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Sediment Assessments for Remedial Investigations

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October 2005

Sediment Investigation Topics

- **Regulatory basis**
 - Remedial investigations
 - NRDA
- **Project design and strategy**
- **Sampling and testing methods**
- **Data analysis, interpretation, and risk assessment methods**

Today's Outline

- **Overview of typical remedial investigation components**
 - Sediment quality triad
 - Human health risk
 - Ecological risk
- **Shipyard-specific issues**
 - Bioavailability
 - Physical disturbance
 - Other sources

Sediment Investigation Objectives (Technical)

- **Determine nature and extent of sediment conditions**
- **Characterize potential adverse effects to:**
 - Aquatic life
 - Aquatic-dependent wildlife
 - Human health
- **Support development of remedial alternatives**

Sediment Investigation Objectives (Procedural)

- **Do what is necessary to characterize the site accurately**
- **Don't do anything unnecessary**

Characterize Potential Adverse Effects

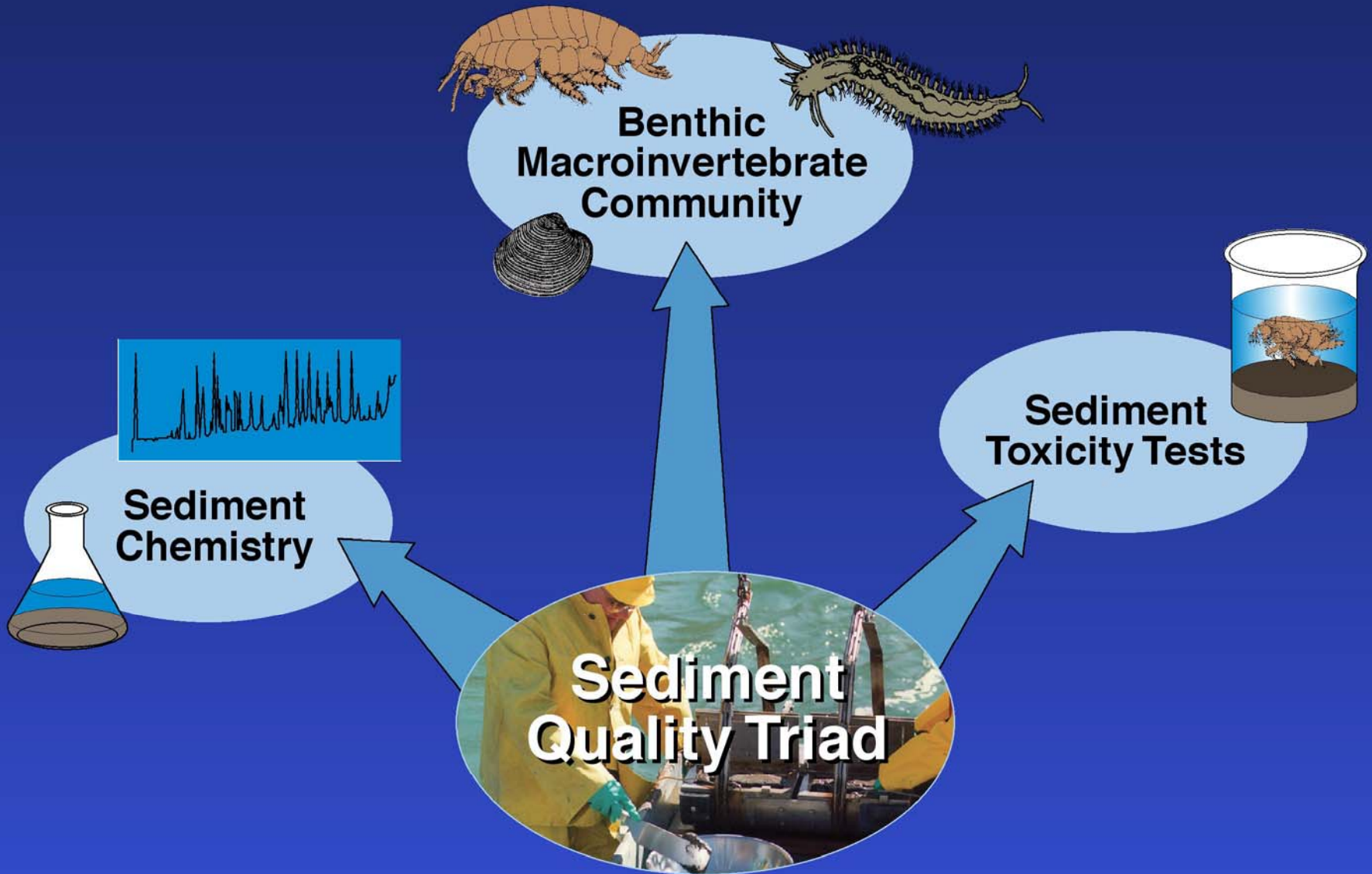
- Aquatic life
- Aquatic-dependent wildlife
- Human health



Sediment Quality Triad

- **The foundation of most sediment remedial assessments**
- **Addresses only aquatic life effects**
- **Regulatory basis**
 - Widely cited in state and federal guidance
 - Established in Washington sediment quality standards
 - Will be established in upcoming California sediment quality standards

Sediment Quality Triad



Common Sediment Toxicity Tests

- Amphipod survival (reburial)
- Echinoderm fertilization
- Bivalve larva development (survival)
- Polychaete (*Neanthes*) growth
- MICROTOX—bacterial bioluminescence

Benthic Macroinvertebrates



Benthic Macroinvertebrate Data Interpretation

- Total abundance
- Total richness (number of species)
- Major taxa abundances
- Swartz' dominance index (SDI)
- Percent dominance
- Shannon-Wiener diversity index
- Multivariate statistical techniques
 - Cluster analysis
 - Non-metric multidimensional scaling

