Dredging Operations and Environmental Research

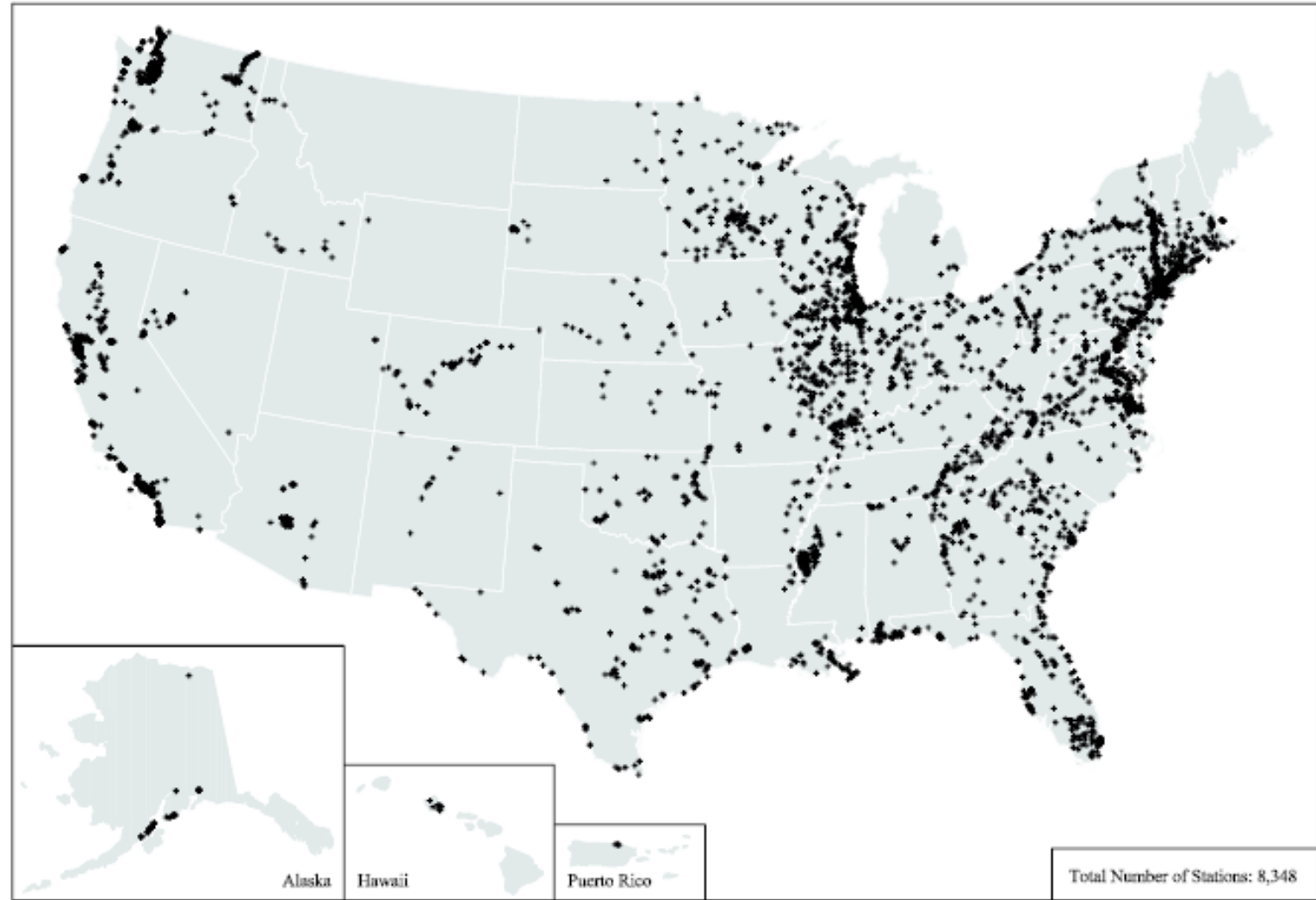# Improved Bioaccumulation Modeling
Preliminary Observations

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Contaminated Sediments in the United States

Alaska | Hawaii | Puerto Rico

Total Number of Stations: 8,348

Source: U.S. EPA (2004)

USACE Dredging and Contaminated Sediments

Impact on Navigational Dredging:

- Federal, state, and regional requirements that dredging won't significantly degrade aquatic resources and must minimize adverse impacts.

