Los Angeles and Long Beach Harbors and San Pedro Bay Modeling

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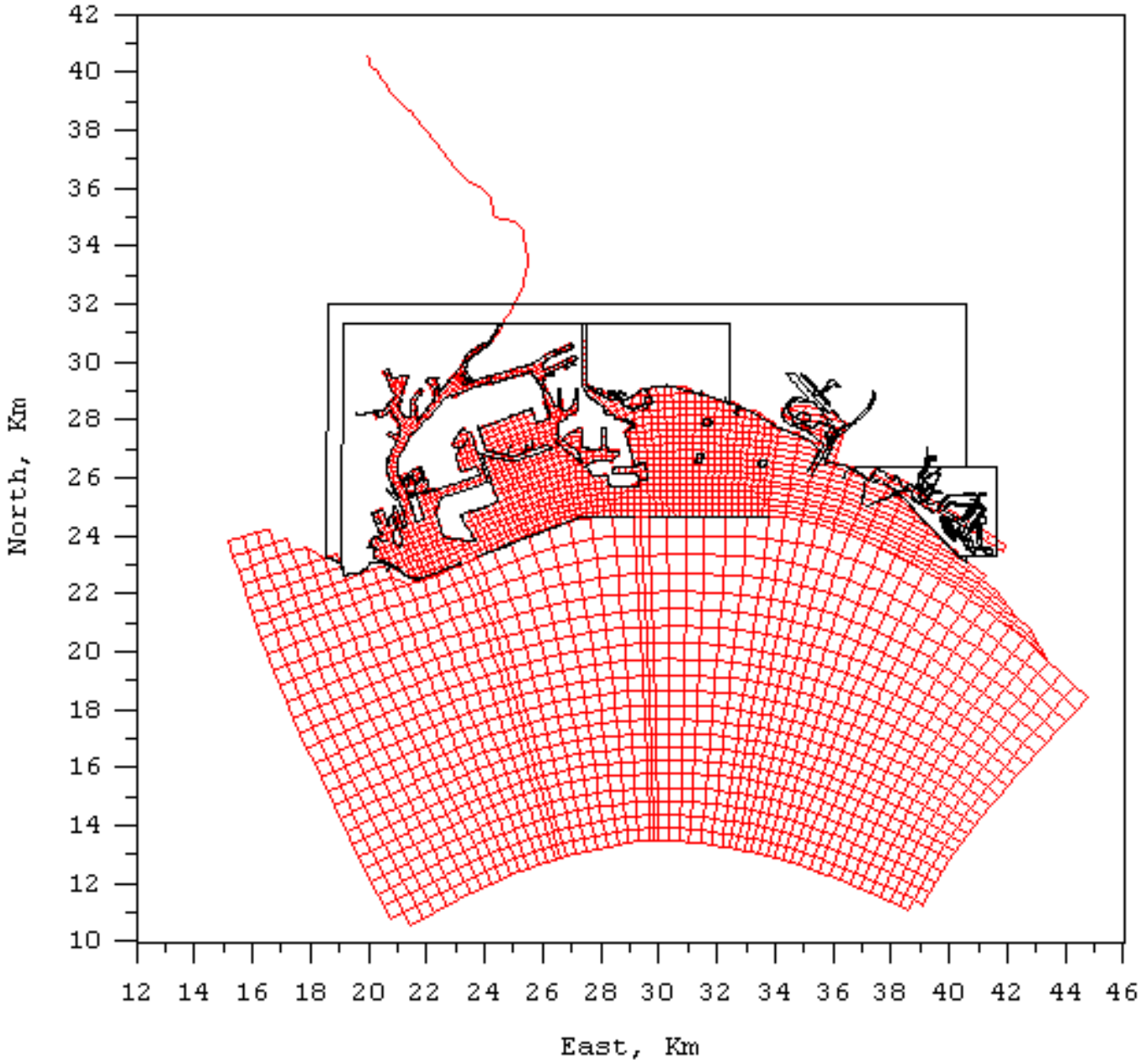
Presentation Outline

- Modeling Approach
- Status of Model Components
- Configuration of Sediment/Contaminant Model
- Sediment/Contaminant Calibration
- Sensitivity Analysis
- TMDL Modeling

Greater Harbors Modeling Approach

- Generic EFDC Modeling System
  - Hydrodynamics (Including S & T)
  - Sediment Transport
  - Contaminant Transport (Metals and Organics)
- Observational Data to Support Model Configuration and Calibration
- Modeling System + Configuration Data = Application Specific Model
- Model Calibration, Sensitivity, and Uncertainty to Establish Utility of Model with Respect to TMDL Scenario Simulations

Greater Harbors Grid



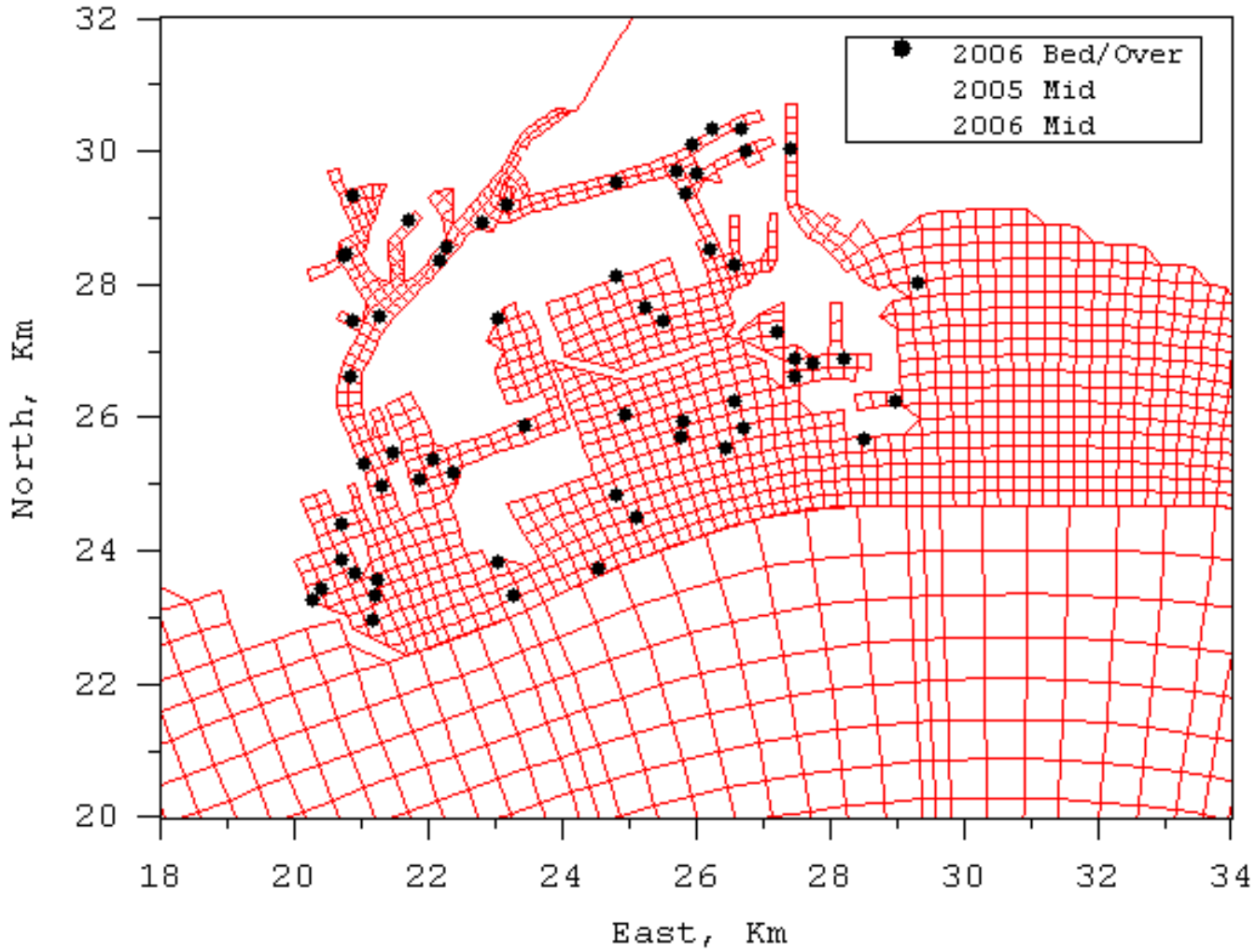
Status of Model Components

- Hydrodynamic Component Completed Fall 2006
- Development of Sediment and Contaminant Components Were on Hold Awaiting Fall 2006 Field Observations
- Observational Data Received in April 2007
- SED/CON Configuration and Calibration Completed
- Limited Sensitivity and Uncertainty Analysis Completed
- Ready for TMDL Modeling

Fall 2006 Observational Data

- Approximately 60 Bed and Overlying Water Observational Sites
- Bed Physical Properties: Grain Size Distribution, Bulk Density, Per Cent Organic Carbon
- Bed Chemical Properties: Dissolved and Particulate Metals and Organics Concentrations, Pore Water DO
- Overlying Water Sediment, DOC, and Total Metal and Organic Contaminant Concentrations
  - Missed Opportunity to Measure Dissolved Phase Concentrations

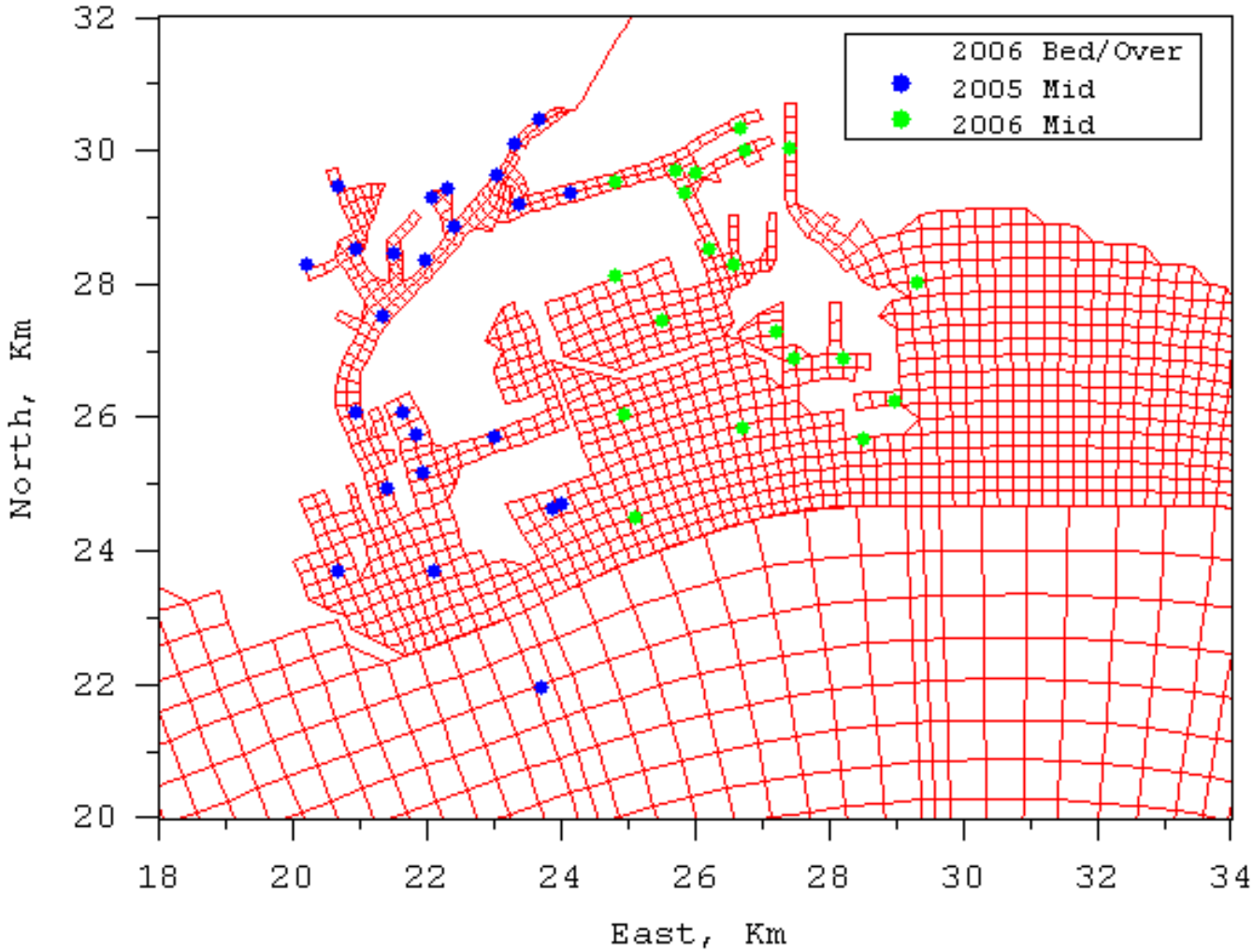
Fall 2006 Bed and Overlying Water Sites (Bed=>Initialization, Over=>Calibration)



Additional 2005/06/07 Observational Data

- POLB 2006 Mid-Water Column, (20 Sites) and POLA 2005 Mid-Water Column, (55 Sites)
  - Dissolved and Particulate Metals Concentration
  - Organic Carbon Concentrations
  - Missed Opportunity with Suspended Sediment Concentrations not Recorded
- POLA 2007 Water Surface TSS (8 Sites)
- SCCWP 2006 Organics Data
  - Water Column (1) and Pore Water (4) at Con Slip
- SPME 2006 Organics Data
  - (10 Sites with some reps)

2005 and 2006 Mid-Water Column Sites (Used for Metals Calibration)



The Rest of the Data

- Various Sediment Bed Physical Property Data Sets Going Back Until 1993
  - Did Not Use Data Inside Breakwater Prior to 1998
  - Extremely Limited Data Outside Breakwater
- Various Sediment and Water Column Total Metals and Organics Concentrations
  - Did Not Used Data Prior to 2000
  - Extremely Limited Data Outside Breakwater

How the Observational Data Is Used

- Sediment Bed Physical Property Data Used to Initialize the Bed for Sediment Transport
- Sediment Bed Metals and Organic Concentrations Use to Initialize the Bed for Contaminant Transport and Fate
- Above Two Data Types Used to Estimate Partition Coefficients
- Water Column Sediment and Contaminant Data Used for Calibration

Configuration of the Sediment/Contaminant Model Components

- Sediment and Contaminant Loads form Rivers and Near Shore Watersheds
- Sed/Con Boundary Conditions in San Pedro Bay
- Initial Sediment Bed Physical Properties
- Initial Contaminant Concentrations in Sediment Bed
- Water Column ICs Not Critical
- Sediment and Contaminant Transport Parameters From Observational Data and Literature

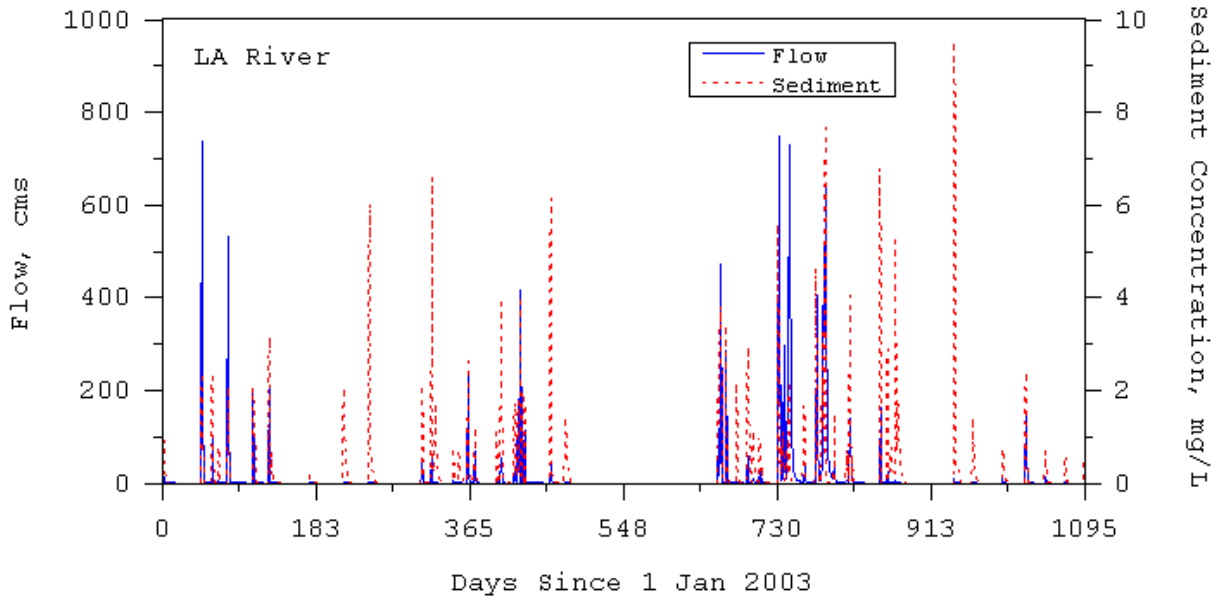
Sediment and Contaminant Loads and Open Boundary Conditions

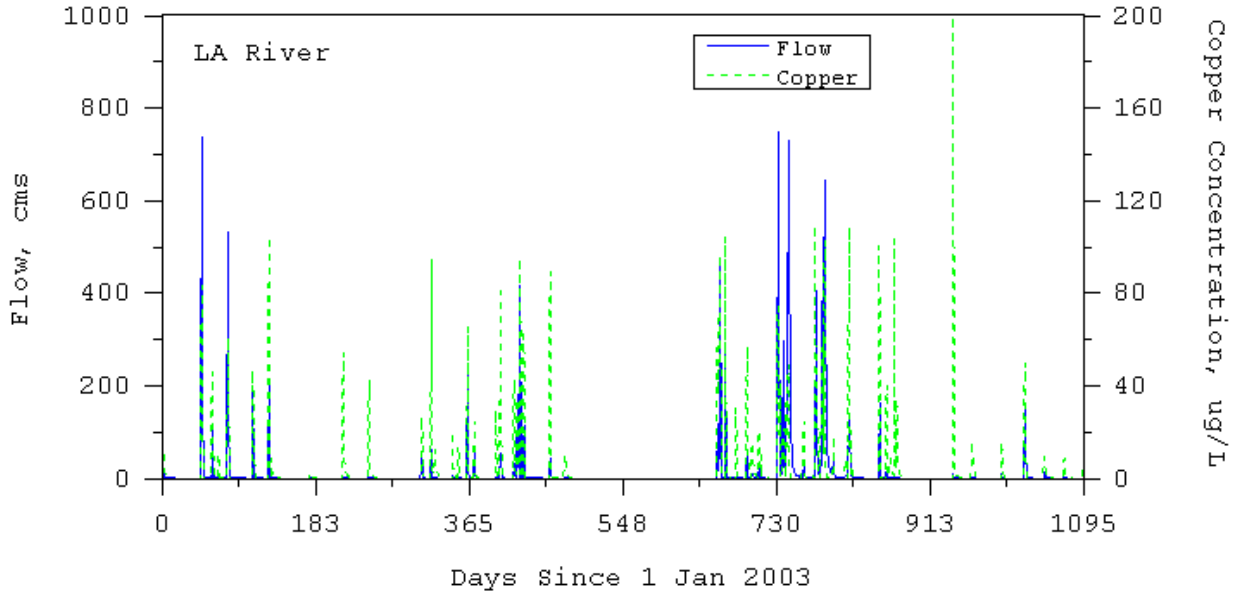
- Sediment and Contaminant Loads From Watershed Models
  - Sediment and Metal Land Loads Reasonable
  - Organics Loads Used Different Procedure
  - Wet Loads Could Be Calibrated Further
- Open Boundary Conditions in San Pedro Bay
  - Little Data Except for DDT
  - Calibrate and/or Demonstrate Low Sensitivity
  - Start With Lowest Interior Values