Decision Matrix for Toxicity Tests

Amphipod Survival	Echinoderm Fertilization	Bivalve Development	Likelihood of Toxicity
Yes	Yes	Yes	High
Yes	Yes	No	High
Yes	No	Yes	Medium
Yes	No	No	Medium
No	Yes	Yes	Medium
No	Yes	No	Low
No	No	Yes	Low
No	No	No	Low

Decision Matrix for Triad Results

Likelihood of Toxicity	Benthic Community Differences from Reference	Likelihood of Adverse Biological Effects
High	Major	Highly likely
High	Moderate	Highly likely
High	Minor	Likely
High	None	Possible
Medium	Major	Highly likely
Medium	Moderate	Likely
Medium	Minor	Possible
Medium	None	Possible
Low	Major	Highly likely
Low	Moderate	Likely
Low	Minor	Unlikely
Low	None	Unlikely

Triad Data Applicability

- Triad data can broadly **characterize** site conditions and effects
- Triad data may be insufficient to **explain** site conditions and effects

Human Health and Ecological Risk

- **Human health**

- Consumption of fish and shellfish
- Recreational exposure
- Occupational exposure
- Cancer and non-cancer (toxicity) risks evaluated

- **Ecological risk**

- Consumption of fish, shellfish, and benthic macroinvertebrates
- Only toxicity risks evaluated

Human Health and Ecological Risk Assessment

- **Risk assessment models**
 - Well established for human health risk assessment
 - May vary from simple to complex for ecological risk assessment
- **Tissue concentrations of chemicals**
 - Site-specific data
 - Estimated using simple models
- **Exposure assessment**
 - Frequency of exposure

Shipyard-specific Issues

- **Bioavailability**
- **Physical disturbance**
- **Other sources**

Issues ↔ Inconsistencies

- **Possible issues**
 - High chemistry and low toxicity
 - Benthic impacts and low chemistry
 - No relationships between adverse biological effects and shipyard chemicals
- **Inconsistencies → uncertainty**
- **Uncertainty → conservatism**

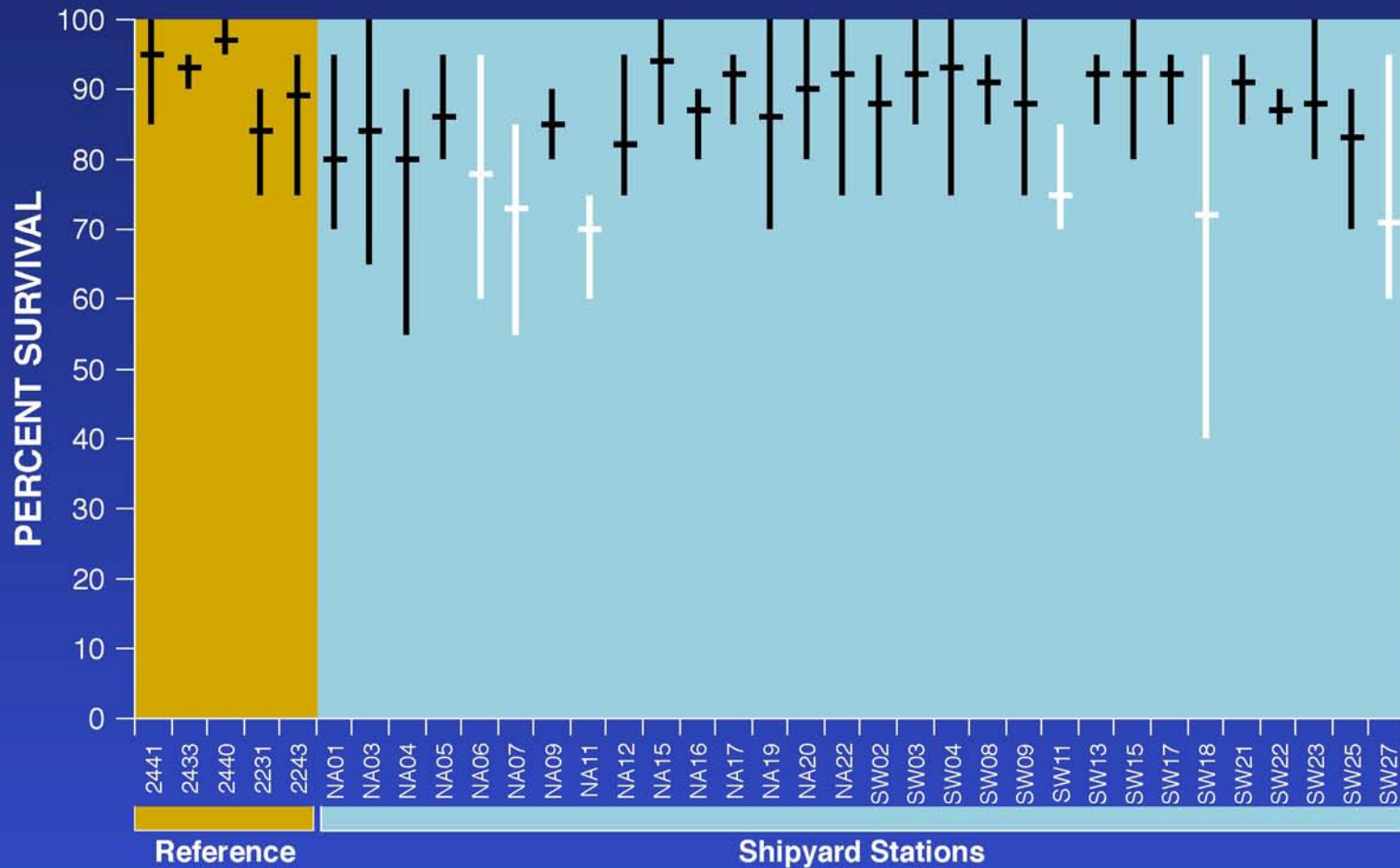
Causes of Limited Bioavailability

- **Material characteristics**
 - Paint chips
 - Blasting grit
 - Metal chips
- **Sediment characteristics**
 - Sediment type and grain size
 - Sulfide
 - Organic carbon

