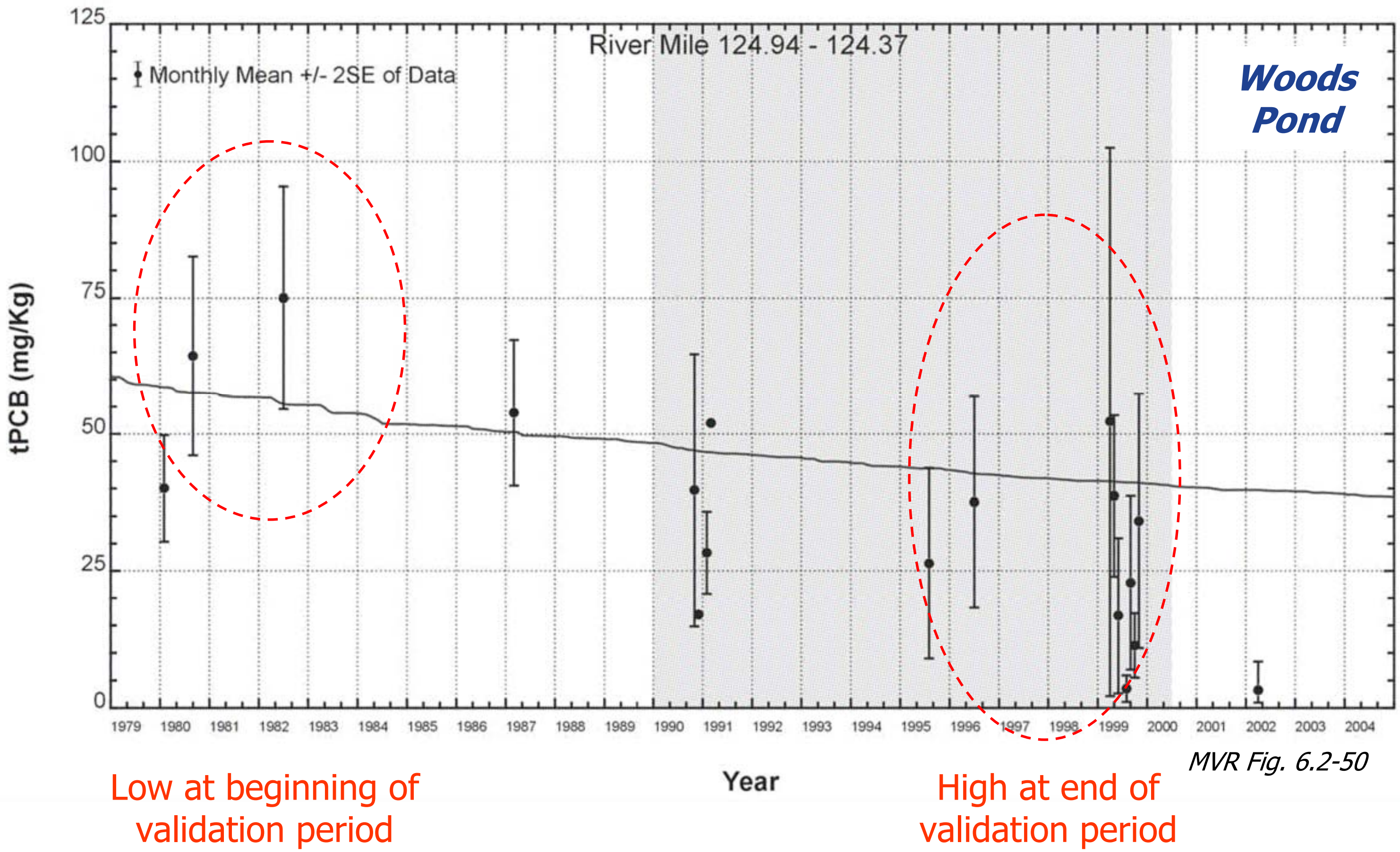
- **Model's temporal trends in surface sediment PCBs are inconsistent with existing data, which suggests the model will inaccurately predict future trends, including response to remediation (*Charge Questions 1, 2, 3, and 7*)**
  - Problems may be due to inaccurate characterization of some processes
    - PCB fate processes under low flow conditions
    - Vertical transport within the sediment
  - Likely has resulted in inaccurate representation of PCBs obtained by fish from the water column vs. sediment in the FCM, affecting future predictions

- **The model framework is unworkable in its current form (*Charge Question 7*)**
  - EFDC has excessive simulation time and potential instabilities
  - MVR's uncertainty analysis approach is not suitable for future projections

- **Portions of the model are incomplete or have not been fully tested (*Charge Questions 1, 2, and 7*)**
  - "Upstream" and "Downstream" models are incomplete

Model's Predictions of Temporal Trends in Surface Sediment PCBs are Inconsistent with the Data

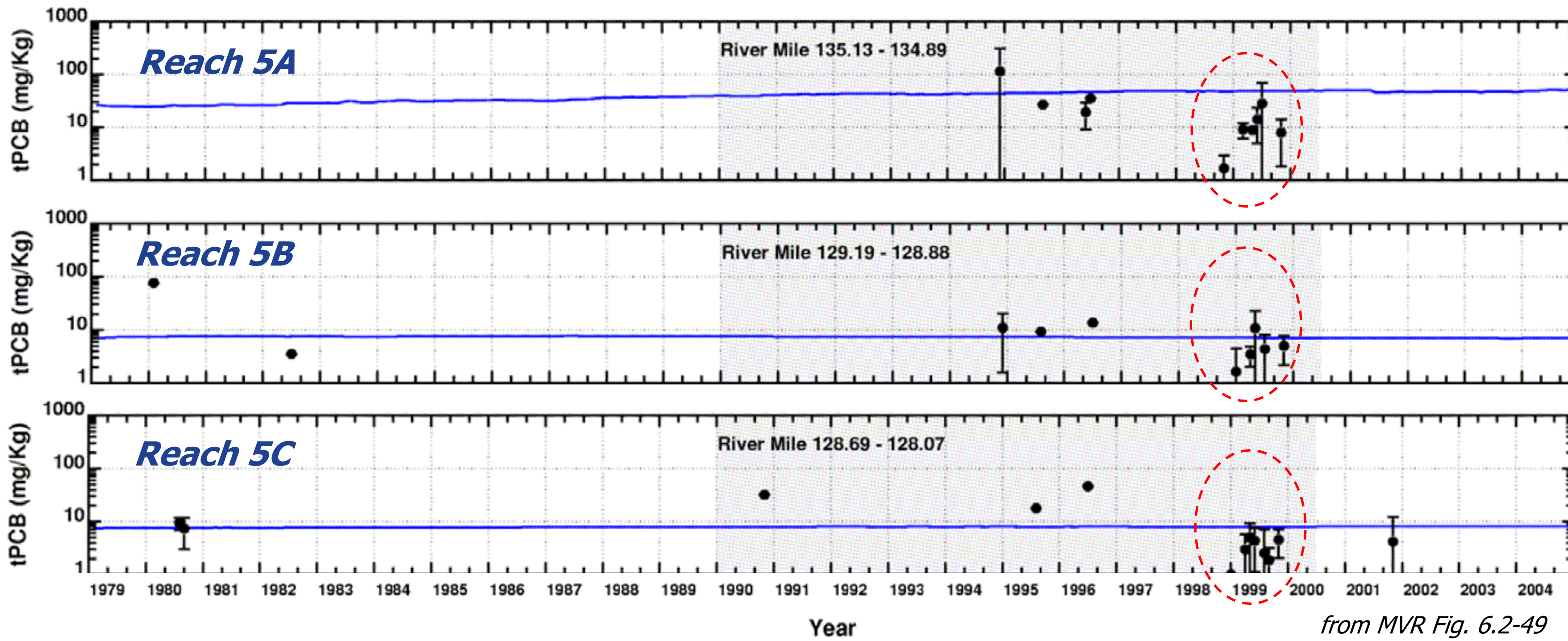
- **Model under-predicts data at the beginning and over-predicts data near end of the validation period in many "spatial bins", resulting in incorrect prediction of temporal trend**



