Sediment and Floodplain Remediation: Tools for Site Characterization

Presented by:

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Ann Arbor, Michigan

Technology Benchmarking Workshop:

Sediment and Floodplain Remediation

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Presentation Outline

- Goals of Site Characterization
  - Exposure and risk : Sources – pathways - receptors
  - Remediation endpoints
- Site Characterization Framework
  - Screening investigations, IRAs
  - Development of a conceptual model
  - Refinement of conceptual model
- Tools for Site Characterization
  - Hydrology/Hydraulics/Hydrodynamics
  - Solids
  - Contaminants
  - Biota
- Relevance to Selection of Remedial Alternatives

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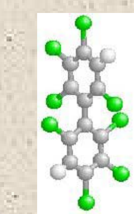
Goals of Site Characterization

- Focusing on Exposure and Risk
  - Site assessment should be risk-based (both human and ecological) rather than mass-based (*EPA 11 principles for managing contaminated sediment risks*)
  - Understanding risk requires understanding of **Sources → Pathways → Receptors**
  - Goal is to quantify and rank potential pathways for exposure / risk (i.e., build site-specific conceptual models)

Current Challenges to Quantitative Risk Assessment

- Need to develop a better mechanistic understanding of sediment and associated chemical stability
  - Cohesive sediment erosion
  - Non-resuspension sediment-water flux
- Need to better understand exchange of contaminants between bedded sediments and floodplain soils
  - Groundwater – surface water interactions
  - Floodplain deposition, redistribution
- Need to better quantify food web bioaccumulation
  - Effects of habitat and food web structure/function

Sediments/soils



contaminants

biota

Goals of Site Characterization

- Remediation Endpoints
  - Risk assessment must recognize bioavailability of contaminants of concern based on:
    - Physico/chemical form,
    - location relative to exposure pathways
- Quantitatively link loss of beneficial uses to risk pathways to exposure pathways

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EPA Guidance on CSM Development

Overview — Purpose

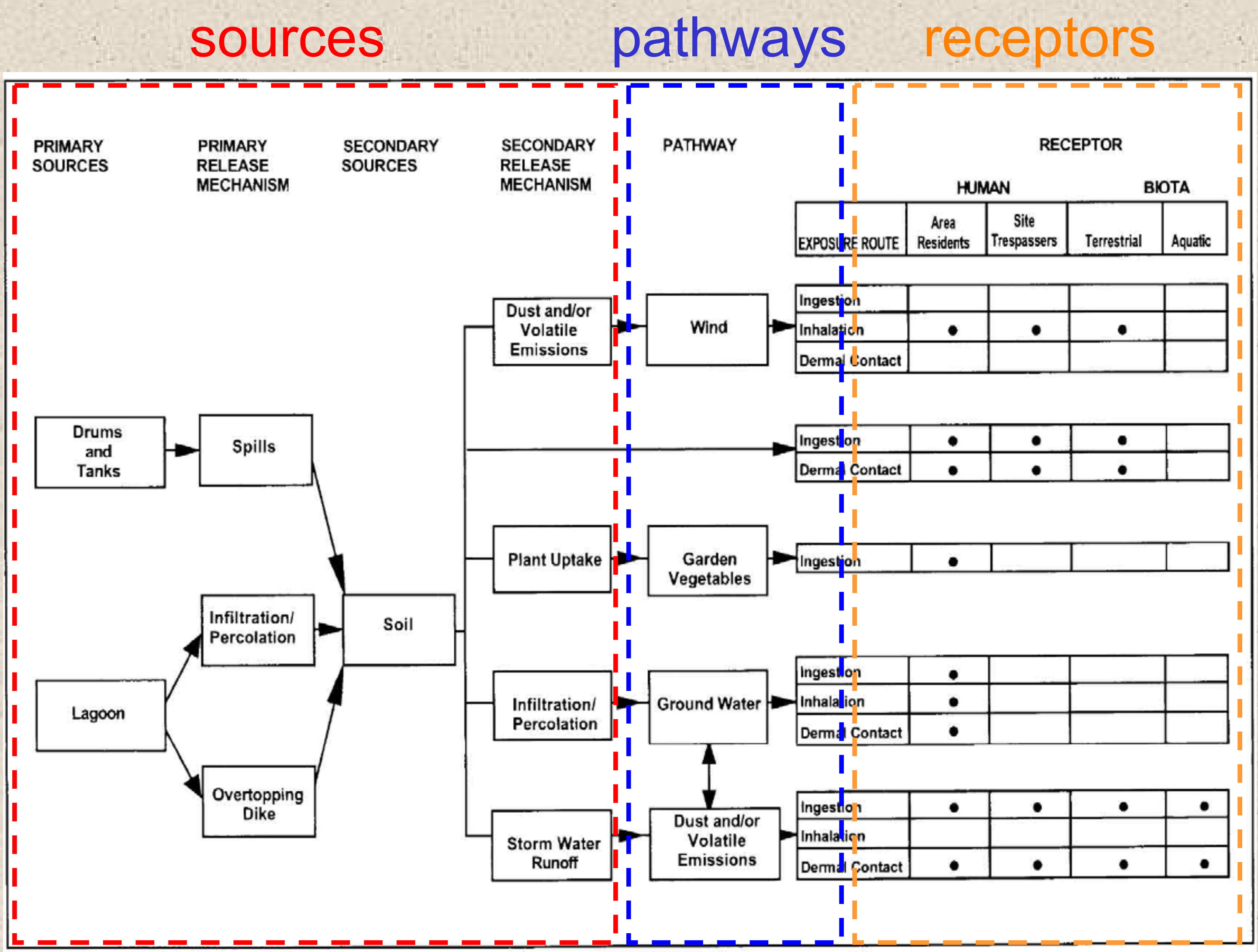
- Describes a site and its environs
- Presents hypotheses about types of contaminants - SOURCES
- Presents hypotheses about routes of migration of contaminants, with a focus on the geologic and hydrologic model - PATHWAYS
- Presents hypotheses about receptors and exposure routes - RECEPTORS
- Tests and refines hypotheses through site characterization and represents the core of site characterization

EPA

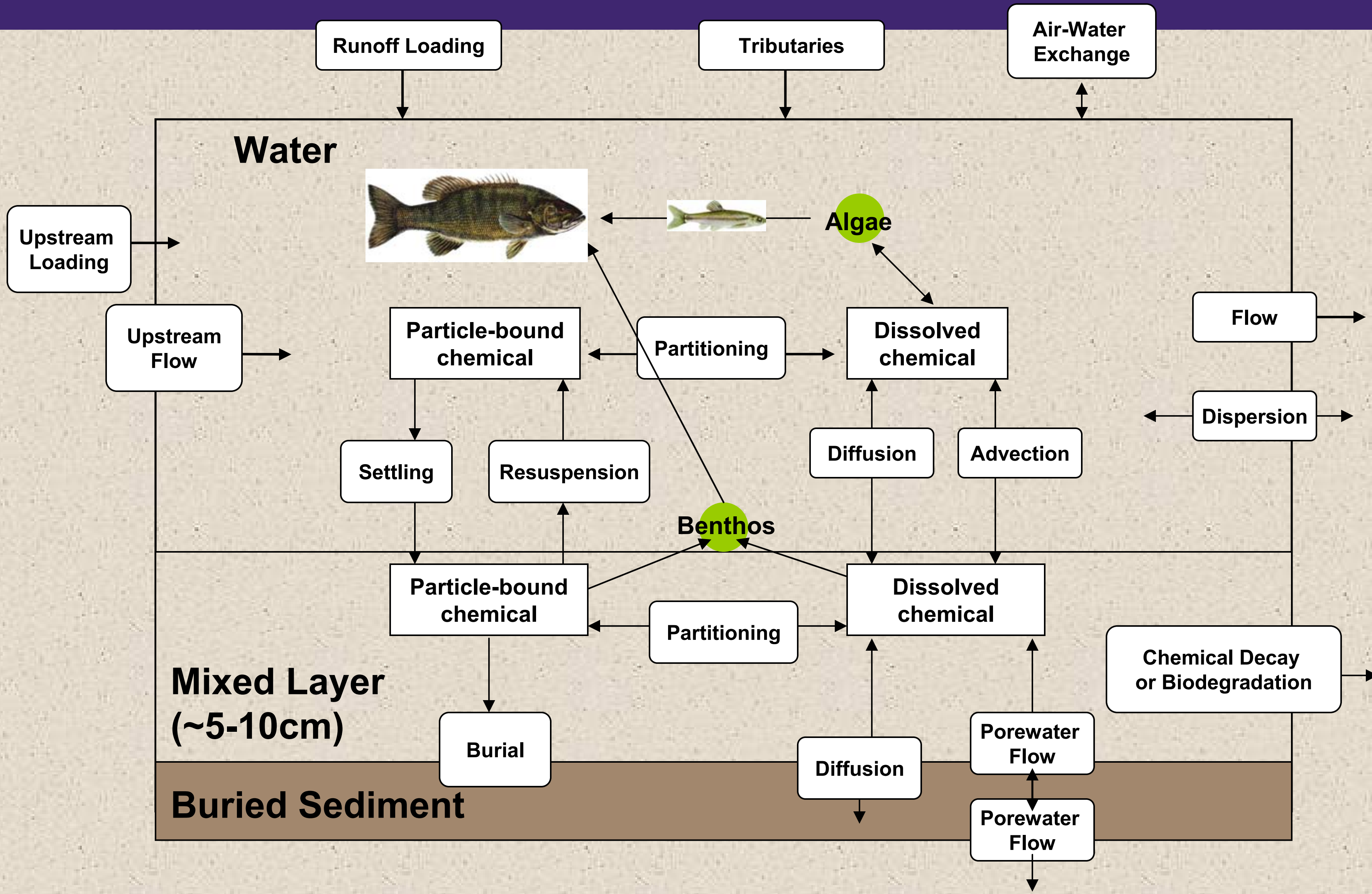
CSM-5

ASTM Standard: E1689-95(2003)e1 Standard Guide for Developing Conceptual Site Models for Contaminated Sites