Effects of Limited Bioavailability

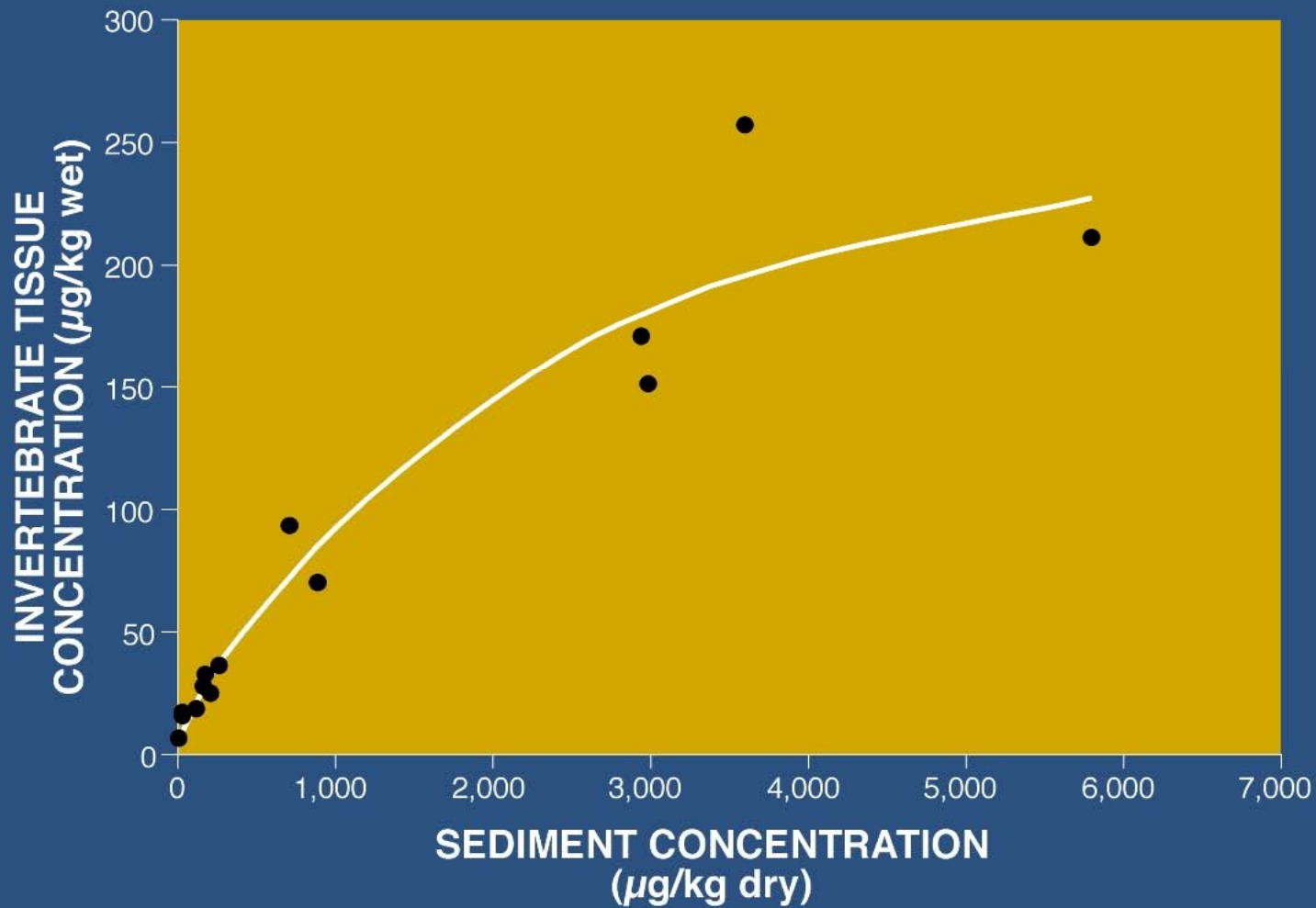
- **Low toxicity**
- **Minor benthic effects**
- **Limited bioaccumulation**