Sediment

LA River Flow and Load

Copper

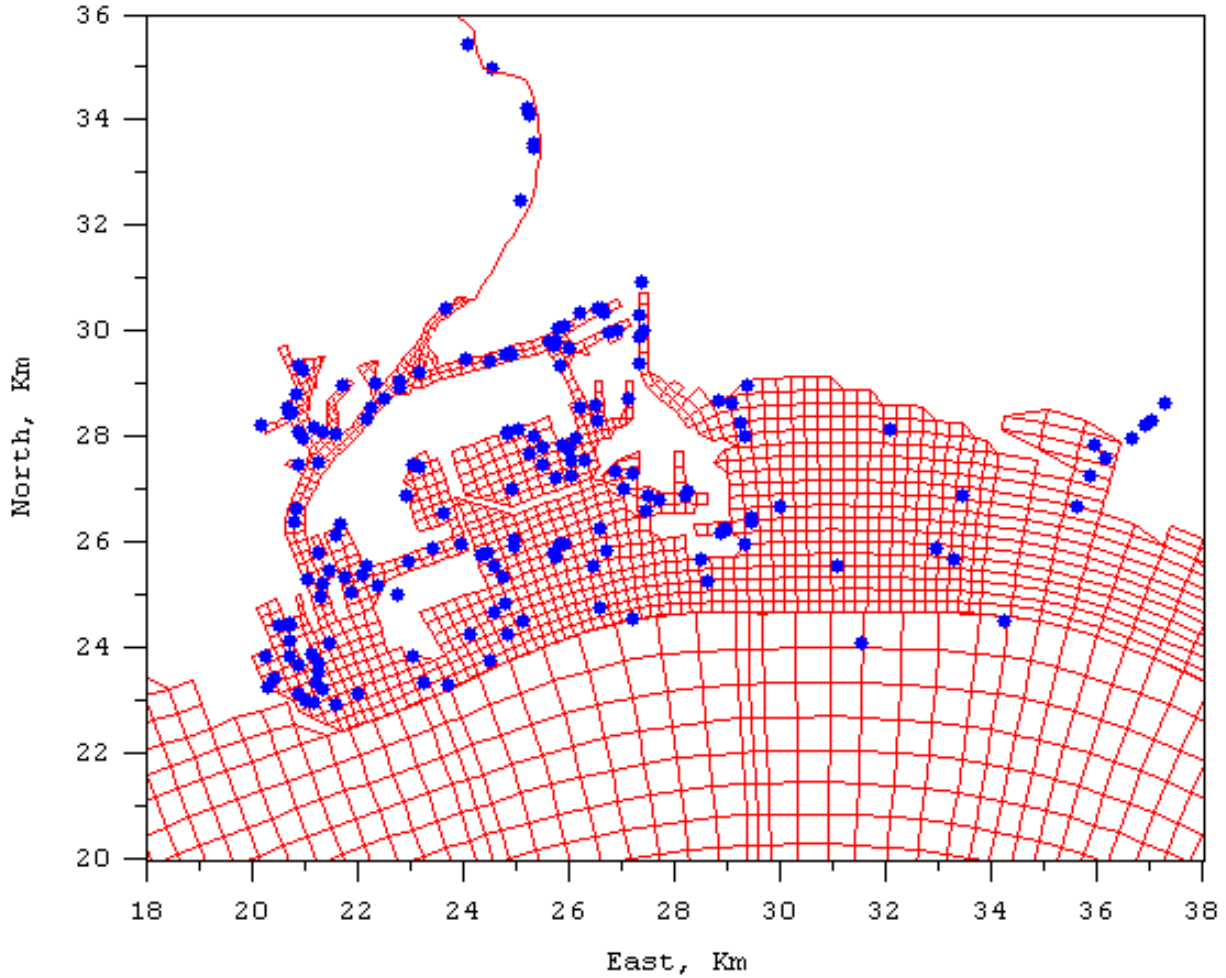




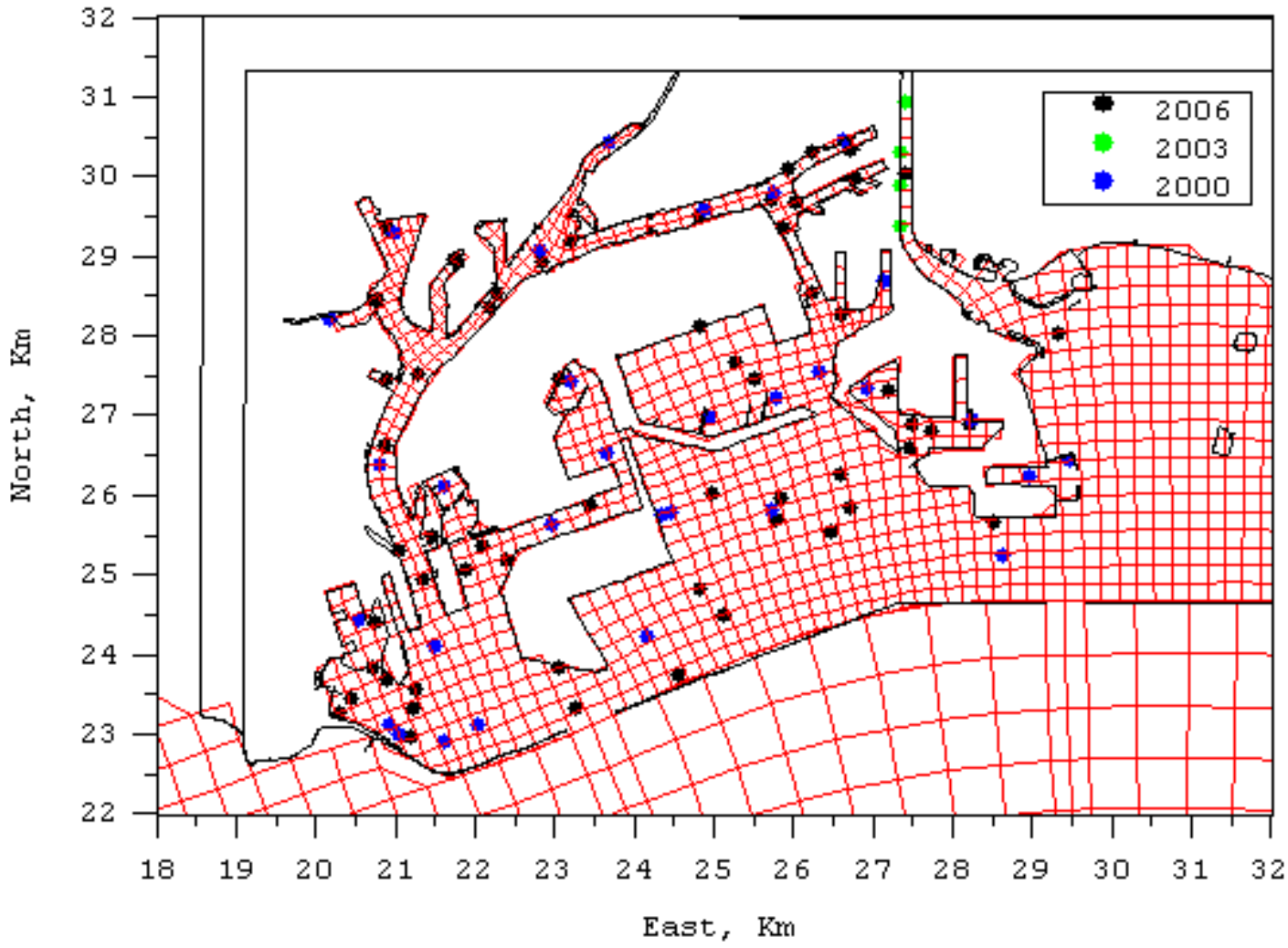
Initialization of the Bed Sediment

- Contaminants Are Adsorbed to Bed Sediment
- Model Needs Sediment Size Class Fractional Composition, Porosity (or Bulk Density), and TOC
- Best Data Has Grain Size Distribution, Porosity, and Organic Carbon Fraction
- Worst Data Has Fraction of Fines
  - Correlate Porosity and FOC with Fraction Fines Using Best Data
- Size Classes
  - Cohesive Behaving or Fine Class (<63 um)
  - 1-3 Non-cohesive Behaving Classes

Location of Data Sites Used to Initialize Sediment Bed Physical Properties (300 Sites)

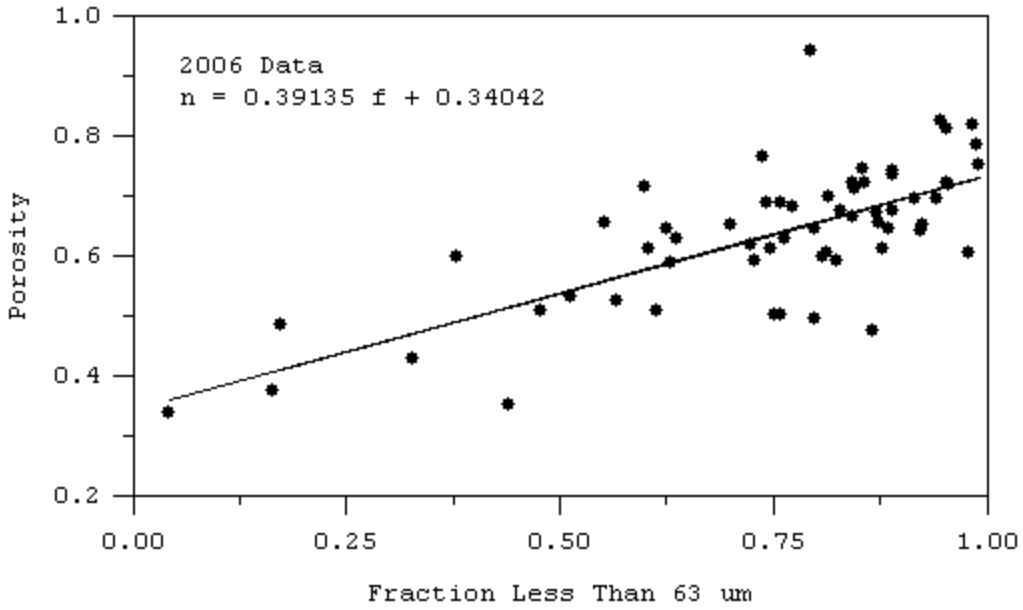


Zoom Shows Most Recent Bed Physical Data Sites

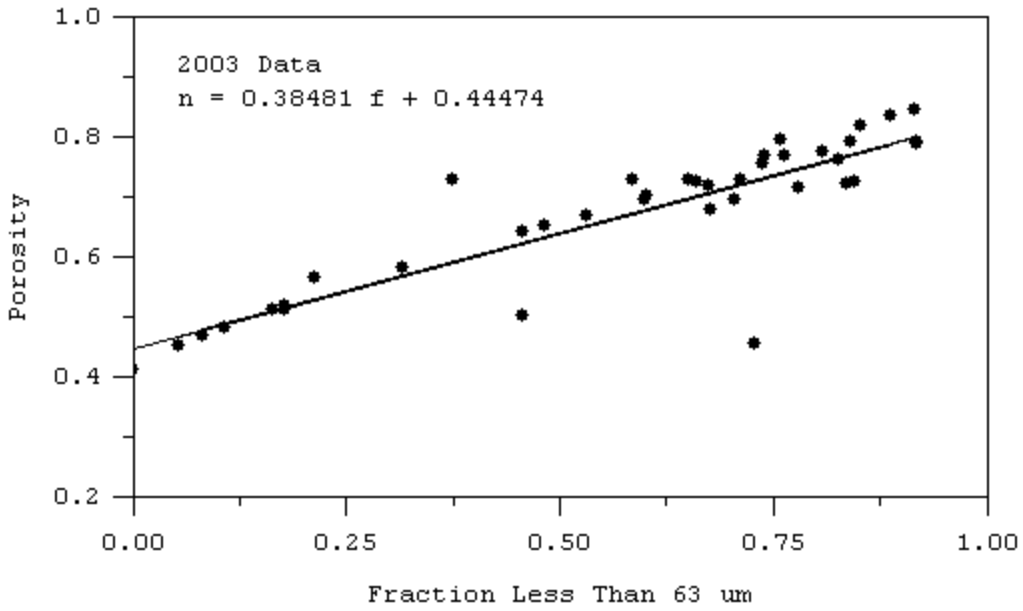


Estimating Bed Porosity

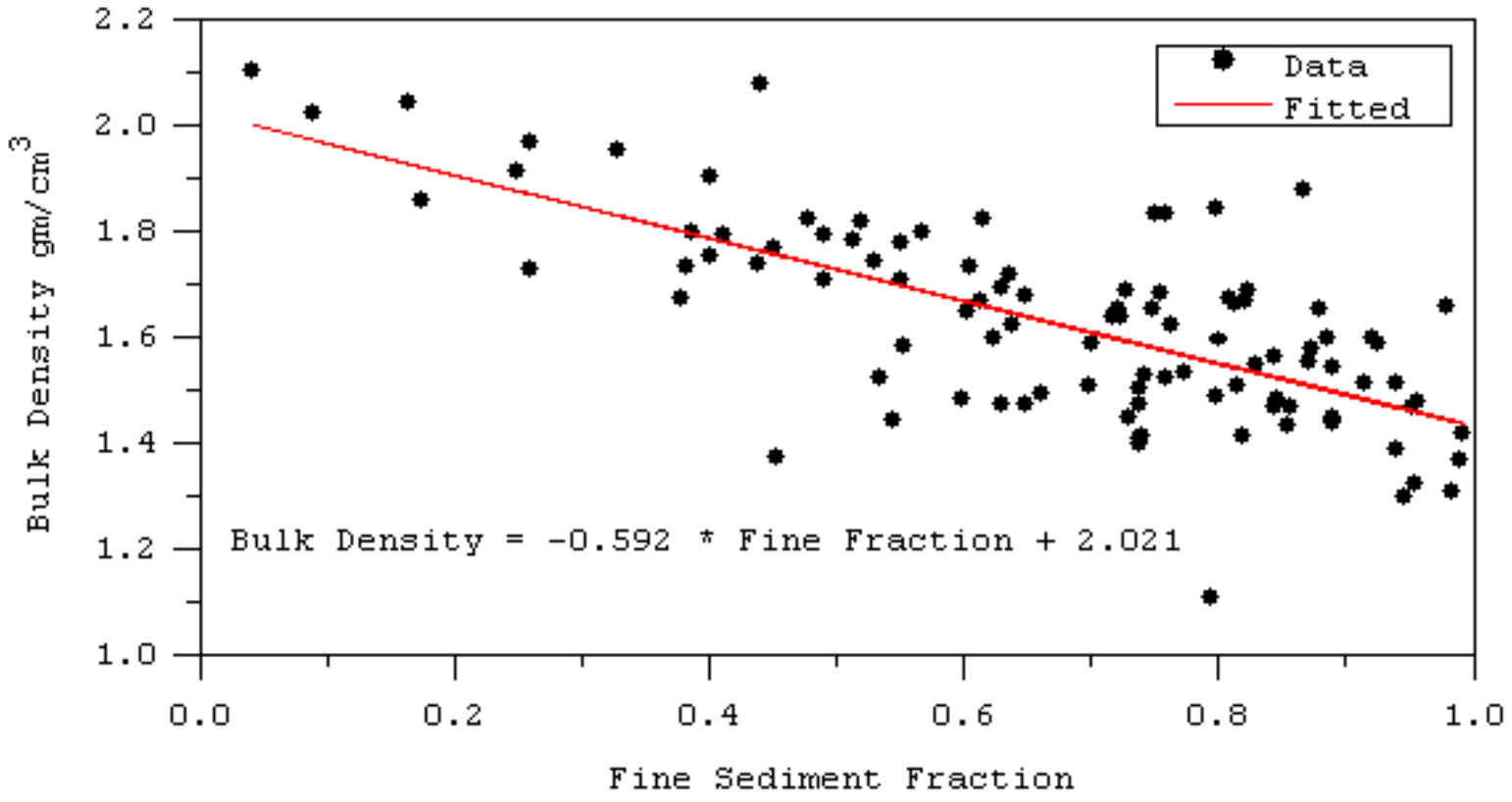
2006 Data



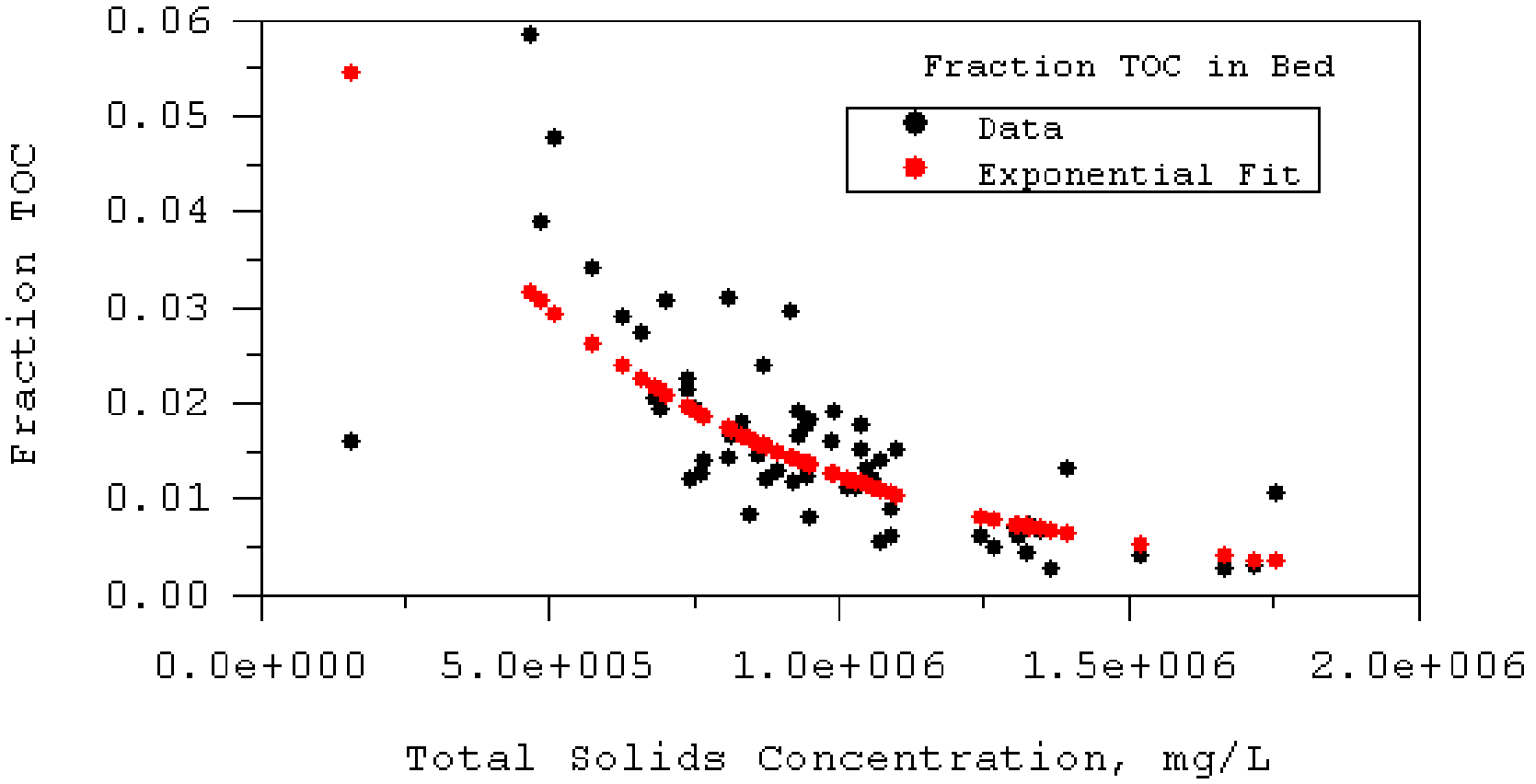
2003 Data



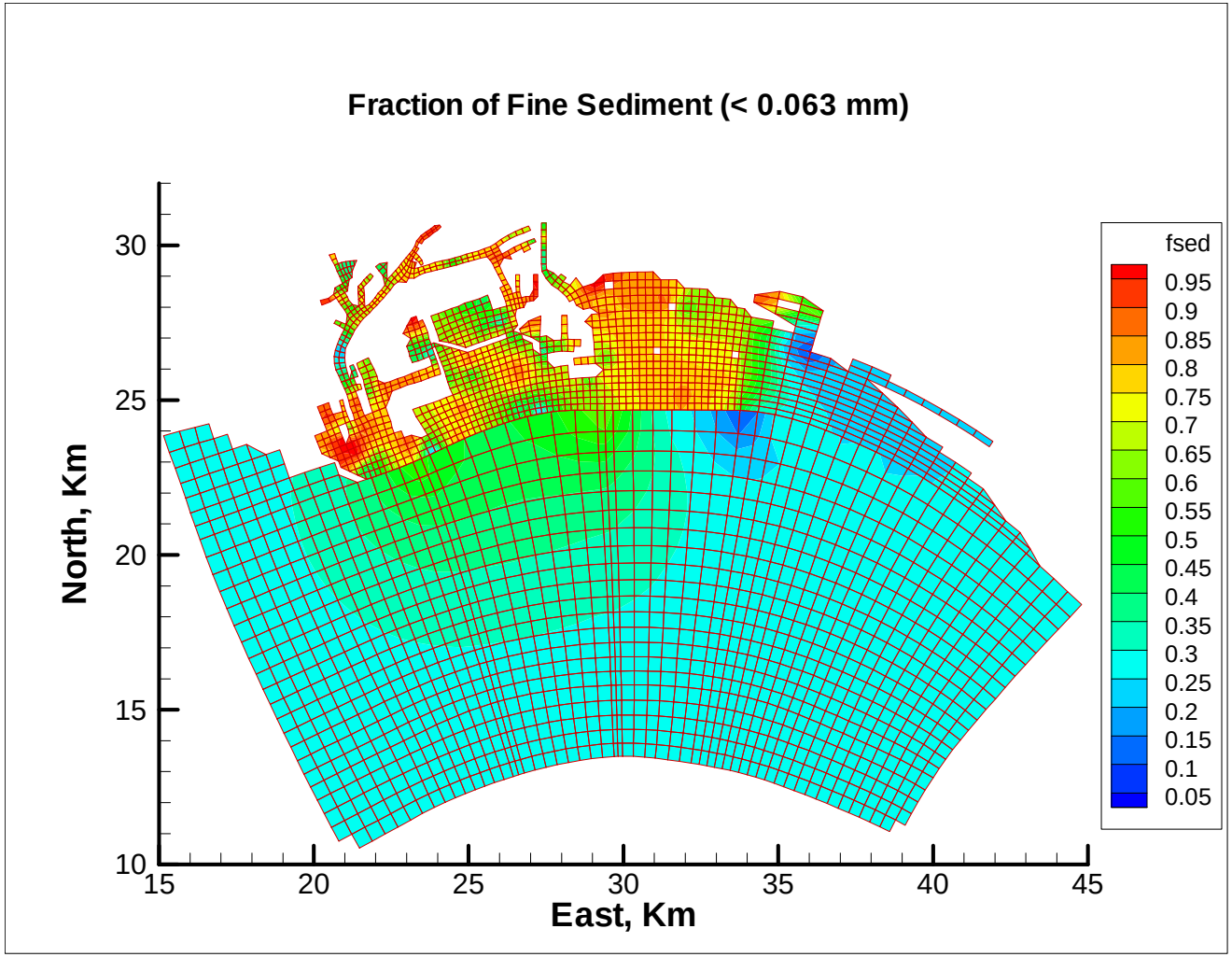
Estimating Bed Bulk Density



Fraction TOC Correlation Using 2006 Bed Data



Sediment Bed Fine Fraction



Sediment Transport Configuration: Other Parameters

- Internal Widely Accepted Parameterizations for Settling, Deposition and Erosion of Non-cohesive Sediment Size Classes Are Used
  - Based on Effective Diameter of Size Class
  - Number of Classes and Effective Diameters Can Be Calibrated
- Initial Estimate of Fine Size Class Settling Velocity and Critical Stress for Deposition
  - Literature Values
  - Subject to Calibration
- Initial Estimate of Fine Size Class Critical Stress for Erosion and Erosion Rate
  - Literature Values
  - Sed-Flume Test
  - Subject to Calibration

Estimating Sediment Erosion

- UC Santa Barbara Study (Jepson et al 1997)
- Sediment Flume Testing of Field Cores
  - 2 Cores Queen's Way, 5 Cores Queen's Gate
  - "there is no obvious correlation between erosion rate and any of the bulk properties listed" Jepson et al
- Sediment Flume Testing of Composite Cores
  - 4 Cores reformed form Queen's Gate Sediments
  - Allowed to Consolidate for 2, 6, 20, and 60 days
  - Testing Results Showed Significant and Well Defined Bulk Property Dependence

Grain Size Distribution of Composite Samples

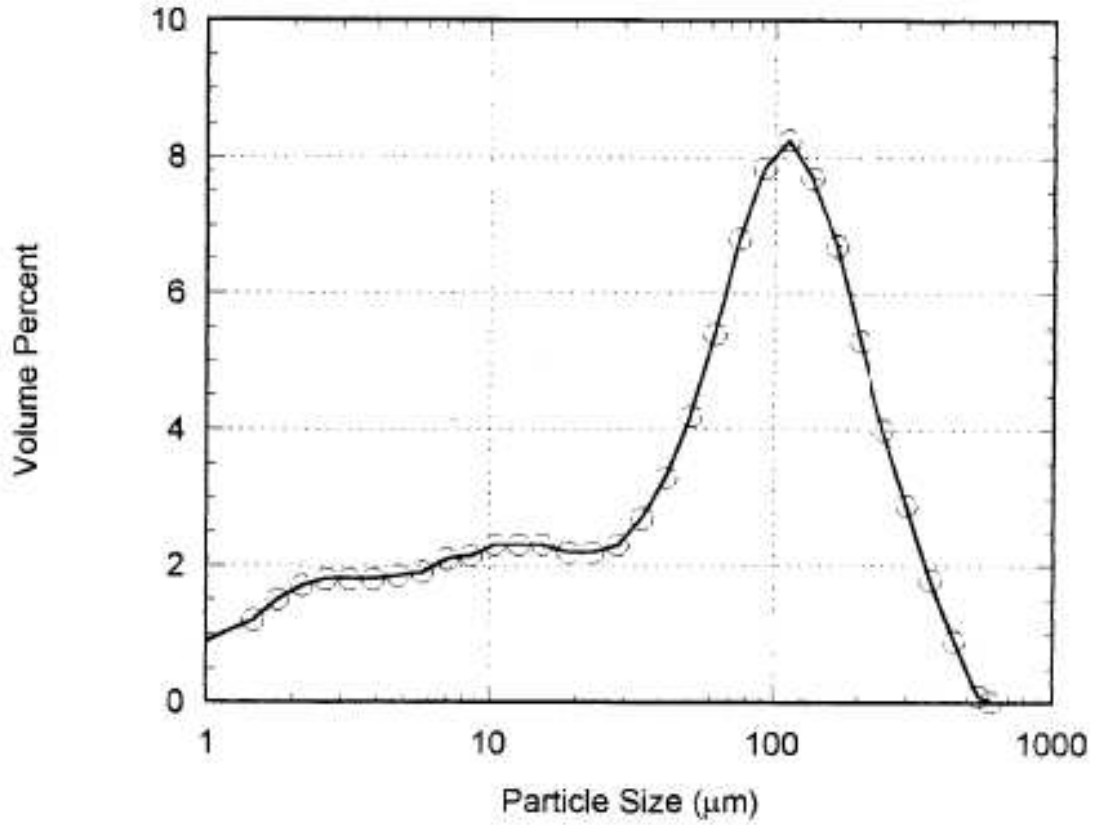


Figure 10. Dissaggregated particle size distribution for the composited sediments from the entrance to the Long Beach Harbor. The median particle size is 70 μm.