EPA Example CSM



Development of a Conceptual Model



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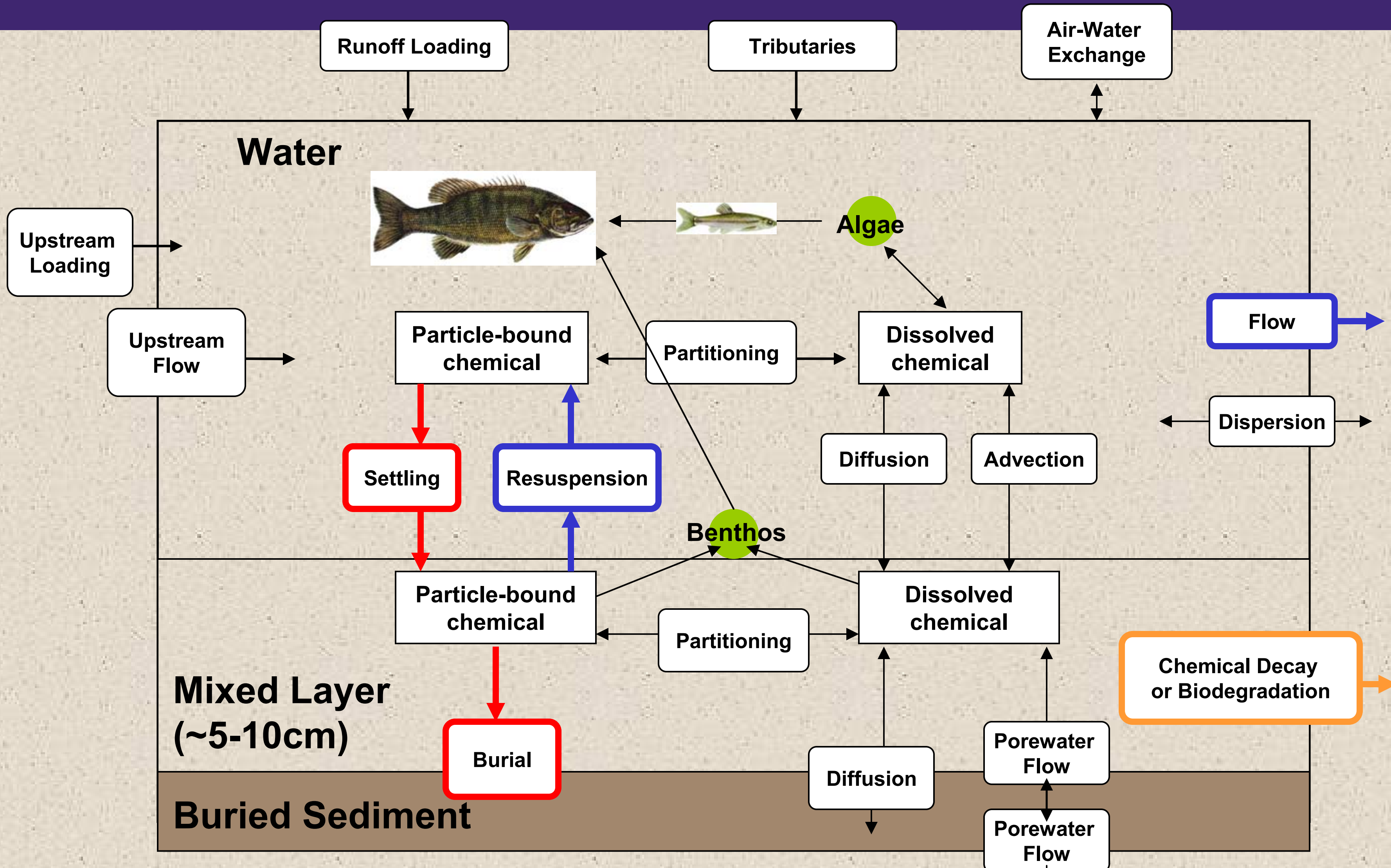
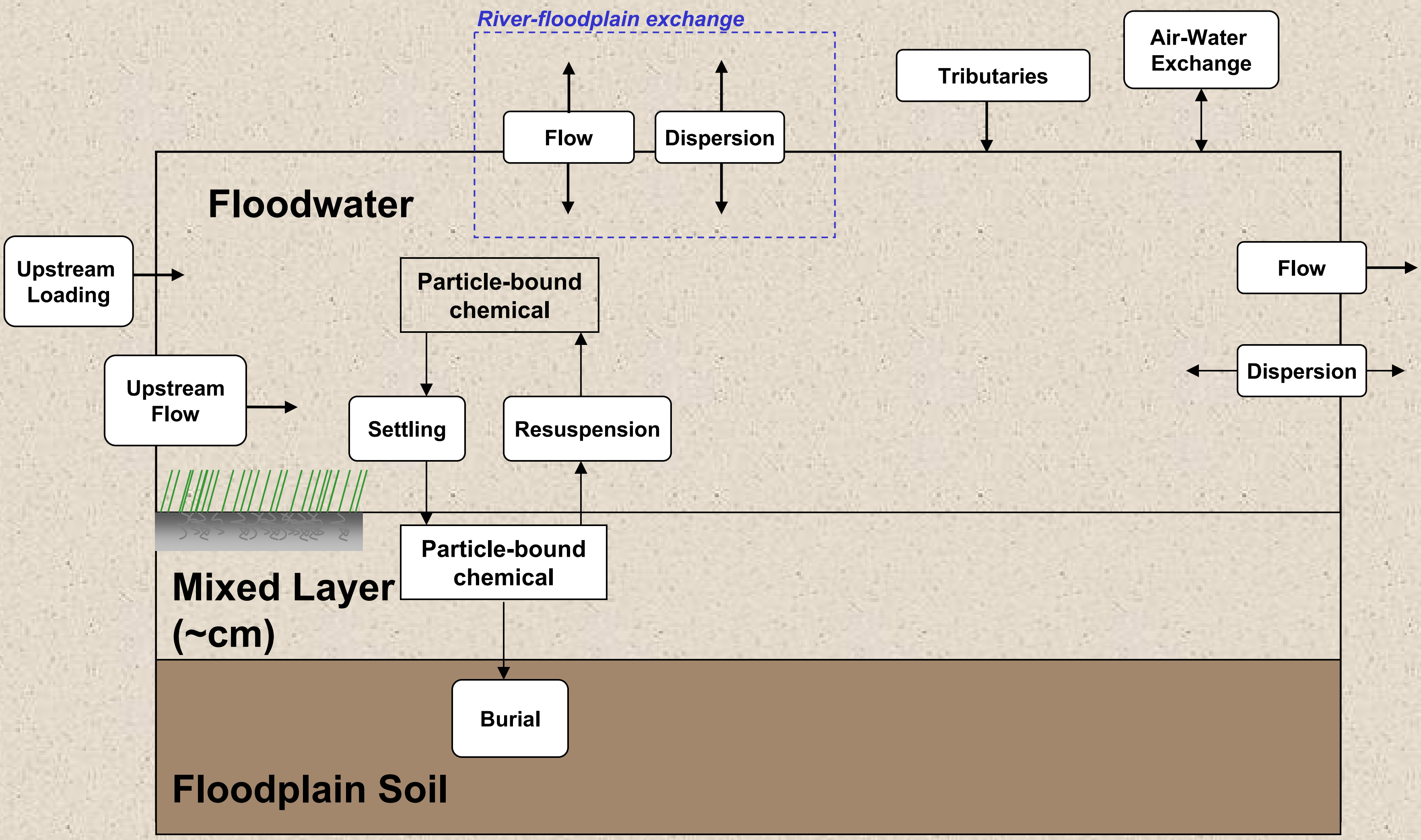


Primary modes of attenuation: settling/burial, resuspension/advection, chemical decay/biodegradation

Development of a Conceptual Model

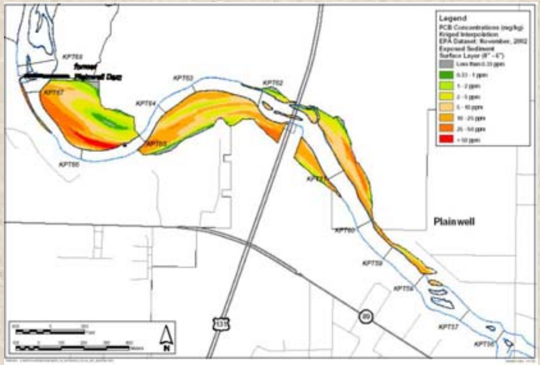


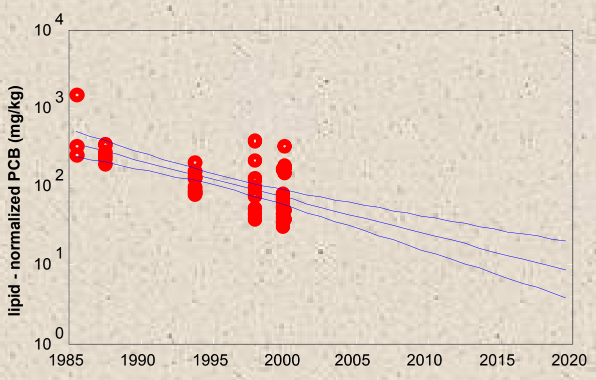
Refinement of Conceptual Model

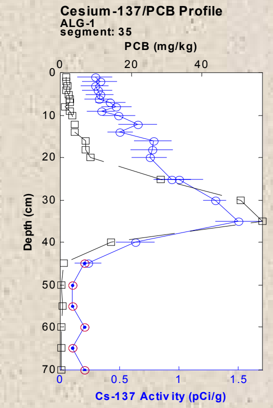
- Conceptual model is continually refined by:
  - Hypothesis development
  - Data gathering
  - Hypothesis testing

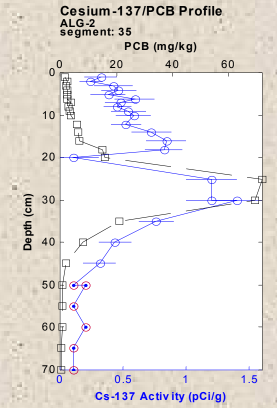
Conceptual Models are Informed by Spatially and Temporally Appropriate Data

- Spatial trends over relevant exposure areas
- Time trends over relevant exposure periods
- Time trends over periods of sufficient duration to show important system changes