Model's Predictions of Temporal Trends in Surface Sediment PCBs are Inconsistent with the Data

- **Other examples showing model results that do not match the data:**

High at end of validation period

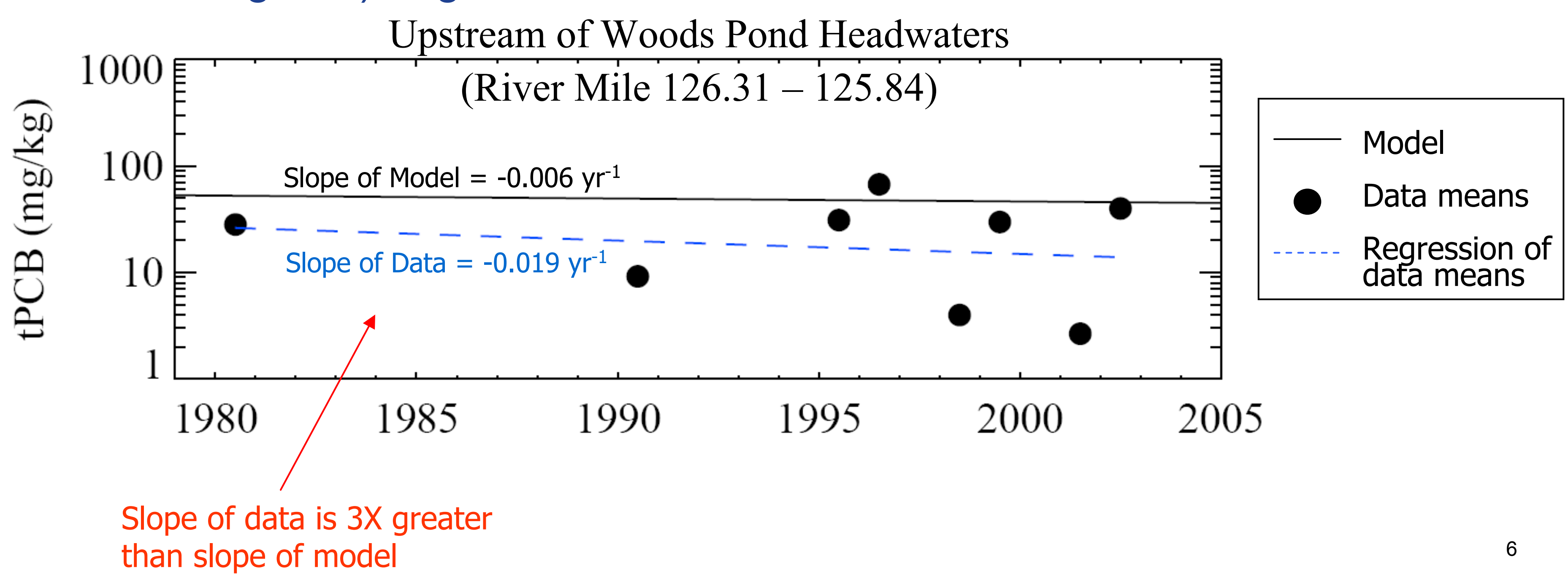


from MVR Fig. 6.2-49

Note: Filled circles and bars are monthly mean ±2 standard errors.

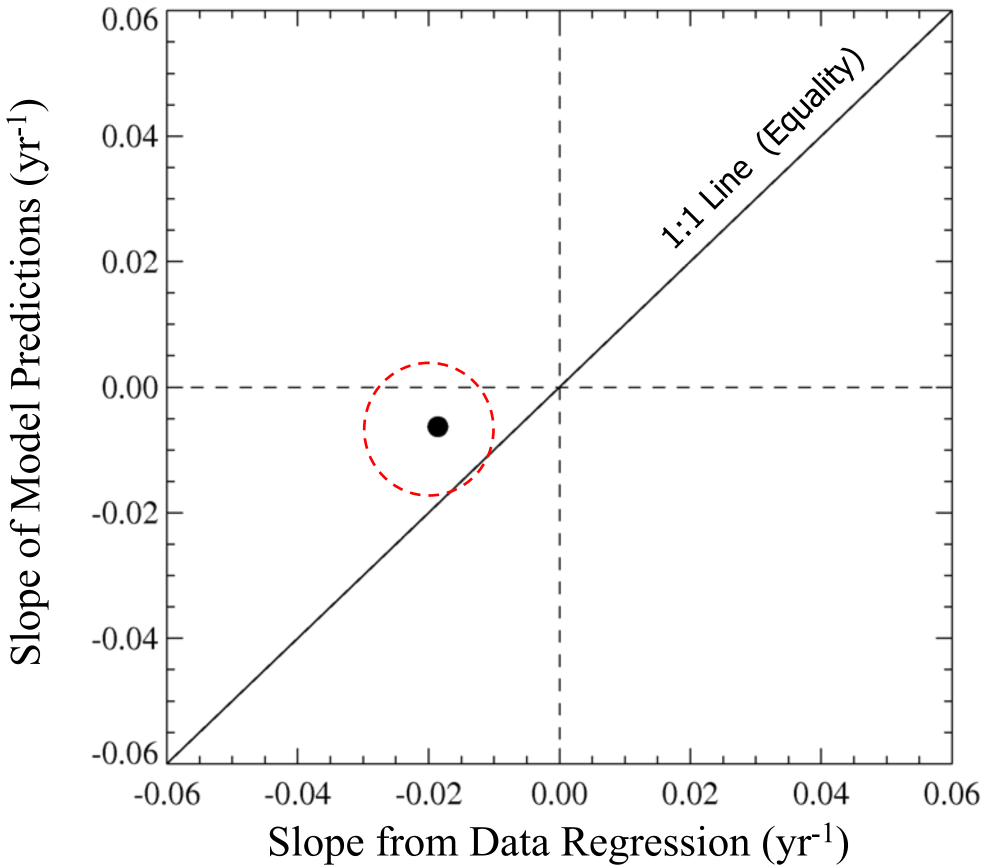
Model's Predictions of Temporal Trends in Surface Sediment PCBs are Inconsistent with the Data

- **To evaluate if the model captures the trend in the data, QEA conducted an analysis to compare slopes by spatial bin:**
  - For a given spatial bin, annual means of data were regressed (log-linear) and the computed slope was compared with the slope of model predictions (from the MVR Doc. Overview Mtg. figures), e.g.:



Model's Predictions of Temporal Trends in Surface Sediment PCBs are Inconsistent with the Data

Relationship between slope of model and slope of data for example spatial bin from previous slide (slope of data is 3X greater than slope of model)