Bulk Density as Function of Depth in Sediment Bed (UCSB Study) (void ratios 0.95 to 1.35)

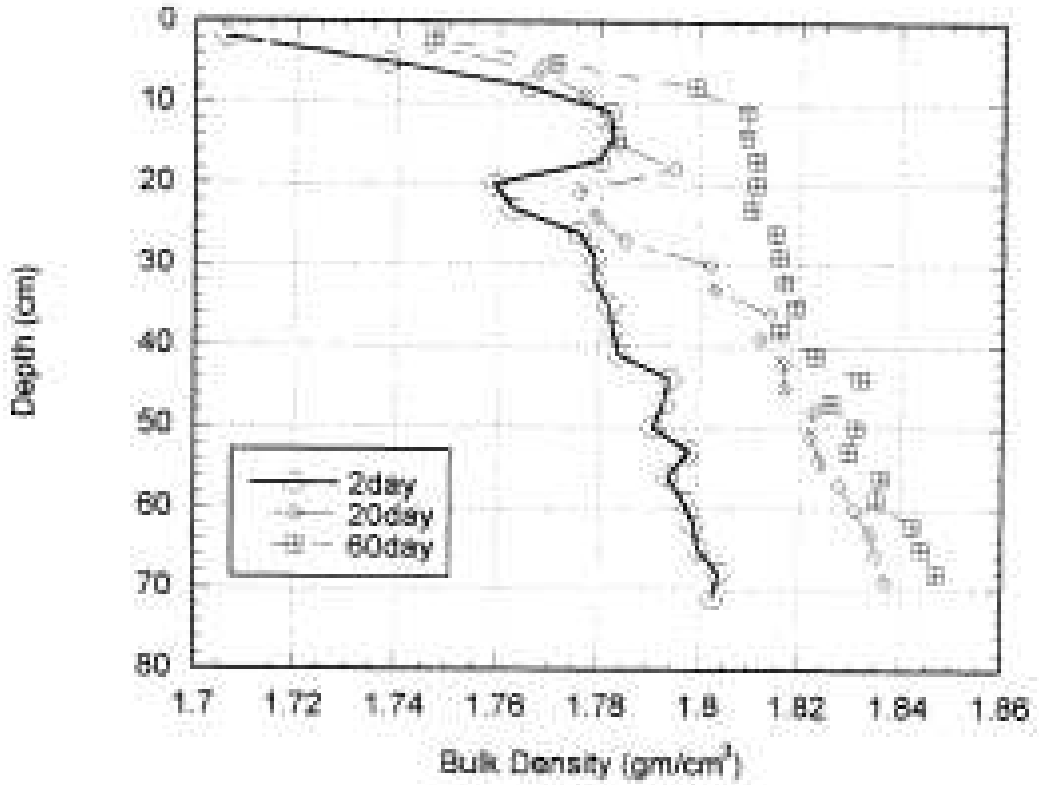


Figure 13. Bulk density as a function of depth for the 80 cm composited sediment cores at consolidation times of 2, 20, 60 days.

Erosion Rate As Function of Bed Stress and Bulk Density (UCSB Study)

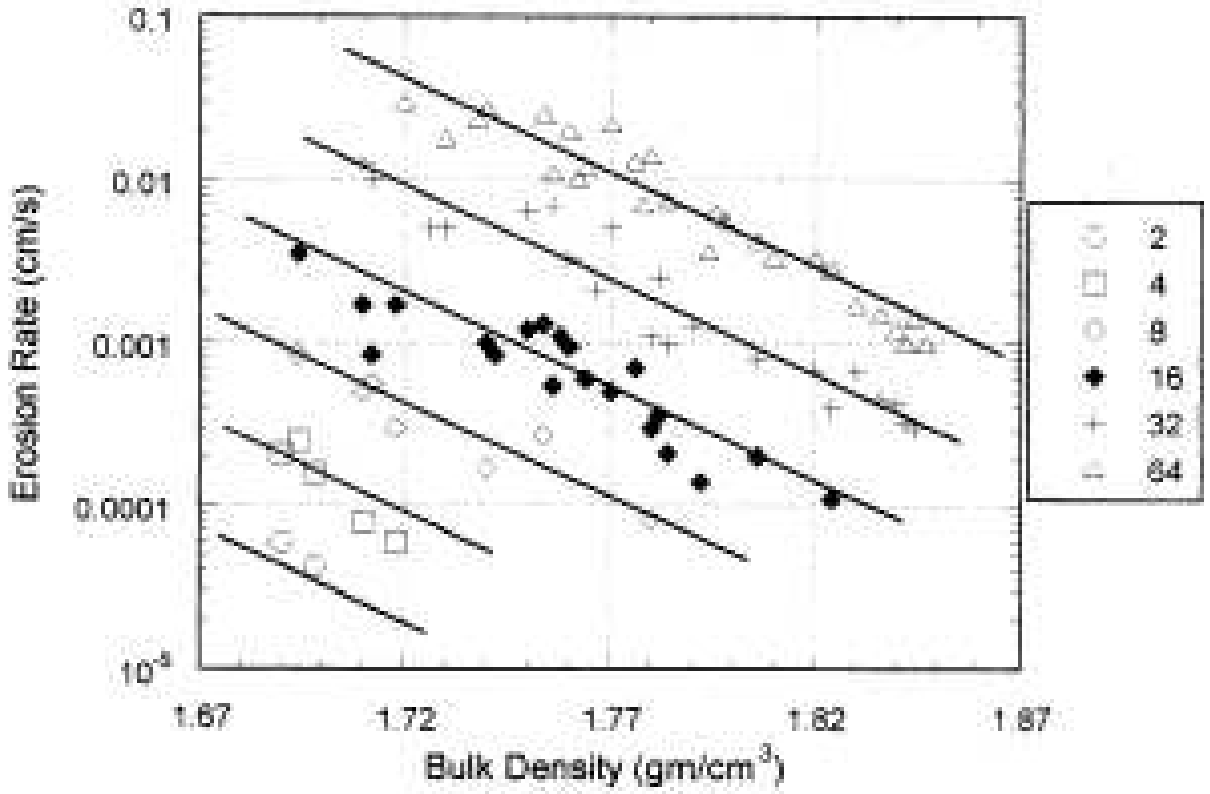


Figure 19. Erosion rates as a function of bulk density for the composited sediments. Erosion rates for shear stresses of 2, 4, 8, 16, 32, and 64 dynes/cm^2 are shown.

Erosion Rate As Function of Applied Stress and Void Ratio (as solids volume fraction)

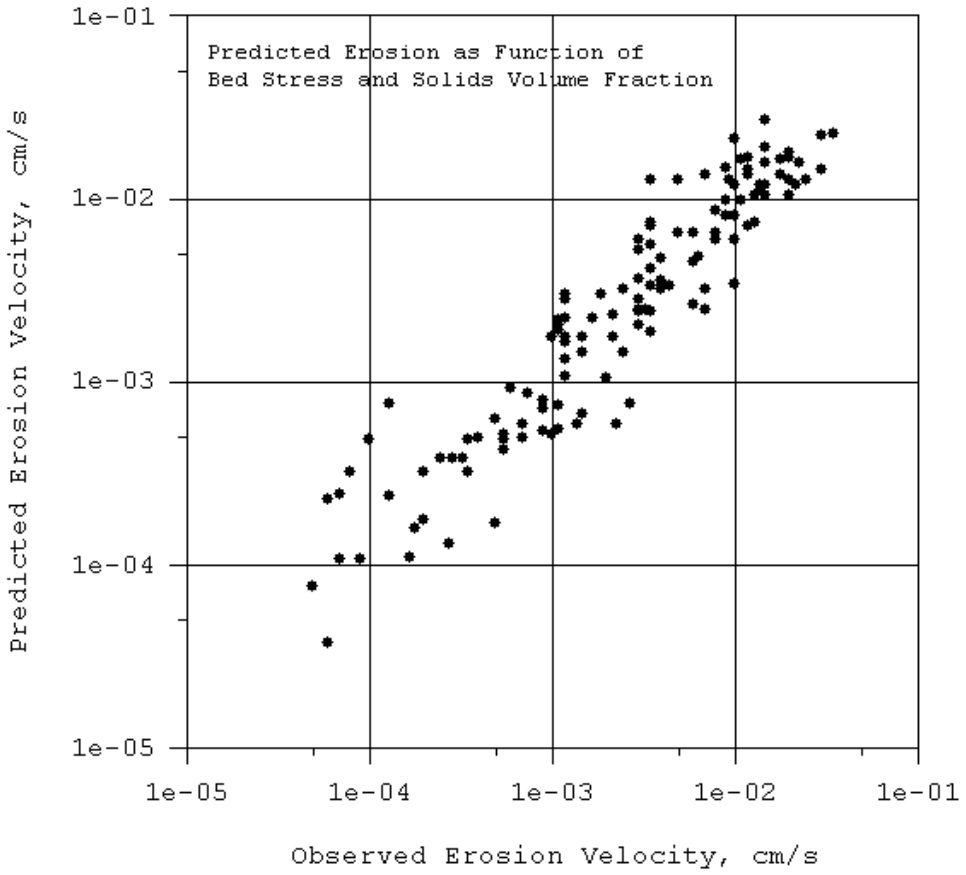
$$\frac{E}{V} = \alpha \left(\frac{\tau}{V^2} \right)^{\beta} \exp\left(\frac{\gamma}{1+\varepsilon} \right)$$

$$\alpha = 0.237$$

$$\beta = 2.18$$

$$\gamma = -32.05$$

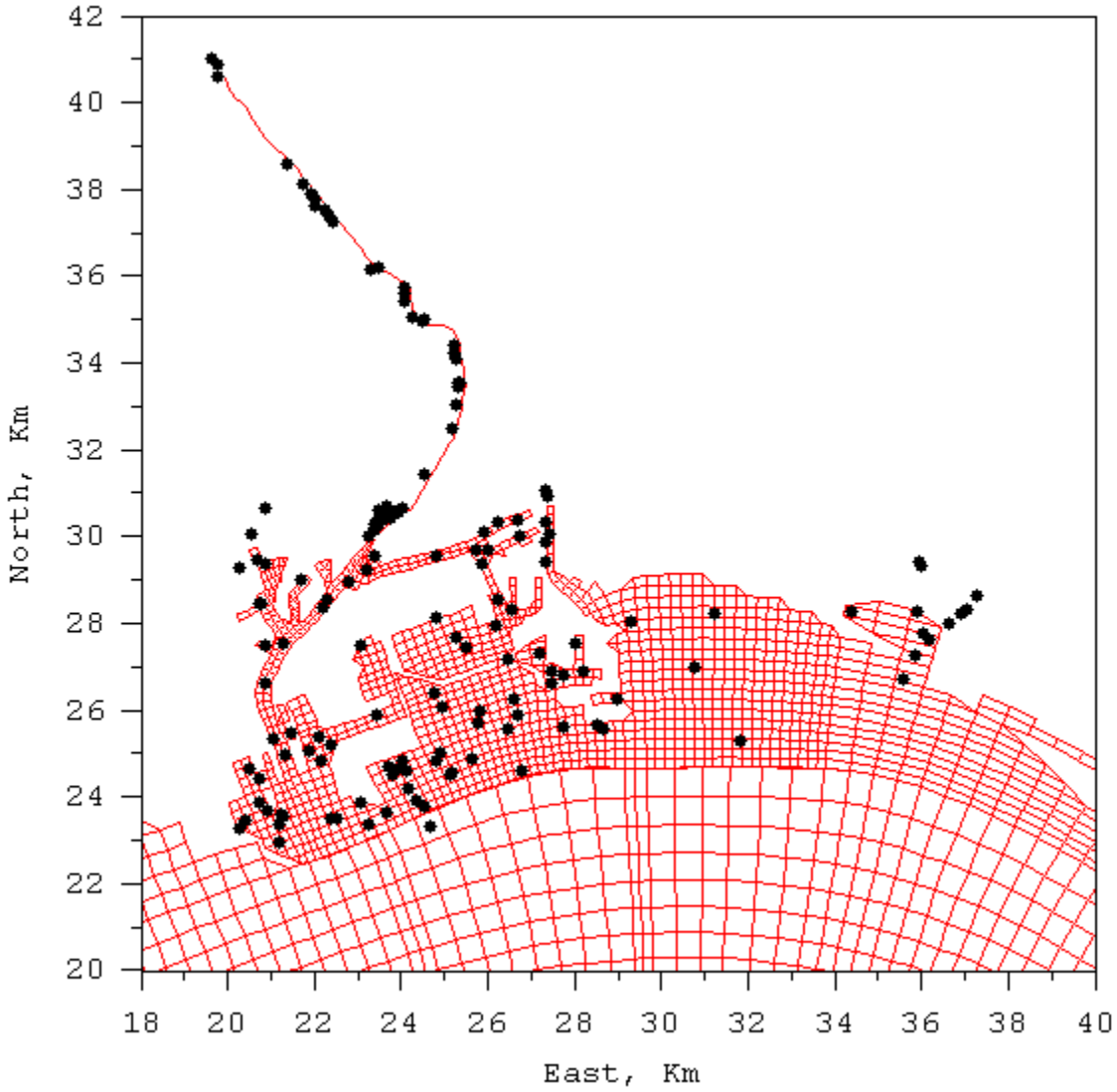
$$V = (\nu g)^{1/3}$$



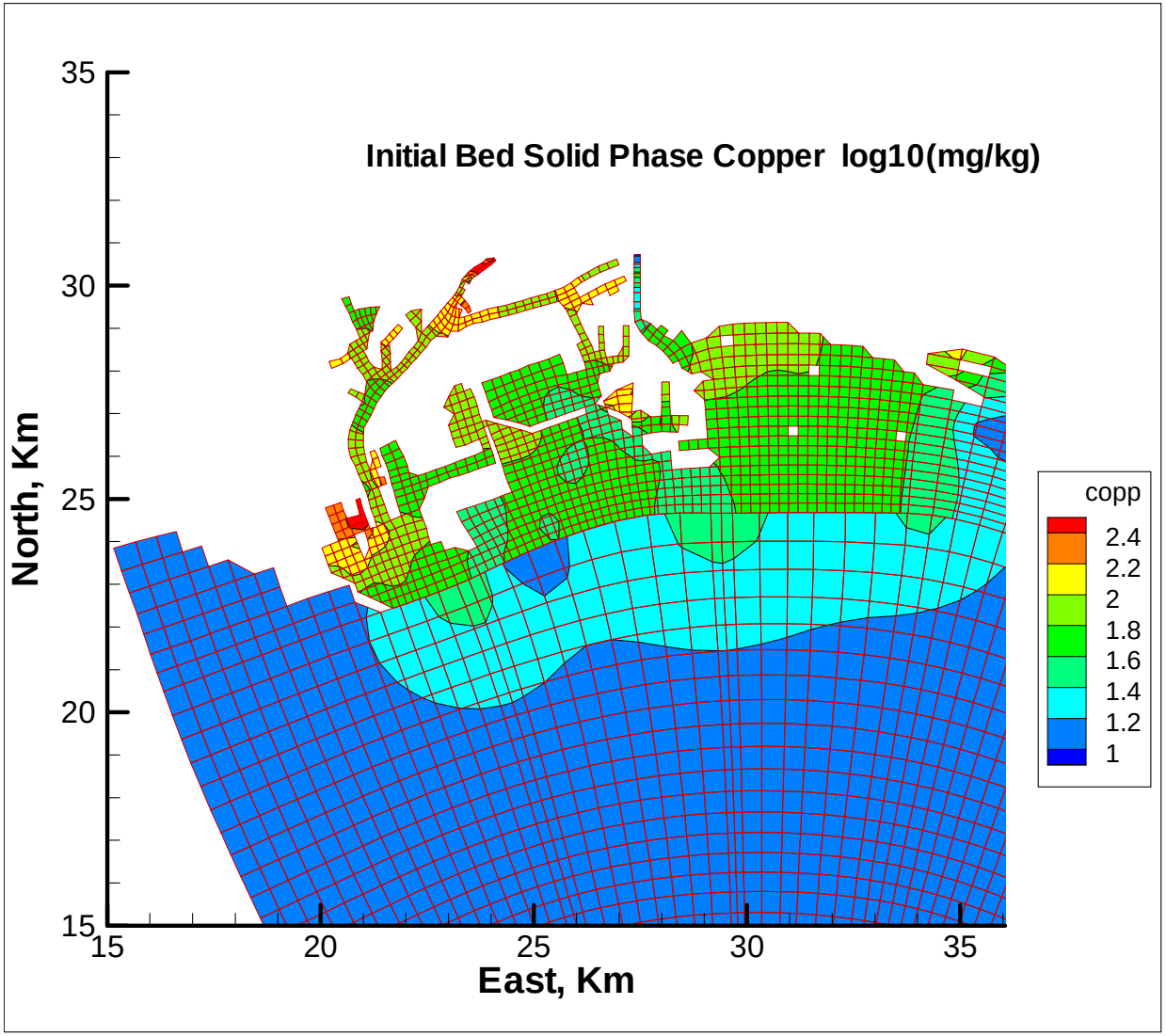
Initialization of the Bed Contaminant Concentrations

- Bed Is Major Reservoir of Contaminants
- Model Needs Total Concentration or Mass per Sediment Mass Concentration
- Depending on Partitioning Option, POC, FPOC, and/or Pore Water DOC May Be Needed
- Best Data Has Dissolved and Particulate Concentration and Appropriate OC Data
- Worst Data Has Total or Mass/Mass Concentration
- No Data In San Pedro Bay (except DDT)

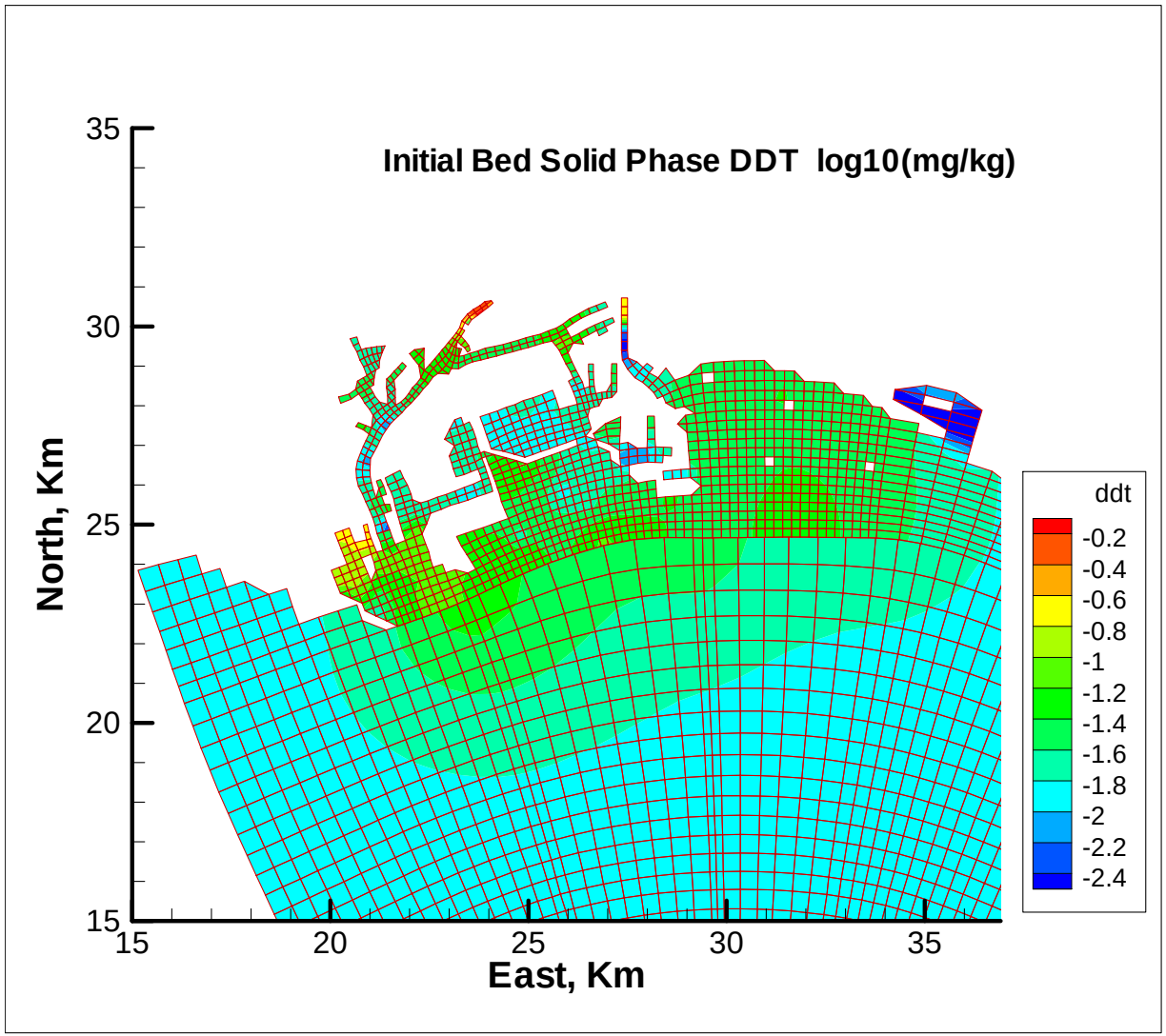
All Data Sites Used to Initialize Sediment Bed Metals and Organics Concentrations (Includes 2006 Sites)