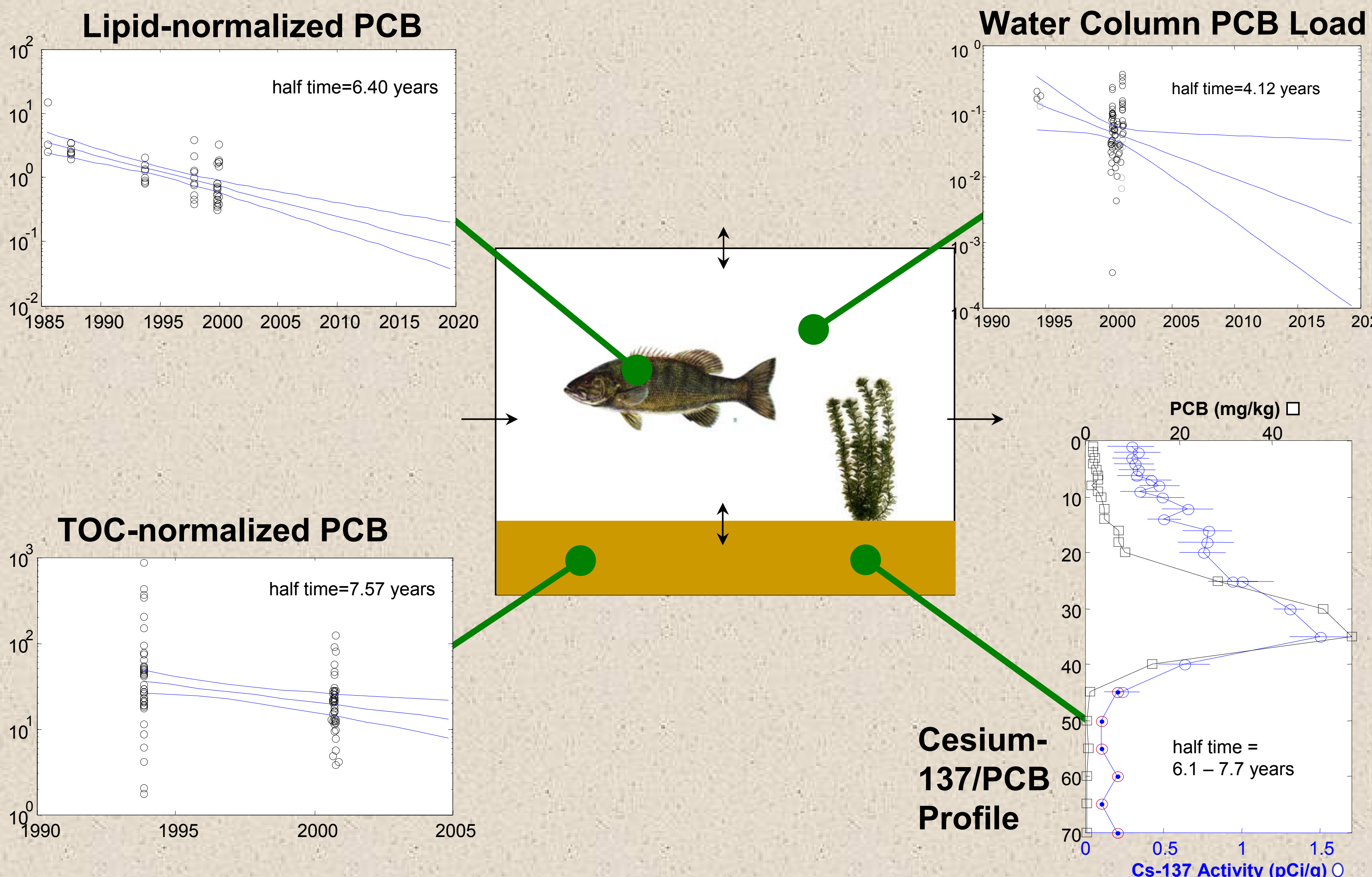




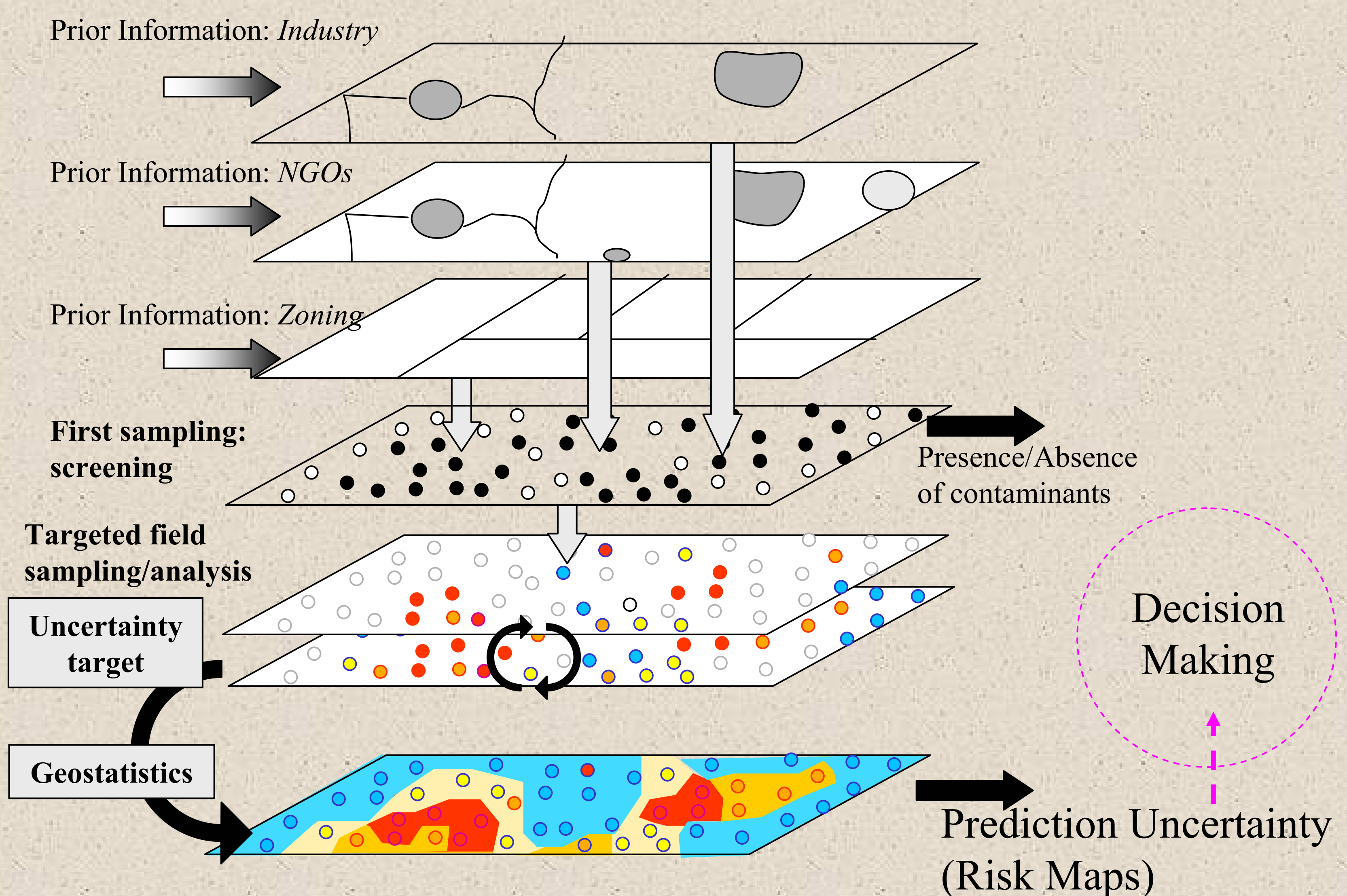




Conceptual Models are Refined and Tested with Data from Numerous Sources



Integrating Data Sources and Their Uncertainties



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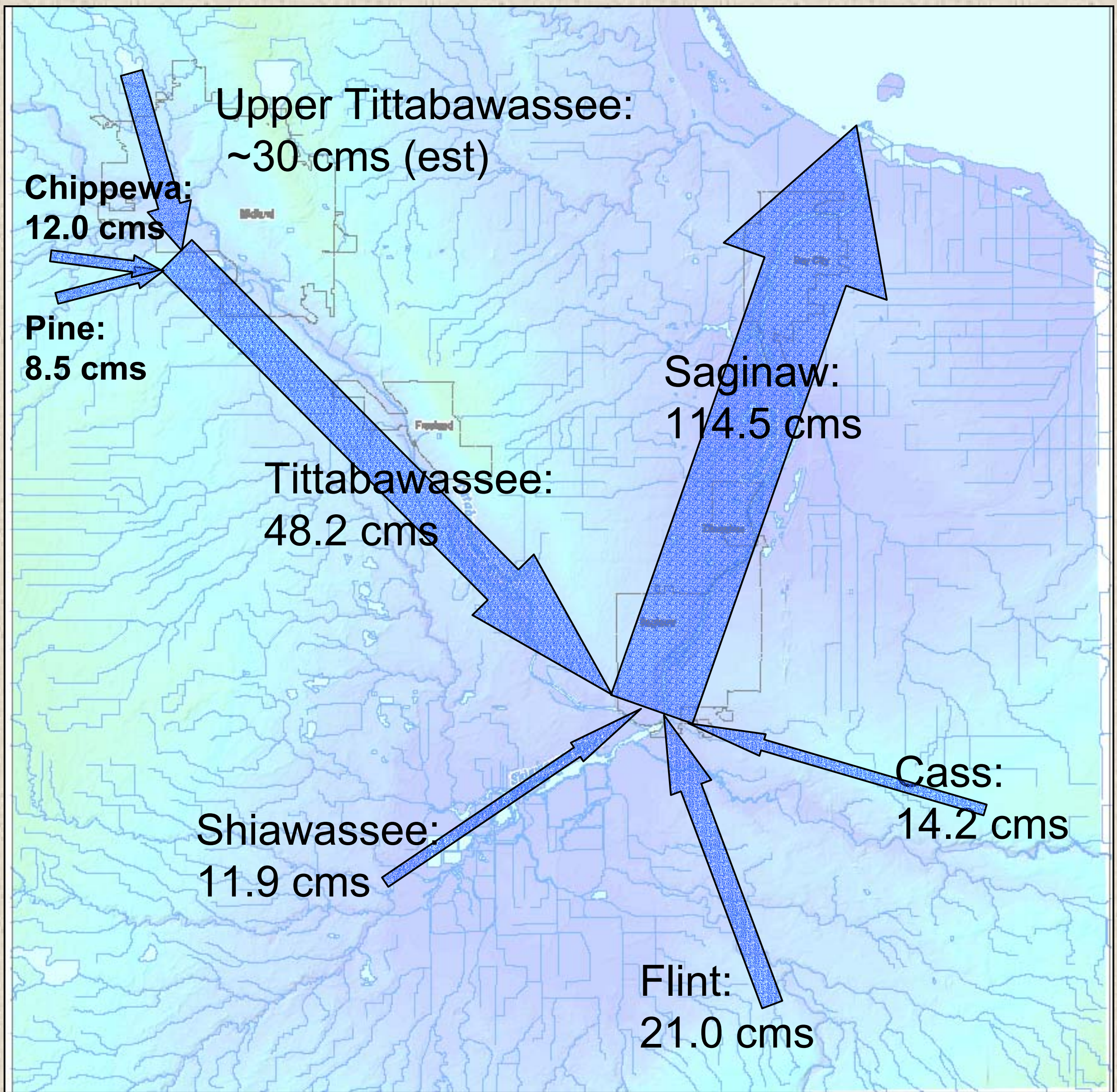
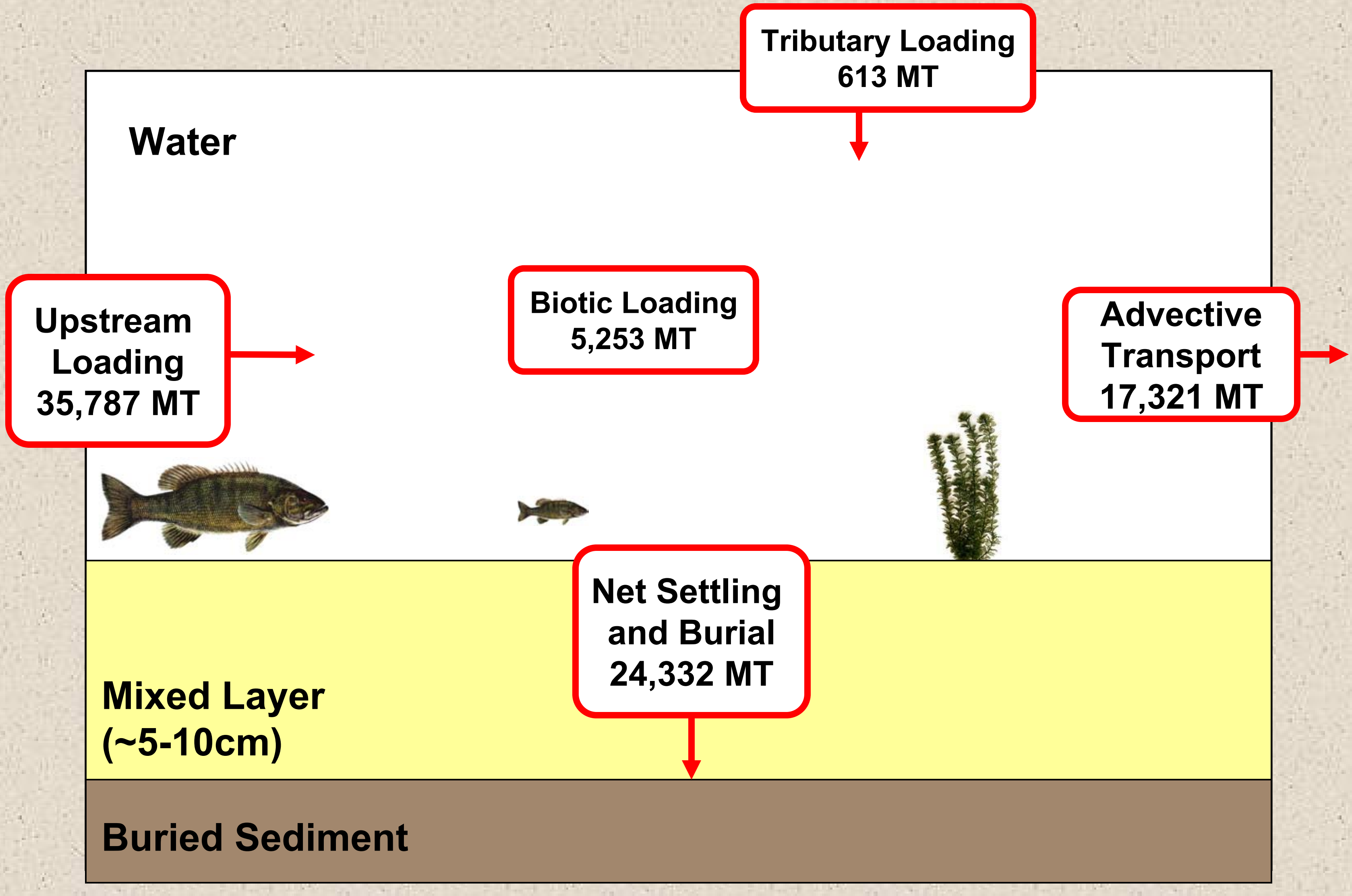
Flow and solids sampling