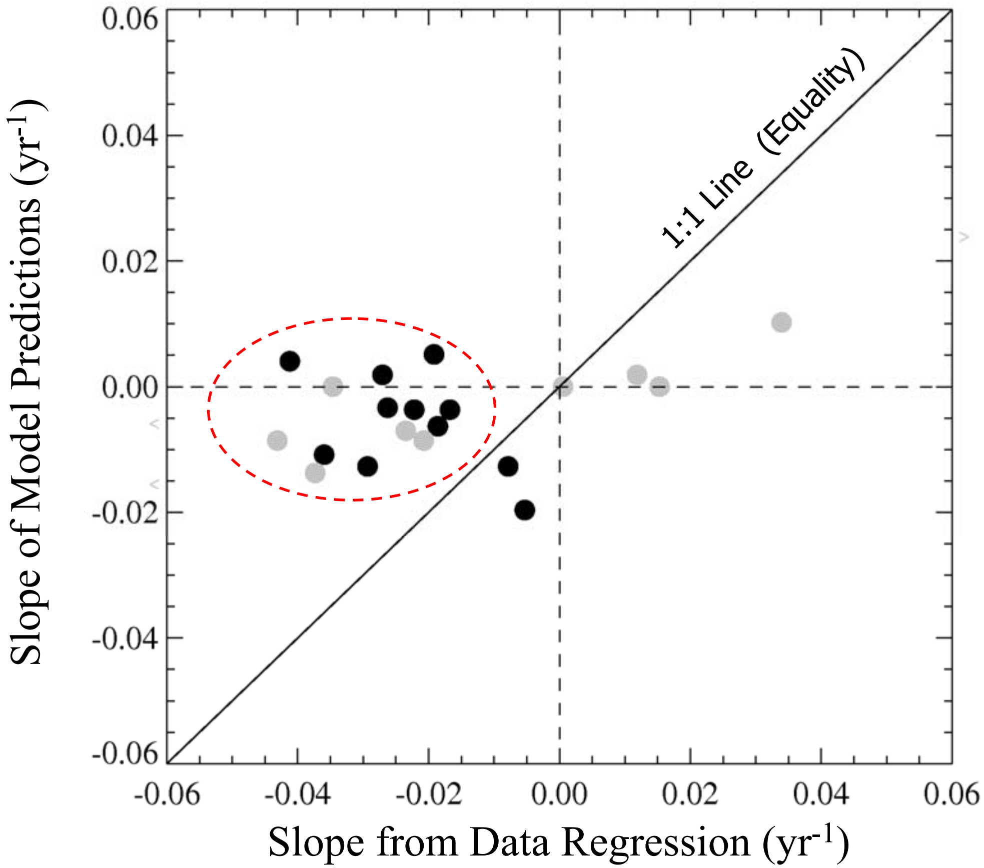
– This analysis was then repeated for all 23 of EPA's spatial bins over the validation period (1979-2005); results shown on next slide

Model's Predictions of Temporal Trends in Surface Sediment PCBs are Inconsistent with the Data

For a majority of the spatial bins:

- Slopes of the model generally near zero (i.e., no change over validation period)

- Slopes of the data means more variable, but generally negative (i.e., decrease over validation period)



Note: gray symbols represent slopes based on data means that could not be reproduced exactly

Model-predicted trends of surface sediment PCBs are inconsistent with the data during the validation period, which draws into question the model's ability to predict the system's long-term response to potential remedial actions.

Possible Reasons for Model Deficiency

- **The exact cause cannot be determined from the information presented in the MVR**
  - The model-data comparisons lack sufficient detail to evaluate long-term trends
    - Long term sediment trends were not evaluated as part of the sensitivity analyses
    - Plot scales make interpretation of trends difficult
    - No model results for deeper sediments are presented

- **Some issues that may account, at least in part, for this model deficiency have been identified:**
  - Low flow PCB fate processes are not properly represented
  - Bed model structure is inconsistent with biological mixing rate, particularly in more quiescent regions of the river

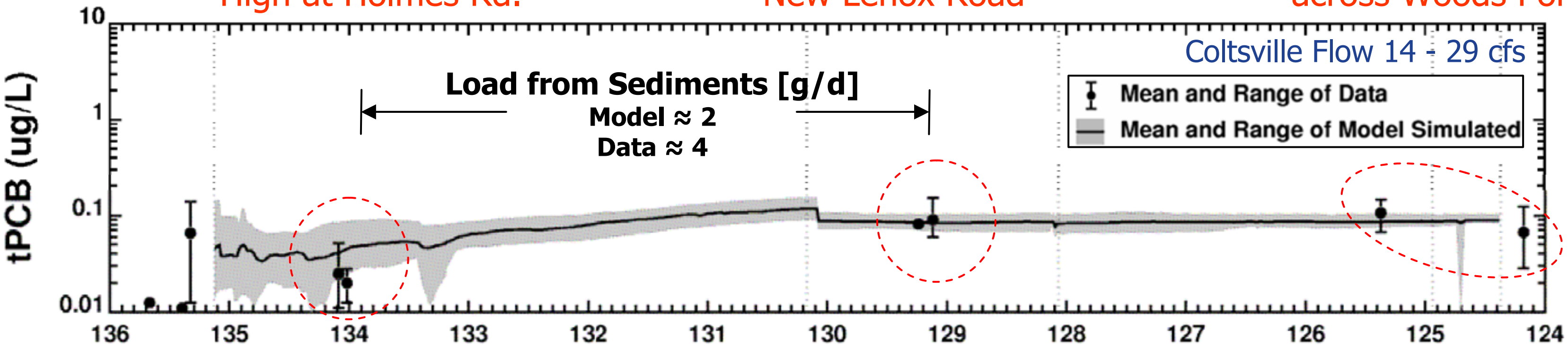
Low Flow PCB Fate Processes are not Properly Represented

- **EPA model does not capture longitudinal gradients in low flow water column PCBs**

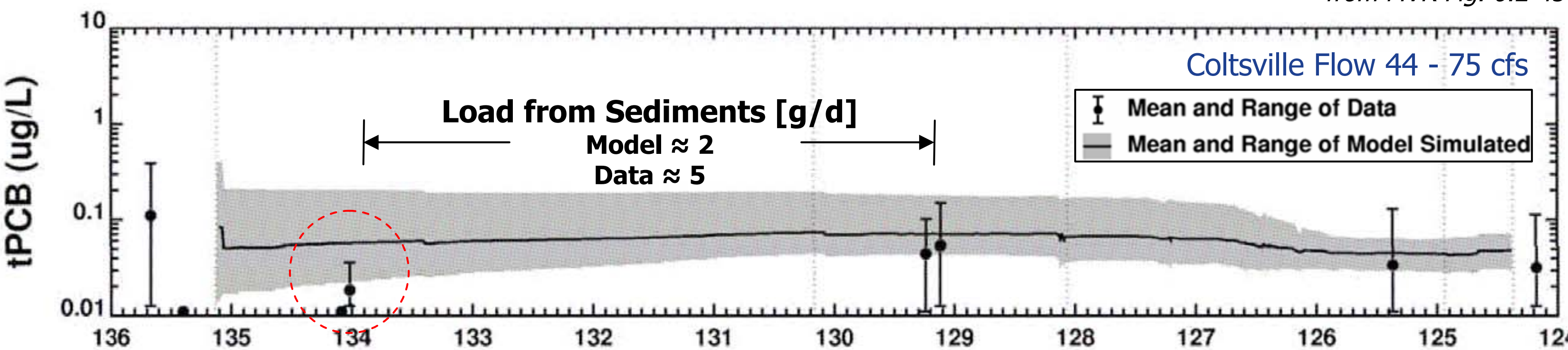
High at Holmes Rd.