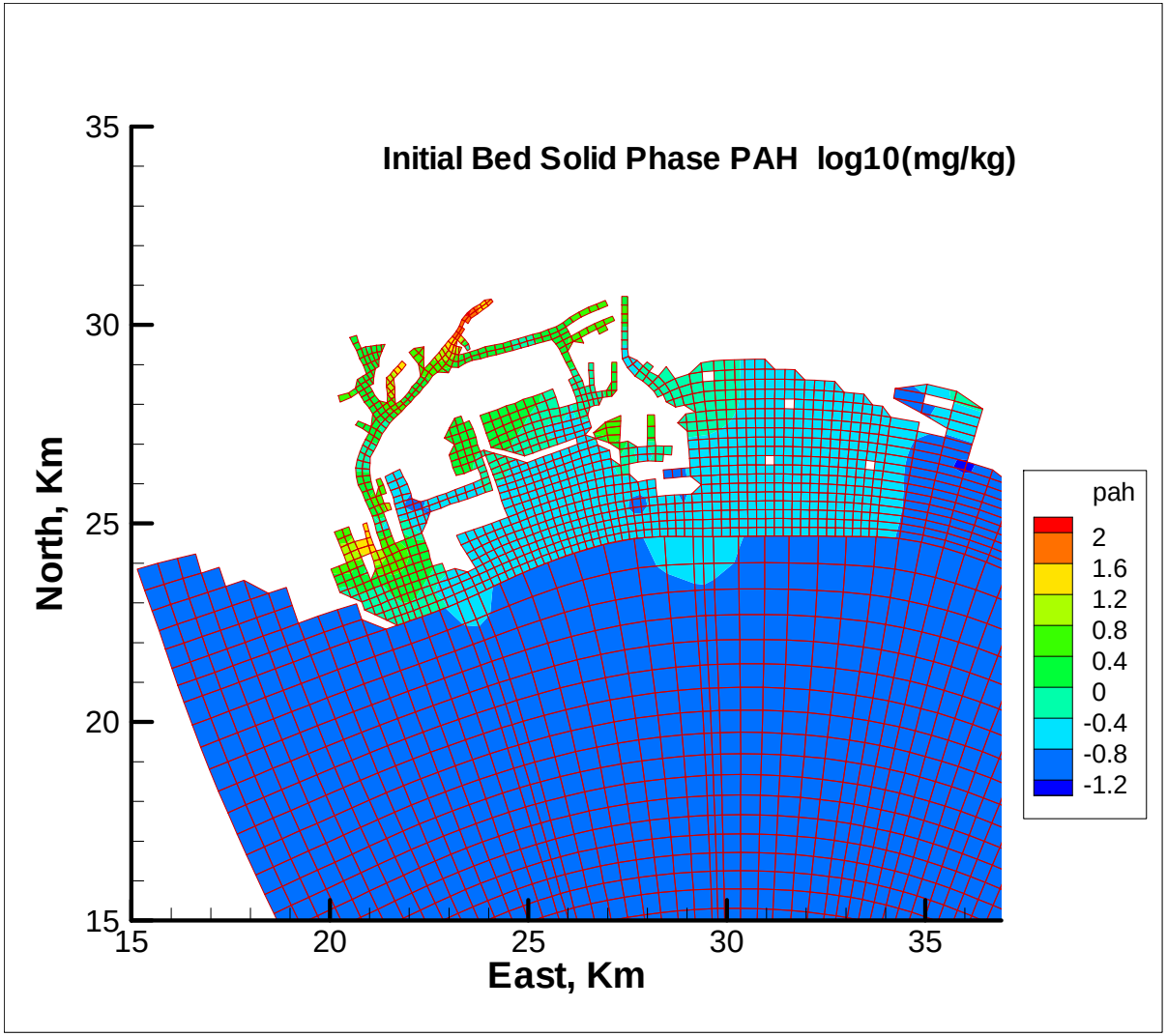
Bed Copper Initial Condition



Bed DDT Initial Condition



Bed PAH Initial Condition



Contaminant Transport Configuration: Partition Coefficients

- Choice Between 2 or 3 Phase Partitioning
- 2 Phase: Particulate and Dissolved
  - Inorganic Sediment, POC, or TOC Can Be Particulate Phase
- 3 Phase: Particulate, DOC Adsorbed Dissolved, and Free Dissolved
  - Requires Specification of Sediment Pore Water and Water Column DOC
- 2006 Bed Data Used to Estimate Partition Coefficients for Metals and Organics
- 2005/06 Water Column Data Used to Confirm Metals Partition Coefficients in WC

Simplified Equilibrium Partitioning

$$C_d = \left(\frac{n}{n + S \bullet K_p} \right) C = dissolved \ \ per \ total \ volume$$

$$C_p = \left(\frac{S \bullet K_p}{n + S \bullet K_p} \right) C = particulate \ \ per \ total \ volume$$

$$C = contaminant \ concentration \ \ per \ total \ volume$$

$$n = porosity$$

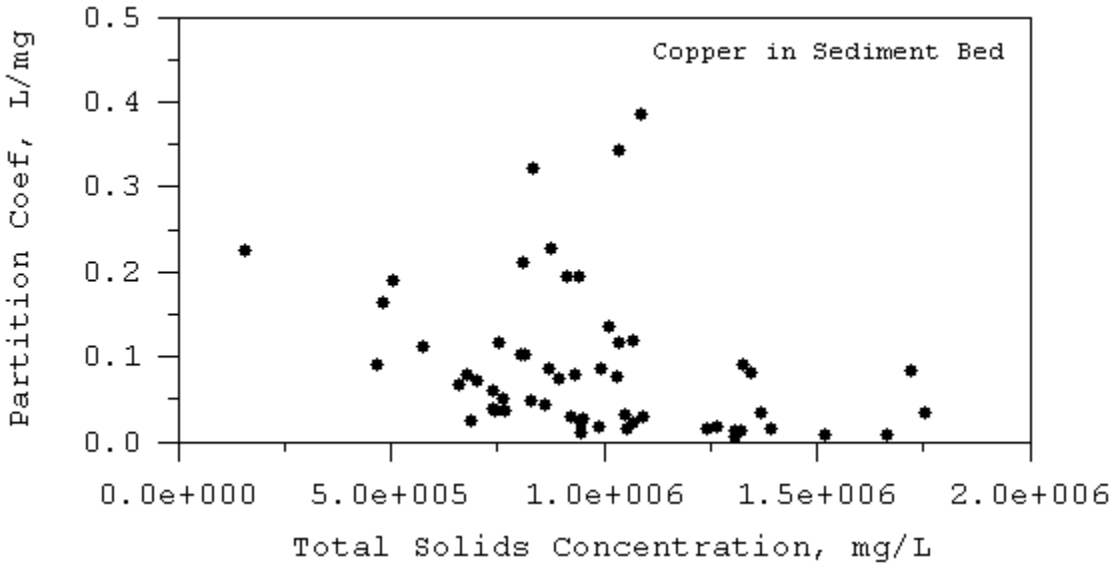
$$S = sediment \ concentration \ \ per \ total \ volume$$

$$K_p = partition \ coefficient$$

$$K_p = \frac{C_p}{S} \bullet \frac{n}{C_d}$$

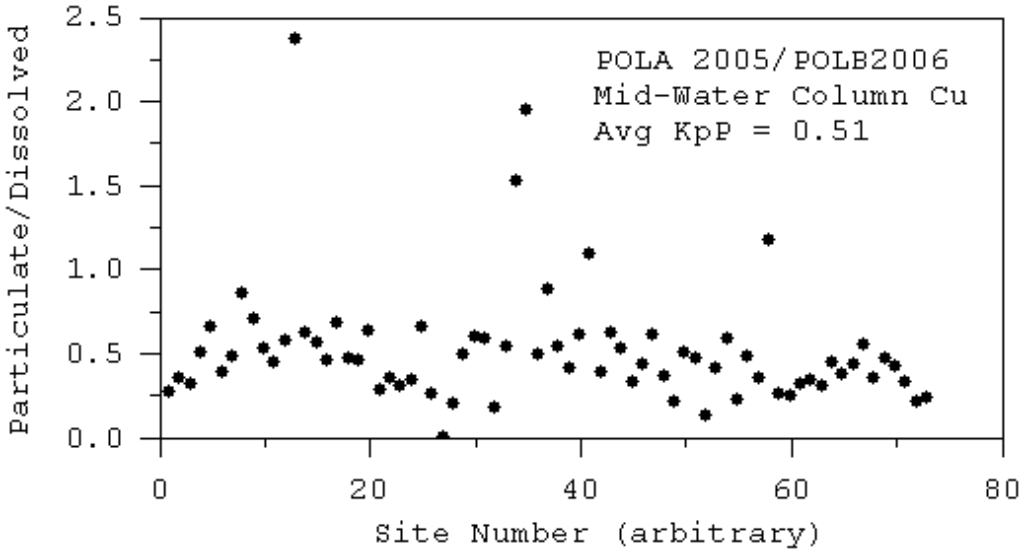
Partition Coefficient Bed

Copper



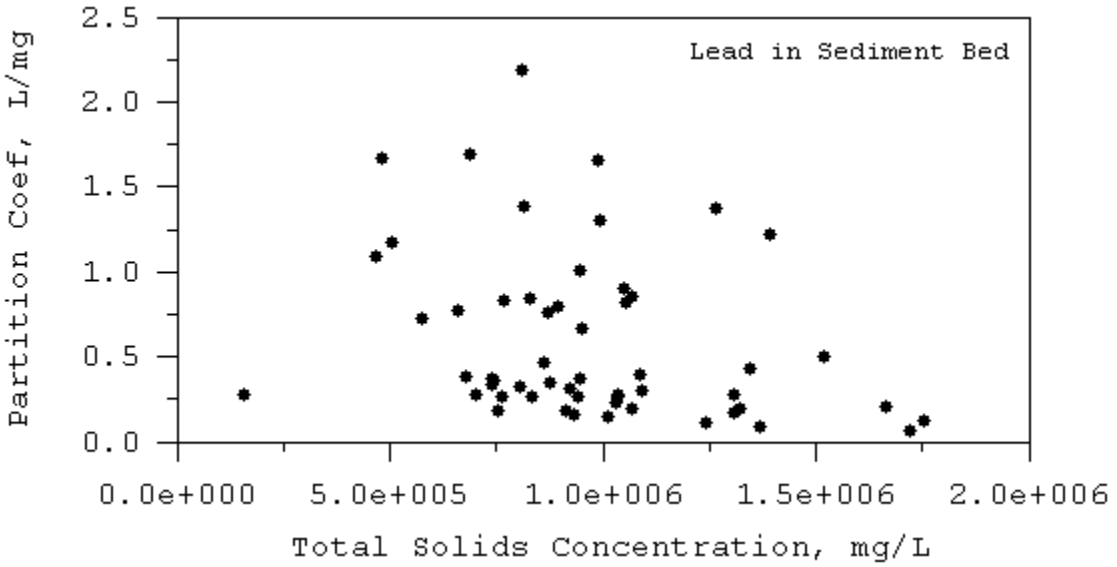
Part/Diss Water Column

(divide by Sed to get Kp)



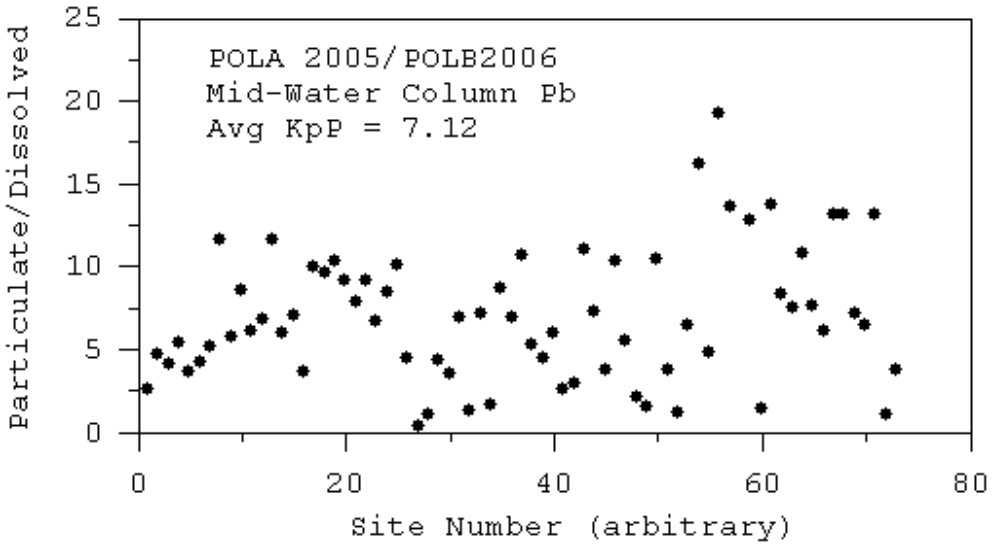
Partition Coefficient Bed

Lead



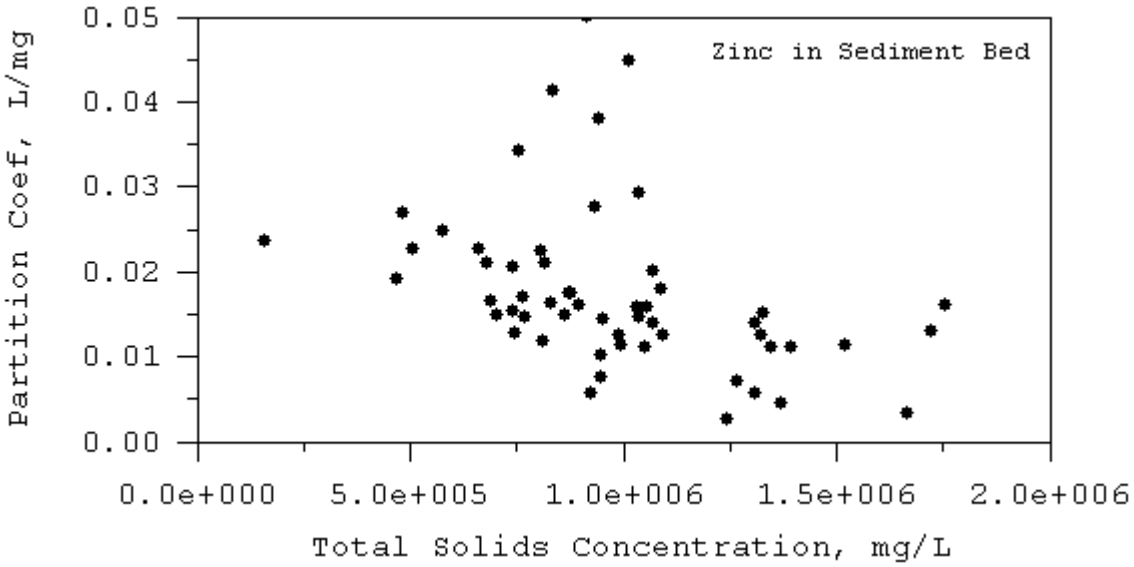
Part/Diss Water Column

(divide by Sed to get Kp)



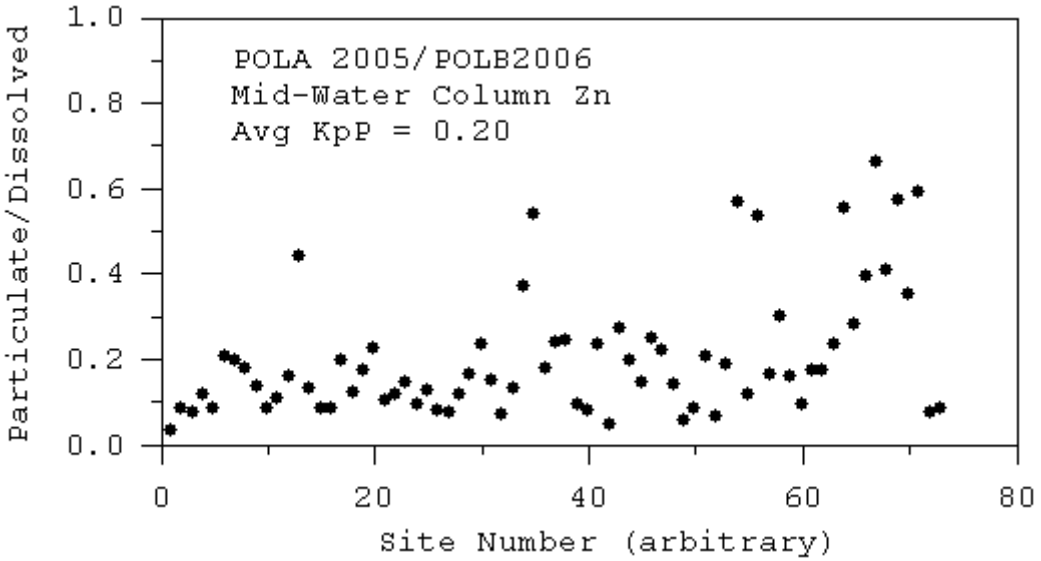
Partition Coefficient Bed

Zinc



Part/Diss Water Column

(divide by Sed to get Kp)



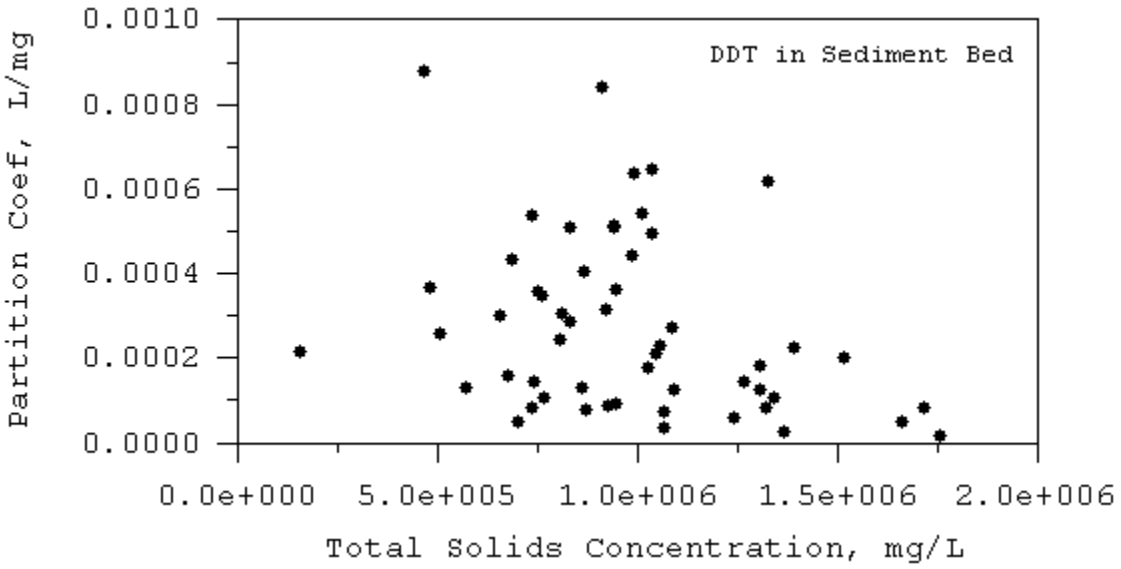
Equilibrium Partition Coefficients and Particulate to Dissolved Concentration Ratios for Metals

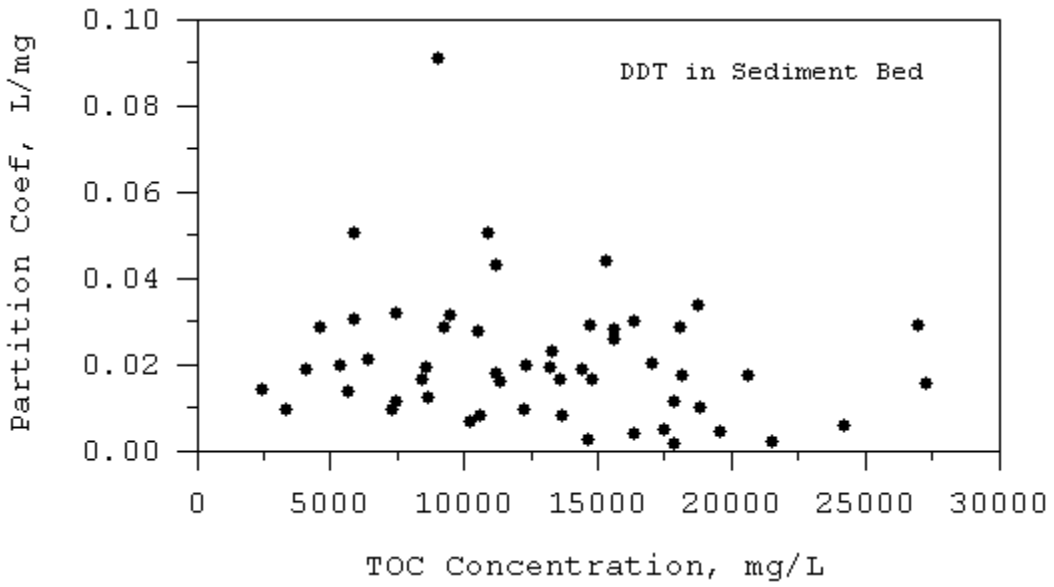
Contaminant	Average Bed Partition Coefficient Based on Total Solids (L/mg)	Visual Best Fit Bed Partition Coefficient Based on Total Solids (L/mg)	Water Column Particulate to Dissolved Concentration Ratio	Estimated Water Column Partition Coefficient, 5 Times Column 3 (L/mg)
Copper	0.09	0.05	0.50	0.25
Lead	0.54	0.25	7.12	1.25
Zinc	0.02	0.01	0.20	0.05