Amphipod Survival Response by Station

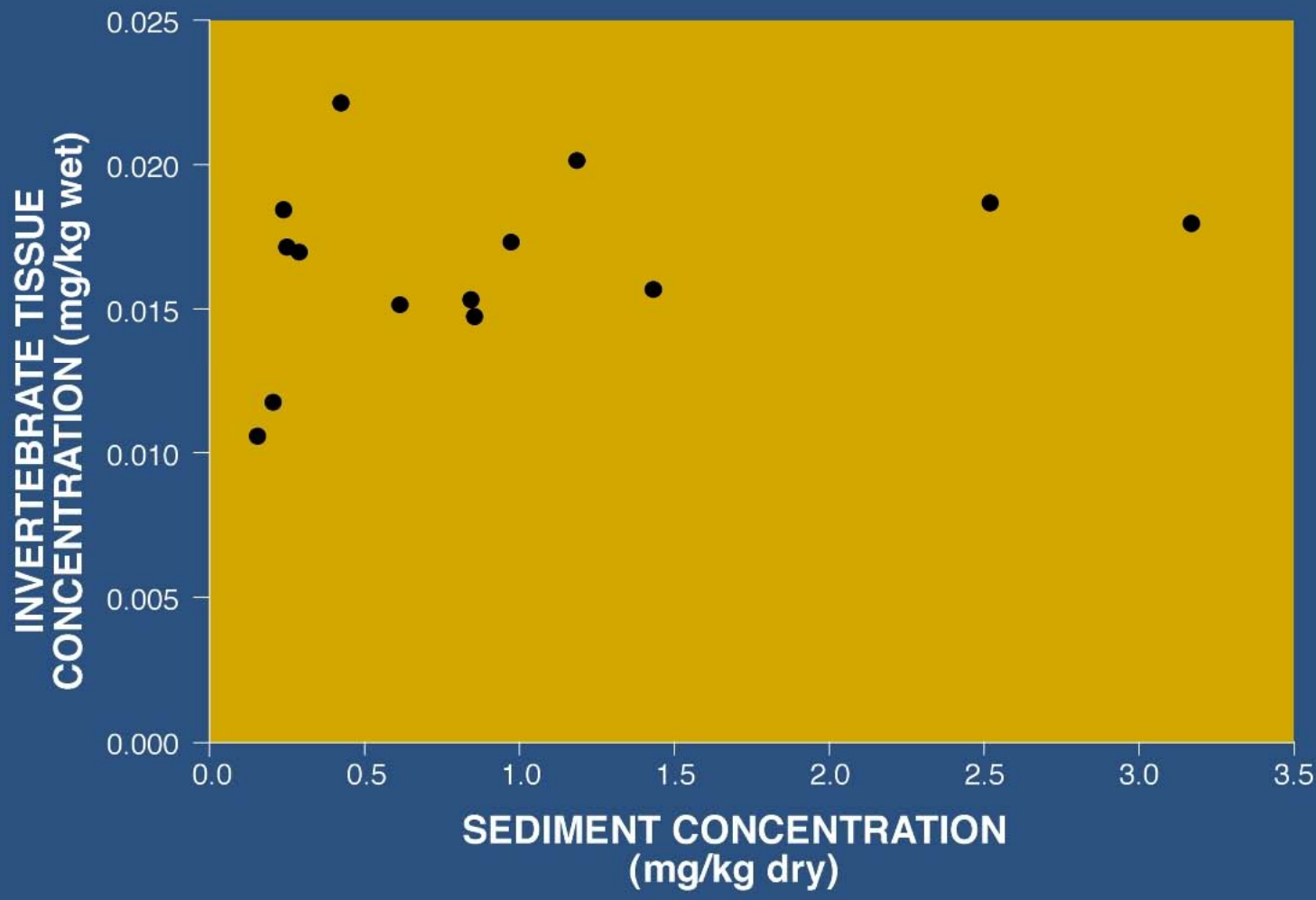


- Significantly less than final reference pool stations
- Not significantly less than final reference pool stations

Bioaccumulation Test – PCBs



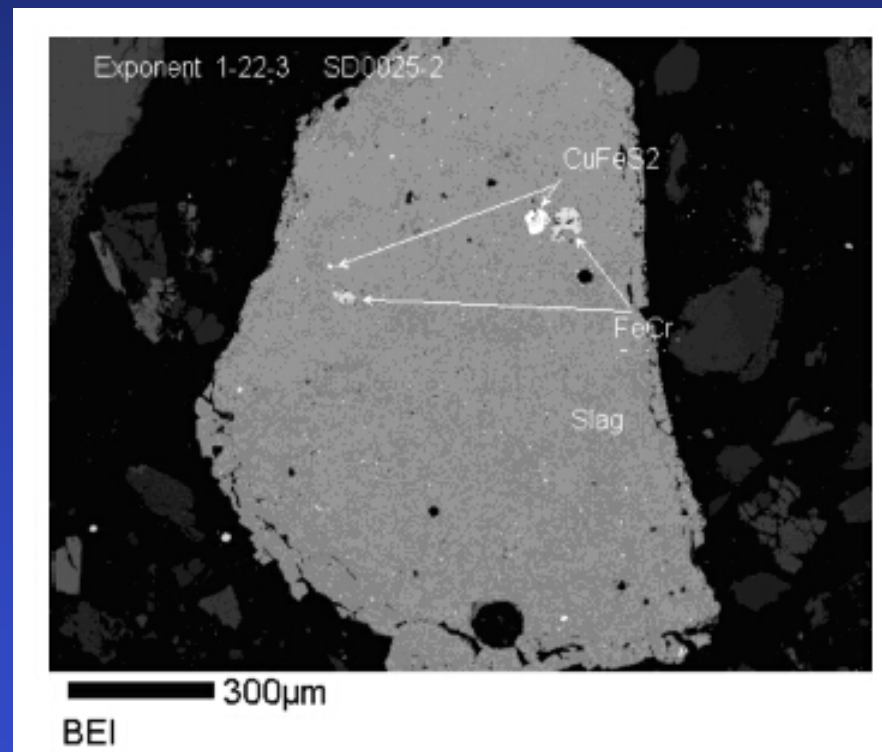
Bioaccumulation Test – Mercury



Methods of Assessing Bioavailability

- **Microscopic analysis of sediment**
- **Electron microprobe analysis**
- **Sulfide (AVS/SEM), grain size, and TOC analyses**
- **Additional chemical analyses (special substances)**
- **Bioaccumulation tests**
- **Special analytical methods (such as TCLP)**
- **Tissue chemistry**

