



# Monitoring Remedy Performance

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# Goals and Objectives of Remediation

- Remedial-action objectives “are intended to provide a general description of what remediation is expected to accomplish” are generally risk-based and narrative in form
- Remediation goals are paired contaminant-specific and media-specific concentrations intended to protect human and ecologic health that incorporate site-specific information about exposure patterns and toxicity.
- Cleanup levels are chemical-specific operational goals developed by weighing a number of factors, including site-specific uncertainty factors and the criteria for remedy selection found in the NCP

# Purposes of Remedial Monitoring

- Evaluate exposure and risks during implementation
- Document achievement of cleanup levels
- Evaluate progress toward achievement of remedial action objectives and identify need for maintenance or adaptation
- Inform future remedial decisions

# Measures of Sediment-Remedy Effectiveness in the Superfund Program

*Remedy effectiveness* is the achievement of cleanup goals (remedial-action objectives and cleanup levels that are derived from appropriate site-specific risk modeling) in the predicted timeframe with a reasonable degree of confidence that the achievement will be maintained.

- **Interim Measures**

- ◆ Short and long-term remedy performance
- ◆ Short term risk reduction

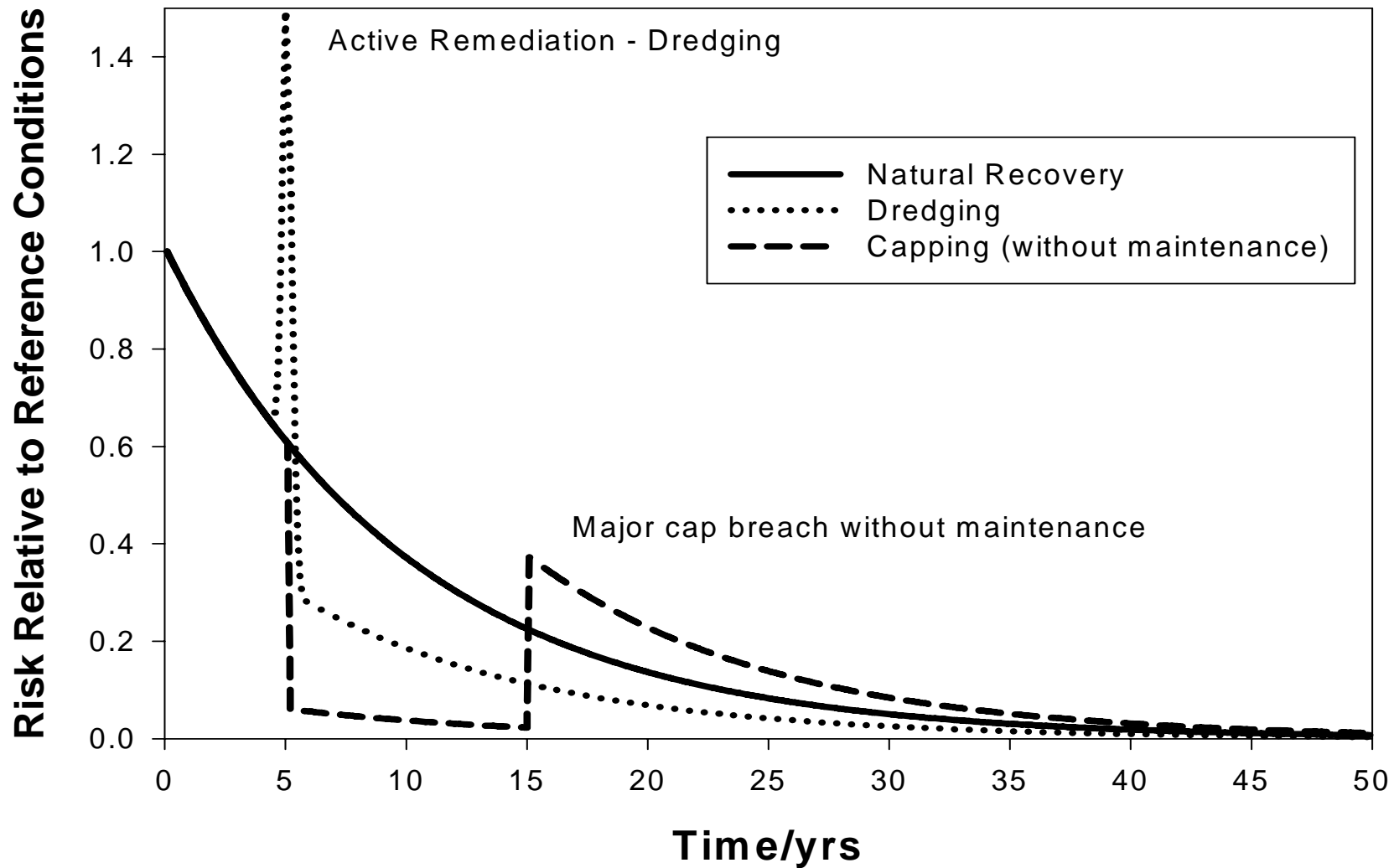
- **Key Measure**

- ◆ Long-term risk reduction

# Remedy Performance and Effectiveness

- Short-term remedy performance.
  - ◆ Have sediment cleanup levels been achieved after dredging?
- Long-term remedy performance.
  - ◆ Have sediment cleanup levels been maintained for at least 5 years, and thereafter as appropriate?
- Short-term risk reduction.
  - ◆ Have remedial-action objectives been achieved?
  - ◆ Do data demonstrate or at least suggest a reduction in fish tissue concentrations, a decrease in benthic toxicity, or an increase in species diversity or other community indexes after 5 years?
- Long-term risk reduction.
  - ◆ Have remedial-action objectives been maintained for at least 5 years, and thereafter as appropriate?
  - ◆ Has the predicted magnitude and timing of risk reduction been achieved or are they likely to be achieved?