- USACE and USEPA Guidelines for Dredged Material Disposal require an assessment of the potential for aquatic organisms to bioaccumulate sediment-associated contaminants.

- USACE has developed foodweb bioaccumulation models (e.g., trophic trace, fishrand-migration) to address requirements.
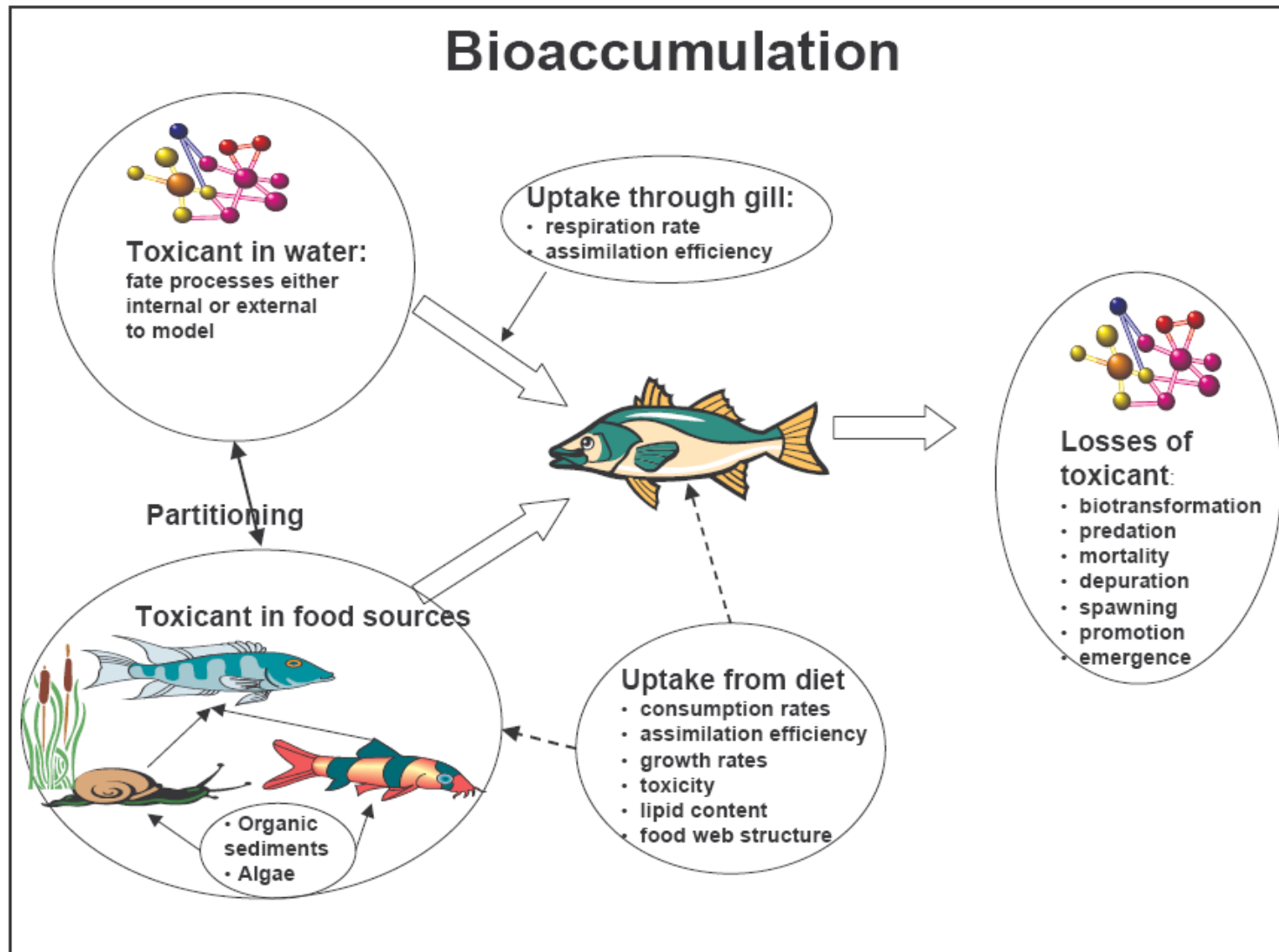
Potential risks from contaminated sediments have a large impact on ability to dredge and create the need to evaluate bioaccumulation:

- Dioxin-contaminated dredged material from New York/New Jersey Harbor and Puget Sound;
- PCB-contaminated material from Portland Harbor (OR);
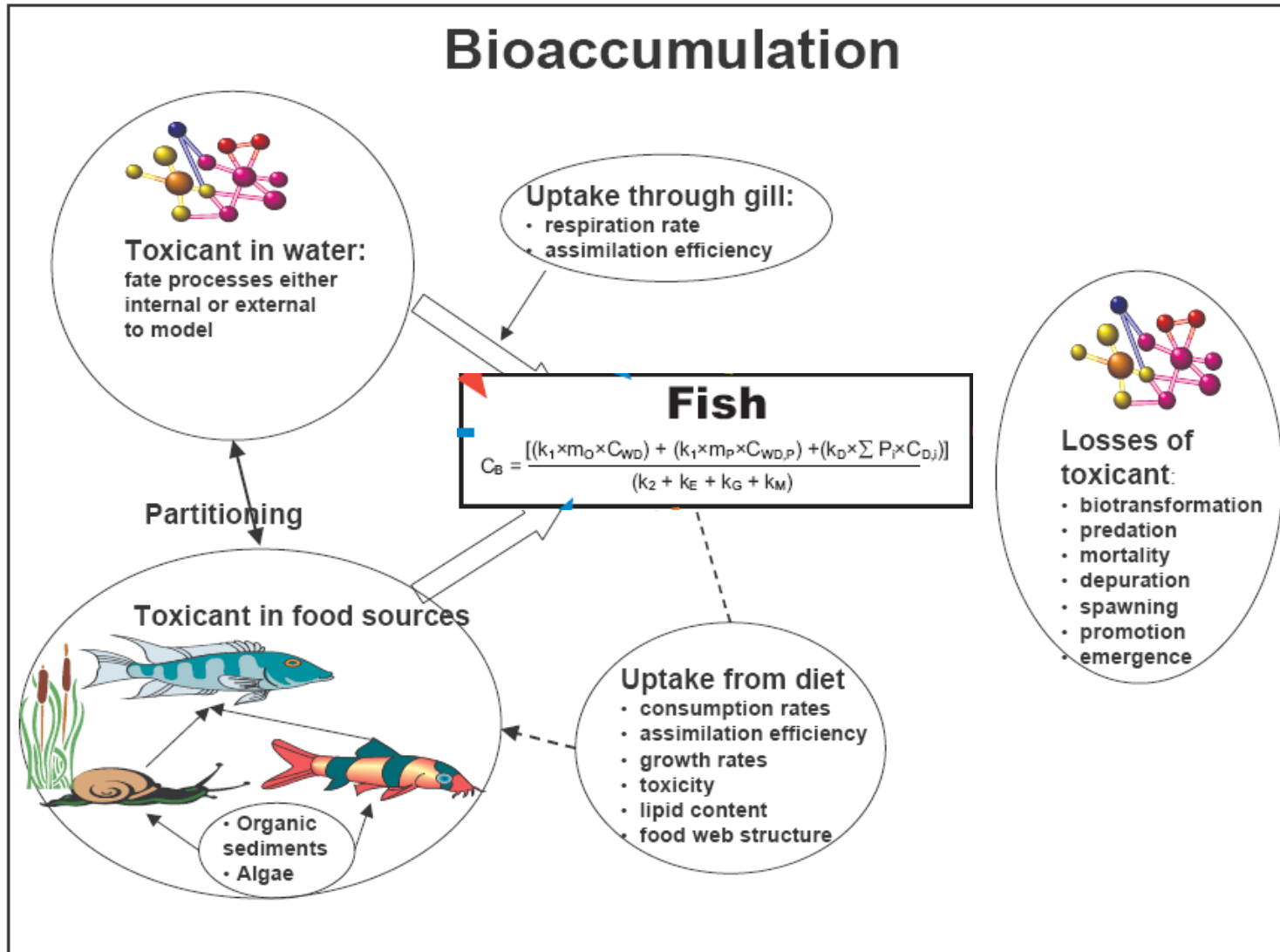- PAH-contaminated material in Boston Harbor and Portland Harbor (ME).