Photomicrograph From Microprobe



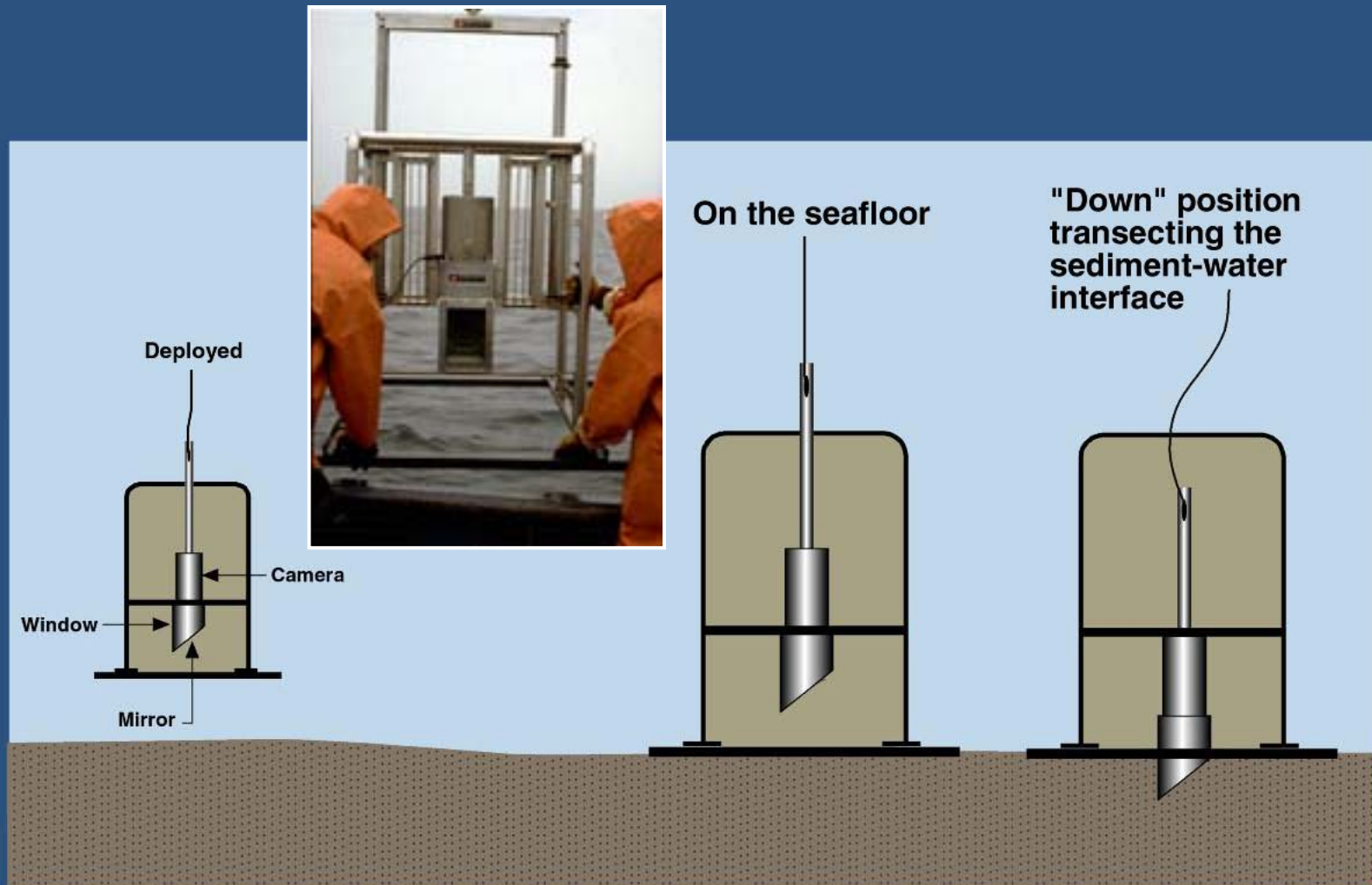
Causes of Physical Disturbance

- Ship and dry dock movements
- Shoreline construction
- Dredging
- Episodic high flows
- Unique events (e.g., groundings)

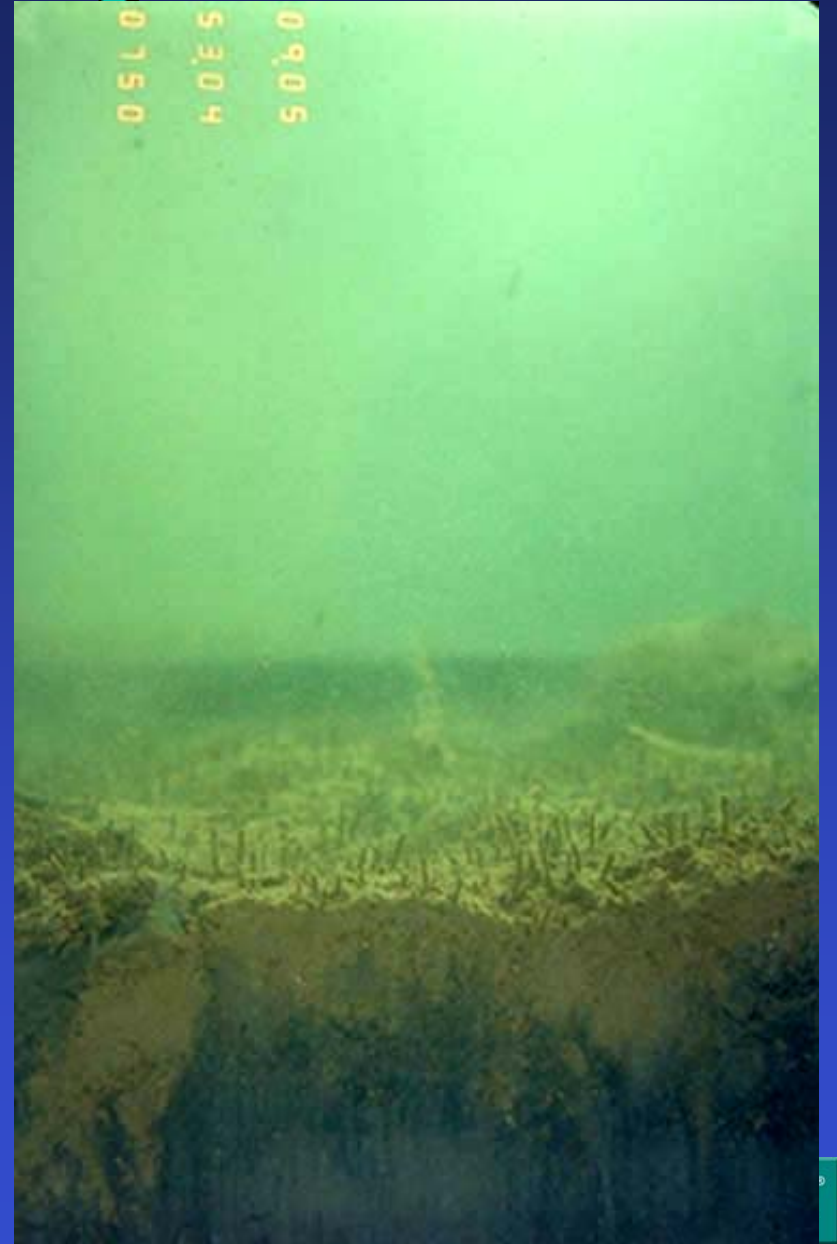
Methods of Assessing Physical Disturbance