Total Solids

DDT Partition Coefficient Bed

TOC

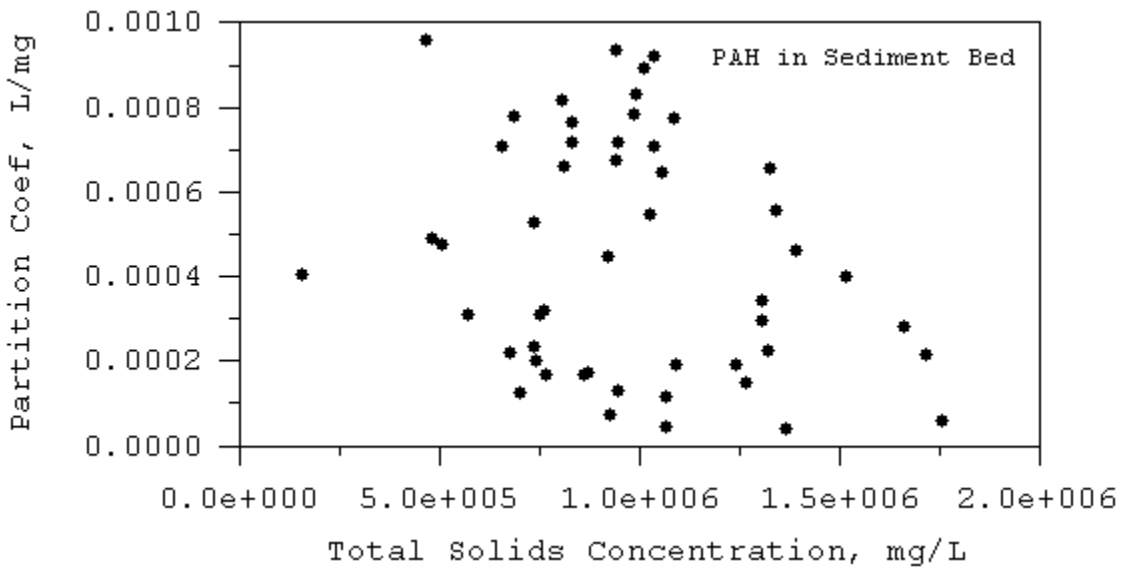


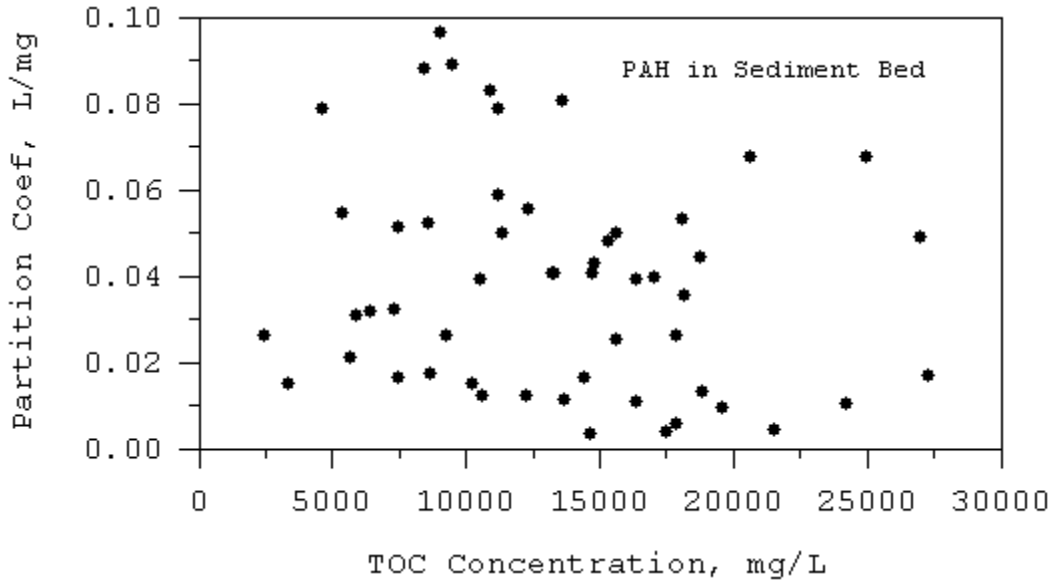


Total Solids

PAH Partition Coefficient Bed

TOC

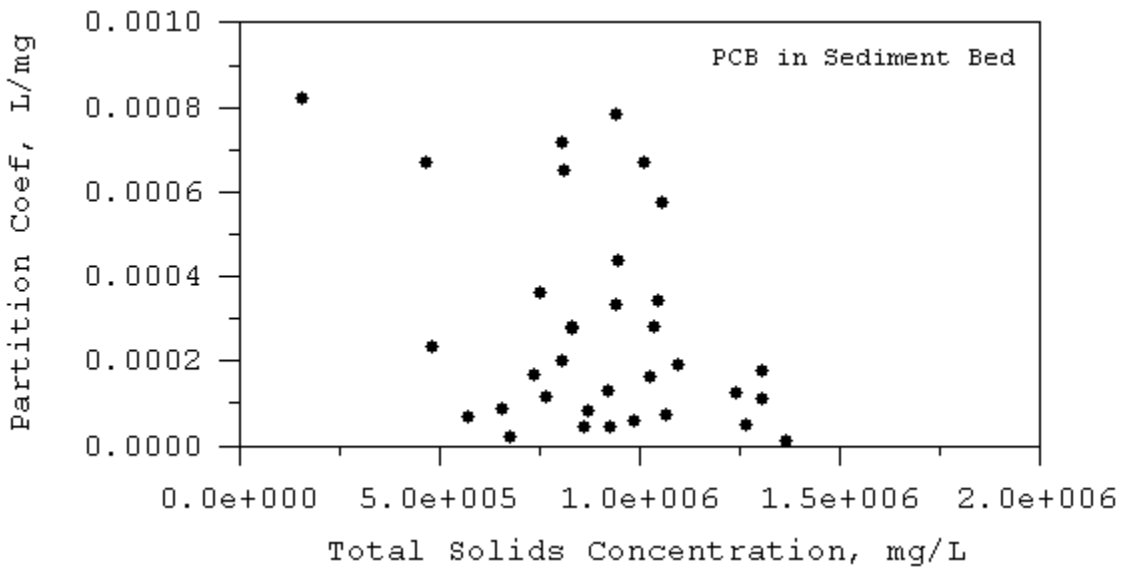


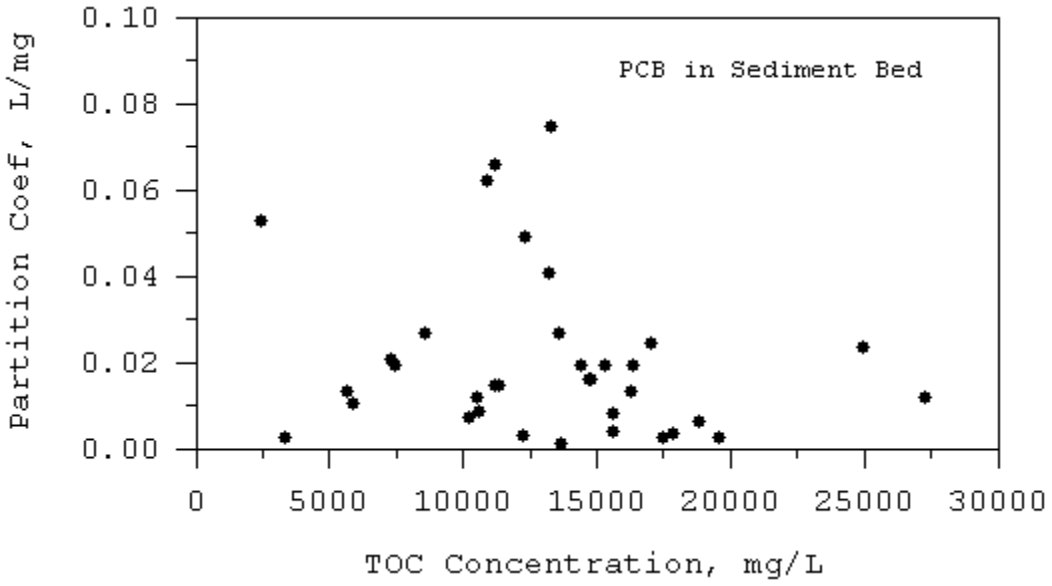


Total Solids

PCB Partition Coefficient Bed

TOC





Equilibrium Partition Coefficients for Organics

Contaminant	Bed Solids (L/mg)	Bed TOC (L/mg)	Low Range TOC Based (L/mg)	High Range TOC Based (L/mg)
DDT	0.0002	0.02	0.0002	0.2
PAH	0.0004	0.04	0.01	2.0
PCB	0.0002	0.02	0.005	0.5

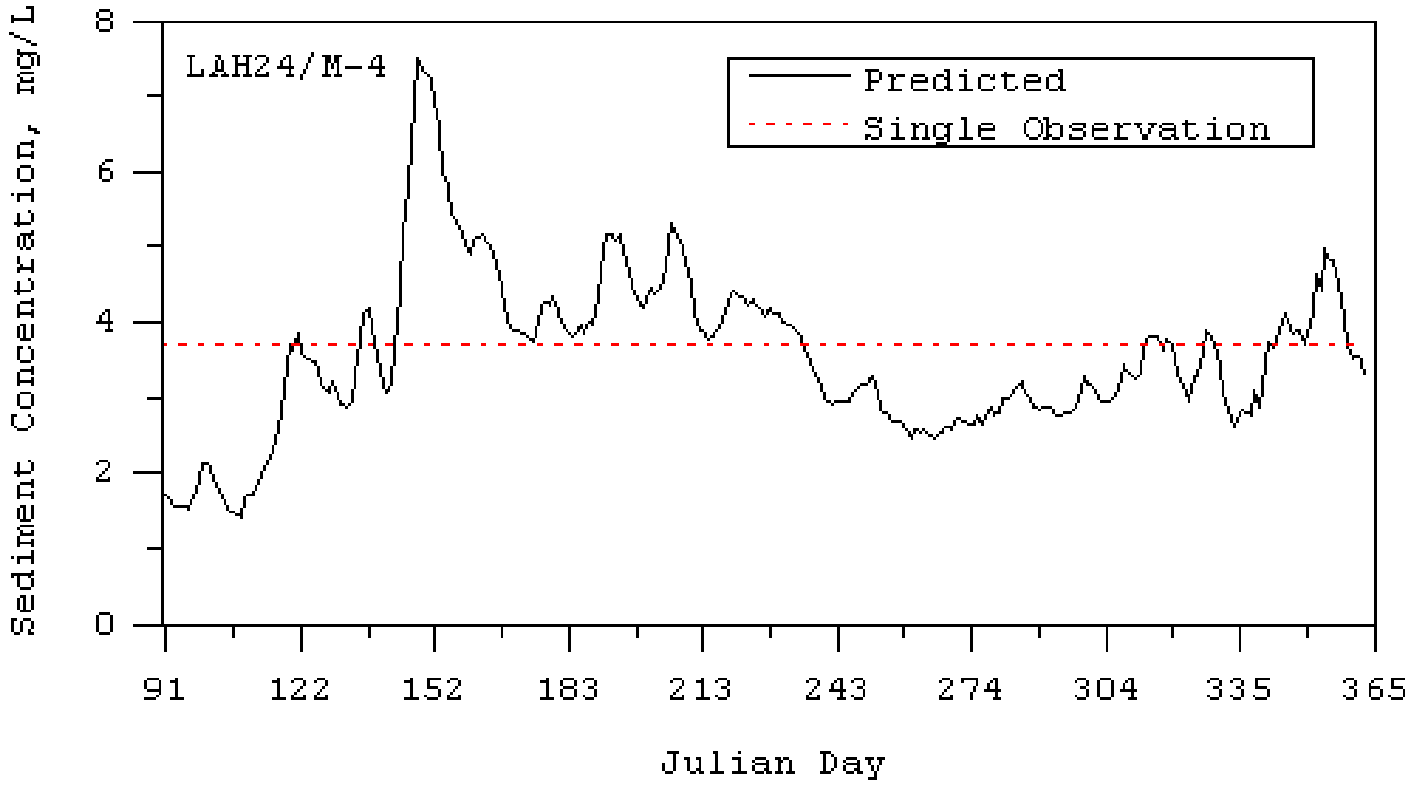
Sediment Transport Model Calibration Approach

- Calibrate Sediment Transport First
  - Water Column Sediment Concentrations Strongly Influence WC Contaminant Concentrations
- Calibrate to Observed Water Column Sediment Concentrations
  - Not Much Observational Data to Do This, Particularly During Events
  - 2006 Overlying Water Observation Significant In Determining Near Bottom Sediment Dynamics

Sediment Transport Model Calibration Approach

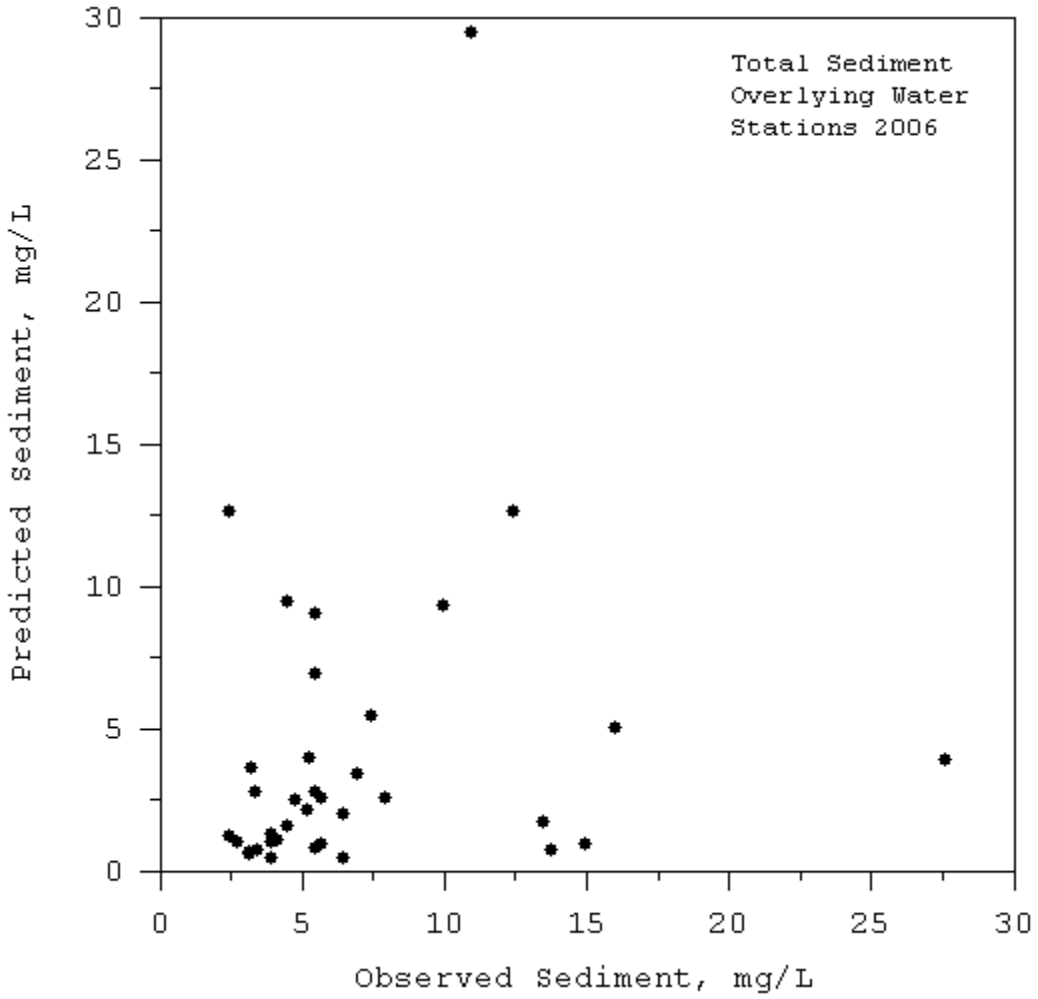
- Watershed Sediment Loads Can Be Adjusted for Calibration
- Calibration Parameters for Fine or Cohesive Behaving Sediment
  - Settling Velocity and Critical Stress for Deposition
  - Critical Stress for Erosion and Erosion Rate (and Formulation)
  - Splits of Watershed Sediment Loads Between Sand, Silt, and Clay

Example of Comparison of Single Observation Extended Interval Model Prediction



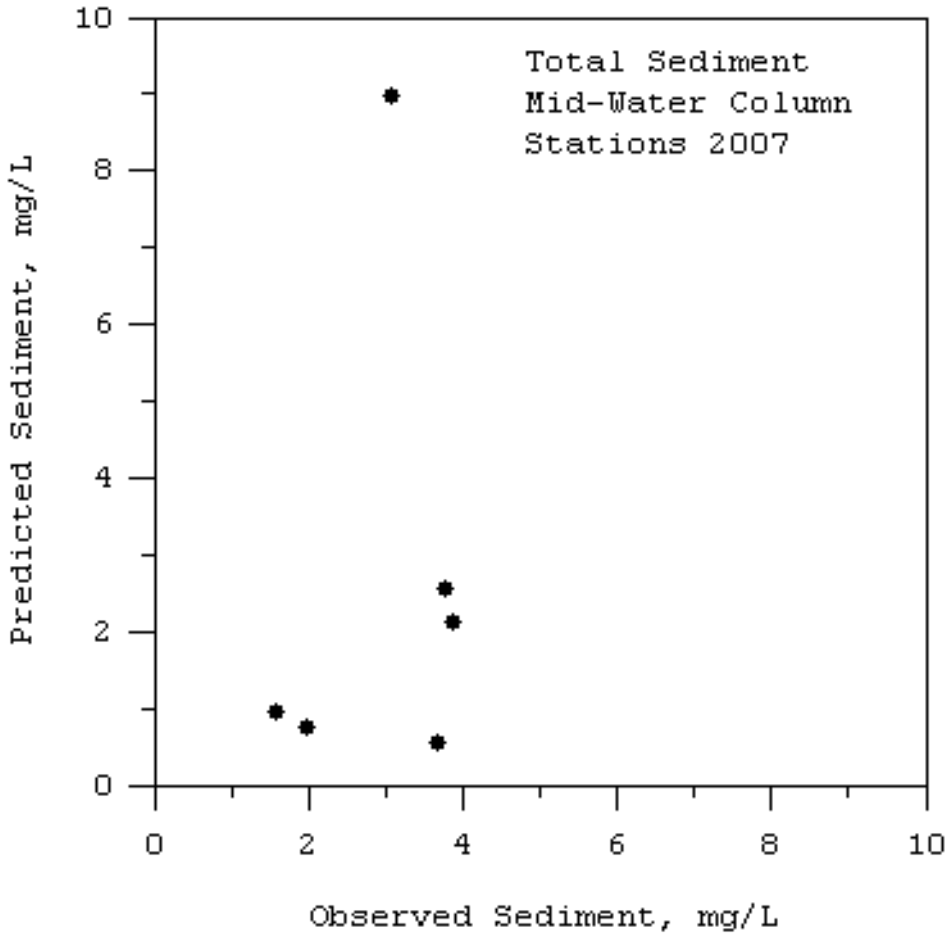
Sediment Transport Model Calibration Results

- Comparison of 2006 Overlying Water and Predicted Mean Dry Weather Concentrations



Sediment Transport Model Calibration Results

- Comparison of 2007 POLA Mid-Water and Predicted Mean Dry Weather Concentrations

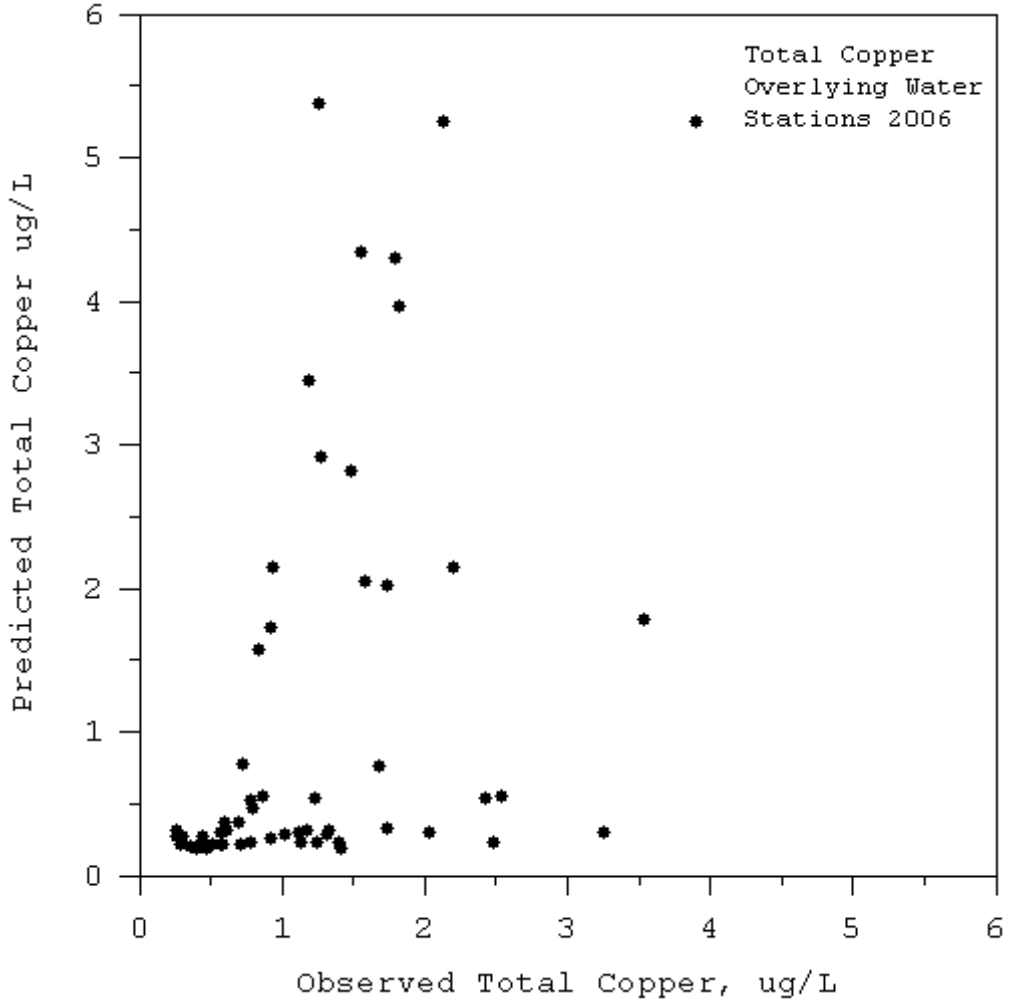


Contaminant Transport Model Calibration Approach

- Calibrate to Observed Water Column Contaminant Concentrations
- Watershed Contaminant Loads Can Be Adjusted for Calibration
- Partition Coefficients Can Be Adjusted for Calibration

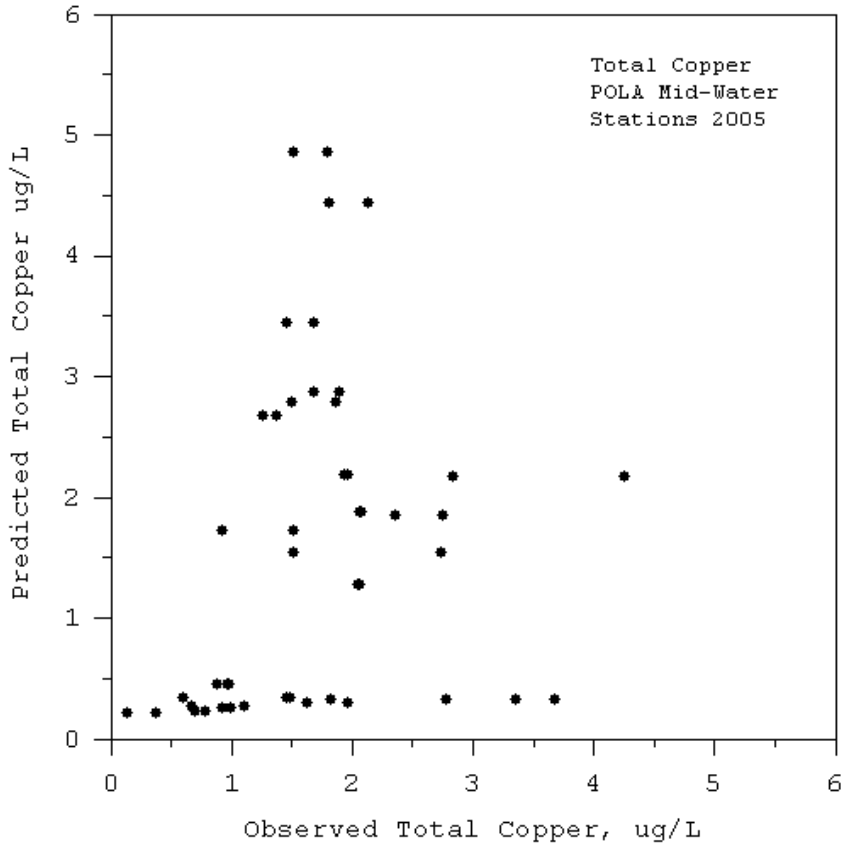
Contaminant Transport Model Calibration Results