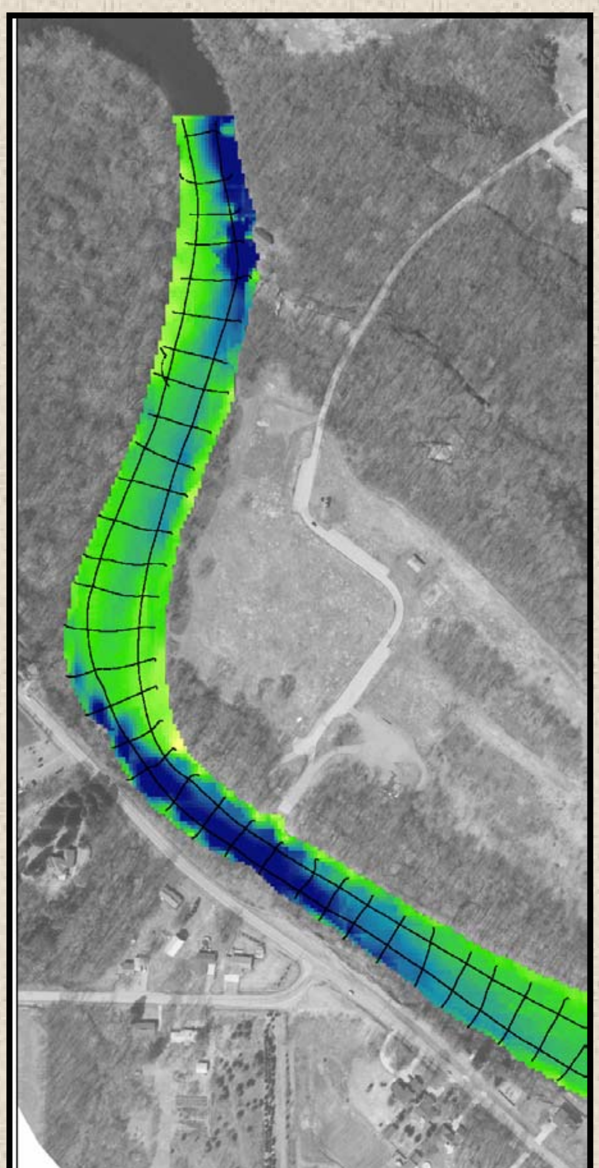


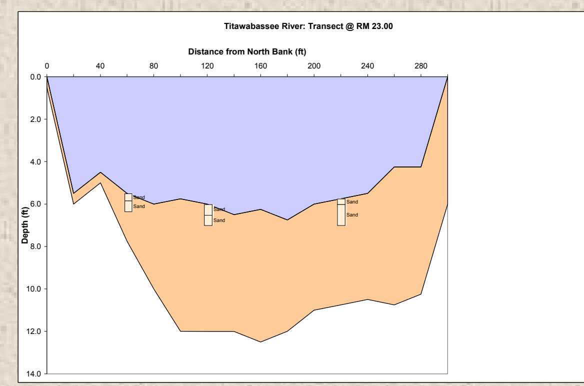
Simple solids balancing

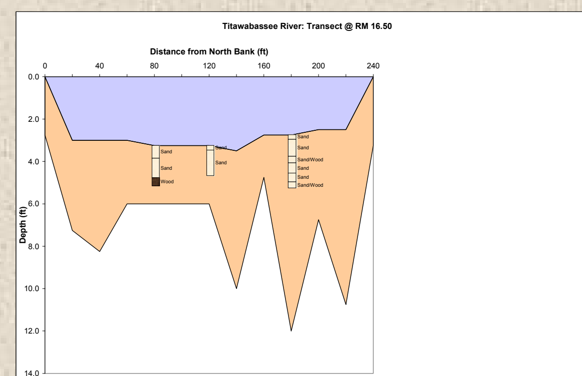


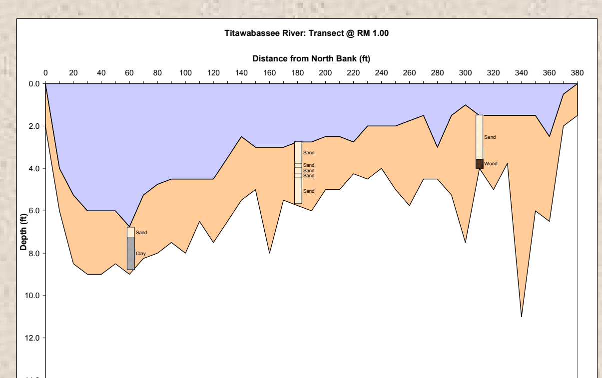
Sediment Characterization: Poling, Bathymetry

- Goals:
  - Gather basic data to support hydraulic/hydro-dynamic analyses
  - Develop a basic understanding of the character, dynamics, spatial variability of the sediment bed







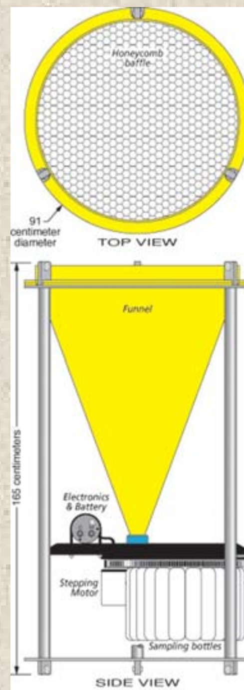


Deposition measurements

USGS
science for a changing world

Figure 4. Feldspar clay pads and plexi-glass sediment plate, Long Branch Creek forested riparian area, Macon, MO

Feldspar clay pads/ plexiglass plates



Sediment traps

USGS
science for a changing world

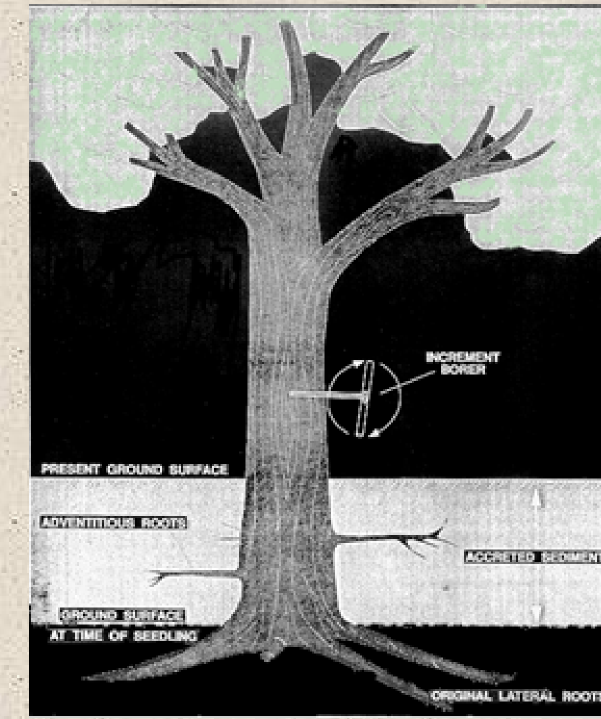


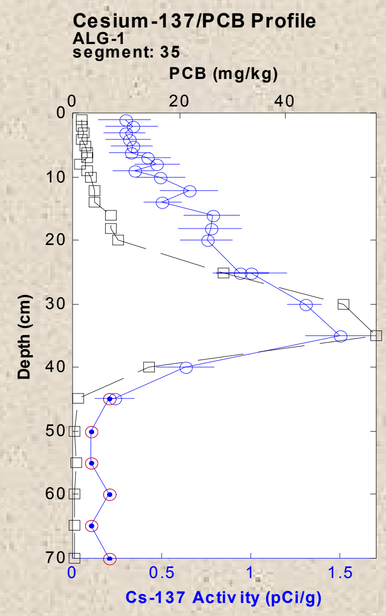
Figure 5. Age of tree determined by sampling and counting tree rings. Accreted sedimet determined by measuring deposited sediment thickness over original tree roots