Better agreement at New Lenox Road

Does not match decrease across Woods Pond



from MVR Fig. 6.2-45

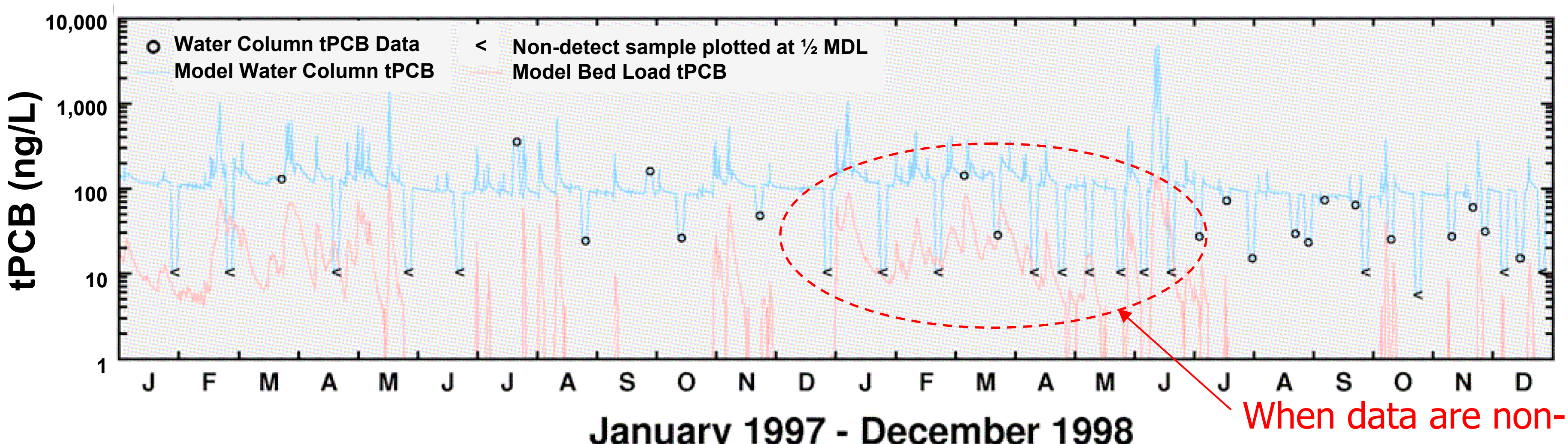


from MVR Fig. 6.2-46

  - PCB flux from sediments between Holmes and New Lenox Rd. is under-predicted by a factor of 2-3

Low Flow PCB Fate Processes are not Properly Represented

- **One possible reason:**
  - East Branch PCB and TSS boundary conditions tend to overestimate non-storm data, by a factor of 2 to 5



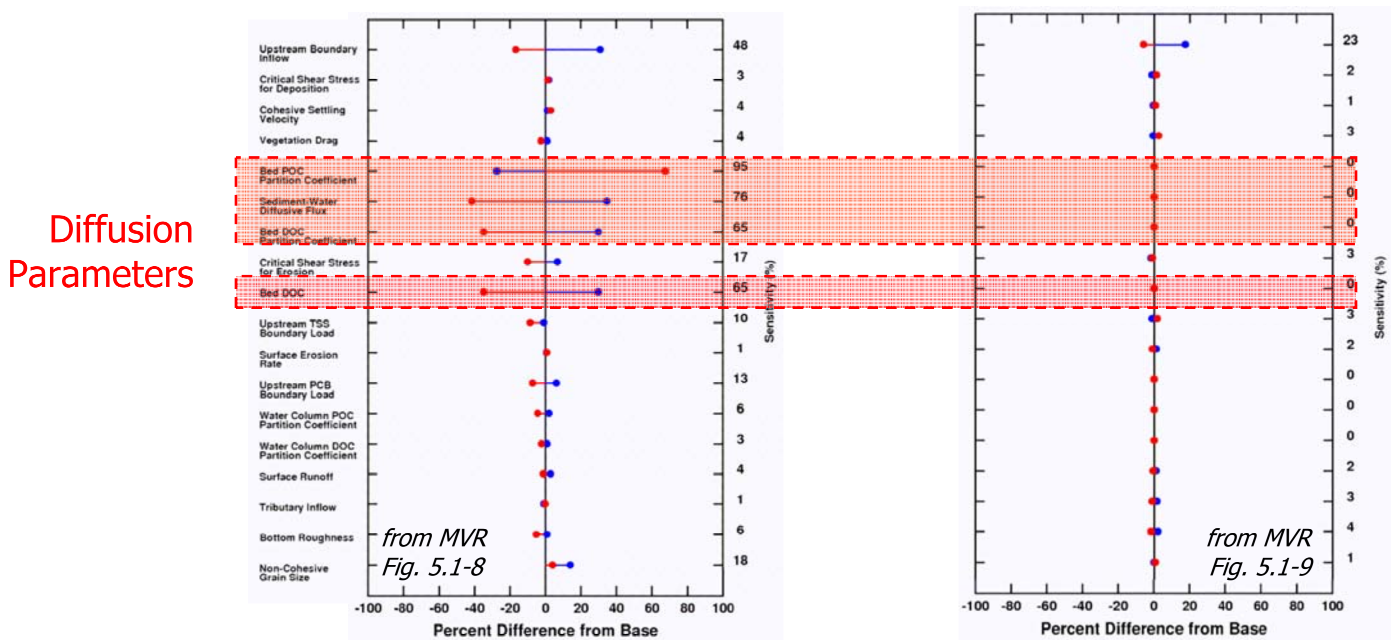
derived from MVR Fig. 6.2-39

Low flow water column PCB concentrations are consistently over-predicted in both the East Branch boundary condition and at Holmes Road. In order to match concentrations at downstream locations, the model must under-predict the PCB flux to the water column from the sediments in Reach 5A

Low Flow PCB Fate Processes are not Properly Represented

- **Another possible reason relates to a problem with the model's representation of pore water diffusion**
  - Model shows substantial sensitivity to diffusion parameters during low flow at New Lenox Road, but none at Woods Pond
  - This is illogical because the water column PCB flux passing New Lenox Rd. accounts for a significant portion of that at Woods Pond

Mean Water Column PCB Flux at New Lenox Road | **Mean Water Column PCB Flux at Woods Pond Footbridge**



Large sensitivity to diffusion parameters | No sensitivity to diffusion parameters

Low Flow PCB Fate Processes are not Properly Represented

- **Low flow PCB concentrations are important in evaluation of fish PCB exposures**
  - River is at low flow (less than mean) during a significant portion of the year (70%)
  - Fish PCB uptake is greater during times of higher metabolic activity (i.e., summer low flow periods)

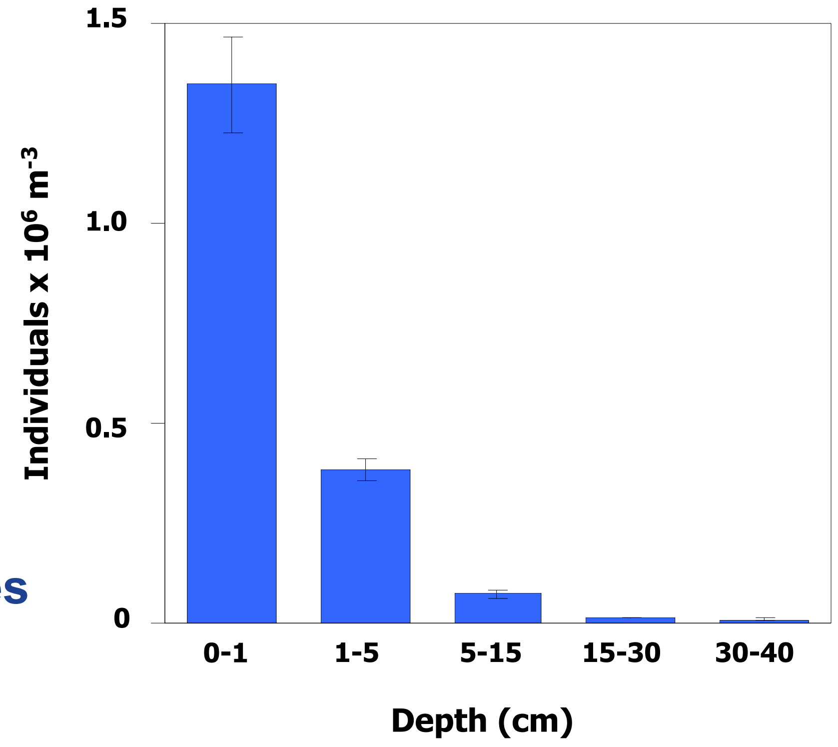
- **High bias in low flow water column PCBs in Reach 5A likely has led to an under-prediction of the sediment PCB contributions to fish in the Food Chain Model**