- Sediment profile imaging
- Core profiles of grain size
- Spatial variation in surface sediment concentrations
- Temporal variation in surface sediment concentration
- Inference from triad data

Sediment Profile Camera

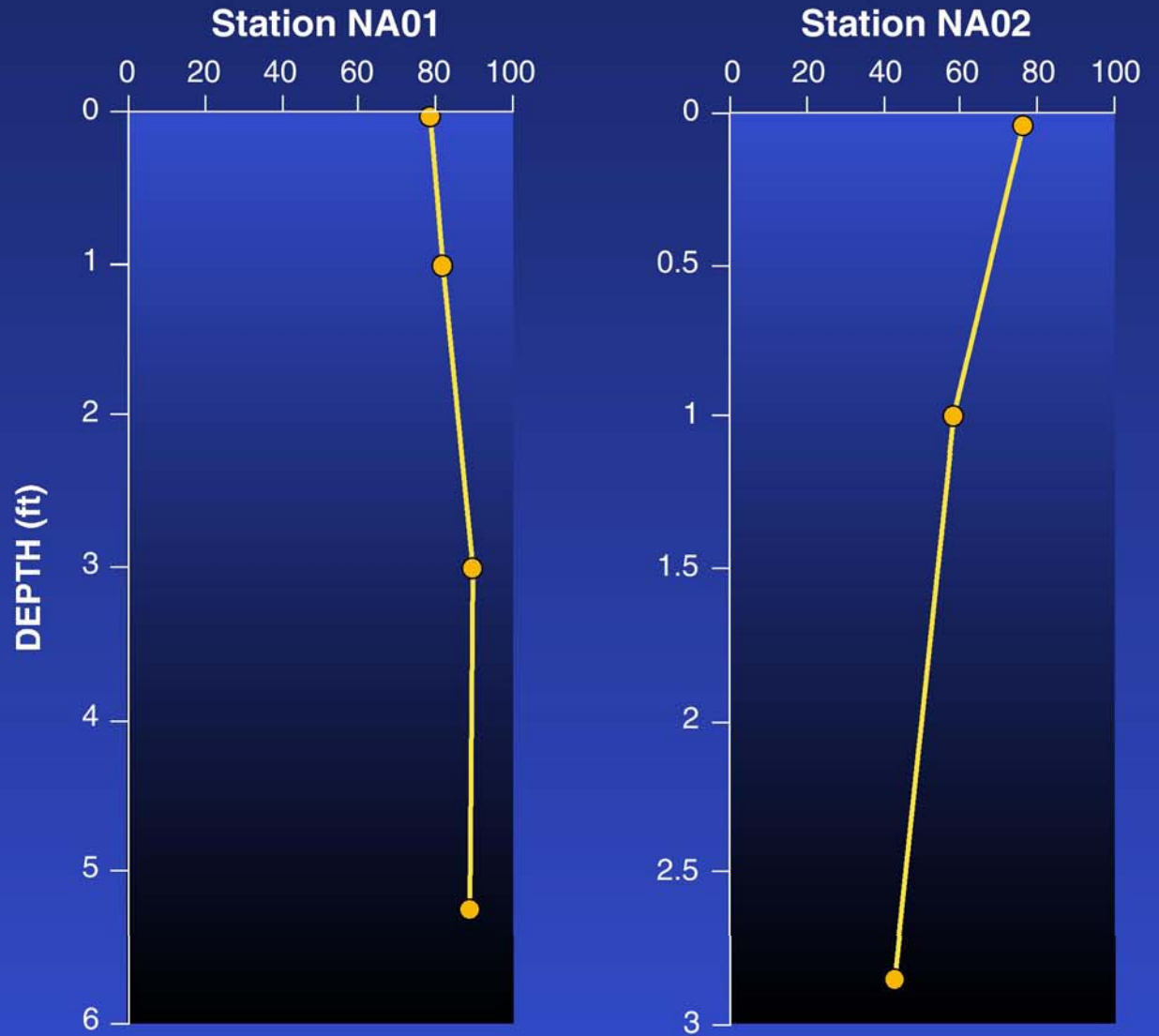


Sediment Profile Images



Profiles of Percent Fines

PERCENT FINES
(clay and silt) (percent dry)