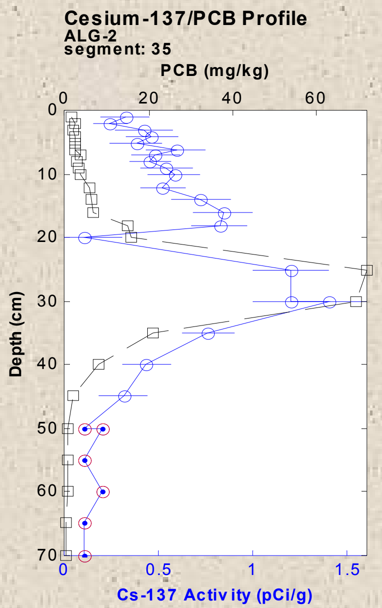
Dendrogeomorphic measurements

http://mo.water.usgs.gov/indep/heimann/longbranch/images/figure4.jpg

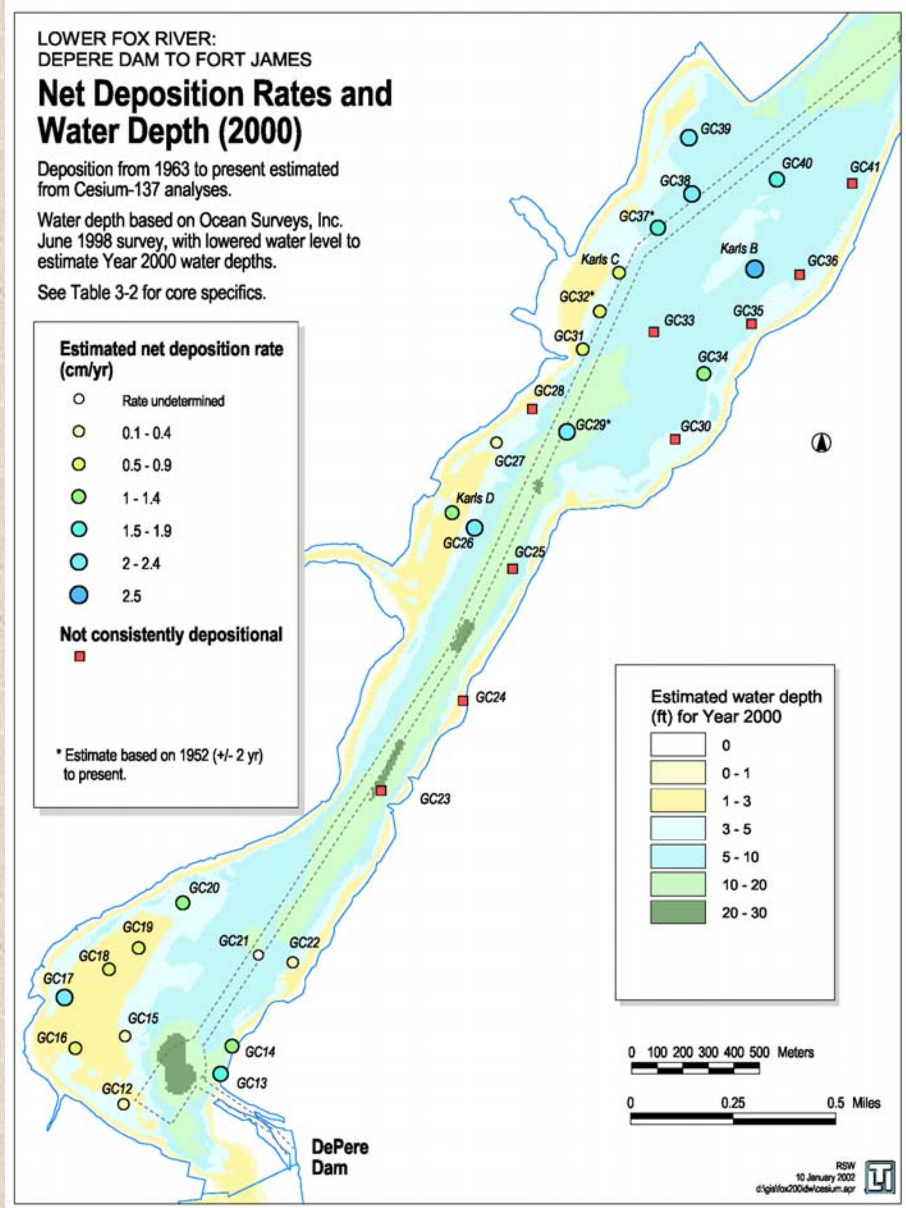
http://mo.water.usgs.gov/indep/heimann/longbranch/images/Figure5b.gif

Geochronological Investigations





$$\rightarrow \quad \frac{\partial c}{\partial t} = -v_b \frac{\partial c}{\partial z} - kc$$

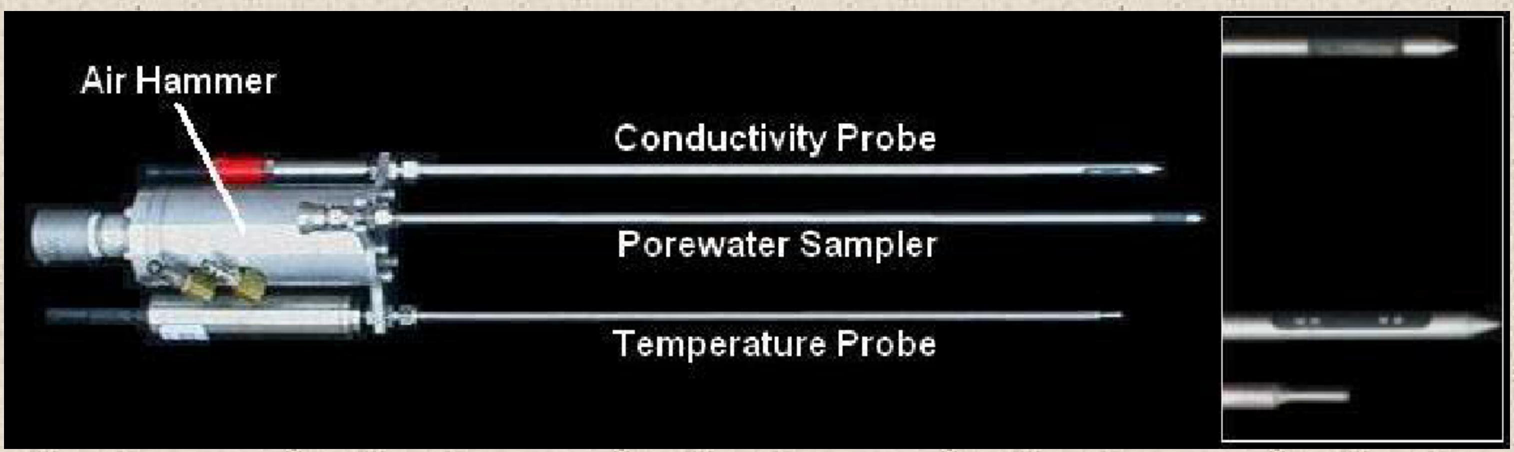


Monitoring/measurement of bank erosion, retreat rate

- Physical observations of bank condition, vegetative cover can be used to infer erodibility of banks
- Erosion pins or other survey techniques can be used to quantify bank retreat rates

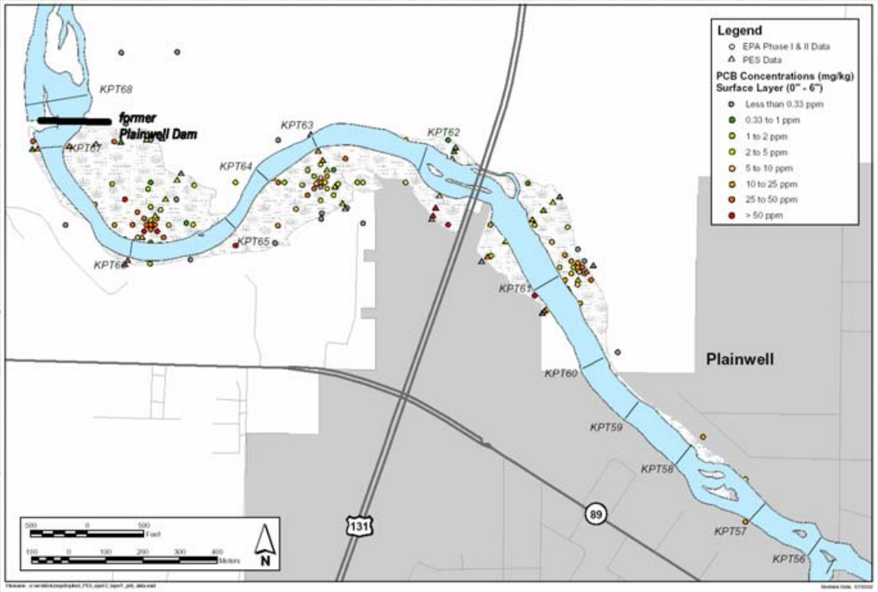
Monitoring/measurement of groundwater/surface water interaction

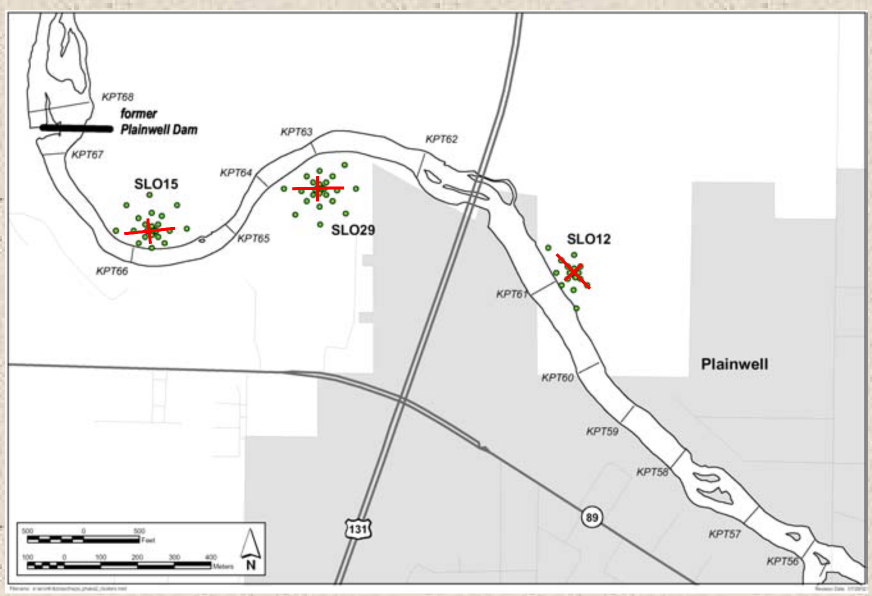
- Temperature/conductivity probing can be used to detect gradients, indicate extent of GW/SW interaction
- Seepage meters can be used to measure GW/SW seep directly