# Response to Remedial Approaches



# Bayou Bonfouca

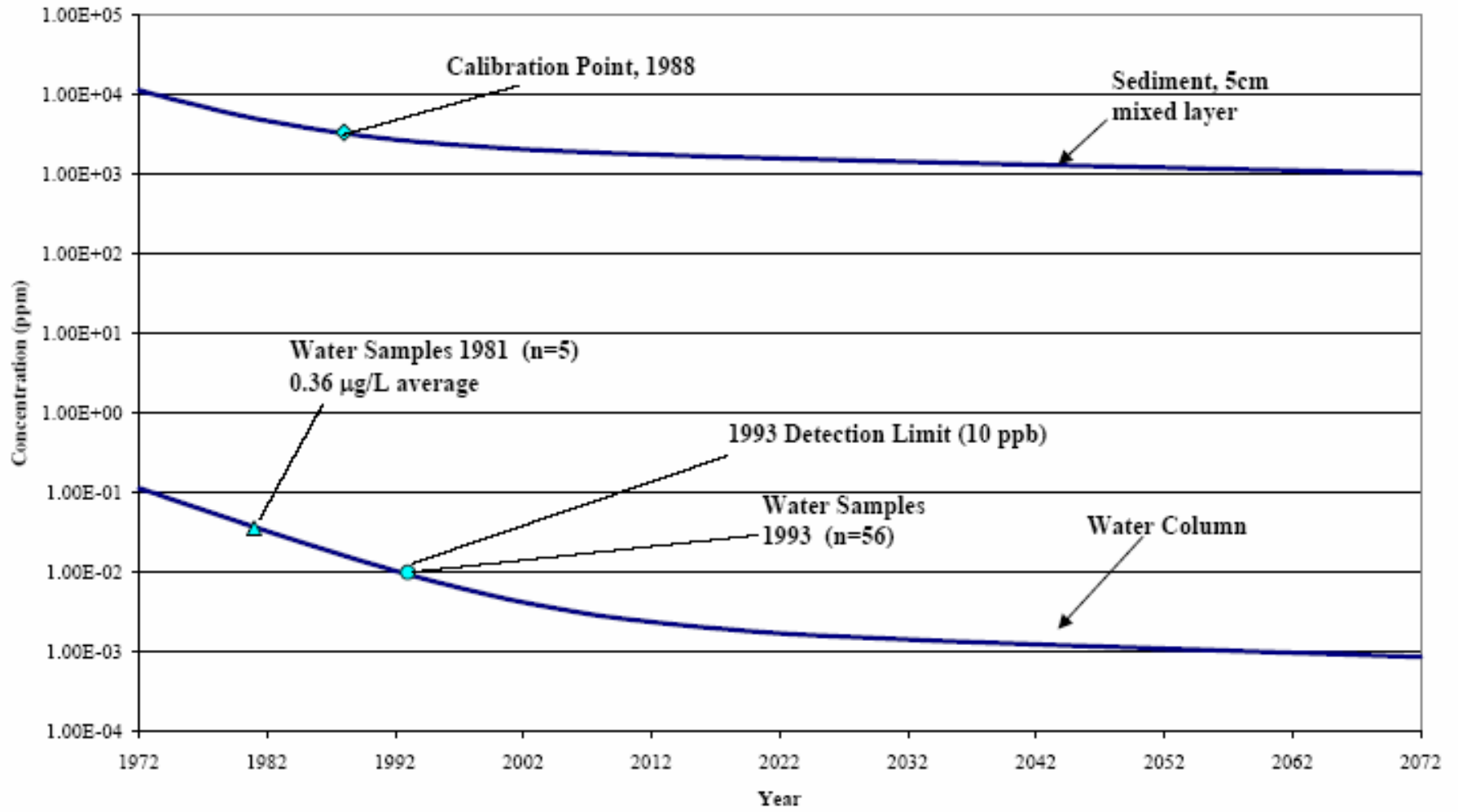


Figure 8. RECOVERY Model Calibration.