Project Objectives

- Review the application of foodweb bioaccumulation models to inform, expedite, and improve USACE approaches.

- Mine the millions of dollars used to apply these models at sites to
    - Understand model output and its value
    - Determine detrimental/beneficial practices
    - Avoid mistakes
    - Avoid unnecessary expenditures.

➔Product: Improved USACE models and approaches.

Bioaccumulation Modeling Overview

Bioaccumulation

Toxicant in water:
fate processes either
internal or external
to model

Uptake through gill:
· respiration rate
· assimilation efficiency

Partitioning

Toxicant in food sources

· Organic
sediments
· Algae

Uptake from diet
· consumption rates
· assimilation efficiency
· growth rates
· toxicity
· lipid content
· food web structure

Losses of
toxicant:
· biotransformation
· predation
· mortality
· depuration
· spawning
· promotion
· emergence

Source: Imhoff et al. (2004)

Bioaccumulation Modeling Overview

Bioaccumulation

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- respiration rate
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Fish

$$C_B = \frac{[(k_1 \times m_O \times C_{WD}) + (k_1 \times m_P \times C_{WD,P}) + (k_D \times \sum P_i \times C_{D,i})]}{(k_2 + k_E + k_G + k_M)}$$

Partitioning

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Source: Imhoff et al. (2004)

Bioaccumulation Modeling
Equations for Predicting PCB Concentrations in Fish

Source: Windward (2007); Model Construct: Arnot and Gobas (2004)
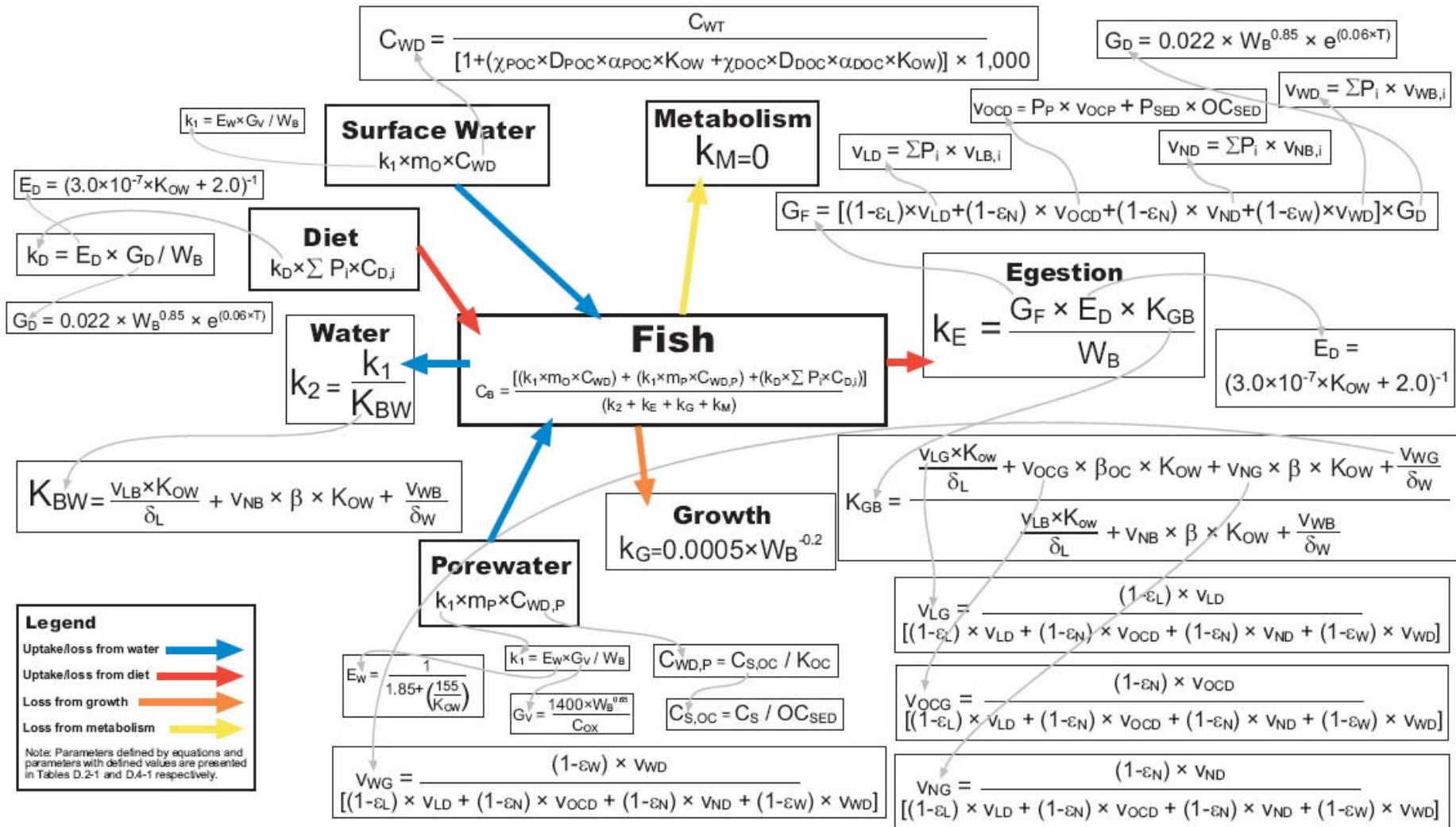
Improved Bioaccumulation Modeling Project