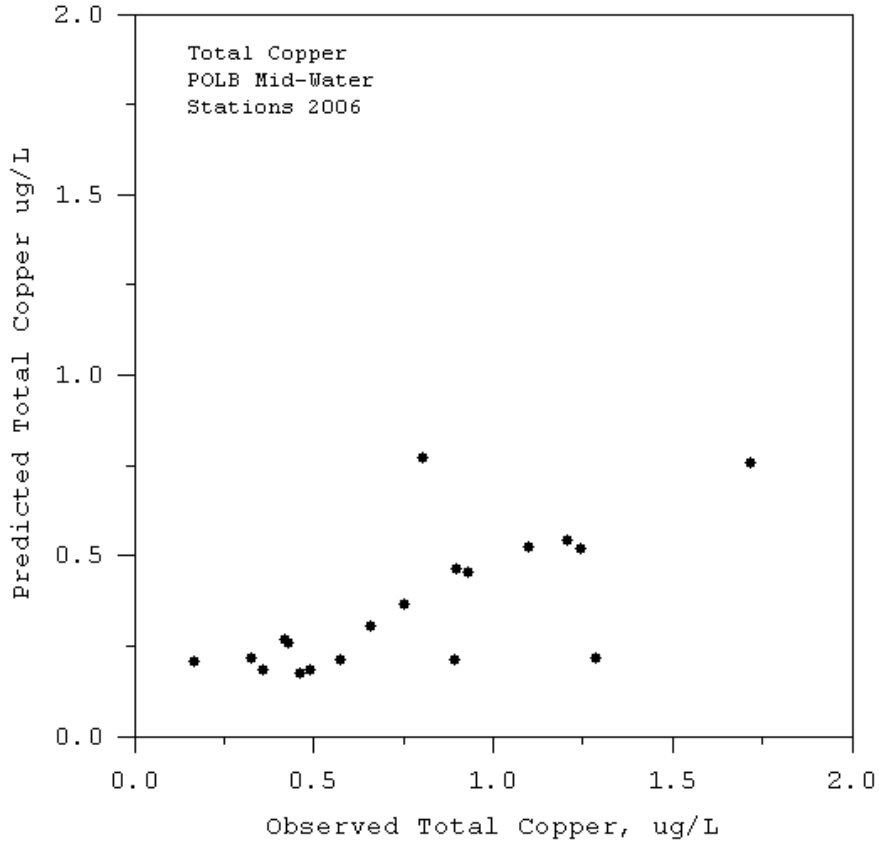
- Comparison of 2006 Overlying Water and Predicted Mean Dry Weather Concentrations of Copper



Contaminant Transport Model Calibration Results

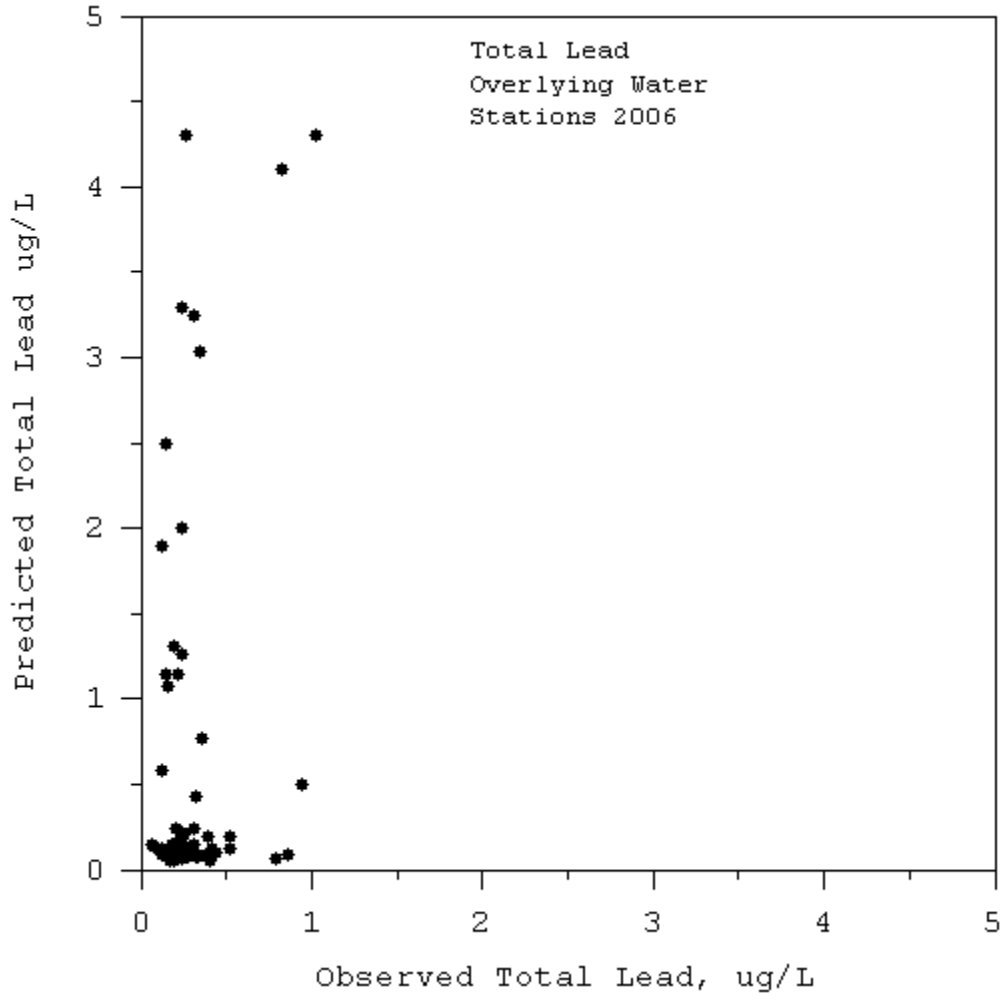
- Comparison of 2005 POLA and 2006 POLB Mid-Water and Predicted Mean Dry Weather Concentrations of Copper





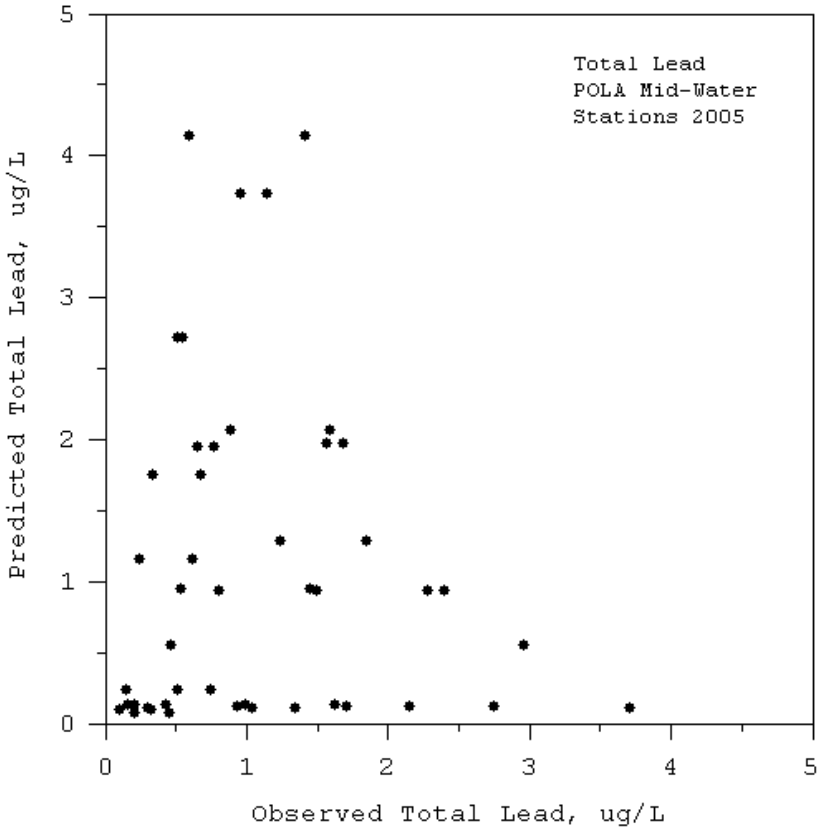
Contaminant Transport Model Calibration Results

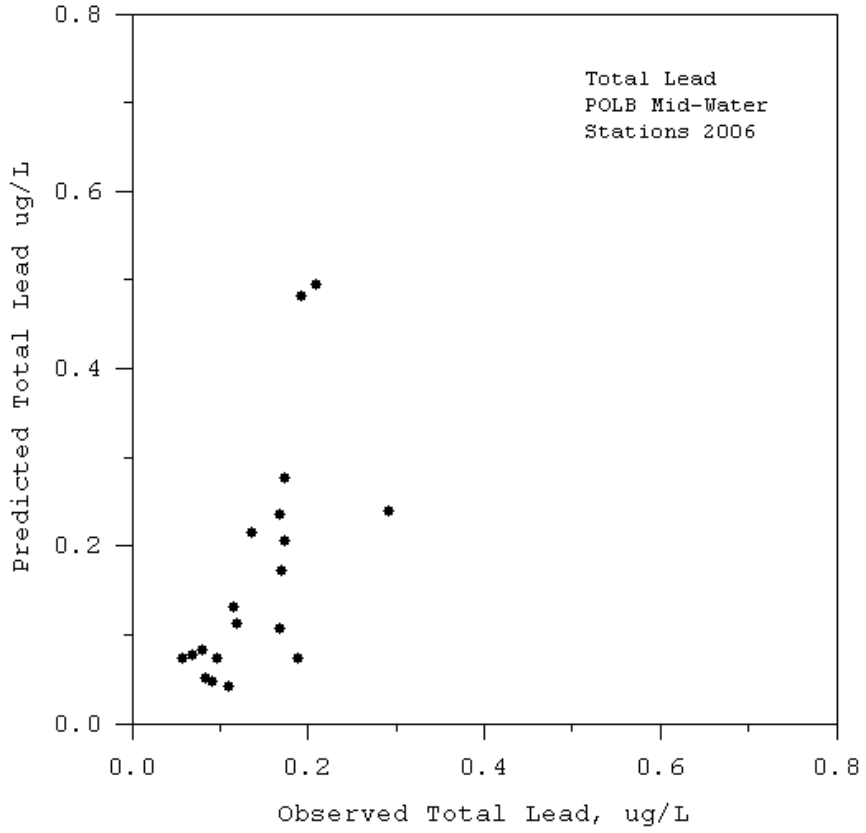
- Comparison of 2006 Overlying Water and Predicted Mean Dry Weather Concentrations of Lead



Contaminant Transport Model Calibration Results

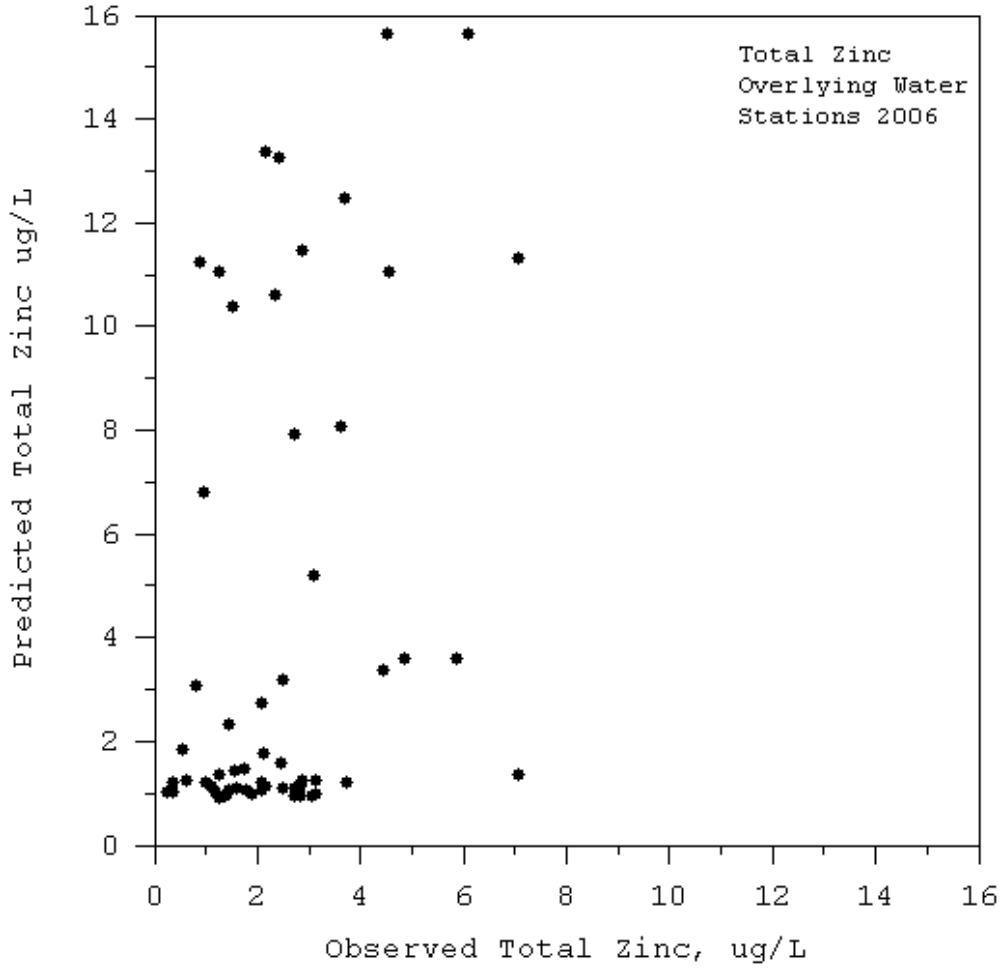
- Comparison of 2005 POLA and 2006 POLB Mid-Water and Predicted Mean Dry Weather Concentrations of Lead





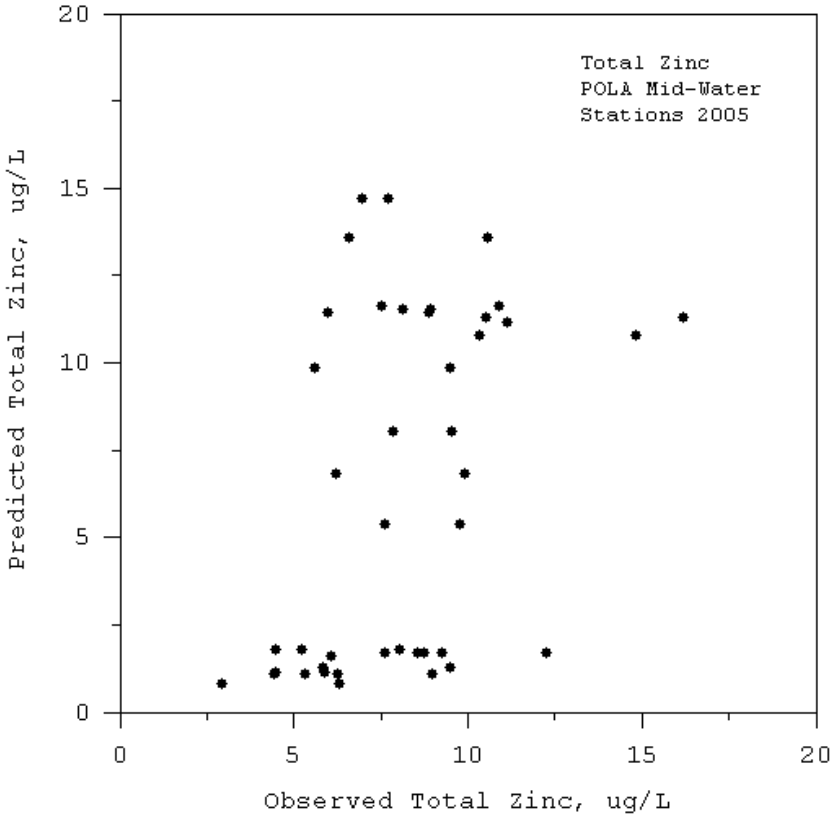
Contaminant Transport Model Calibration Results

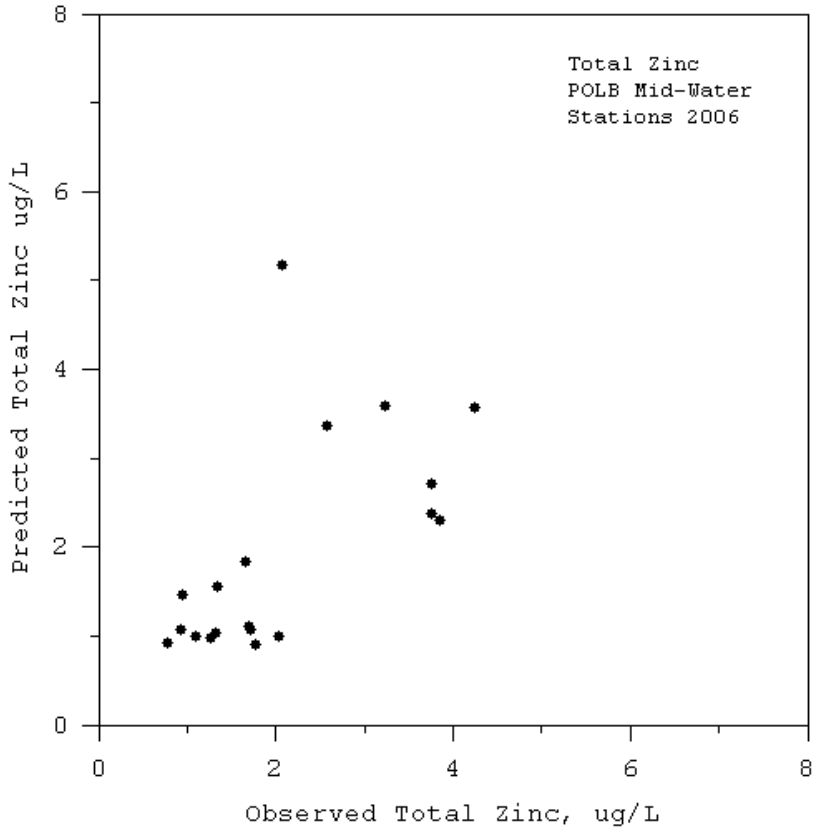
- Comparison of 2006 Overlying Water and Predicted Mean Dry Weather Concentrations of Zinc



Contaminant Transport Model Calibration Results

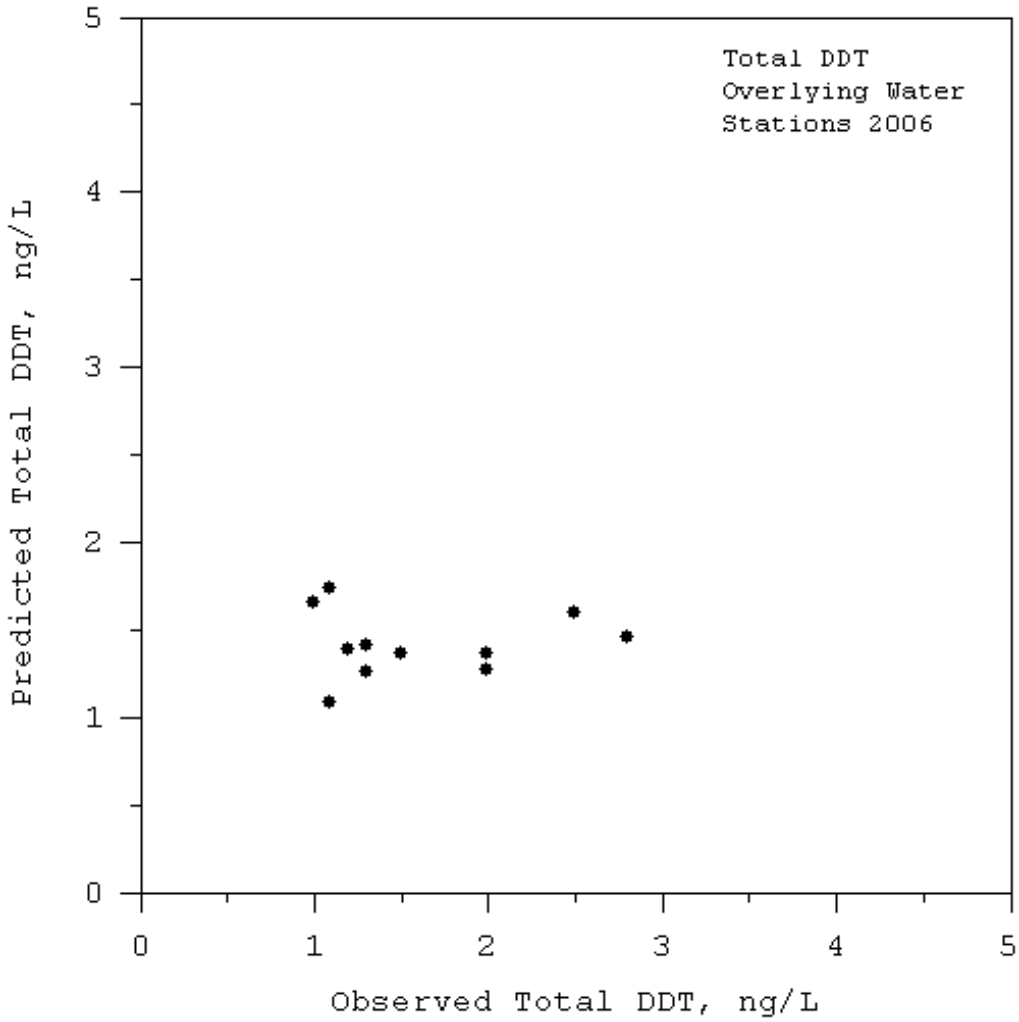
- Comparison of 2005 POLA and 2006 POLB Mid-Water and Predicted Mean Dry Weather Concentrations of Zinc





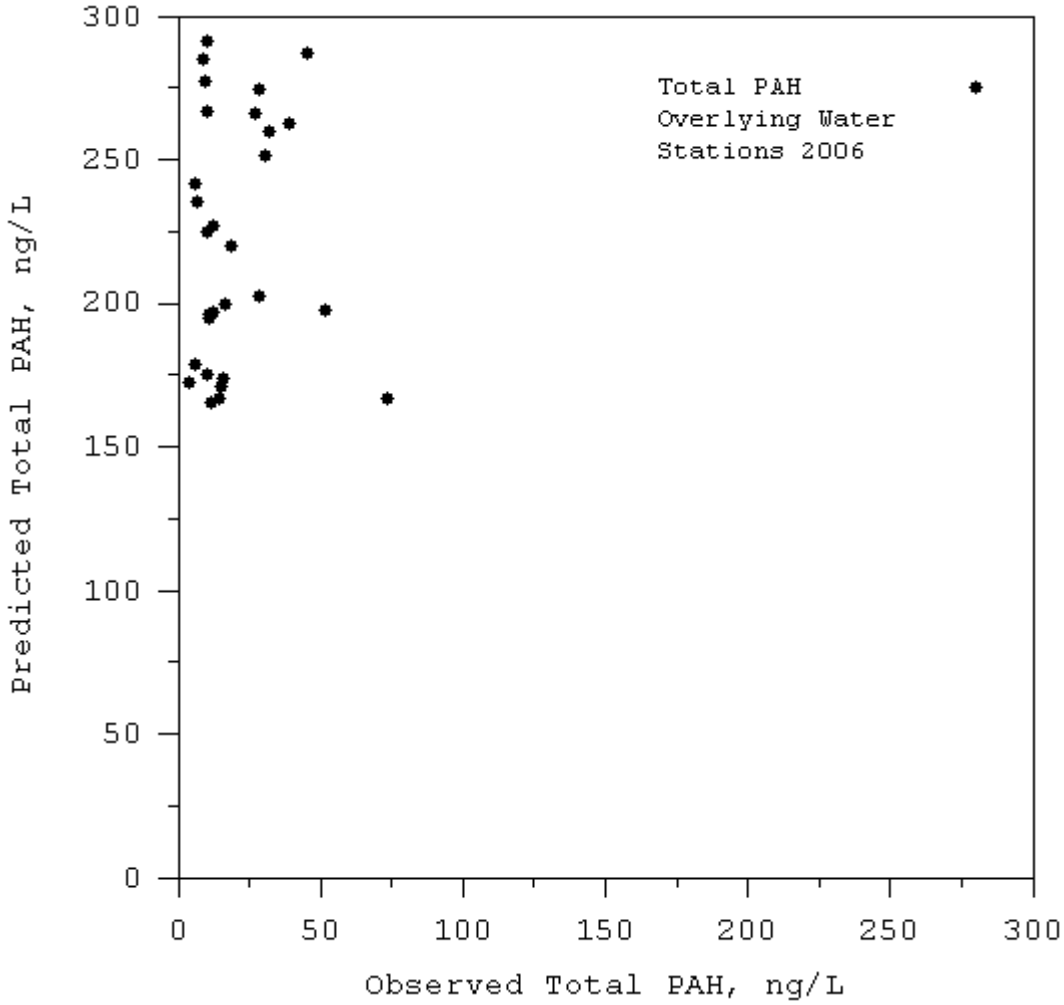
Contaminant Transport Model Calibration Results