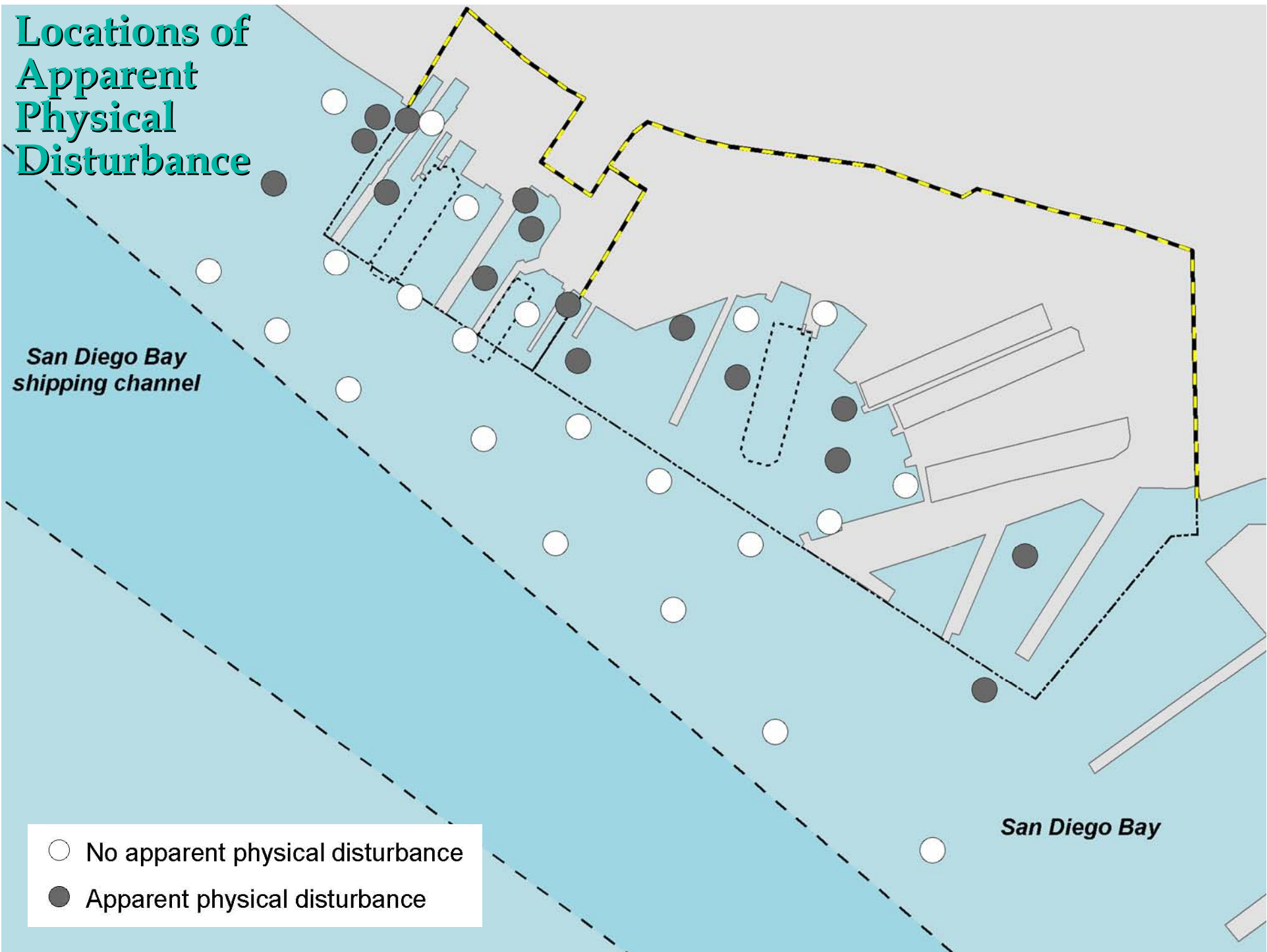


Locations of Apparent Physical Disturbance

San Diego Bay shipping channel

San Diego Bay

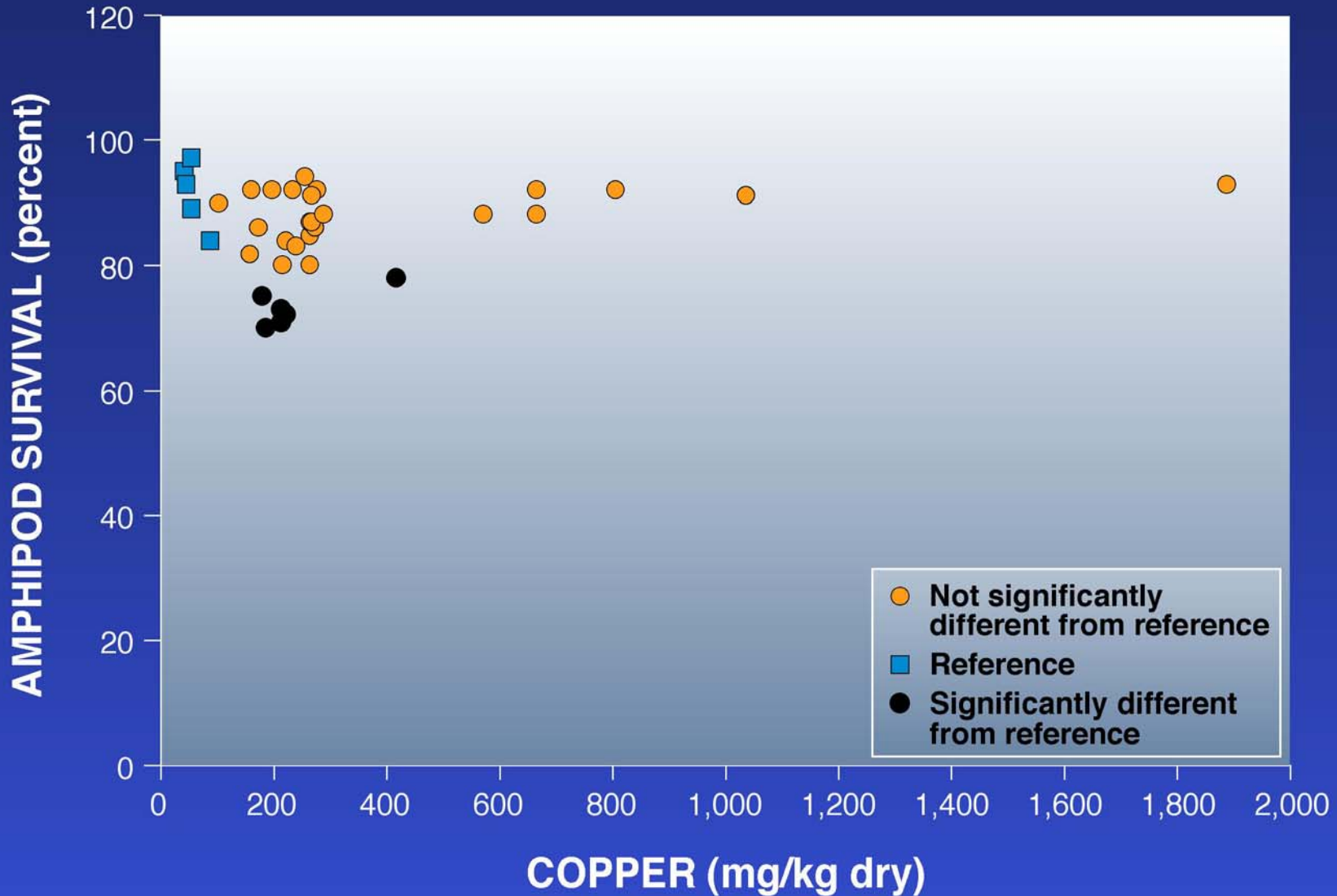
- No apparent physical disturbance
- Apparent physical disturbance