## Bayou Bonfouca

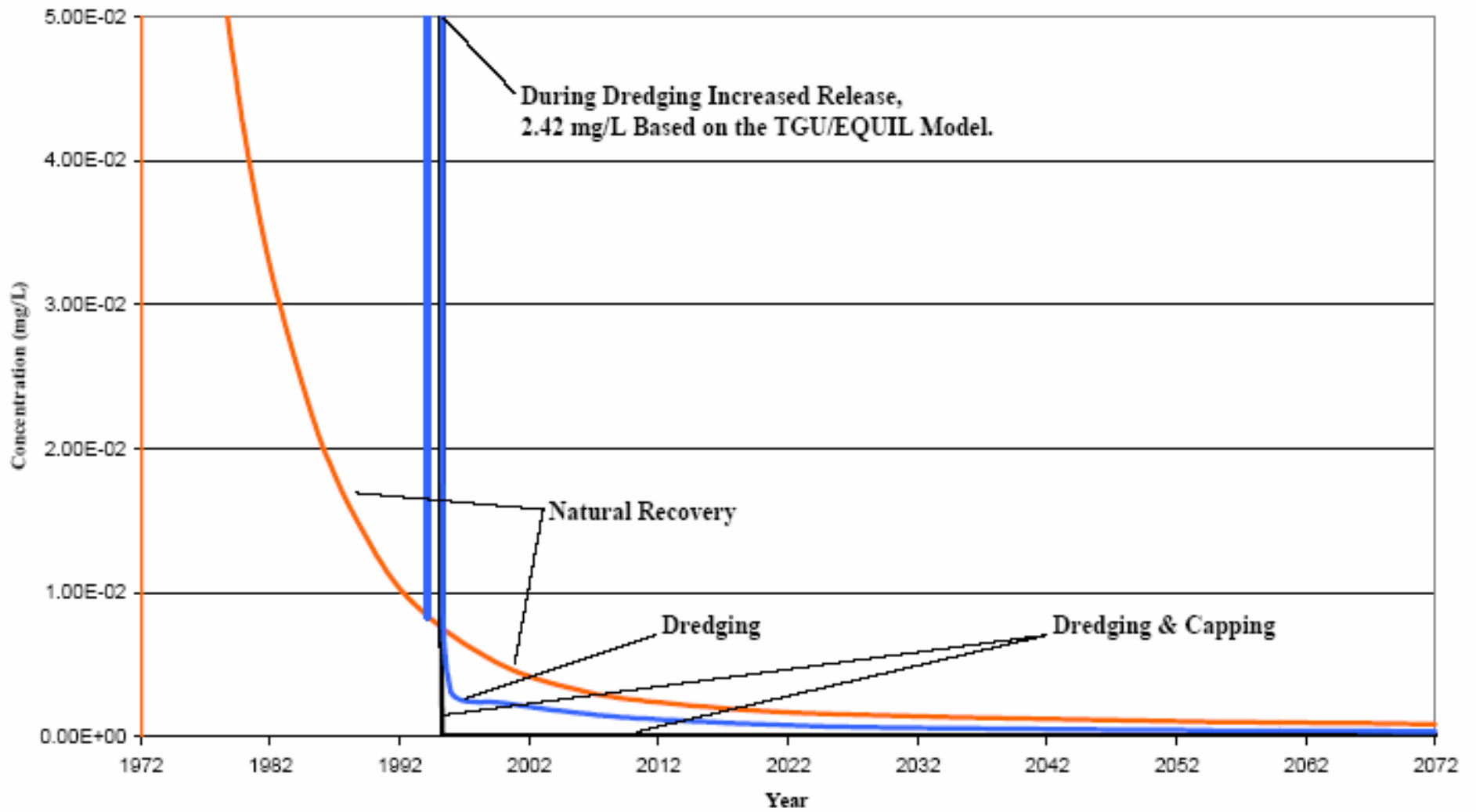
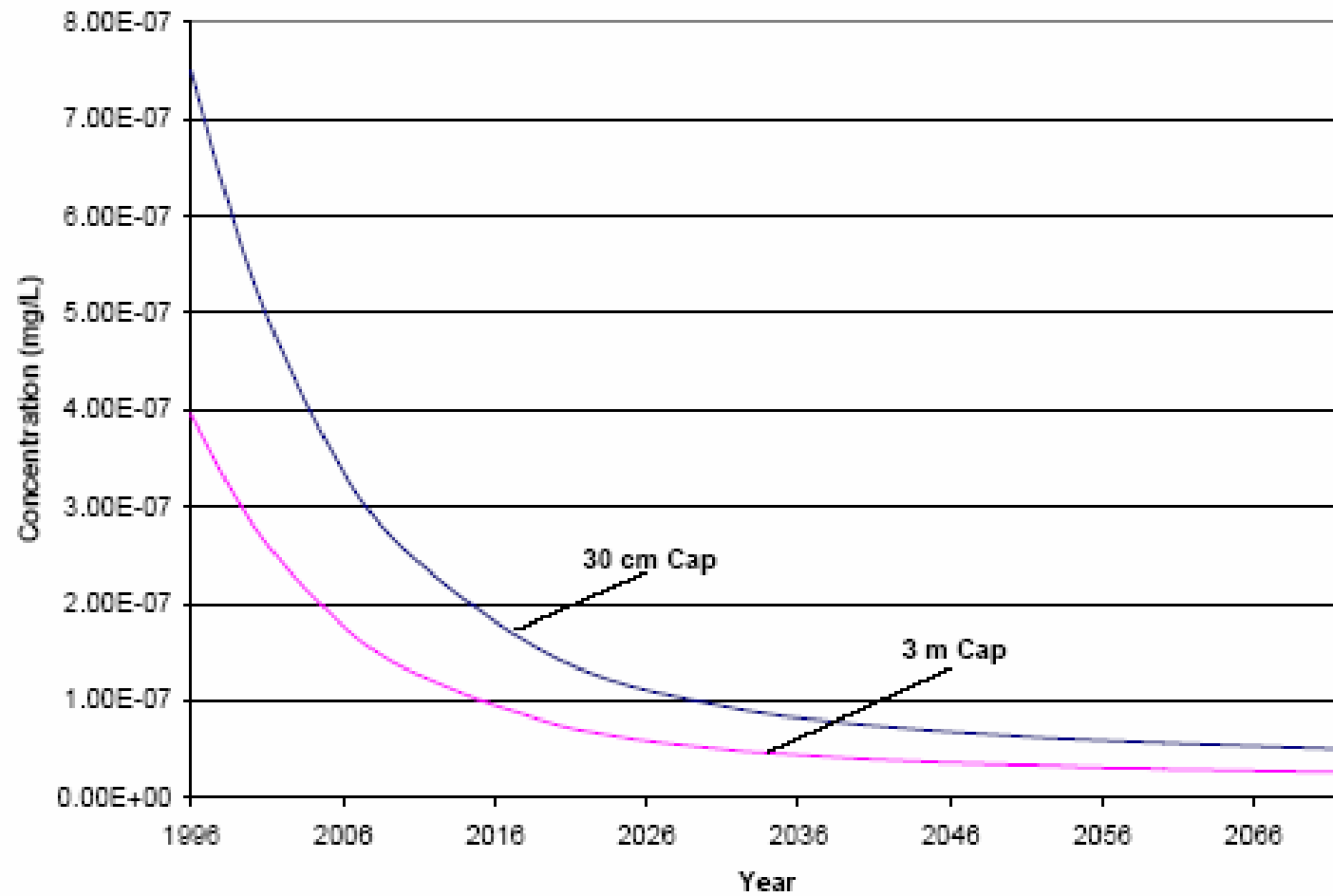
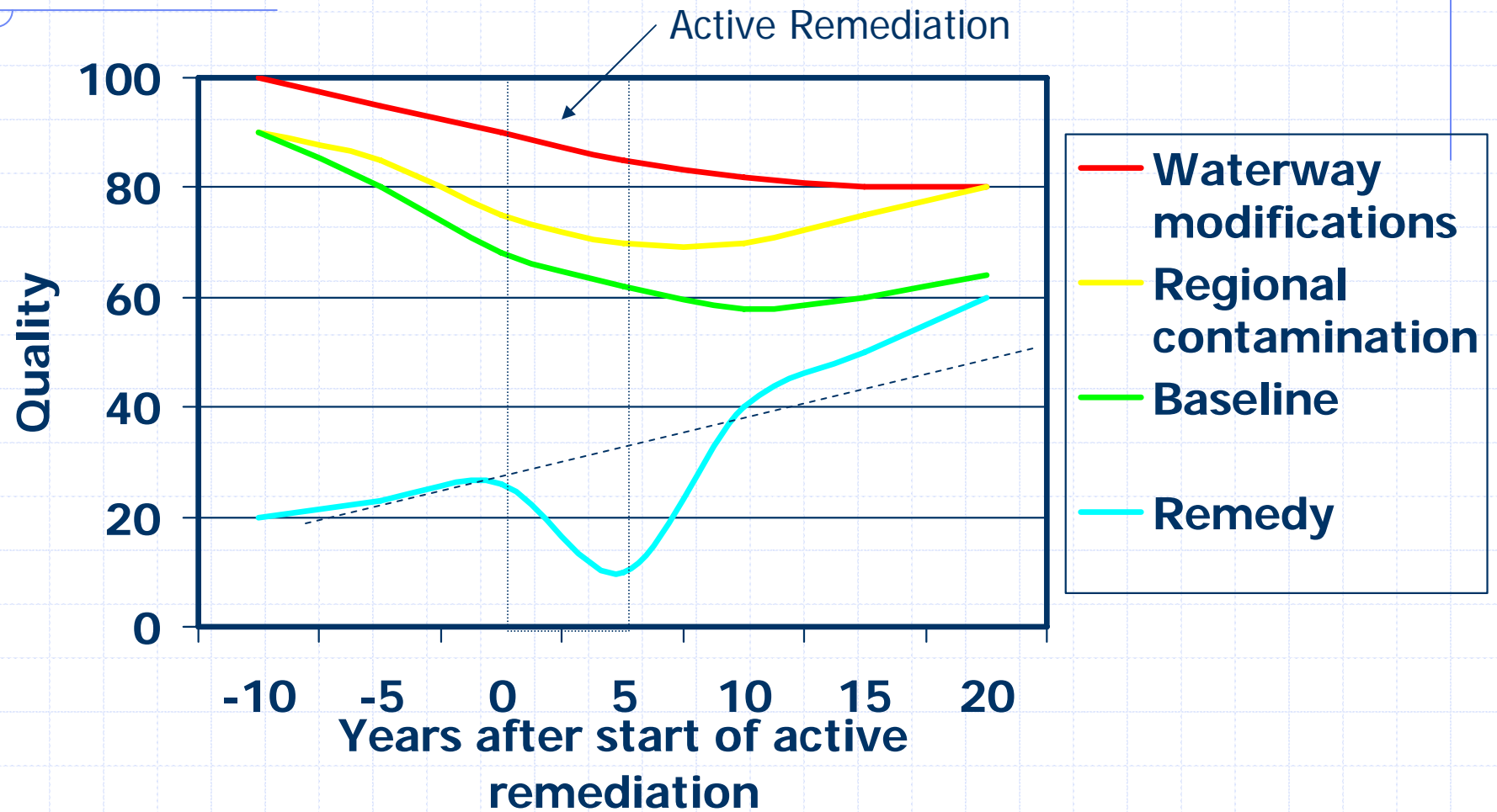