Bed Model Structure in Quiescent Areas is Inconsistent w/ Biological Mixing Rate

- **In quiescent areas of the system (e.g., Woods Pond), biological activity is likely the predominant mechanism for mixing sediments**

- **Literature indicates that population density of benthic organisms declines with depth in the sediments**
  - Most organisms (clams, snails and small oligochaetes) are in the top few centimeters

- **The natural history of the types of organisms found in the Housatonic suggests this system is consistent with the literature, as shown by the data plotted on the next slide**

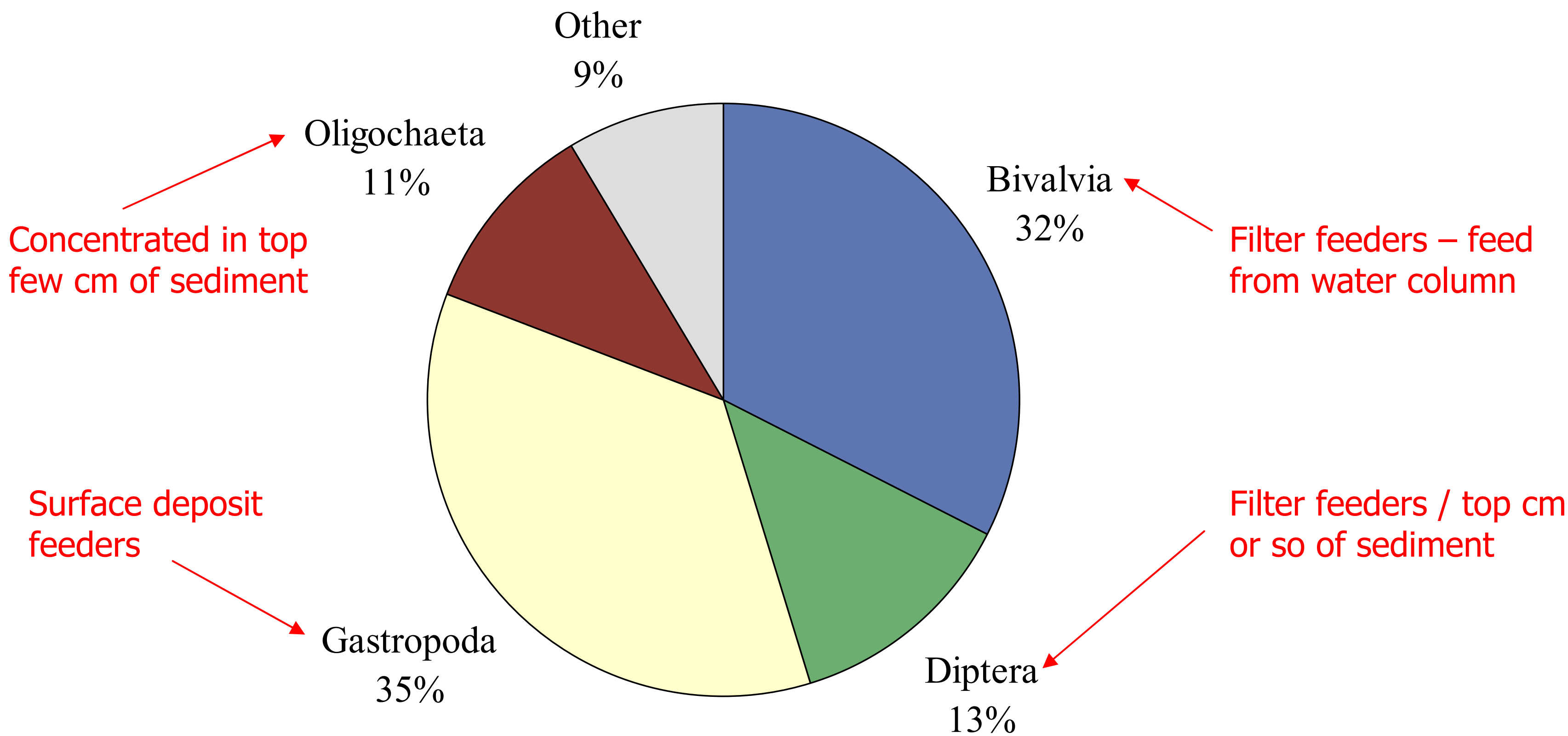


Graphic adapted from Strommer and Smock, 1989. Freshwater Biology (1989) 22, 263-274.

Annual mean density of invertebrates at various sediment depths in sandy substrate of a low-gradient headwater stream

Bed Model Structure in Quiescent Areas is Inconsistent w/ Biological Mixing Rate

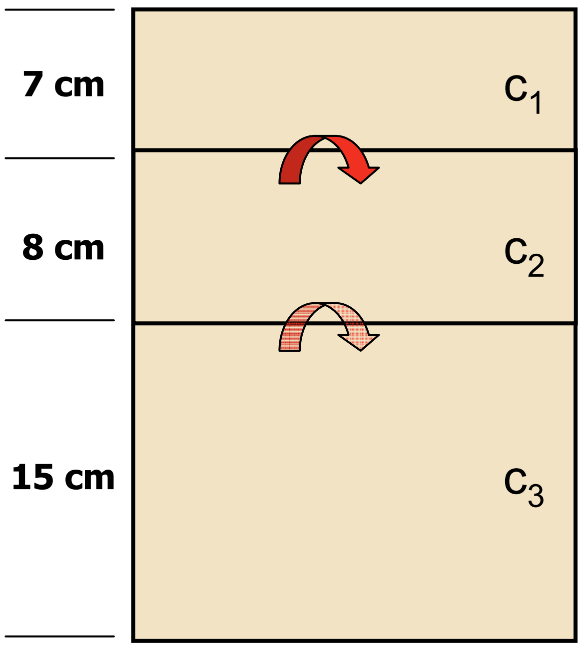
Benthic Invertebrate Data from Just Upstream of Woods Pond: Percent Abundance by Group



Based on natural history, the predominant benthic groups found in the Housatonic River feed at the surface or within the top few cm of sediments.