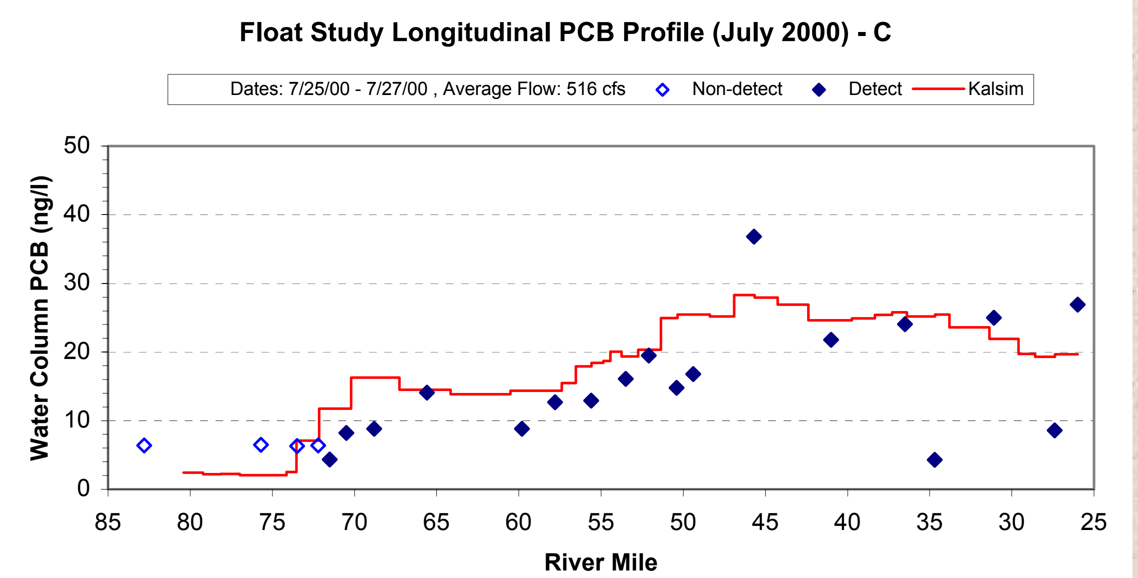
Contaminant sampling – soils, sediments

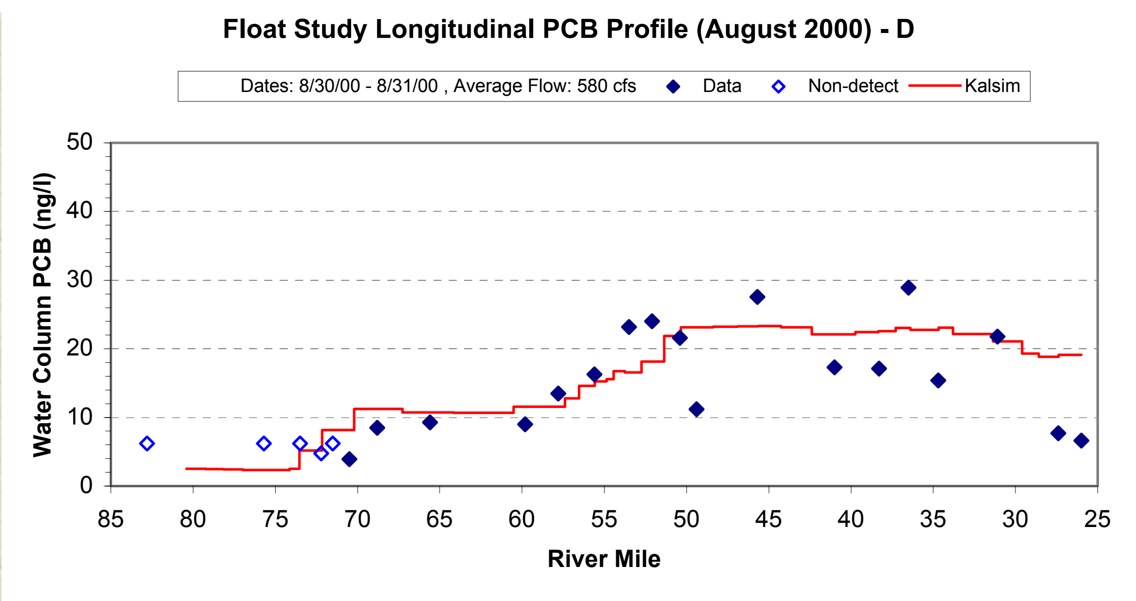
- Sampling plan development
  - Considering exposure pathways, key receptors
  - Iterative, part of CSM refinement
- Methods
  - Phased analyses
  - Geostatistical considerations
  - Screening-level analytical methods