I: State of the Science: Application Survey

Evaluate the application of food web bioaccumulation models at 4 sediment megasites: Fox River, WI; Housatonic River, MA; Hudson River, NY; and Lower Duwamish River, WA.

At these sites, review: purpose of modeling; model used; organisms evaluated; areas predicted; calibration and validation procedures; uncertainty analysis; consideration of spatial variability; linkage to environmental fate and transport models.

II.   Bioaccumulation Model Improvement

Bioaccumulation Modeling

Common Uses at Contaminated Sediment Sites

- Estimate fish tissue contaminant concentrations based on contaminant concentrations in sediment and water.

- Forecast the effect that contaminated sediment will have on fish tissue concentrations.

- Develop risk-based sediment cleanup levels.
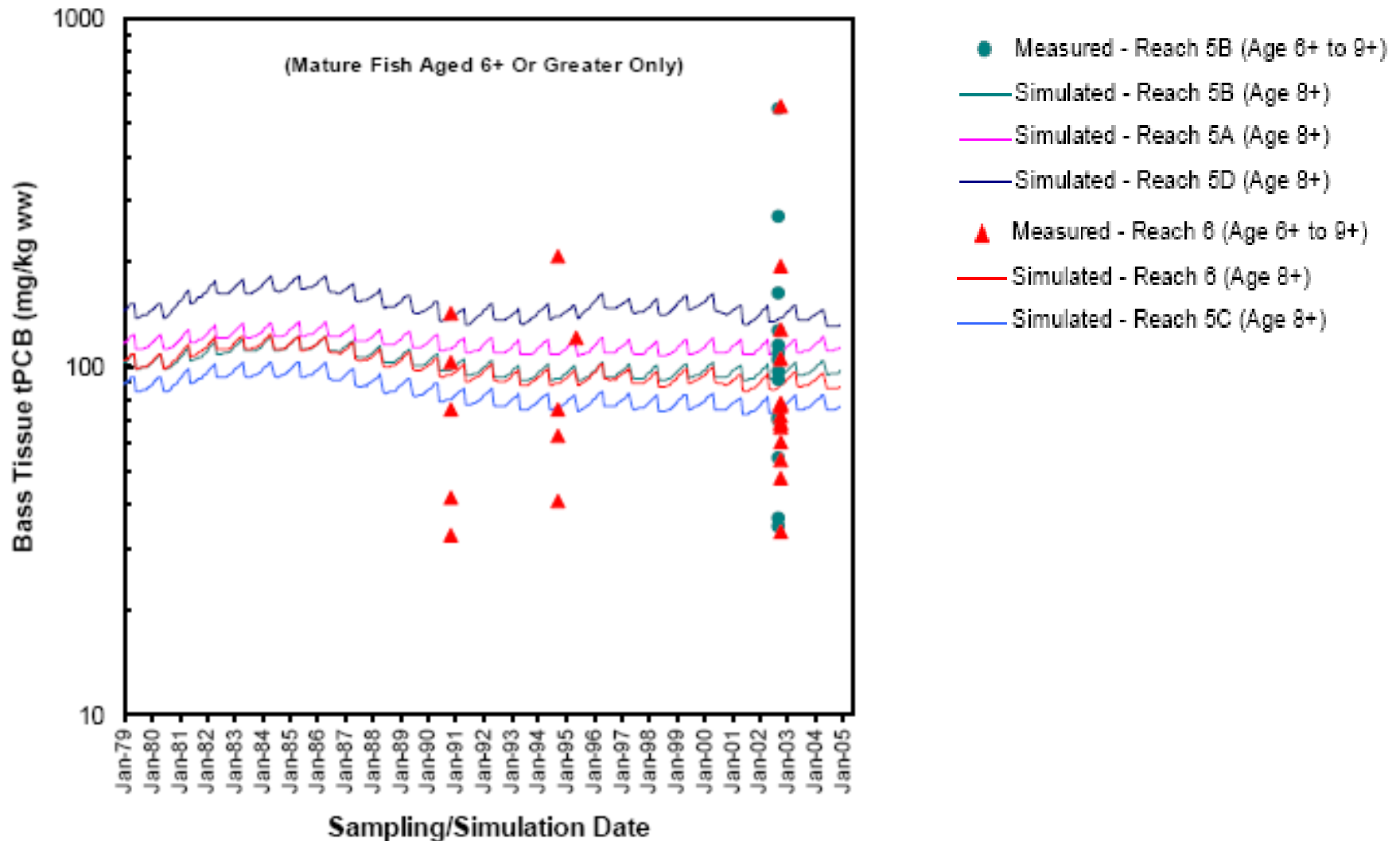
Bioaccumulation Modeling

Calibration and Validation

"Where numerical models are used, **verification, calibration, and validation** typically should be performed to yield a scientifically defensible modeling study"

- <u>Verification</u>: Establishing that the model's code does what it purports and that it's consistent with the theory behind the model.

- <u>Calibration</u>: The process of using site-specific information from a historical period to adjust model parameters and obtain optimal agreement between measured and modeled data.

- <u>Validation</u> refers to running the calibrated model on an independent data set to establish that the calibrated model is predictive of independent conditions.

Source: EPA (2005)

Bioaccumulation Models
Housatonic River; Mature Largemouth Bass

Bioaccumulation Models
Housatonic River; Mature Largemouth Bass

Calibration/Validation

Calibration			Validation Acceptability Metric	Validation			
Period	**Data sets**	**# Fish**		**Period**	**Data sets**	**# Fish**	**Site Report Conclusion**.
1998 to 1999	1998, 1999	38 fish, 3 areas	Modeled fish mean should be within a factor of 2 in either direction of the measured fish mean	1979-2004	1990, 1994, 2002	33 fish; 2 areas; Independent Data	Modeled performance was good