Bed Model Structure in Quiescent Areas is Inconsistent w/ Biological Mixing Rate

- **EPA's model simulates mixing based on a "subduction velocity"**
  - Value was estimated based on the types and abundance of organisms found in benthic invertebrate sampling of the river
- **EPA set mixing between 7-cm Layer 1 and 8-cm Layer 2 by assuming that all the organisms found in the sediment move material across this interface, at the subduction velocity**
  - Model assumes instantaneous mixing <u>within</u> a given layer
- **Mixing in the model can also occur between Layers 2 and 3, depending on the thickness of Layer 1, which varies due to deposition and erosion**
- **Model's assumption of mixing over 15 cm is inconsistent with the literature and natural history information that say organisms are concentrated in top few cm**



Mass Transport = Subduction Velocity x Area x $(c_2 - c_1)$

Bed Model Structure in Quiescent Areas is Inconsistent w/ Biological Mixing Rate

- **EPA model's bed layering and depth at which subduction velocities are applied result in an overestimate of vertical mixing in sediments**
  - Model assumes that sediment processing by benthic invertebrates occurs at the depth of sediment layer interfaces in the model
  - In fact, many organisms included in EPA's calculation of subduction velocity inhabit shallower sediments, and thus do not move sediments across the model sediment layer interfaces
  - EPA's subduction velocity is too low to keep 7 cm completely mixed as the model assumes
- **Overestimation of vertical mixing results in an overestimate of the reservoir of "surface" sediments, which keeps the water and sediment from responding to changes in PCB inputs**
- **This will result in an incorrect prediction of temporal trends in fish PCB concentrations**

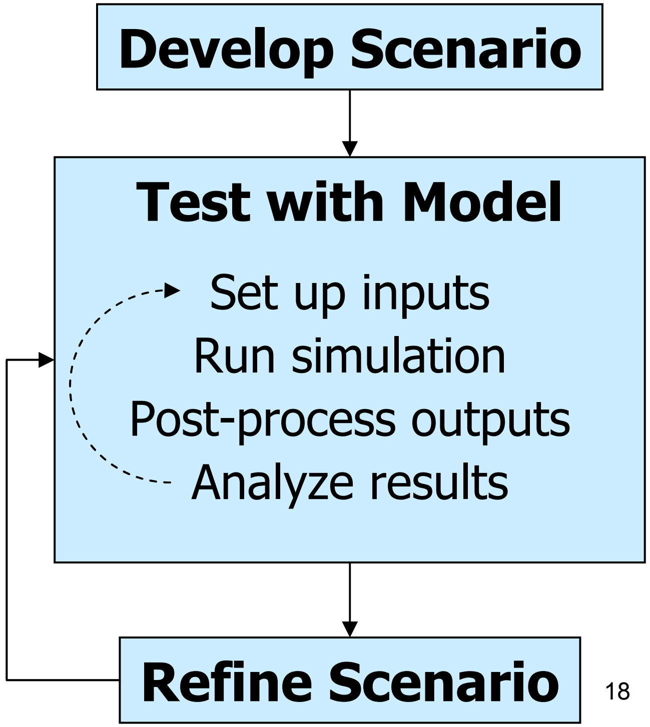
In quiescent areas of the system, where biological activity is likely the predominant mechanism for mixing sediments, vertical mixing is overestimated, which likely leads to incorrect prediction of temporal trends in sediments and fish

Unworkable for Long-Term Projections

- **Execution times are in the range of 10-20 hours per year of simulation**
  - Using multi-processor SGI Altix 350, Whitebox/AMD, and Intel/Xeon systems

- **40-70 year simulations to be used for the CMS will require ~ 25 to 50 days to complete one simulation**

- **Given the size and complexity of this site, the CMS will require a large number of simulations**
  - Potentially large # of scenarios to evaluate
  - Development of scenarios is an iterative process



Unworkable for Long-Term Projections

- **Thus, the time required to conduct the requisite number of simulations precludes an efficient evaluation of remedial alternatives**
  - Minor setbacks in a simulation, such as a mistake in an input file, can lead to a significant delay in the evaluation of remedial options

- **Potential approaches to improve execution time identified during the MCR Peer Review by the Panel and GE were dismissed by EPA:**
  - Separation of hydrodynamics, sediment transport, and PCB fate
  - Use of alternative grid approaches

- **Execution time for a long-term simulation needs to be on the order of a few days to efficiently evaluate potential remedial options with the model**

Unworkable for Long-Term Projections

- **Experience from Other Sites**
  - Hudson River Feasibility Study
    - EPA reported on 12 remedial action alternatives
    - 70-year forecasts took about 1 day of computer time per alternative
    - Entire study took about 1 year
  - Grasse River Analysis of Alternatives Study
    - Alcoa reported on 10 remedial action alternatives
    - 30-year forecasts took about 1.5 days of computer time per alternative
    - Entire study took about 1 year

The execution time for EFDC is unprecedented and may preclude meaningful evaluation of alternatives in a reasonable timeframe. EPA should make additional efforts to improve the model's computational performance.

There is Evidence of Potential Instabilities with the EFDC Model

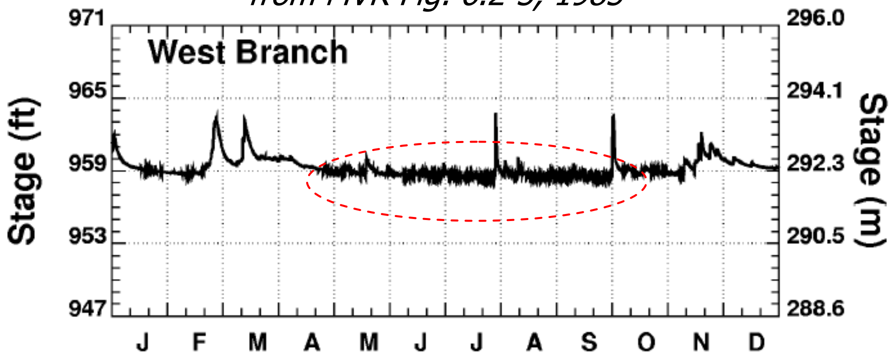
- **Erratic results from complex models such as these, in some cases, are symptoms of a larger problem with the model**

- **Two instances noted in the MVR raise concerns:**
  1. Of the 55 EFDC simulations conducted for the uncertainty analyses, 4 failed for "unknown reasons" (EPA noted during the Doc. Overview Mtg. that 2 of these were purposely stopped because they were going too slowly)
     - Did the model fail or run too slowly due to the choice of parameter sets, or did an instability occur?
     - What portion of EFDC was the cause, hydrodynamics, sediment transport, or PCB fate?
     - More evaluation is warranted

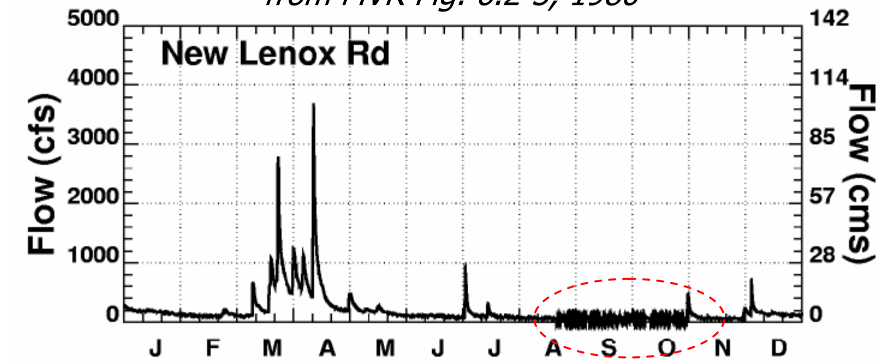
There is Evidence of Potential Instabilities with the EFDC Model