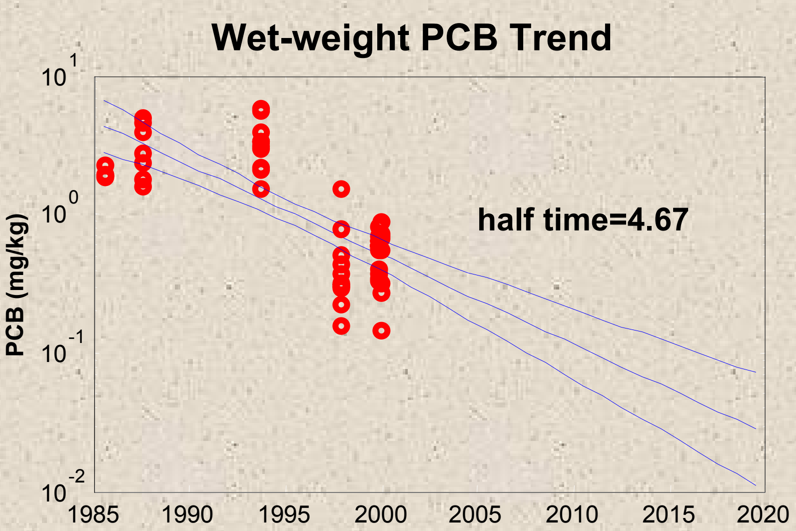


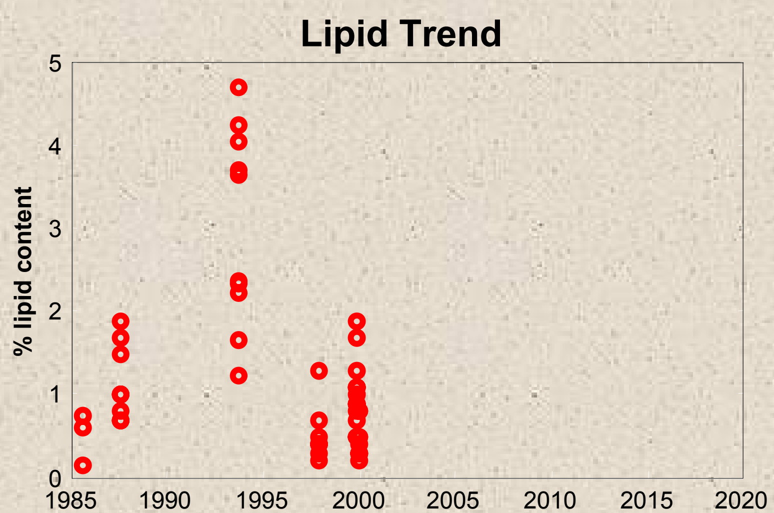
Contaminant sampling – water column

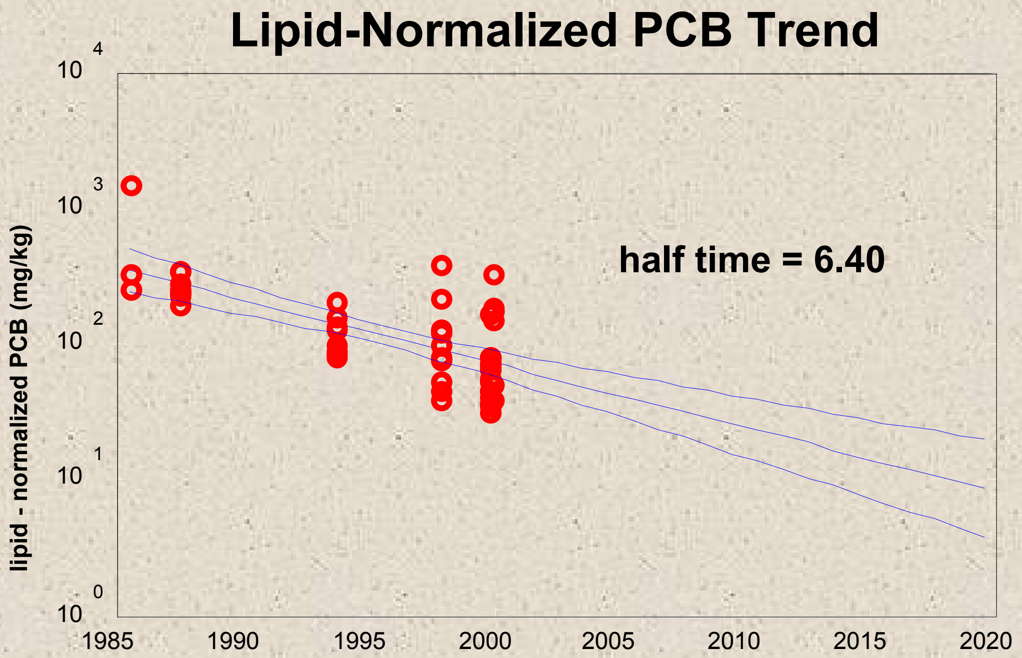




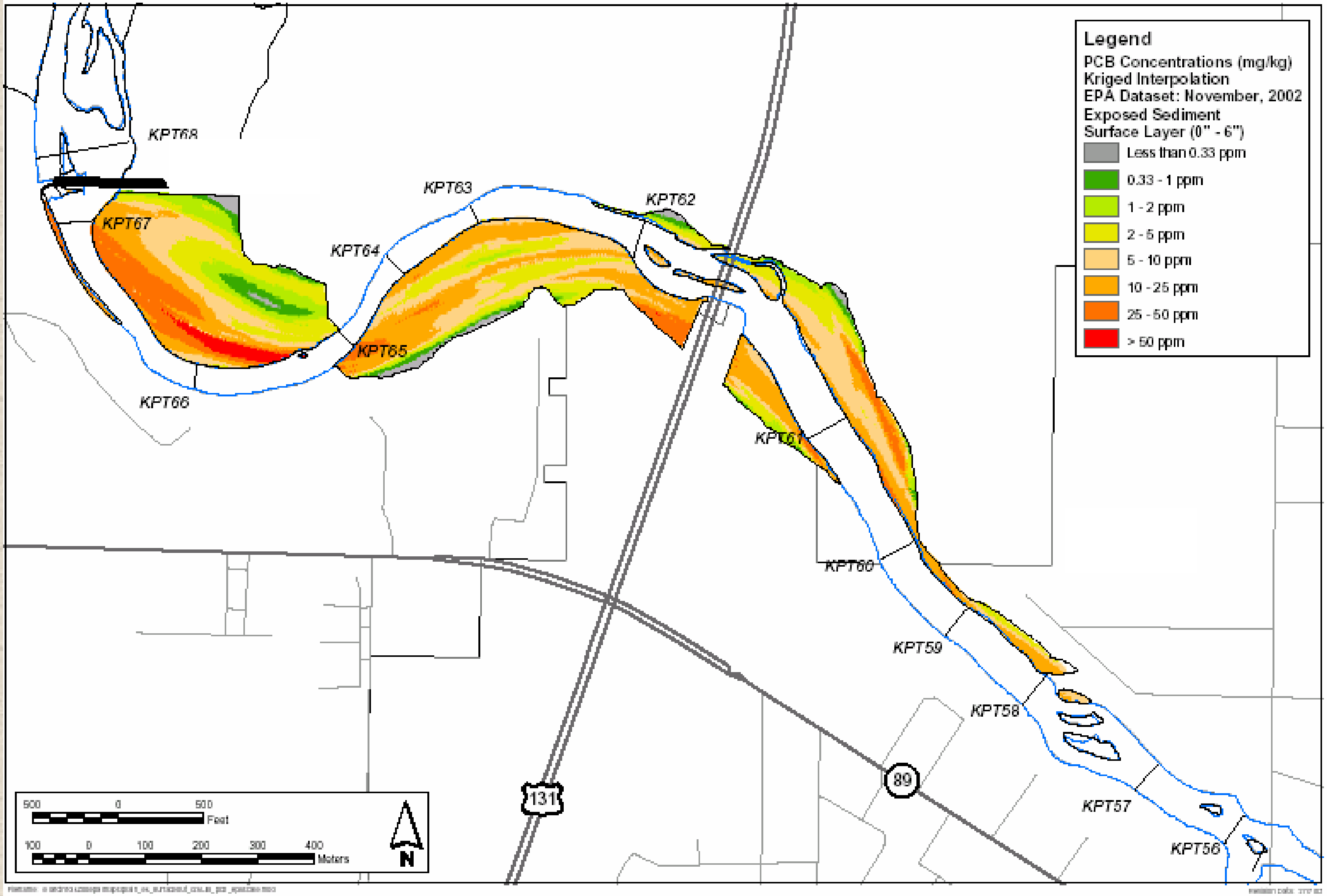
Time trending analysis





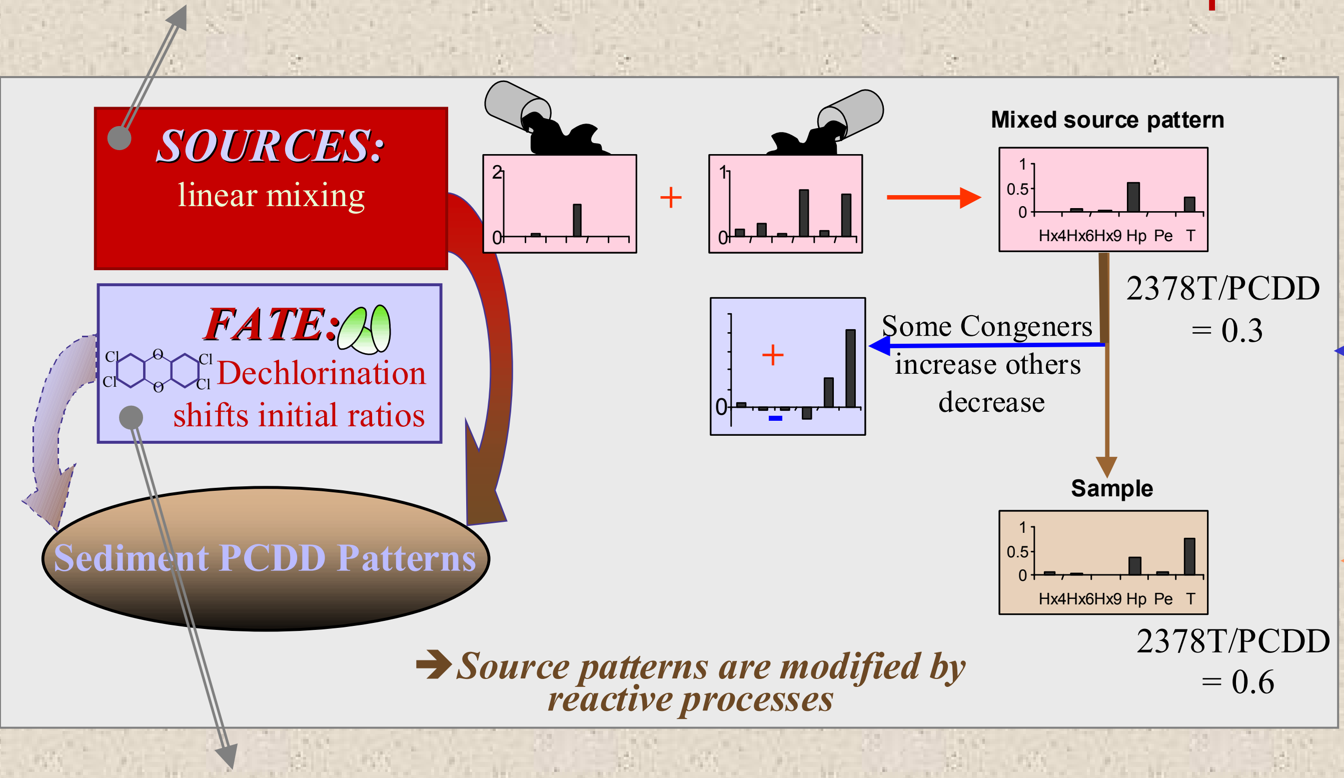


Spatial trending analysis



Polytopic Vector Analysis (PVA)

Traditional PVA: used to model source patterns



Infer source distribution and relevant fate processes

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.
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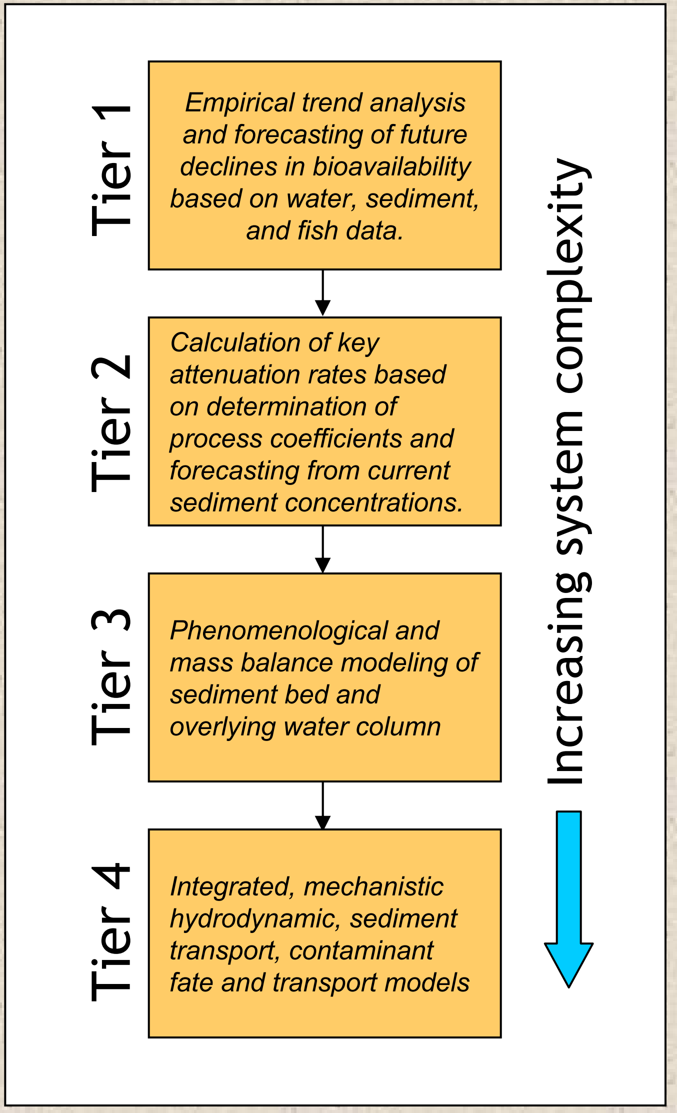
From final distribution

Modified PVA, used to model reactive patterns in dioxins/furans

Numerical models (Tiers of modeling complexity)

- Tier 1: Empirical models of trends
- Tier 2: Attenuation rates, key process coefficients (development of conceptual model)
- Tier 3: Phenomenological and mass-balance modeling
- Tier 4: Mechanistic models of hydrodynamics, sediment transport, contaminant fate and transport



Tools for Site Characterization - Summary

Flow/Solids Sampling

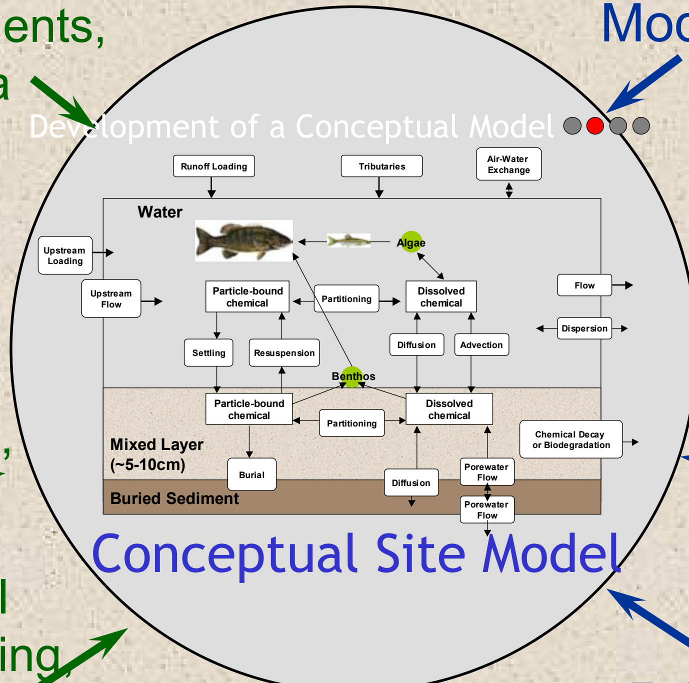
Contaminant Sampling:
Water Column, Sediments,
Floodplain, TSS, Biota

Geochronological
Investigations

Resuspension/Deposition
Measurements (In-stream,
floodplain)

Sediment/soil physical
characterization (probing,
PSD, TOC, etc)

Bathymetric Studies



Mathematical/Numerical
Models:

Statistical Trending Models (Tier 1)
Simple Process Models (Tier 2)
Mass-Balance Models (Tier 3)
Mechanistic Fate and Transport Models (Tier 4)

Geostatistical Tools

PCA, PVA

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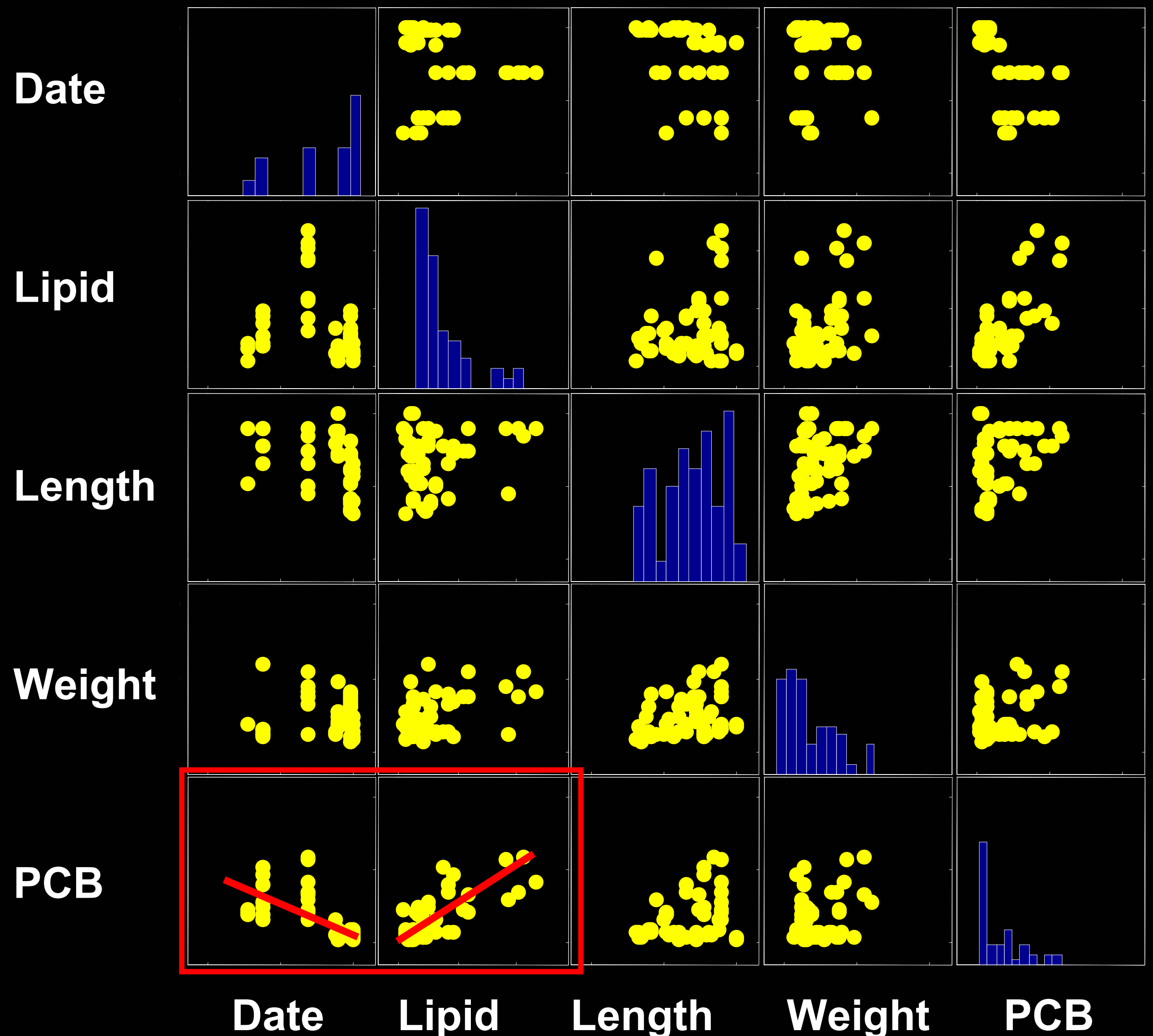
- **Relevance to Selection of Remedial Alternatives**

How does site characterization impact selection of remedial options?