Bioaccumulation Models
Fox River, WI, Little Lake Butte des Morts; Carp and Walleye
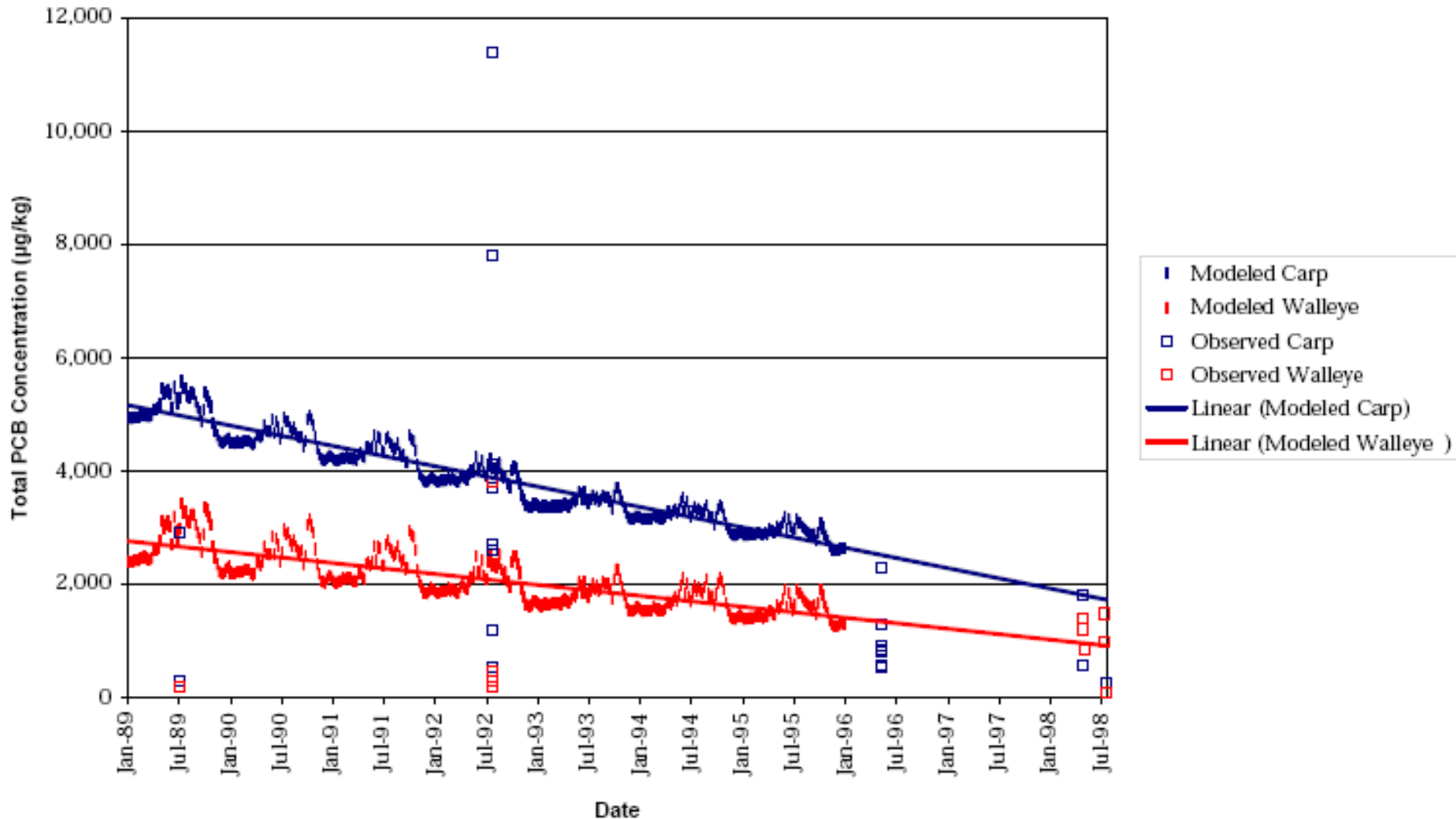
Bioaccumulation Models
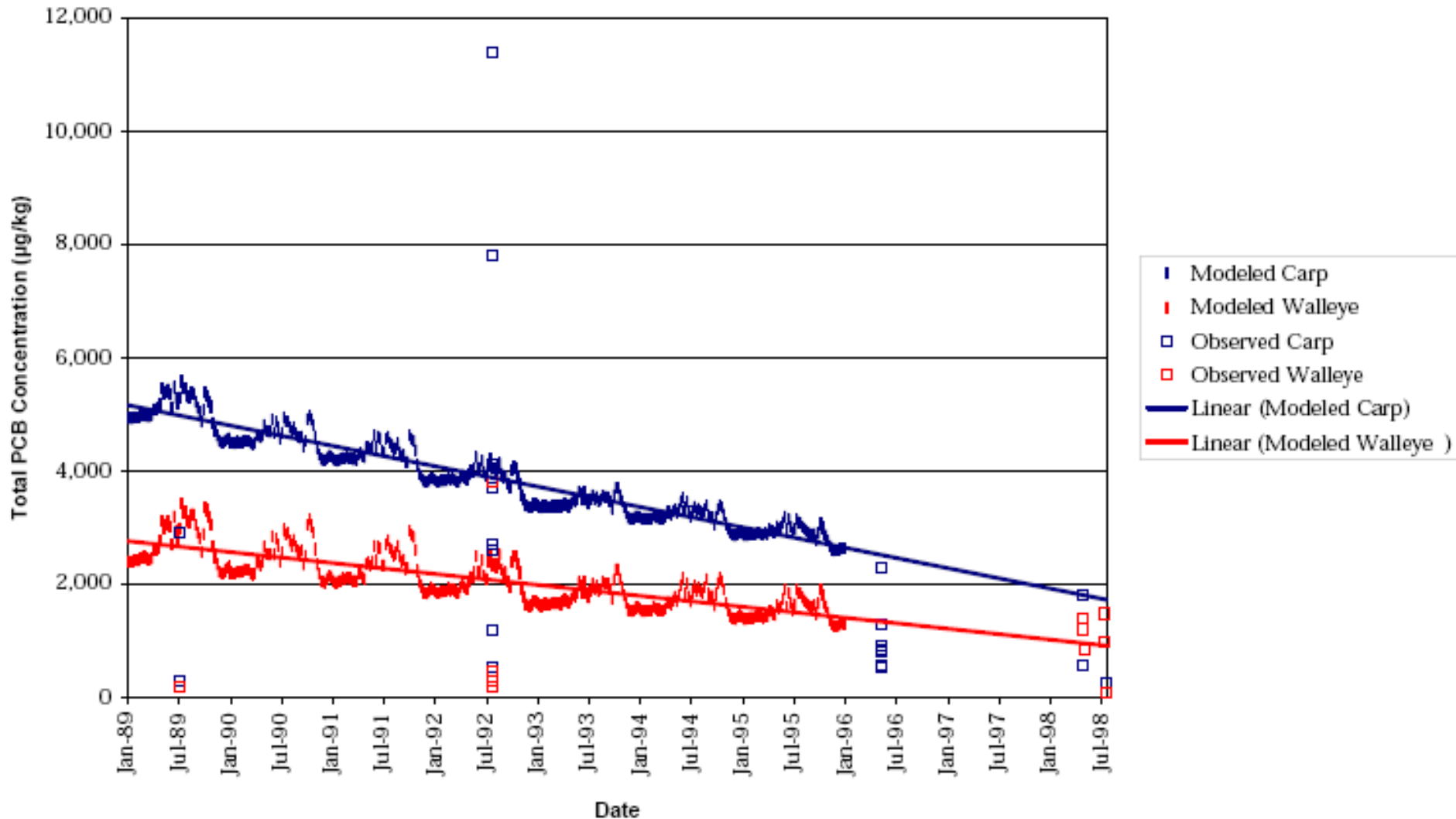## Fox River, WI; Carp and Walleye

Calibration/Validation

Calibration			Calibration Acceptability Metric	Validation			
Period	**Data sets**	**# Fish**		**Period**	**Data sets**	**# Fish**	**Site Report Conclusion**
1989 to 1998	1989, 1992, 1996, 1998	30 carp/11 walleye	Predicted mean/95 UCL within ½ order of magnitude of measured mean/ 95 UCL	No independent validation			Output met model evaluation metric

Discussion

- Value of model output.

- What level of confidence do the models afford that it's predictions will be accurate?

- Can similar information/confidence be provided via other less complex techniques?

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