2. Oscillations and negative flow rates predicted by the hydrodynamic model at low flows

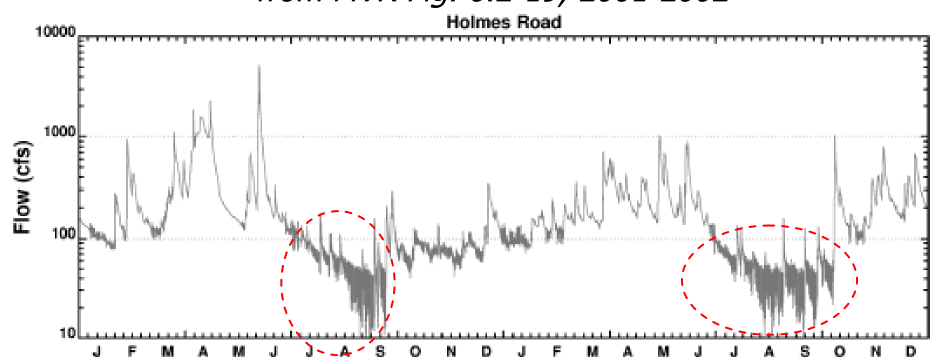
from MVR Fig. 6.2-3, 1985



from MVR Fig. 6.2-3, 1980



from MVR Fig. 6.2-19, 2001-2002



Negative flow rates

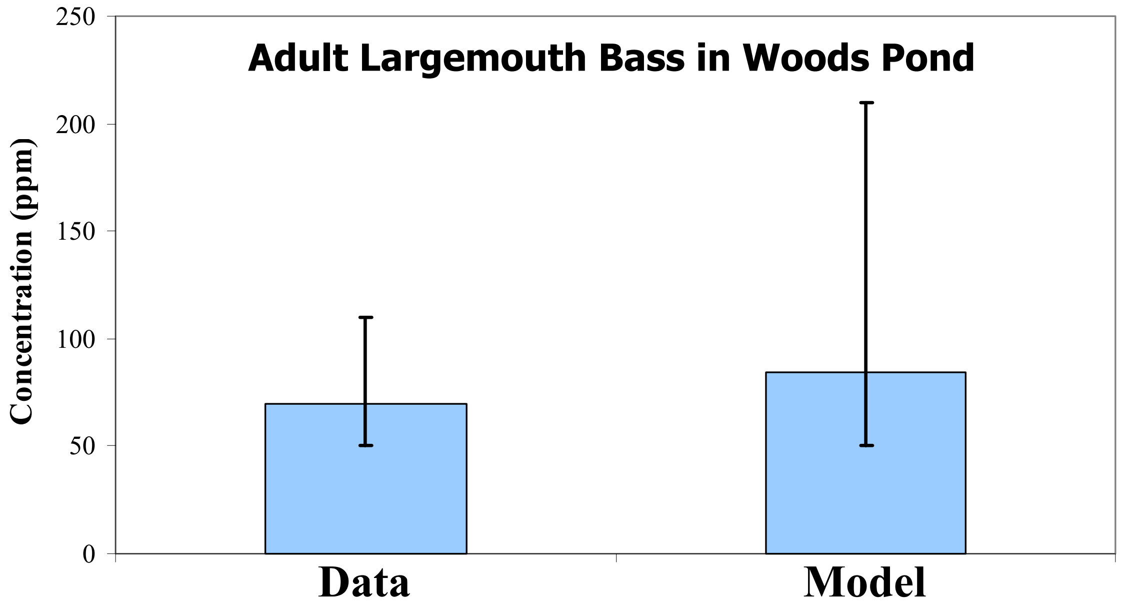
The potential numerical instabilities with EFDC need to be further evaluated, as they may be indicative of larger problems with the model

Approach is not Useable for the CMS

- **During the CMS, uncertainty will need to be addressed in some way when comparing simulations of potential remedial options**
- **EPA's approach is unworkable because it produces unrealistic uncertainty bounds, due to a fundamental flaw in its assumption that parameter uncertainty is known**
  - Distributions are assigned for model parameters (shape, central tendency, and variability)
    - Due to limited data, it is incorrect to assume that the distributions are well understood
    - Correlations among parameters are not fully considered
  - Models are then run based on these parameter sets, and it is contended that results provide a quantification of the model's uncertainty
    - Model runs were not required to match the calibration data

Approach is not Useable for the CMS

- **Unrealistically wide uncertainty bounds produced by the MVR method provide evidence that it is based upon unrealistic parameter distributions, e.g.:**



<u>(from MVR Fig. 4.3-5)</u>
Mean ≈ 70 ppm
2 S.E.M ≈ 45 ~ 85 ppm

<u>(from MVR Table 5.2-14)</u>
EDF = 84 ppm
Left/Right KS Bounds = 50 – 210 ppm

Approach is not Useable for the CMS

- **MVR approach is not useful due to the EFDC computational burden**
  - EFDC uncertainty analyses in the MVR were based on 50+ long-term simulations (KS analysis and Response Surface Model [RSM])
  - Although the RSM runs quickly, this approach would require developing new RSMs for several remedial scenarios during the CMS
    - Boundary conditions (PCBs at East Branch) and initial conditions (sediment PCBs) will be modified for future scenarios in different ways depending on the remedial alternative(s)
    - Each such modification will need a new RSM, thus requiring multiple RSMs
  - Given the excessive EFDC execution time and the # of

The MVR uncertainty approach is not useful for the CMS because it produces unrealistically large uncertainty bounds and the EFDC computational burden is too great.

"Upstream" and "Downstream" Models are Incomplete

- **Documentation of these models provided in the MVR is largely incomplete**
  - PCB fate and transport was not simulated in the upstream model
  - No model-data comparisons for the downstream EFDC model are presented in the MVR

- **Although additional model results and information were provided at the MVR Document Overview Meeting and in EPA's response to questions from this meeting, it is clear that both models are still a work-in-progress (i.e., calibration is incomplete)**
  - Models have not been compared to all available data sets
  - Models do not provide a good representation of the data
  - Documentation is incomplete

- **There is still insufficient information for a complete critique of these models**