Figure 11. Total PNA Concentrations in Water - Model Results

Post Dredge Period: Water Comparison Between  
30 cm And 3 m Caps - Model Simulation



# Ideal Recovery Scenario



# Challenges

- Easier to measure performance relative to cleanup levels rather than Remedial Action Objectives
- Inadequate conceptual model
  - ◆ Continuing sources
  - ◆ Competing risk factors
- Insufficient information to define pre-remedial time trends
  - ◆ Remedial investigation information rarely connected to remedial design data
- Inadequate reference condition
  - ◆ How would conditions be different without remediation?
  - ◆ What is an appropriate baseline?
- Inadequate characterization of post-remedial time trends
- Inadequate characterization of spatial variability

# Measures of Remedy Performance

- Risk based measures

- ◆ Contaminant burden in edible fish
- ◆ Contaminant burden in Caged fish/invertebrates
- ◆ Non-toxic biological endpoints
  - ◆ Abundance/ diversity of fauna
  - ◆ Tumor incidence

- Risk related measures

- ◆ Interstitial or overlying water concentration
- ◆ Contaminant flux to overlying water
- ◆ Bulk sediment concentration
  - ◆ Surface area weighted average concentration
- ◆ Total contaminated sediment or contaminant mass

Decreasing  
connection  
to risk

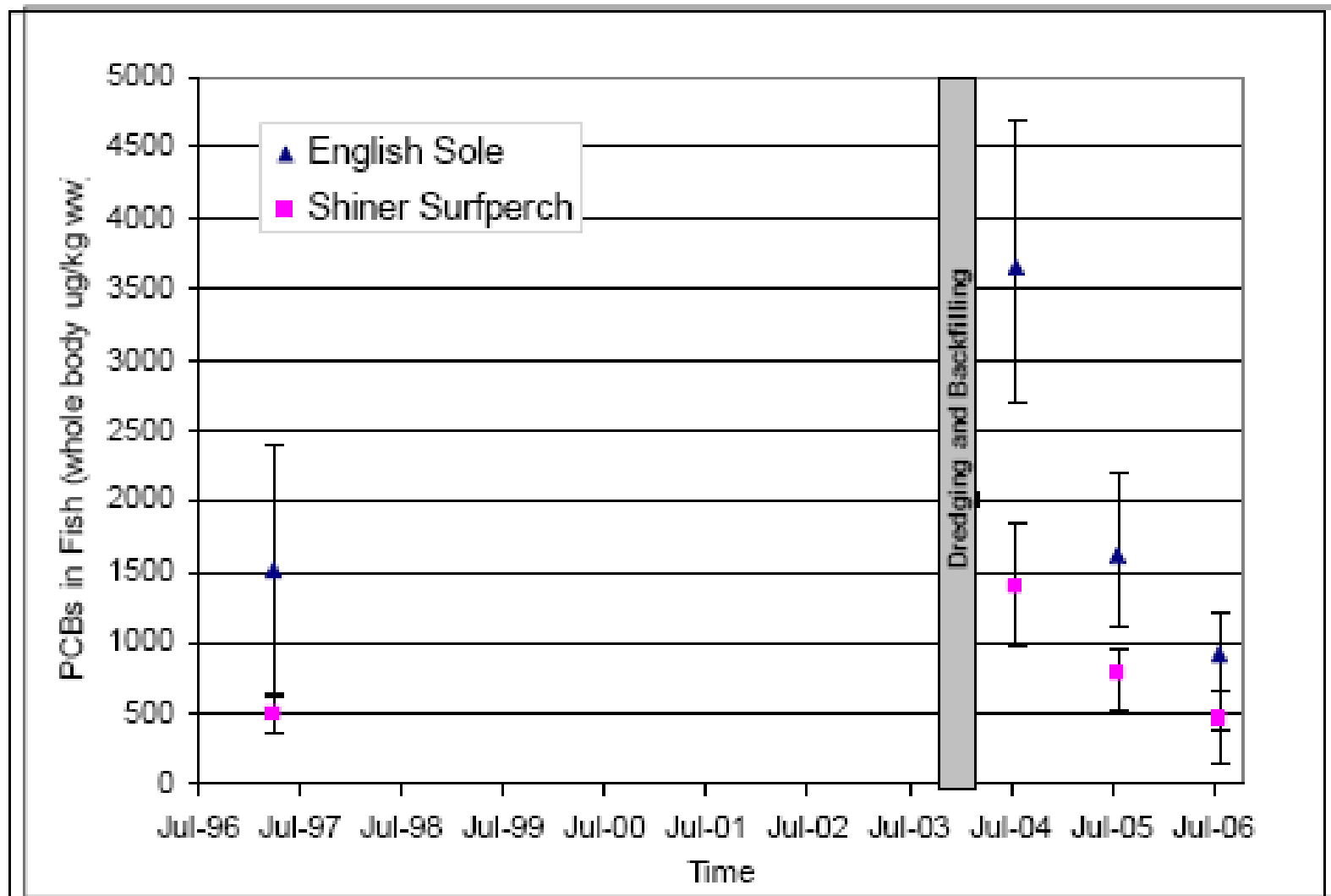


# Comparative Evaluation Metrics

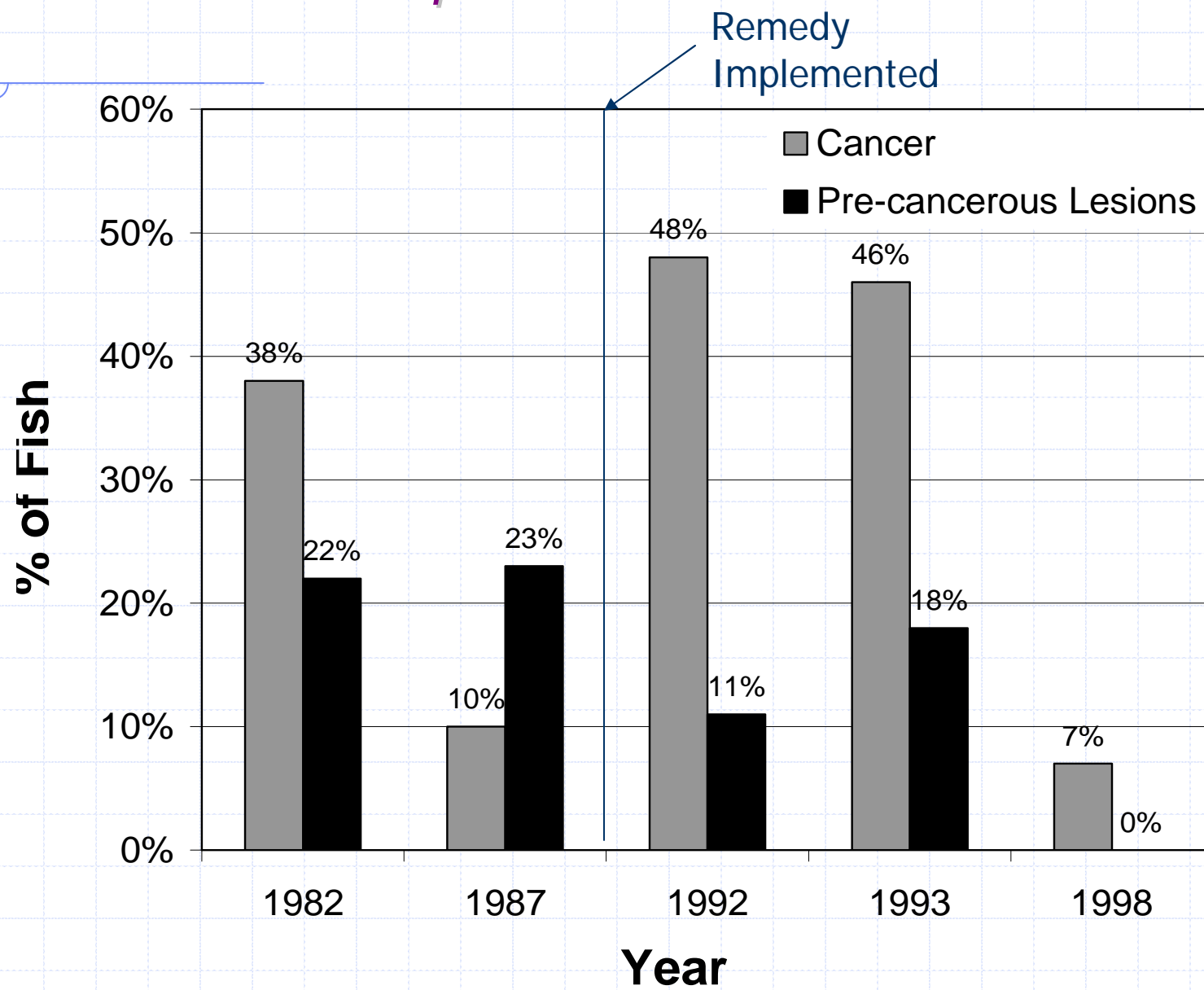
- Primary metric – Risk
- Secondary metrics
  - ◆ Link to appropriate conceptual model of system
  - ◆ Indicator species concentrations (e.g. fish)
  - ◆ Contaminant mass (dynamic environment)
  - ◆ Surficial average concentrations (stable environment)
    - ✦ When risk due to diffuse contamination (not “hot spots”)
    - ✦ SWAC – surface area weighted average concentration
  - ◆ Integral measures (allows incorporation of time)