- Comparison of 2006 Overlying Water and Predicted Mean Dry Weather Concentrations of DDT



Contaminant Transport Model Calibration Results

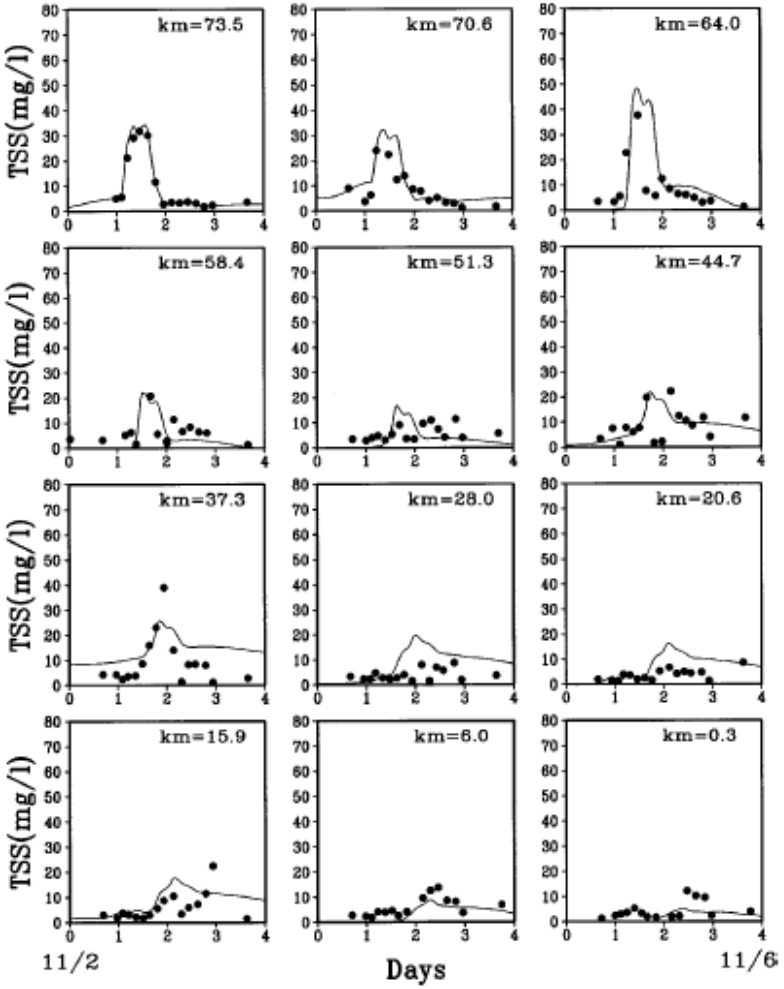
- Comparison of 2006 Overlying Water and Predicted Mean Dry Weather Concentrations of PAH

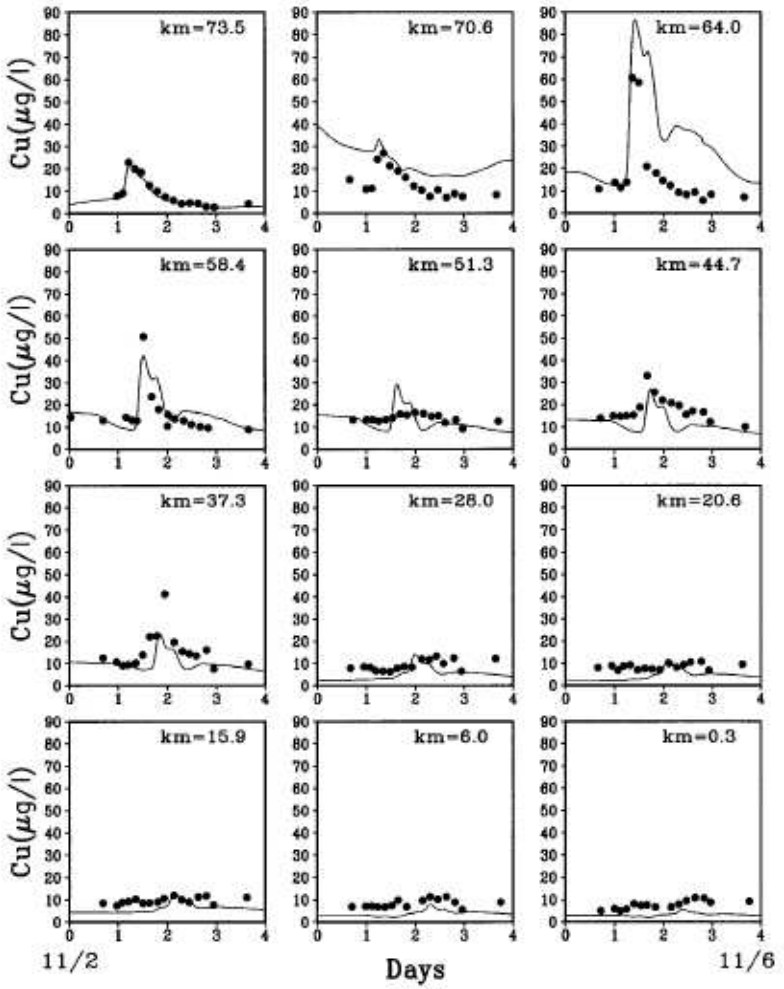


Sediment and Contaminant Calibration Evaluation

- Sparse Data Hinders Definitive Use of Traditional Quantitative Measures
- Model Predictions Are Within Order of Magnitude of Observations
- Compare Calibration Results With Other Similar Studies
- Use Sensitivity Analysis to Demonstrate Best Results Have Been Achieved

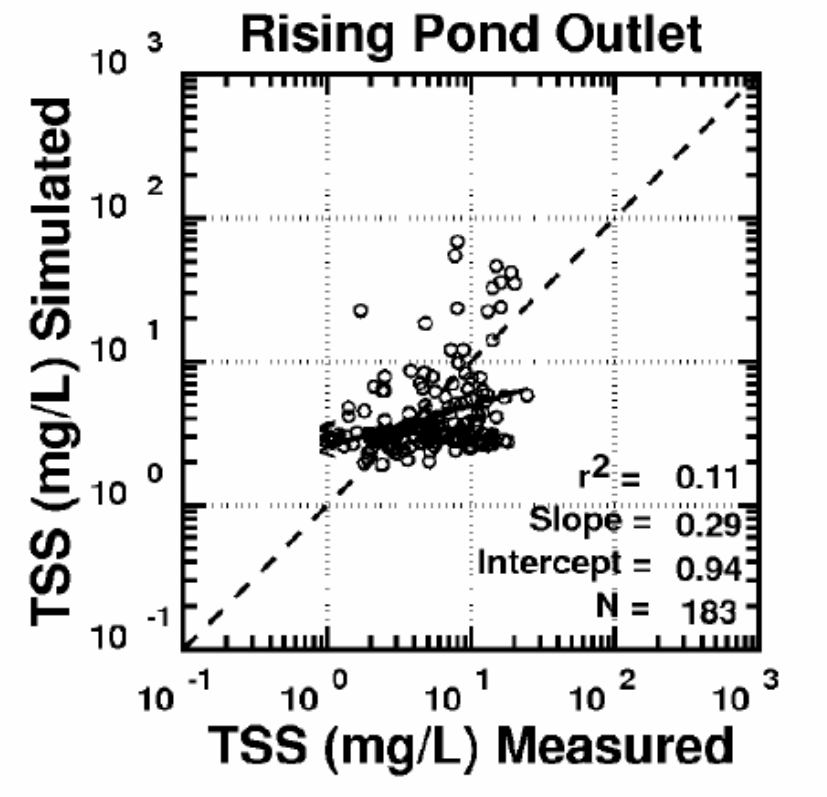
Example of Metals Modeling Results (Ji, Hamrick, & Pagenkopf, J. Environ. Engrg., 2002)

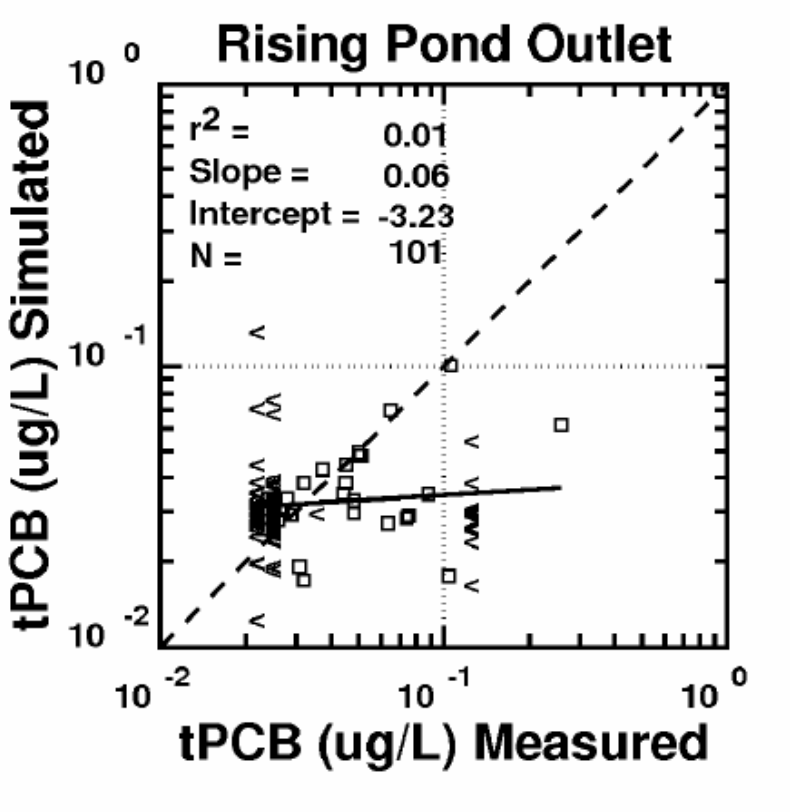




Example of Sediment and PCB Modeling Results

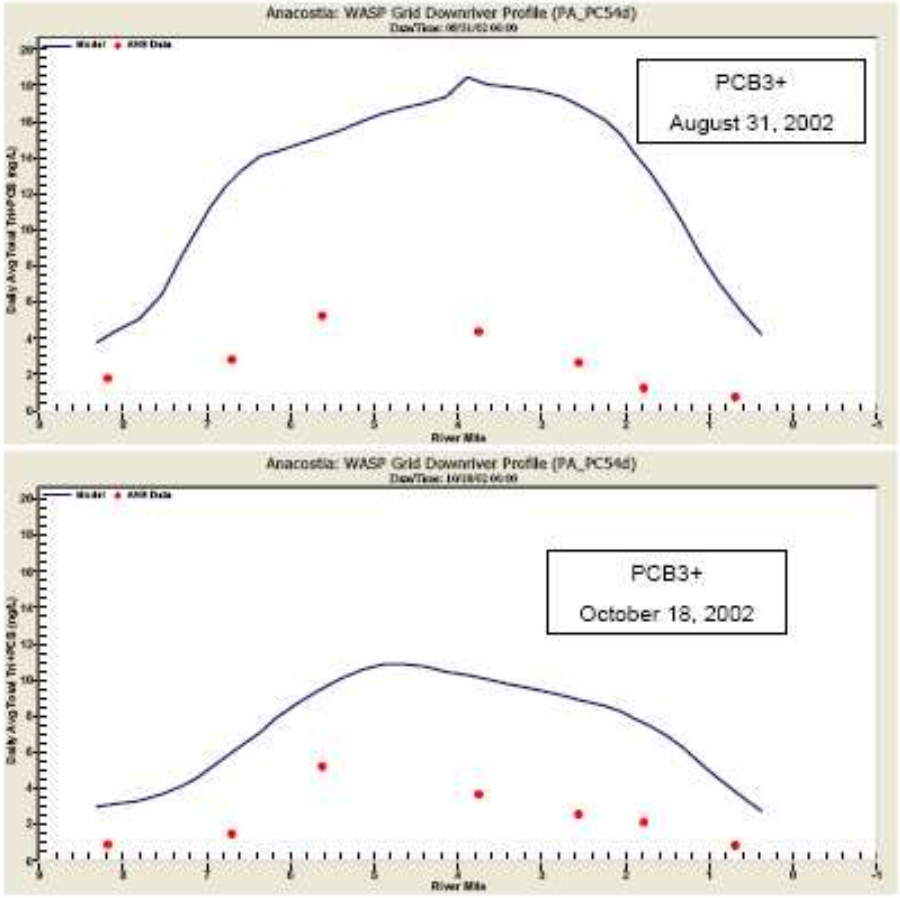
(Hayter, E.J. 2006. Evaluation of the State-of-the-Art Contaminated Sediment Transport and Fate Modeling System. U.S. EPA NERL, Athens, GA.Pub. No. EPA/600/R-06/108)





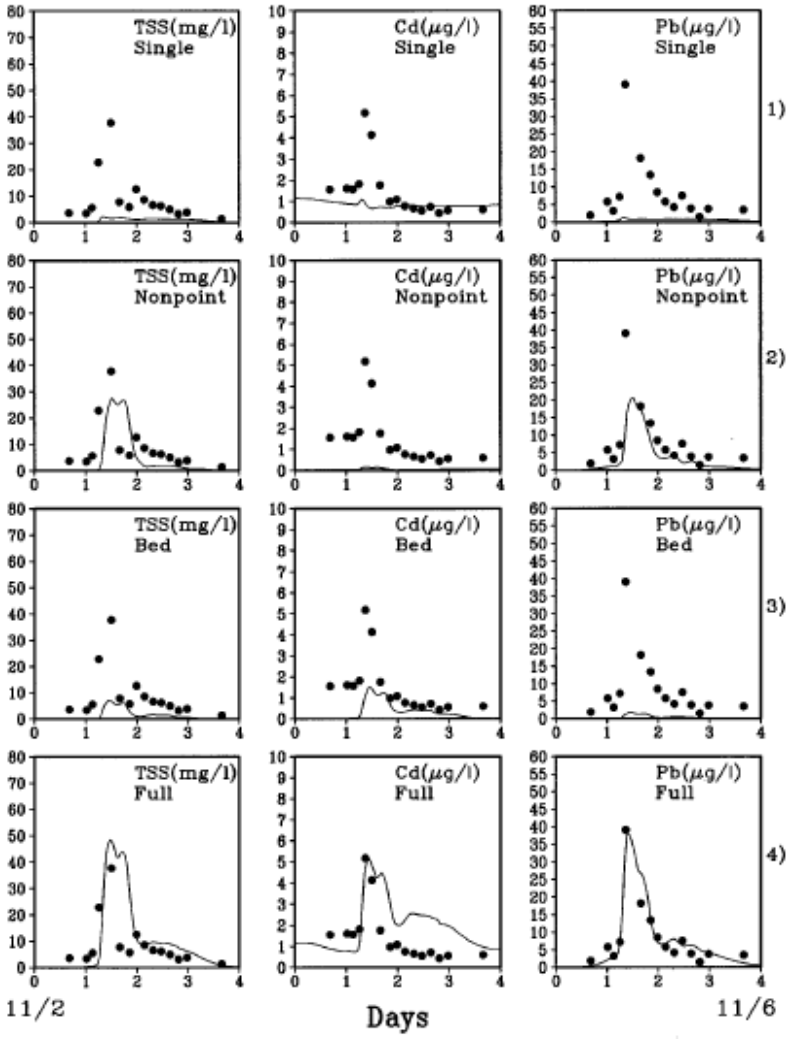
Example of PCB Modeling Results

(PCB TMDL Model for the Potomac River Estuary, LimnoTech, EPA Contract No. 68-C-03-041, Work Assignment No. 4-34, , 2007)



Spatial Profiles of Computed and Observed Daily Average PCB3+ in Anacostia on August 31 and October 18, 2002

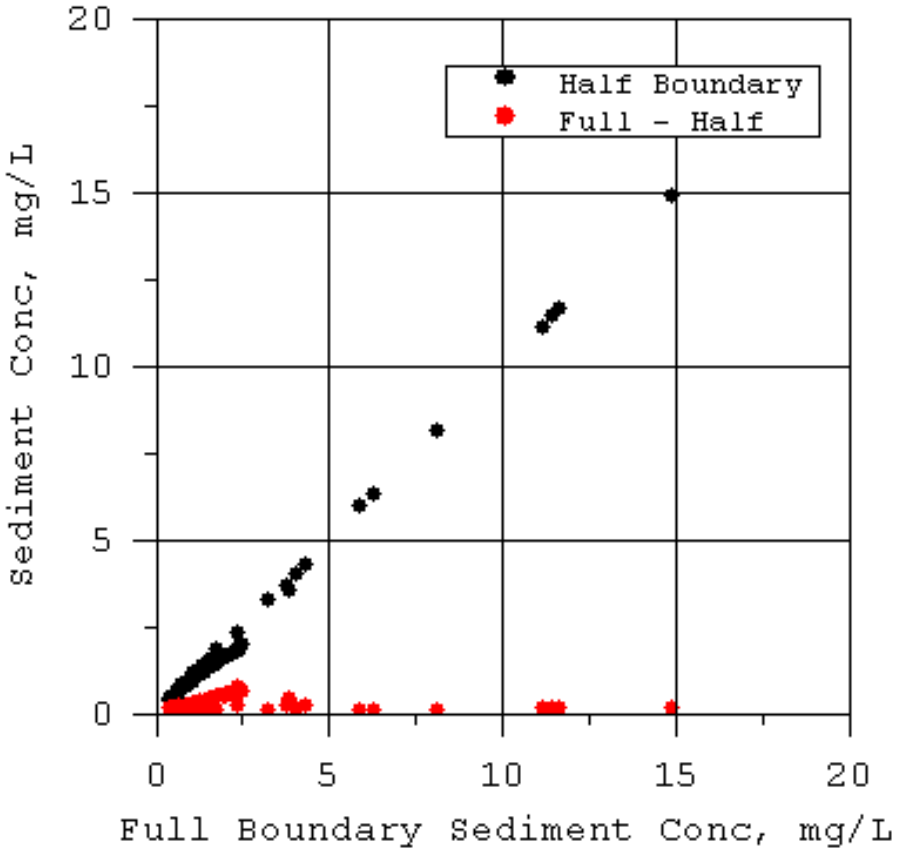
Example of Source Sensitivity
(Ji, Hamrick, & Pagenkopf: J. Environ. Engrg., 2002)

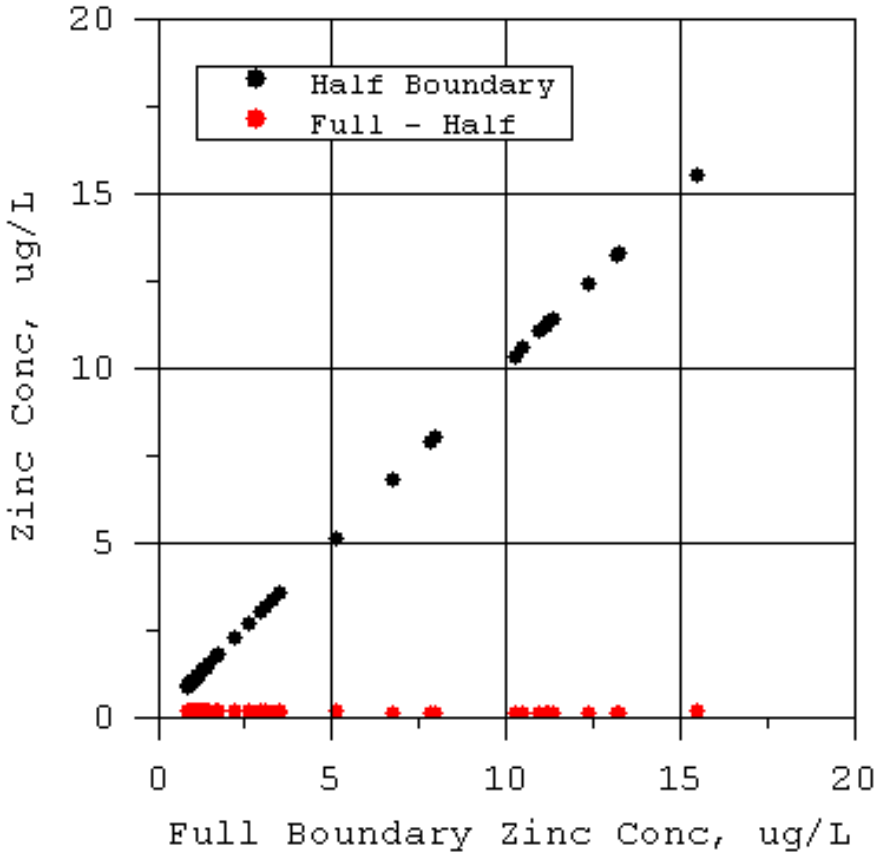


Sediment and Contaminant Transport Sensitivity

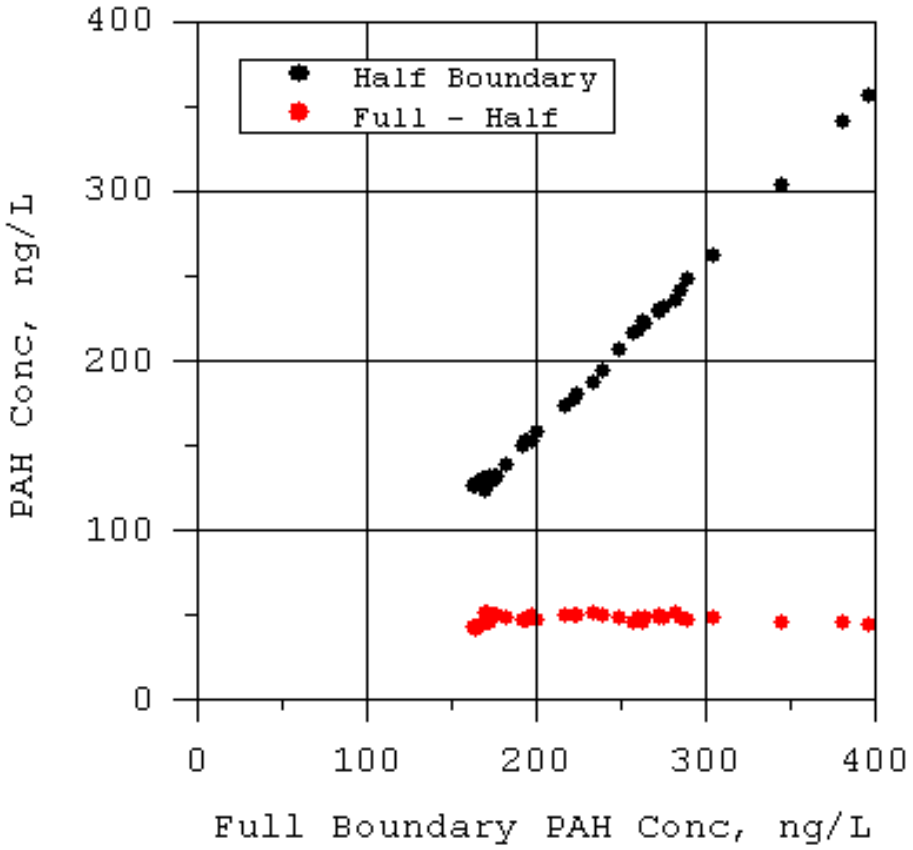
- Preliminary Sensitivity Analysis
- Open Boundary Concentrations
  - Not Controllable
  - Low Sensitivity Desirable
- River and Watershed Loads
  - Controllable
- Bed Erosion Rate
  - Controllable Over Very Limited Area
  - Use to Evaluate Importance of Bed Source
- Approach Uses Simple Halving of Calibration Values