“Upstream” and “Downstream” Models are Incomplete

- **Upstream Model results do not match the data:**

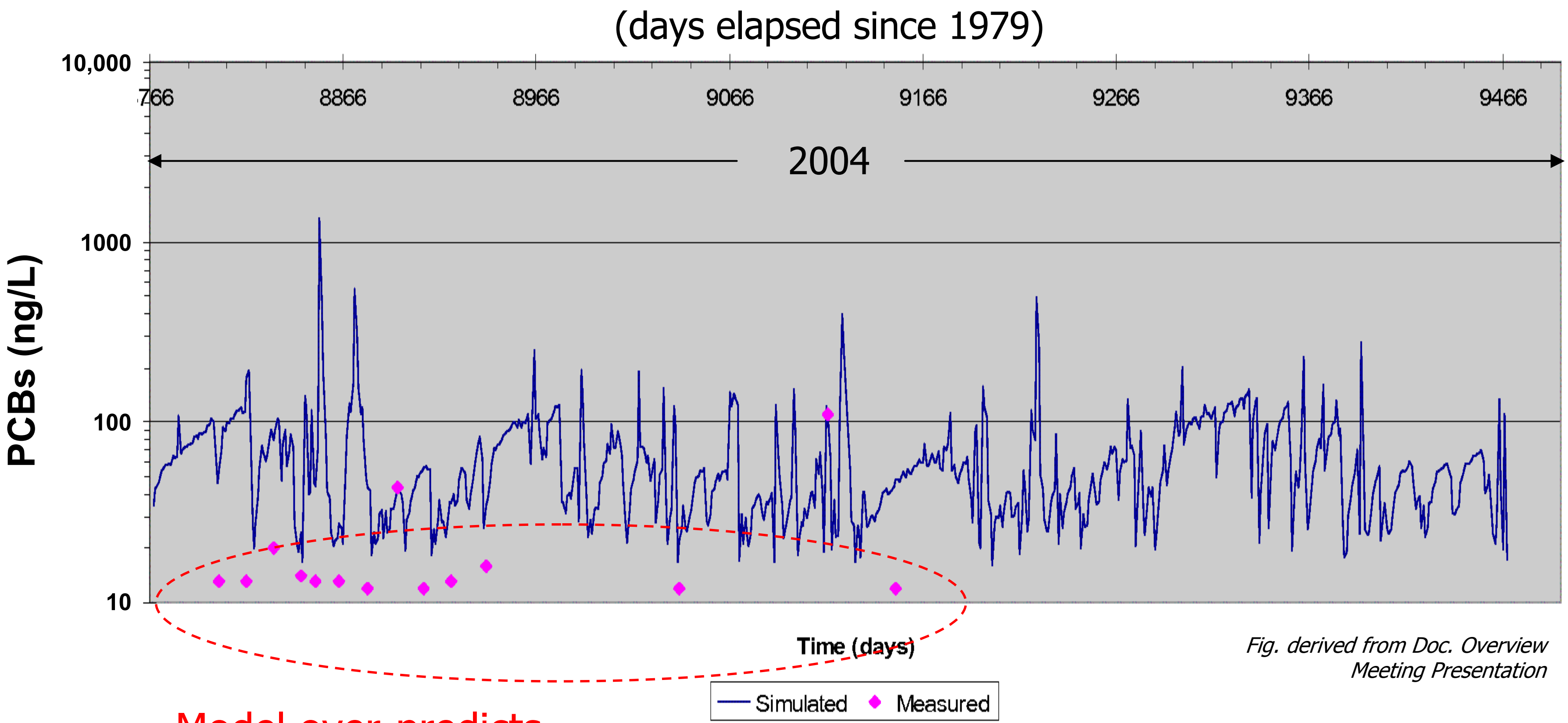
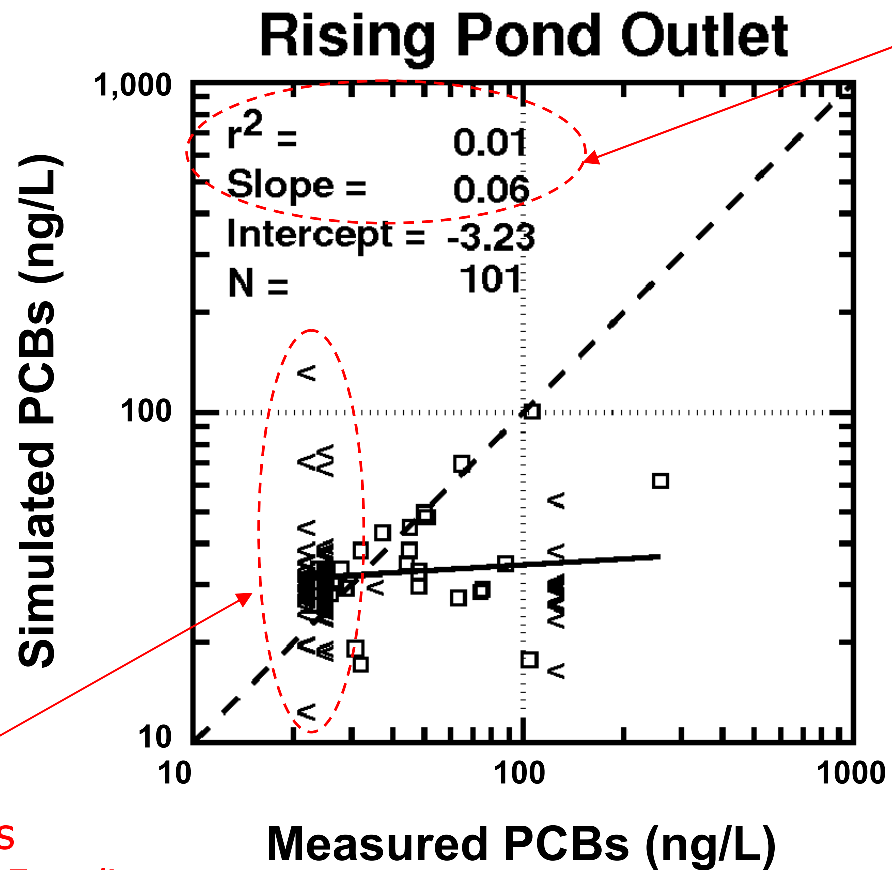


Fig. derived from Doc. Overview Meeting Presentation

Model over-predicts water column PCB data

"Upstream" and "Downstream" Models are Incomplete

- **Downstream Model results do not match the data:**



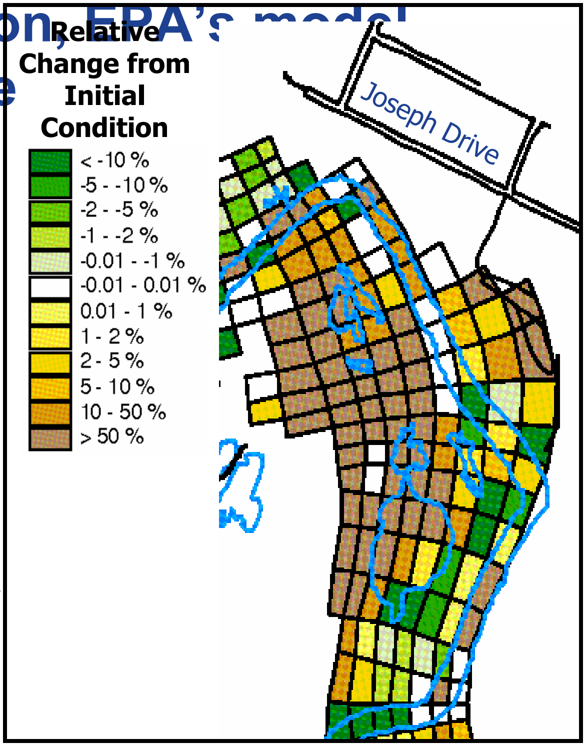
Model provides poor fit to water column PCB data

Large # of samples below MDL of 22-25 ng/L for which model predicts ~30 ng/L or higher

Fig. derived from EPA response to Panel's Doc. Over. Questions

Predictions of PCBs in the Floodplain are Untested

- **The initial conditions (1979) for model validation were specified using floodplain data collected in 1998-99**
  - This approach implicitly assumed the model would calculate little to no change in floodplain PCBs over the 26-year validation period
- **However, at the end of the 26-year validation, EPA's model predicts relatively large changes in surface soil PCBs for some areas of the floodplain**
  - Contradicts underlying assumption that little change occurs
  - Model results at the end of the 26-year validation are inconsistent w/ recent data
  - However, no model-data comparisons were presented for floodplains in the MVR
- **Indicates model in its current form is inadequate for predicting PCB deposition in the floodplains**



from MVR Fig. 6.2-55

Summary of GE's Concerns with MVR

- **Model incorrectly predicts temporal trends in surface sediment PCBs, leading to inaccurate prediction of future trends, including system response to remediation**
- **Excessive EFDC simulation times and potential instabilities prohibit efficient conduct of the CMS**
- **MVR uncertainty approach is not useful for the CMS because it produces unrealistically large uncertainty bounds and the EFDC computational burden is too great**
- **Portions of the model are incomplete (i.e., upstream and downstream models) or untested (i.e., floodplain predictions)**

Recommendations

- **Investigate reasons for incorrect prediction of temporal trends in surface sediment PCBs, and recalibrate the model**
- **Reduce EFDC run times and investigate potential instabilities**
- **Make clear that MVR uncertainty approach is not useable for evaluating remedial alternatives**
- **Complete upstream and downstream model development and calibration for additional review**
- **Make clear that model in its current form is inadequate for predicting PCB deposition in the floodplains**