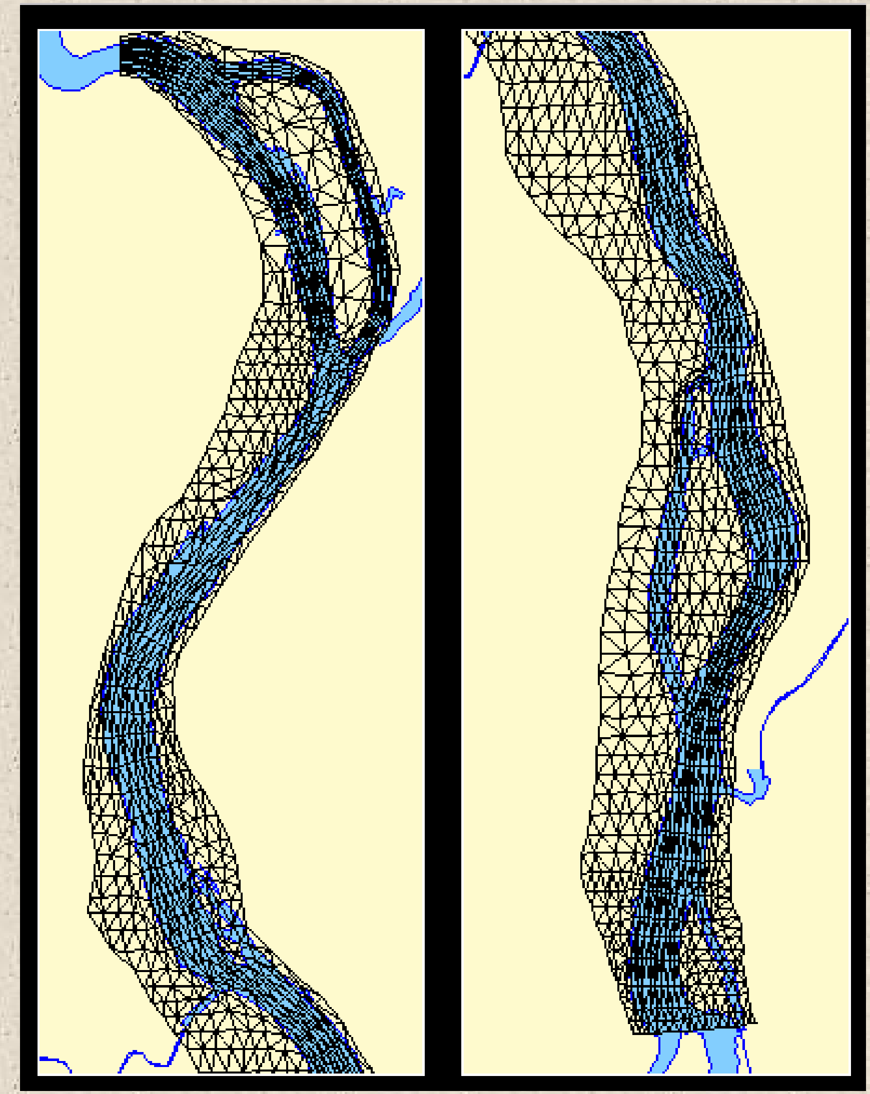
- Evaluate remediation alts using realistic assumptions for:
  - Time to complete remediation
  - Release during remediation
  - Residual contamination
  - Potential for recontamination
- Use risk-based approach for prioritization of areas within site:
  - Utilize spatial statistical methods for comparison
  - Base remediation decisions on relative risk reduction over time
- Consideration of alternatives to dredging for sediment remediation
  - Capping – various materials, including active caps
  - In-place remediation – decontamination/isolation/reduction of bioavailability
- Establish, quantify “natural recovery” as a reference for remediation decisions
  - Understand and quantify processes that contribute to natural attenuation

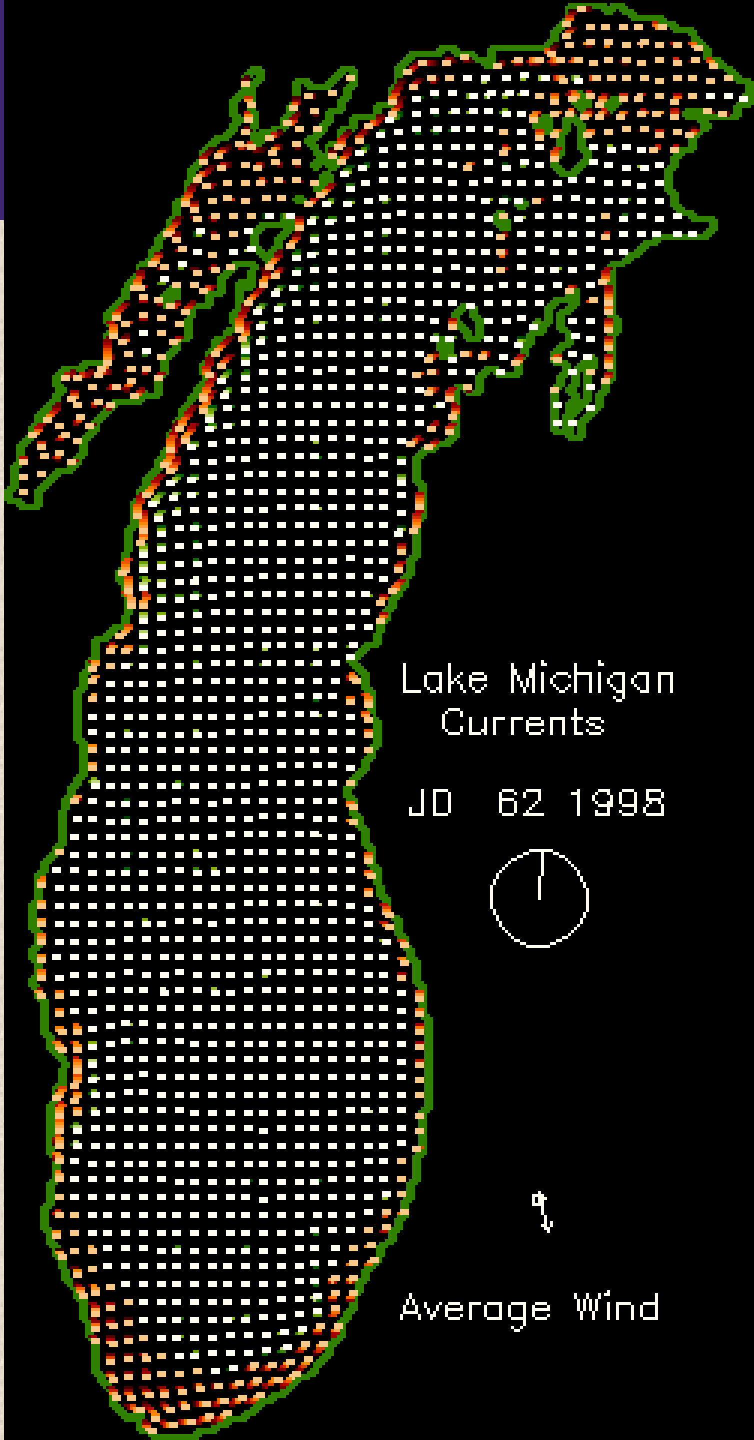
Tier 1: Simple Statistical Trending Models

Explore for confounding factors in fish data

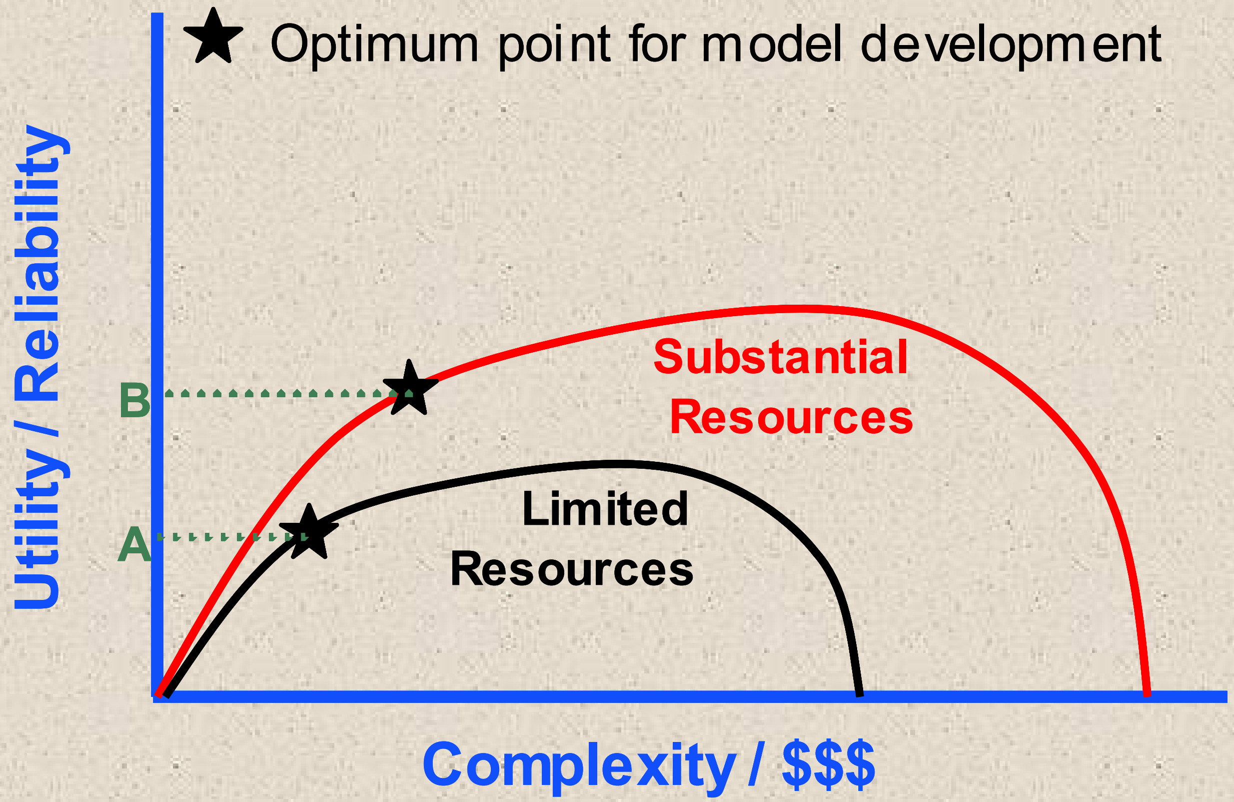


Tier 4:





Balancing model complexity and utility



A well-constrained model

- Observation of key processes and measurement of relevant rate coefficients. (previous presentation on Element 2: Fate and Transport Processes).
- Calibration to long-term trends, and model validation (See previous papers on Elements 3 and 4)
- Sufficient understanding of the system to indicate that future conditions will be similar to conditions during model calibration, or a means for the model to account for changes. (Sometimes called “permanence” of model predictions)
- Model transparency (no “black box”)
- An understanding of major sources of uncertainty

Occam’s Razor

Given the choice of multiple explanations, the simplest one is most likely correct.

Occam’s Razor
(liberally paraphrased)

Modeling translation:

If you don’t understand all of the model’s theory, or don’t have the data to describe model inputs, you’re probably “over the hump.”