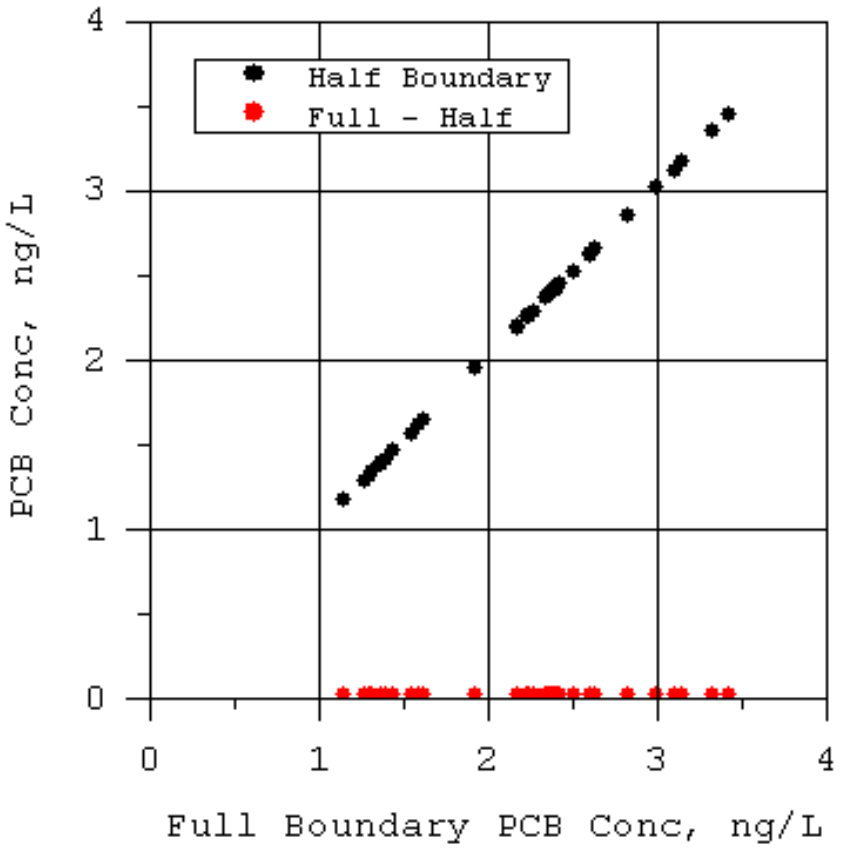
Open Boundary Concentration Sensitivity



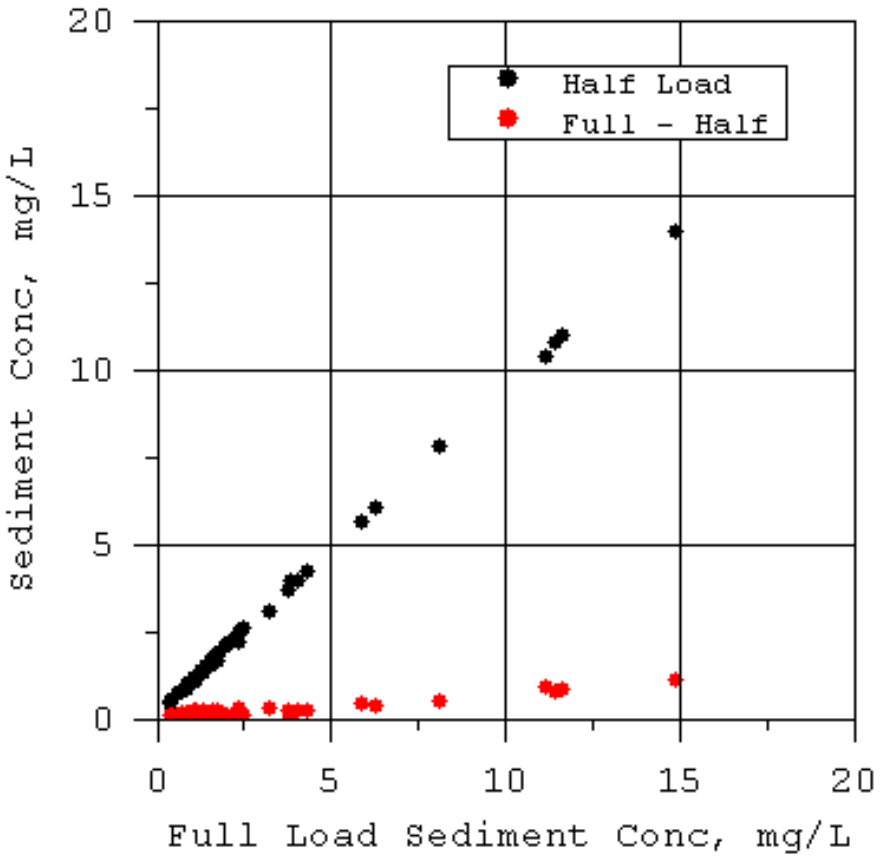


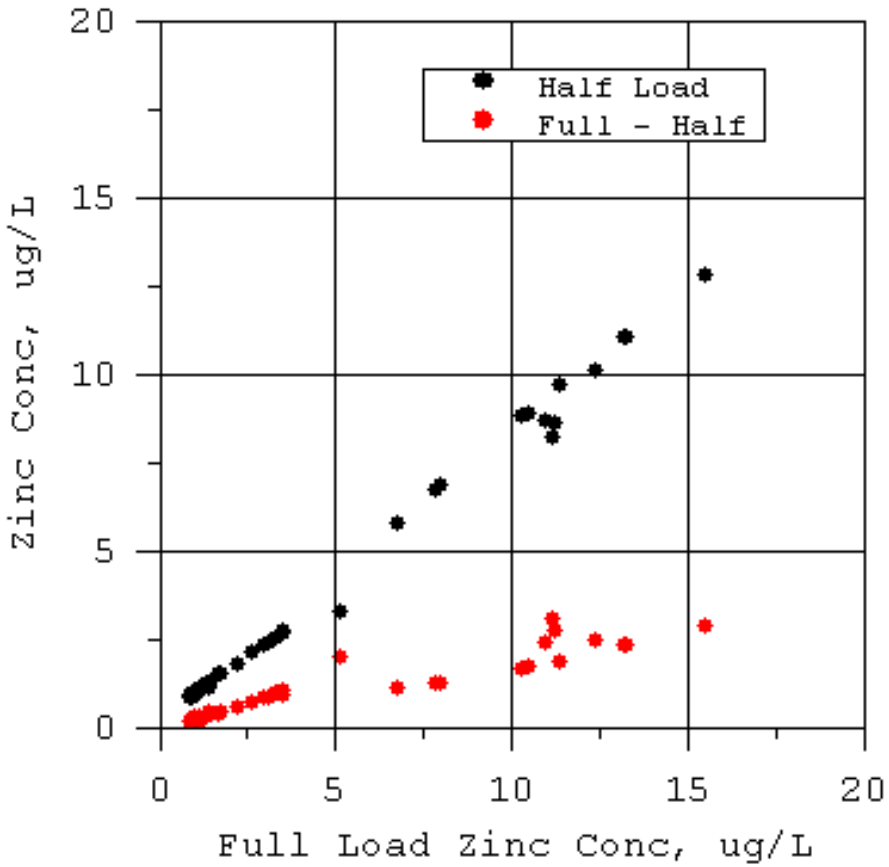
Open Boundary Concentration Sensitivity



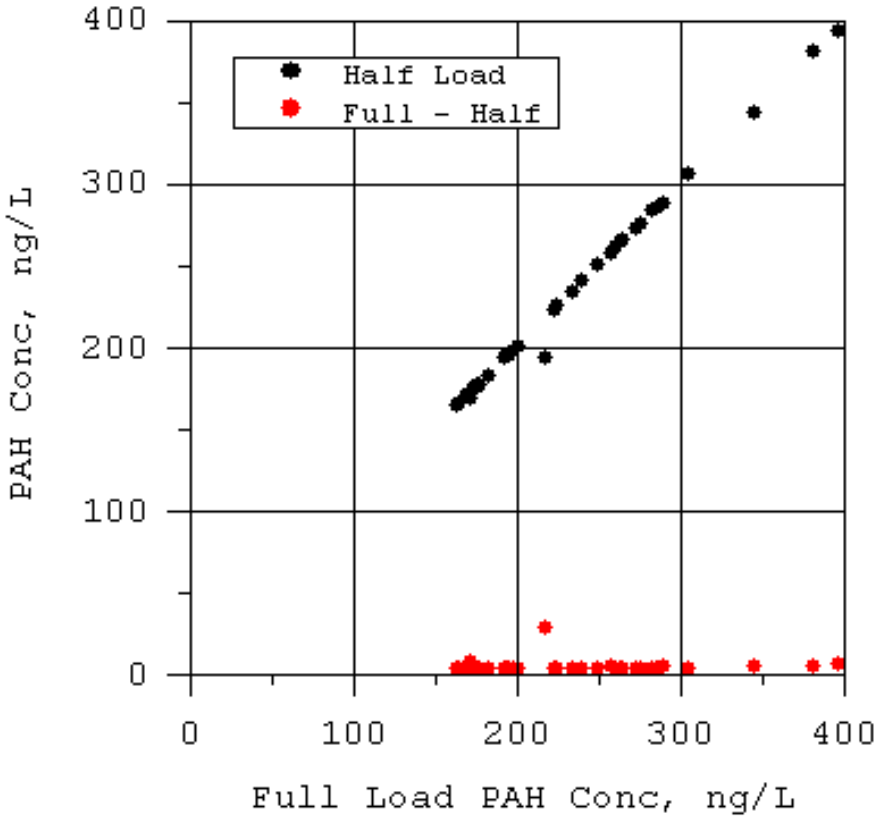


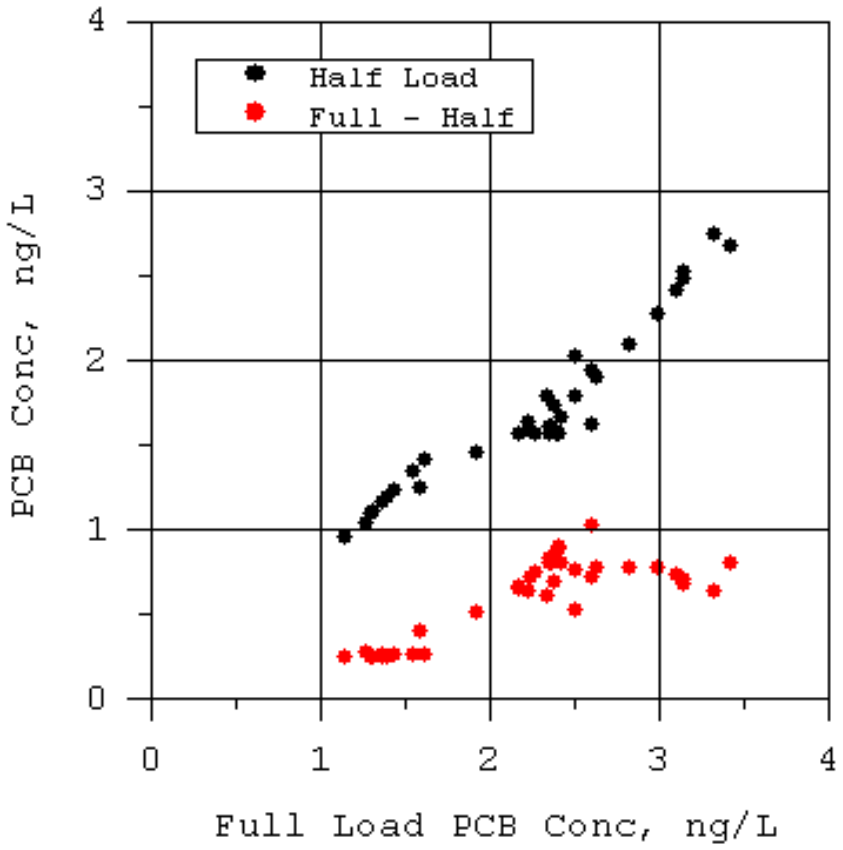
River and Watershed Load Sensitivity



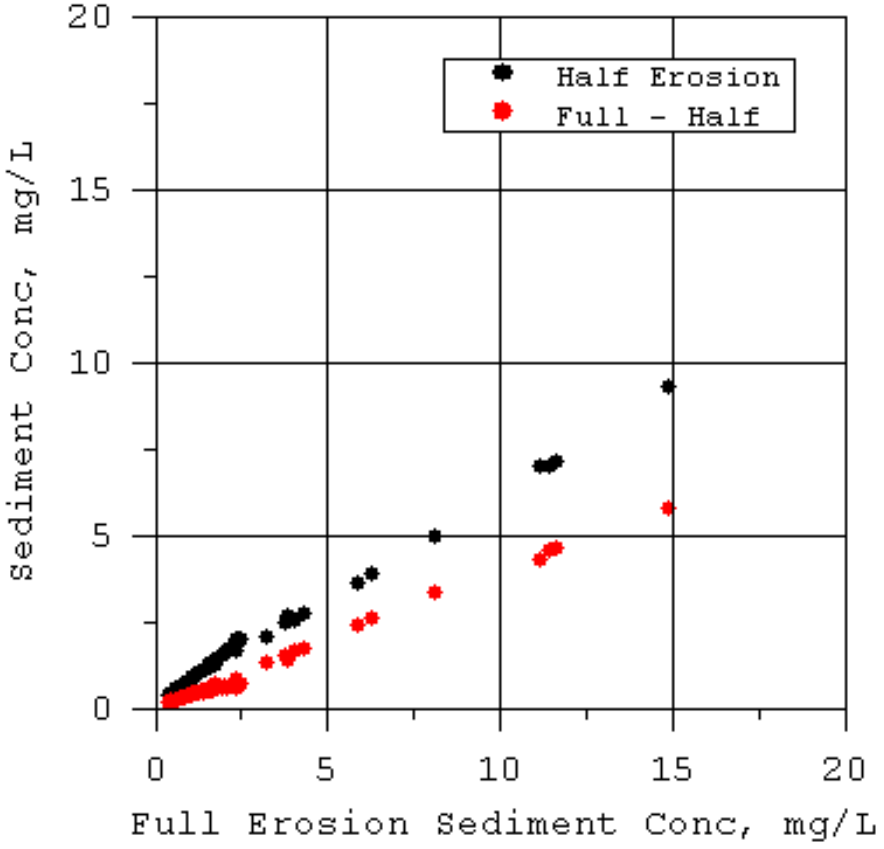


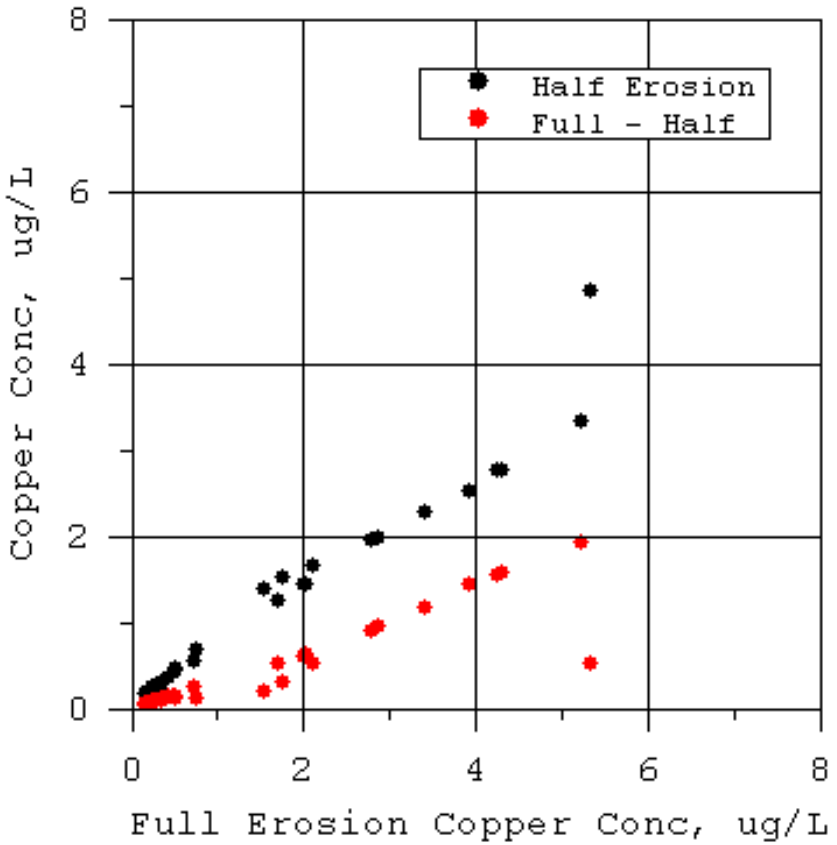
River and Watershed Load Sensitivity



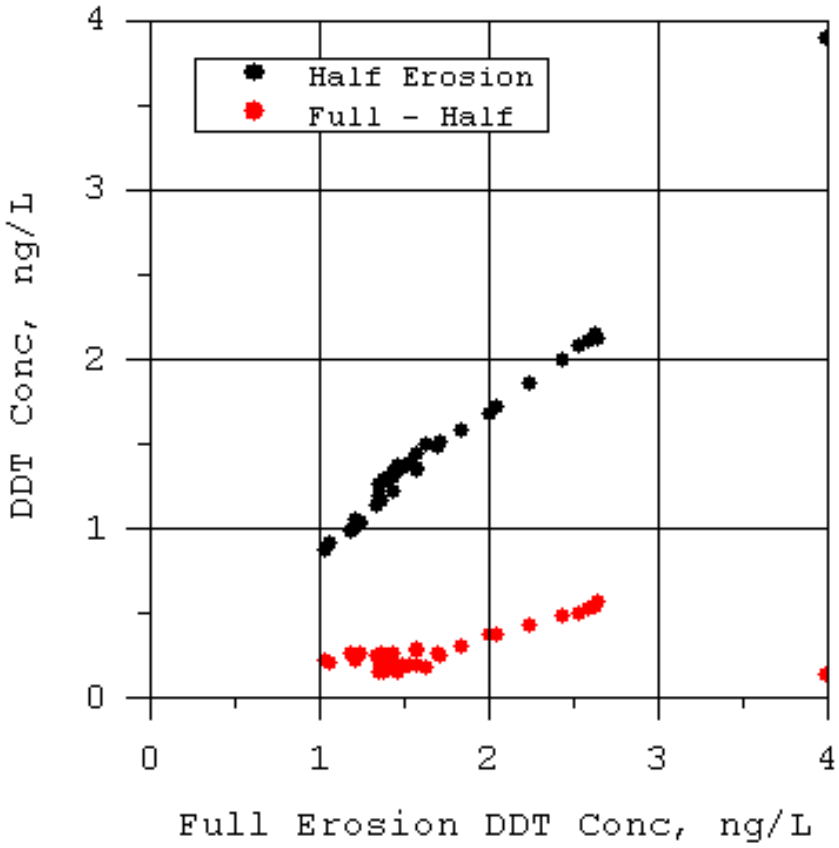


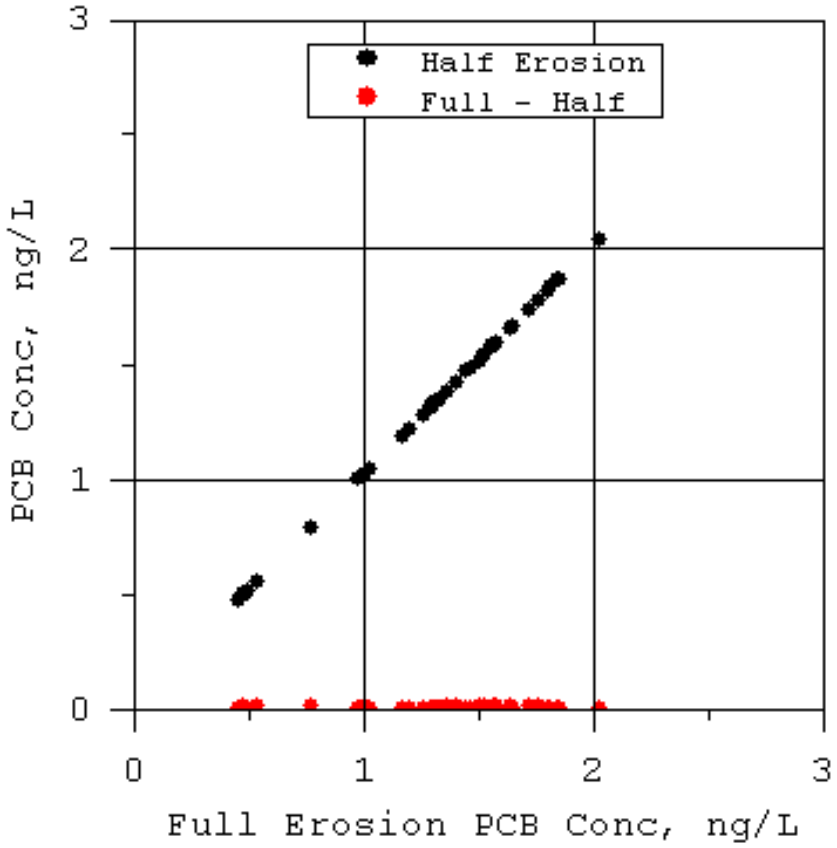
Bed Erosion Rate Sensitivity





Bed Erosion Rate Sensitivity





Summary of Sensitivity Analysis

Contaminant	Sensitivity to Halving Open Boundary Conditions	Sensitivity to Halving River and Watershed Loads	Sensitivity to Halving Sediment Erosion Rate
Sediment	Low	Low	High
Copper	Low	Low	High
Lead	Low	Low	High
Zinc	Low	Medium	Medium
DDT	Low	Low	Medium
PAH	Low to Medium	Low	Medium to High
PCB	Low	Medium to High	Low to Medium

Using the Model for TMDL Development

- What the Model Cannot Do
  - Make Absolute Predictions at Specific Historical and Future Space and Time Locations
- What the Model Can Do
  - Predict Observed Ranges of Sediment and Contaminant Levels
  - Quantify Uncertainty In Predictions
  - Evaluate Relative Difference Between Scenarios
- What If Scenarios
  - Reduce Watershed Loads
  - Remediate Sediment Hotspots