$$\int SWAC \, dt \approx \textit{Cumulative Exposure}$$

# Duwamish Diagonal

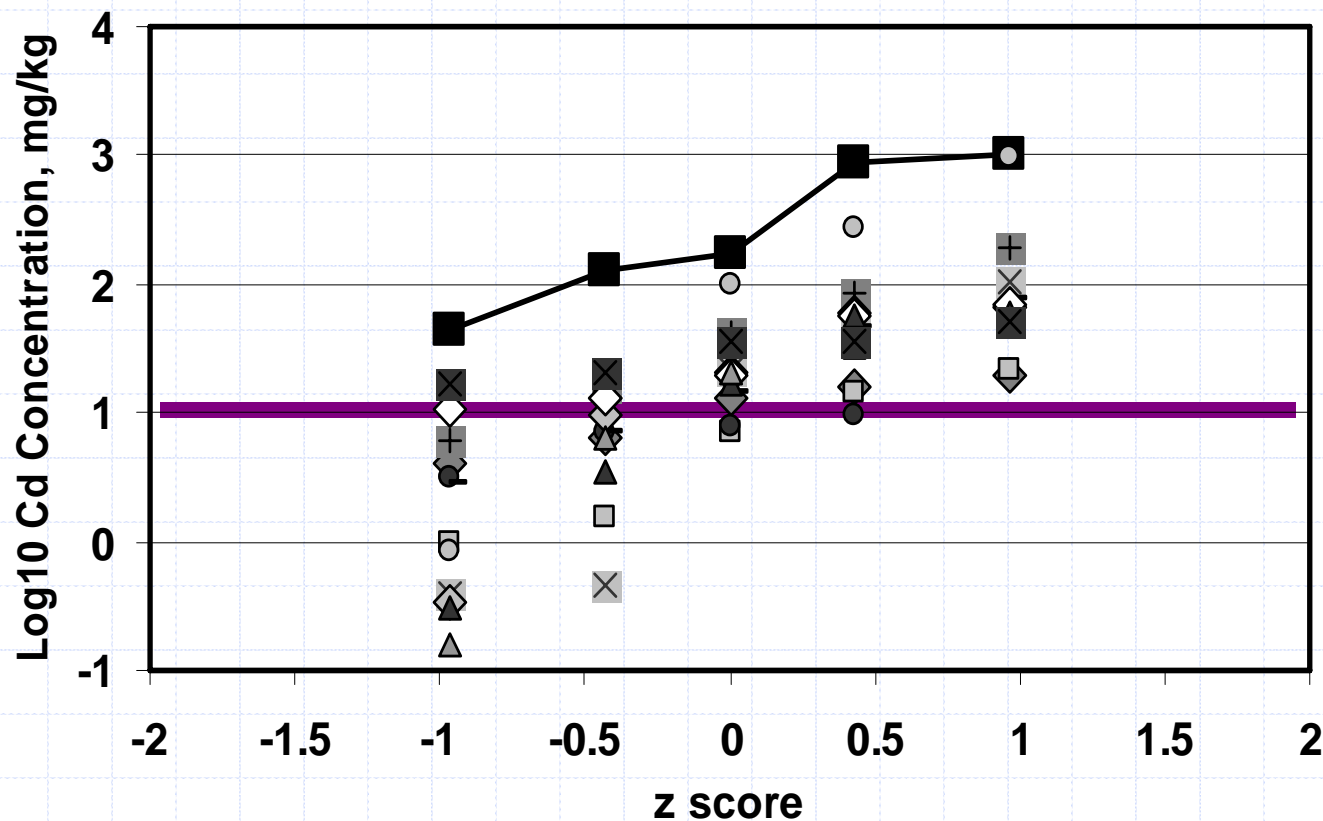


# Black River, OH



# Distribution of Measured Surficial Sediment Concentration

## Marathon Battery East Foundry Cove



- Pre-Remed.
- Post-Remed.
- Nov-95
- Mar-96
- Jun-96
- Apr-97
- Apr-98
- Apr-99
- Apr-00
- Apr-01
- Oct-02
- Nov-03
- Nov-04

Cleanup Level

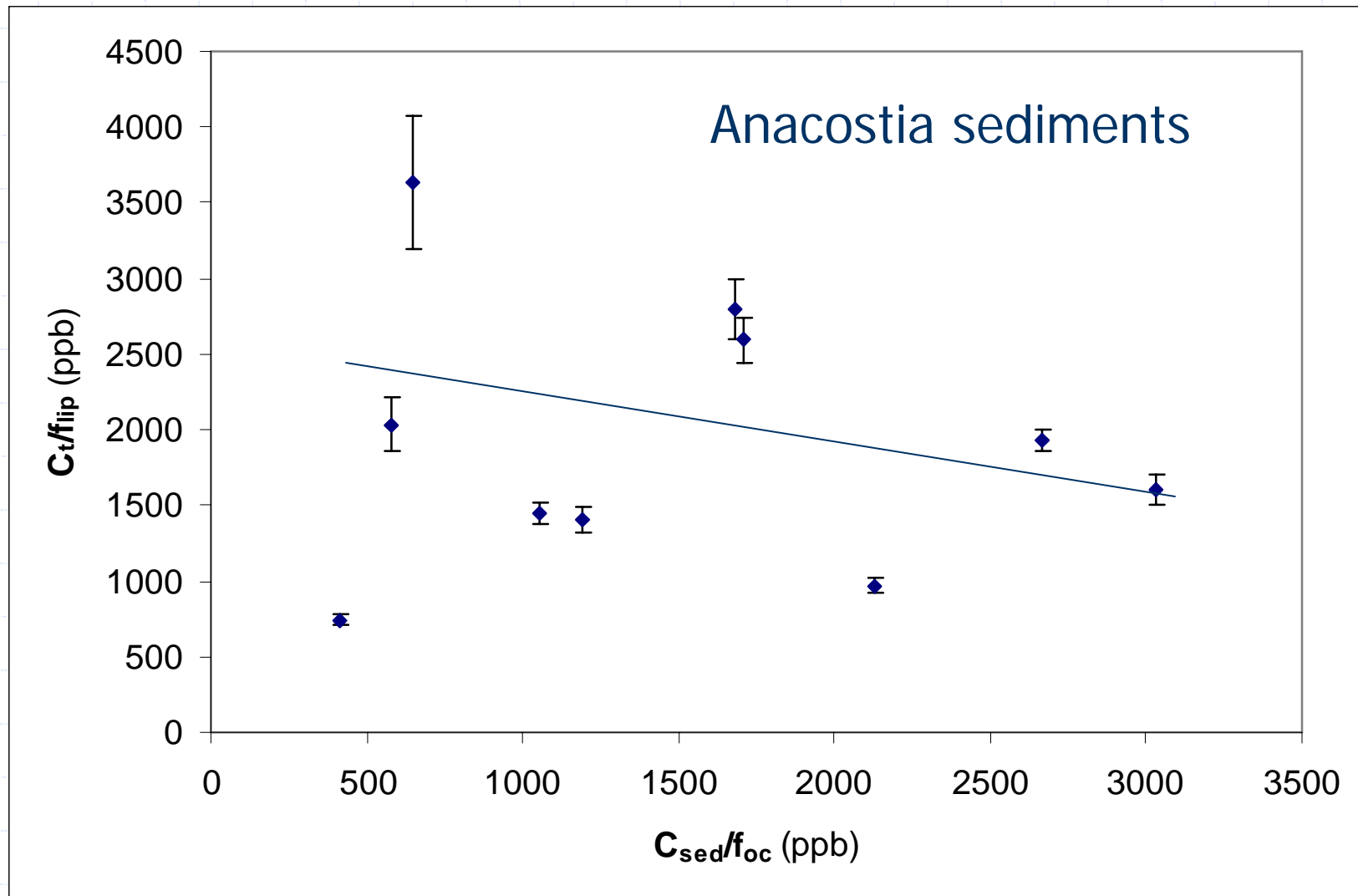
## Bioturbation through a thin sand layer (Residual Cap)

- 2.5 cm sand layer
- 0.5 cm clean sediment at surface
- 28 day bioaccumulation test
- BaP reduced 39%
- Phe reduced 16%