Other Sources/Toxicants

- **Effects of other sources**
 - Biological effects not correlated with shipyard chemicals
- **Methods of assessing other sources**
 - Presence of non-shipyard toxic chemicals
 - “Fingerprinting” analyses
 - Spatial gradients / transport modeling

Amphipod Survival vs. Copper



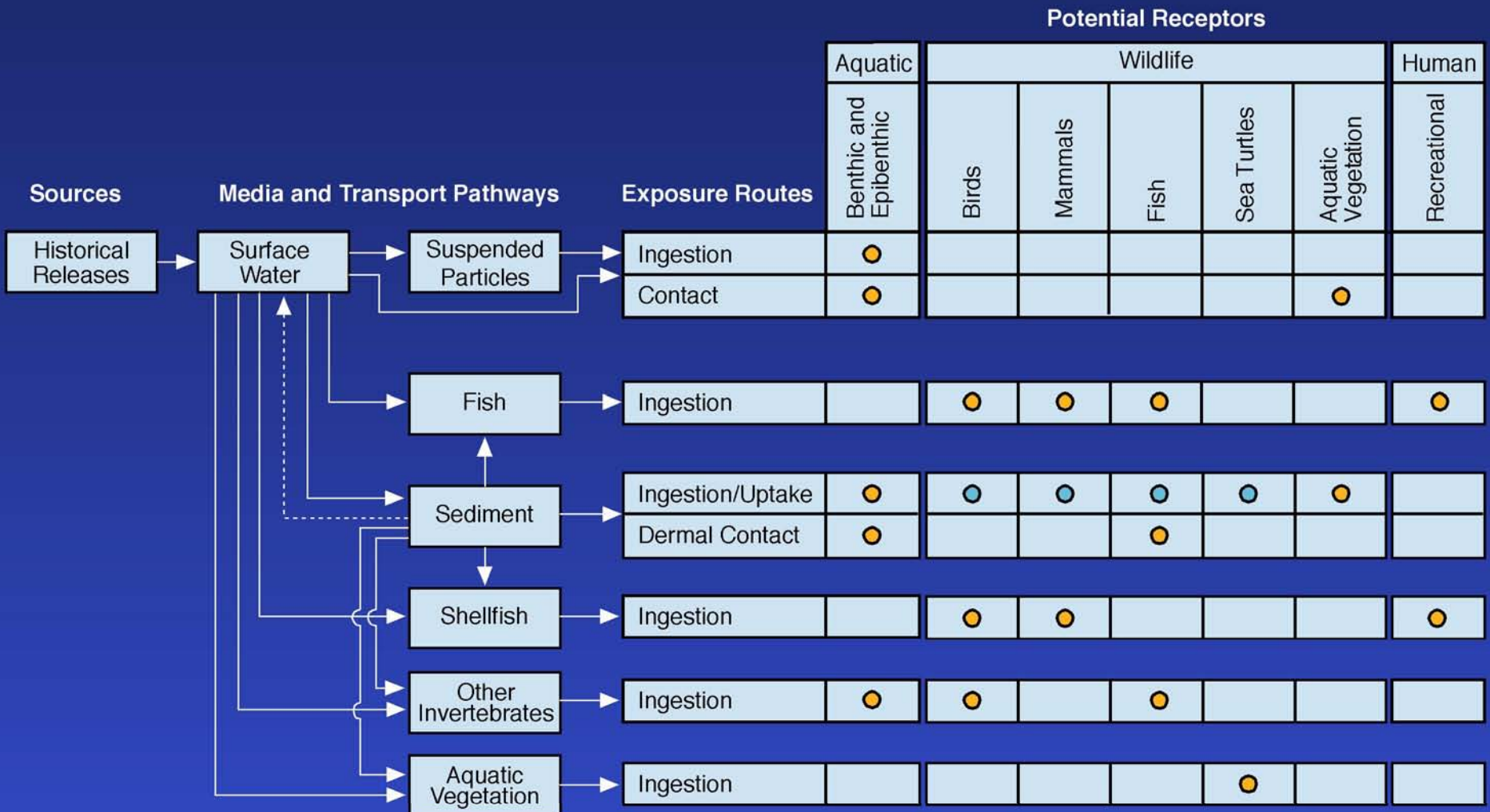
Other Analyses

- **May be required by regulators**
- **Value may be limited**
- **Analyses:**
 - Pore water chemistry
 - PAH breakdown products in fish
 - CYP-1A enzyme induction
 - Fish histopathology

Investigation Design Issues

- **Phased field work**
 - Allows more appropriate selection of additional analyses (enough but not too much)
 - Allows selection of matched reference areas
 - Requires more time
- **Consider needs of feasibility study**
- **Focus on objectives--resource trustees will want data to support NRDA**

Conceptual Site Model



LEGEND

- ▶ Likely pathway
- ▶ Possible pathway
- Likely exposure
- Possible exposure