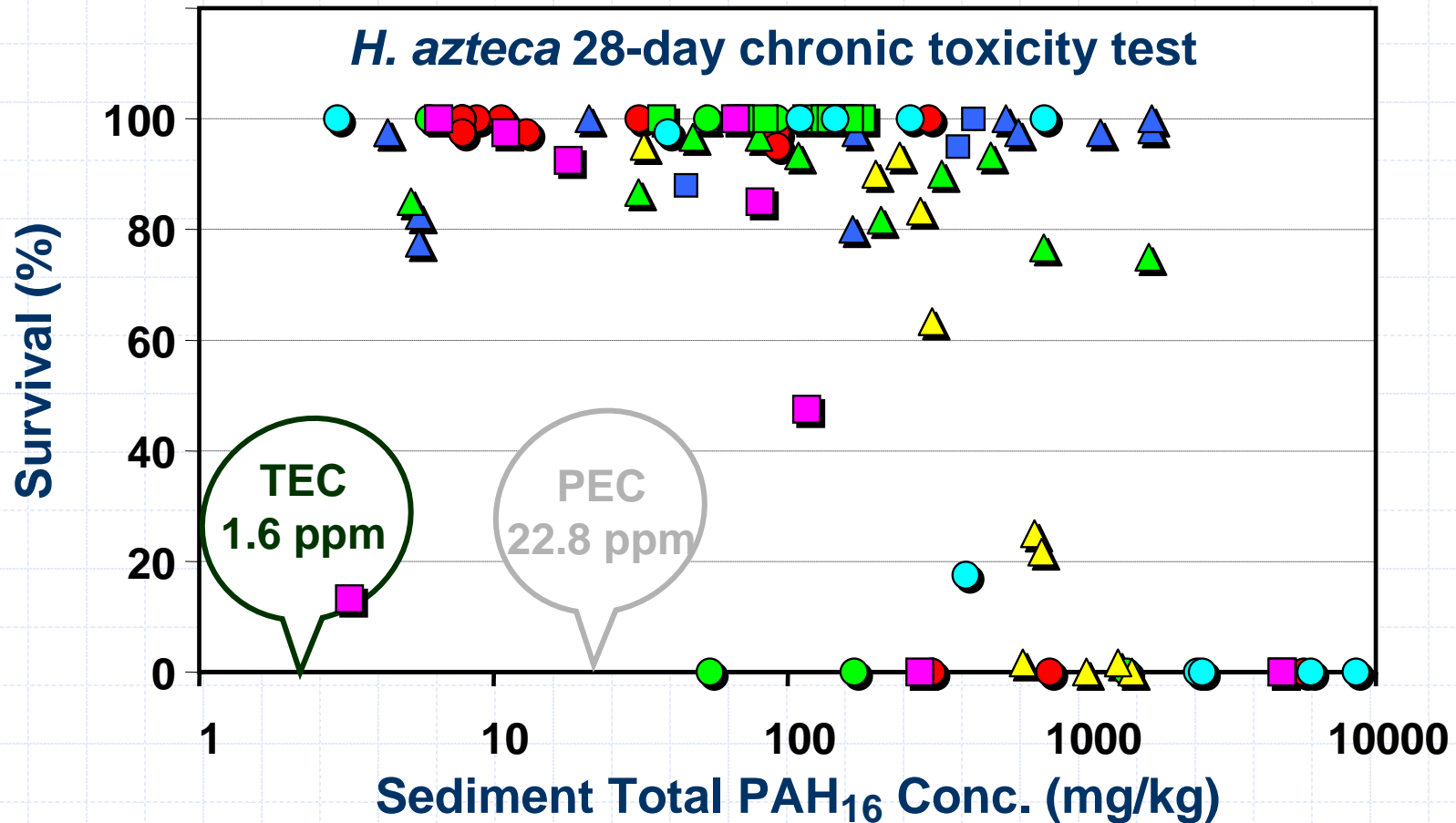


Work continuing with thicker residual caps

# Correlation (?) of PCB Uptake with Bulk Sediment Concentration

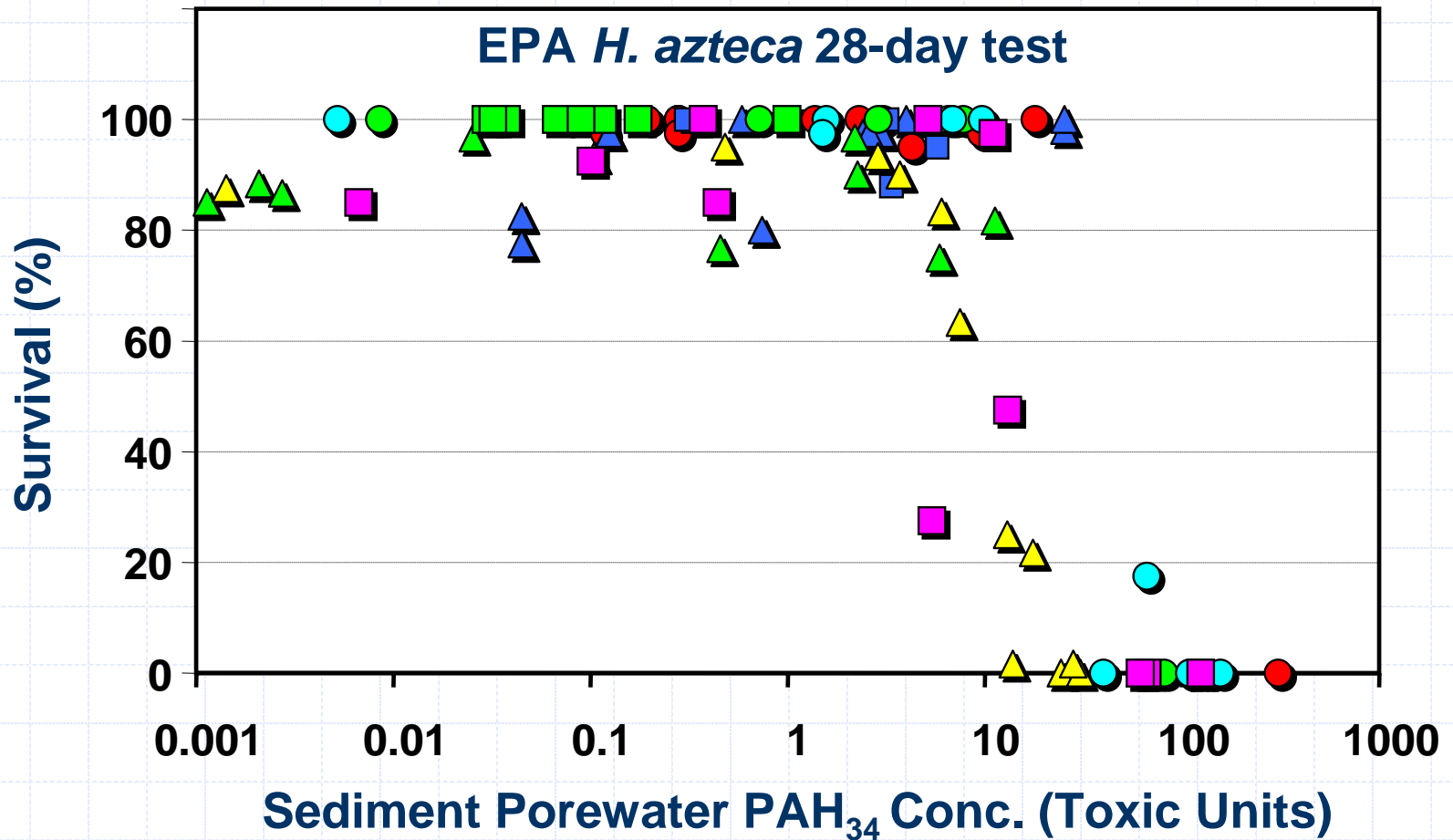


# Bulk Sediment Concentration Correlates only Weakly with PAH Toxic Endpoints



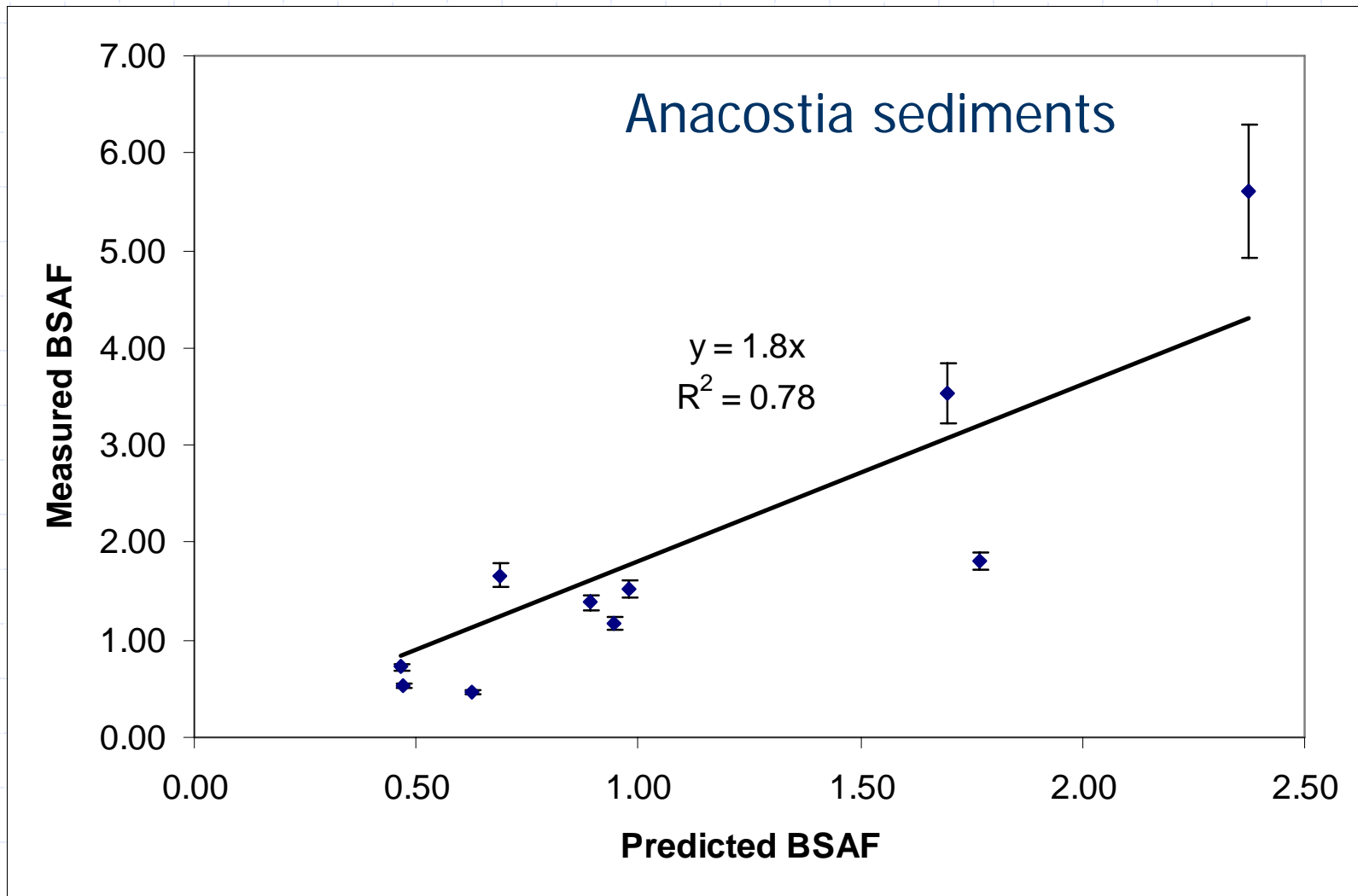
Dave Nakles, RETEC

# Porewater Concentration Better Correlates with Survival



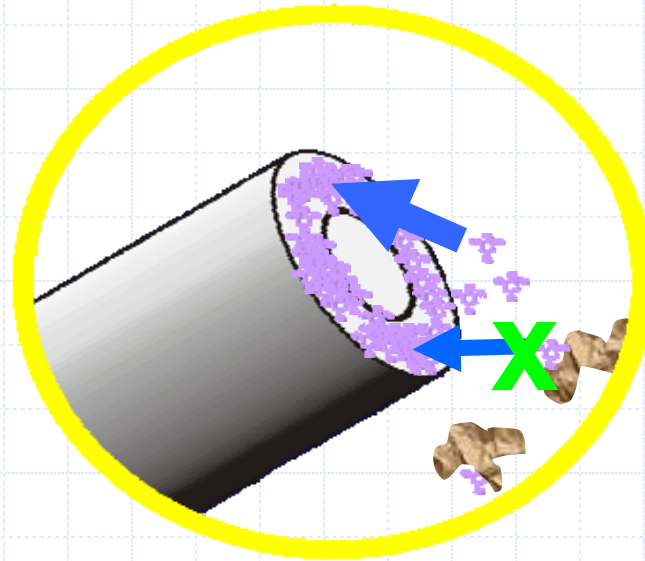
Dave Nakles, RETEC

# Correlation of PCB Uptake with Measured Porewater Concentration



# But How to Measure Porewater ?

- Solid Phase MicroExtraction
- Sorbent Polymer PDMS (poly-dimethylsiloxane)
  - ◆ Thickness of glass core: 114-108  $\mu\text{m}$
  - ◆ Thickness of PDMS coating: 30-31  $\mu\text{m}$
  - ◆ Volume of coating: 13.55 ( $\pm 0.02$ )  $\mu\text{L}$  PDMS per meter of fibre
  - ◆ Easily capable of measuring ng/L concentrations

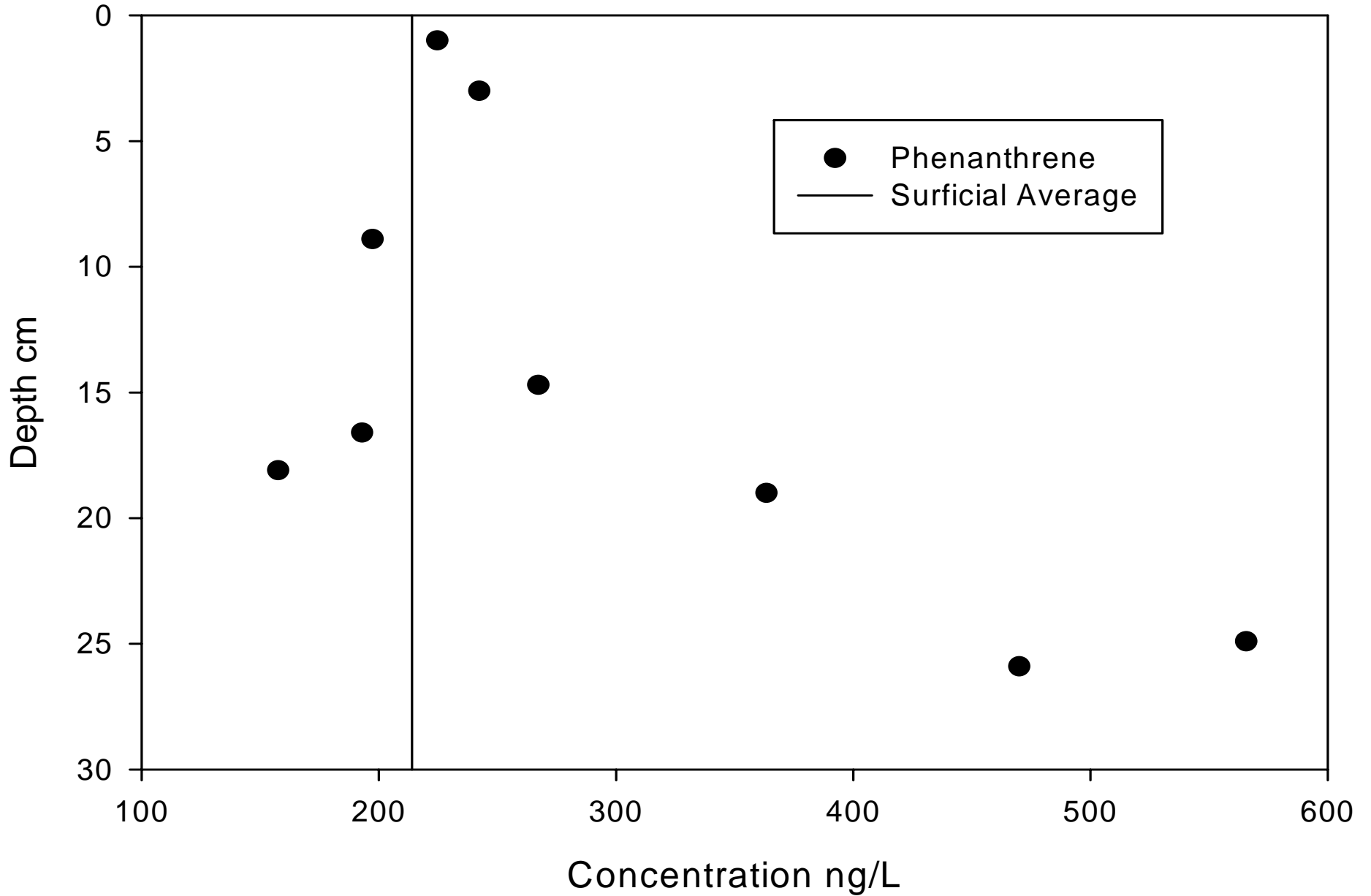


# Field Deployment System

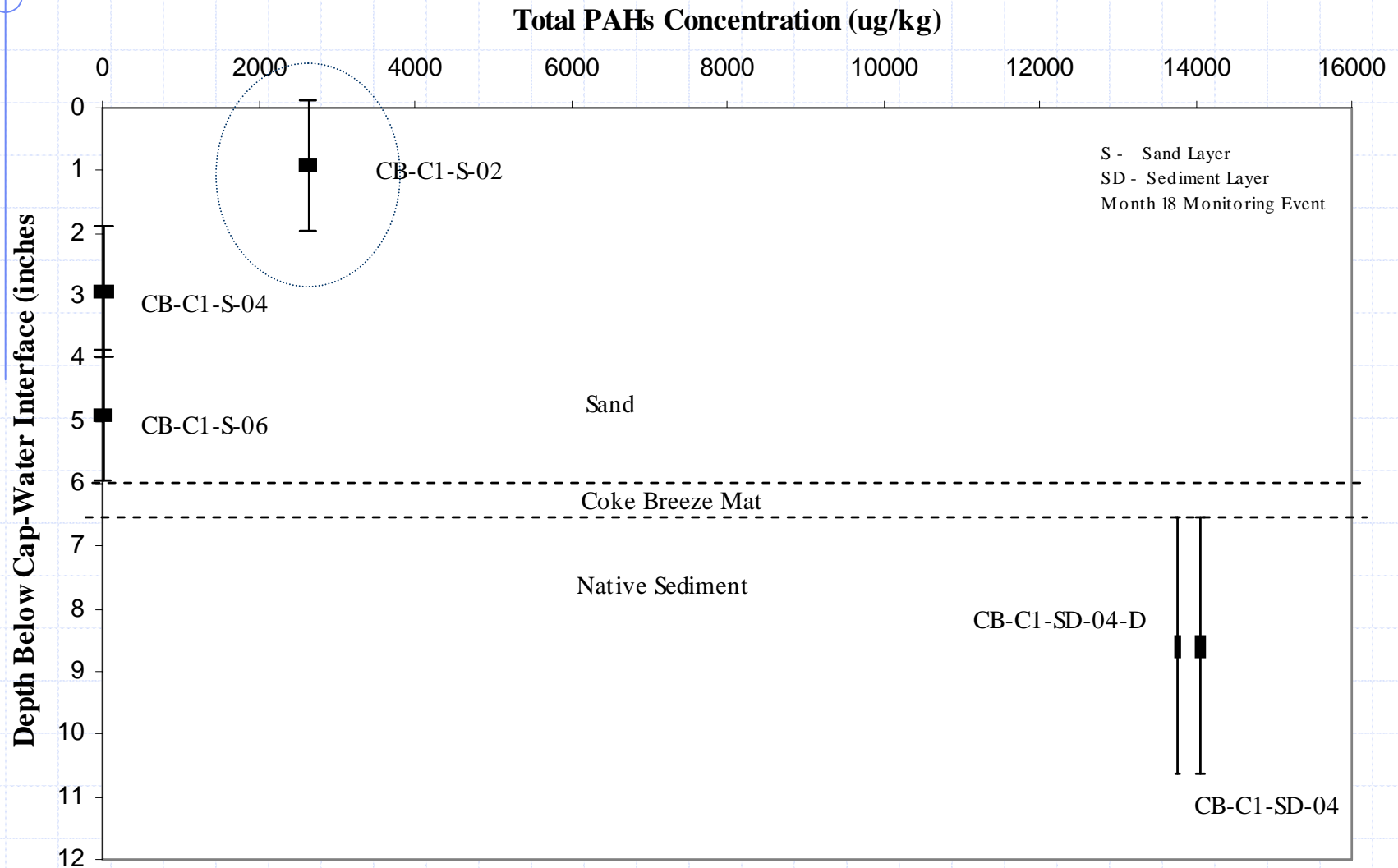


# SPME Measured Porewater Profile

Surface mean

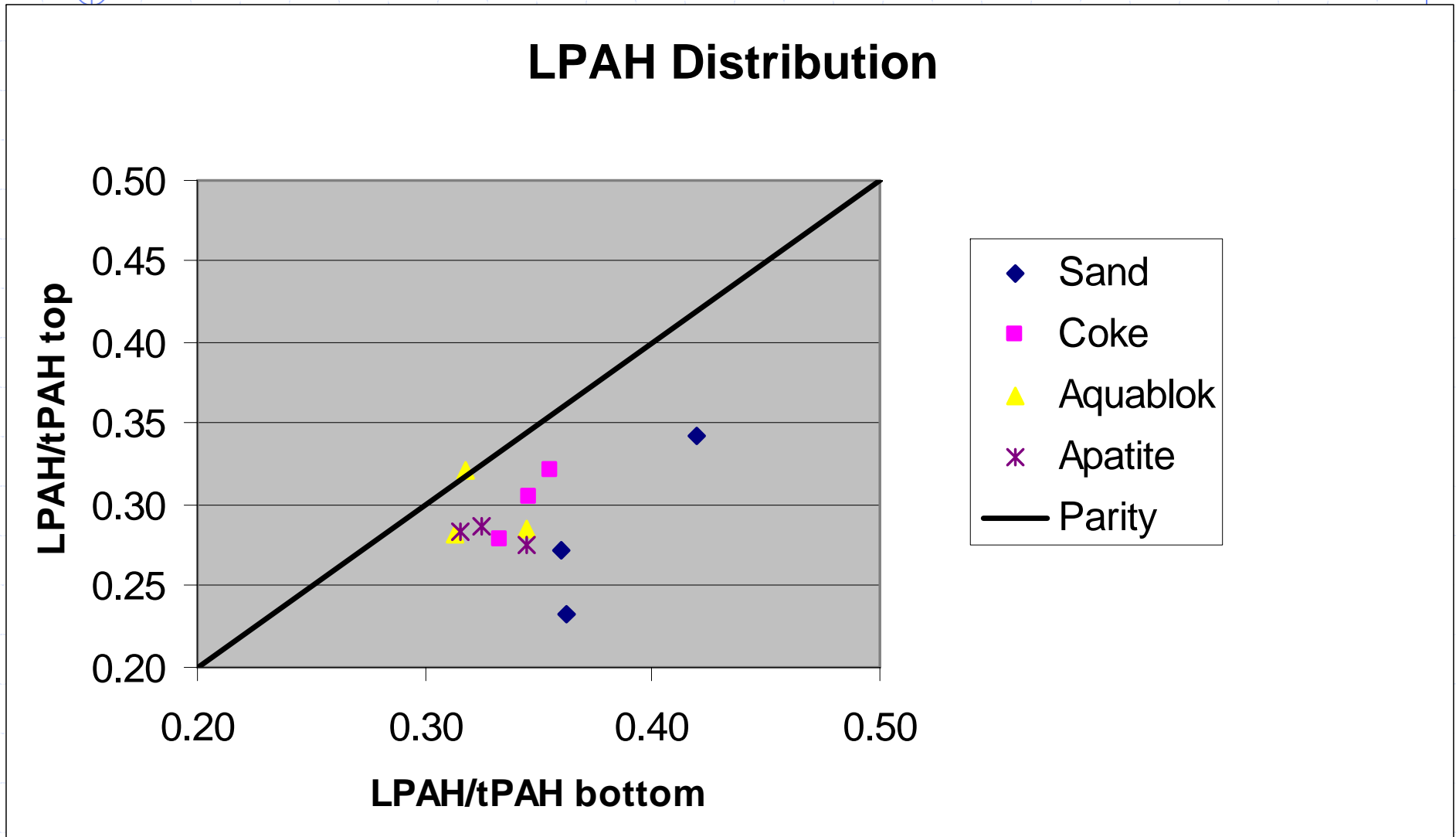


# Other Complications - Recontamination Anacostia River





# Surface depleted of mobile PAHs



# Responding to the Challenges

- Don't measure performance relative to cleanup levels only (just because its easier)
  - ◆ Use appropriate risk indicators (e.g. porewater, fish levels)
- Continuously test and update the conceptual model
- Use all available information to define pre-remedial time trends
- Recognize that an appropriate reference condition is still impacted by human activities
- Monitor post-remedial time trends and compare to the conceptual and mathematical models
- Recognize the limitations imposed by spatial variability
  - ◆ Don't let low probability events manage the remediation!

# Monitoring Goals

- Monitoring should be guided by the conceptual site model and the results used to update the model
- Effective monitoring requires characterization of preremedial trends and definition of appropriate baseline and reference conditions
- *Long term monitoring should be focused on performance relative to remedial action objectives, not cleanup levels*
  - ◆ *Corollary – when risk based monitoring suggests that RAOs are being met in the appropriate timeframe deemphasize cleanup levels*