U.S. Army Corps of Engineers
Engineer Research and Development Center

Physical and Chemical Stability of Contaminants in Sediments: Using Multiple Lines of Evidence

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Previous Workshops – Assessment Methods

- **Sediment Stability Workshop, New Orleans, Jan '02**
  - Technologies for resuspension measurement
  - Modeling approaches, utility/limitations
  - Empirical approaches
  - Conceptual Site Modeling
- **Workshop on Environmental Stability of Chemicals in Sediments, San Diego, April '03**
  - Key processes
  - Measurement technologies
  - Manipulating chemical stability for remediation
  - Research areas

Terminology

- **Chemical stability in sediments**
  - Includes key in-bed transformation/ partitioning/ transport processes
- **Sediment Stability**
  - Includes all aspects of sediment transport
  - Key sediment site study questions typically focus on stability of bed during events – hence the term
  - Term is a misnomer! Real question is whether instability is likely to cause unacceptable risks
- Both chemical and sediment “stability assessment” involve the **quantification of key processes and their impact on future contaminant transport and exposure concentrations**

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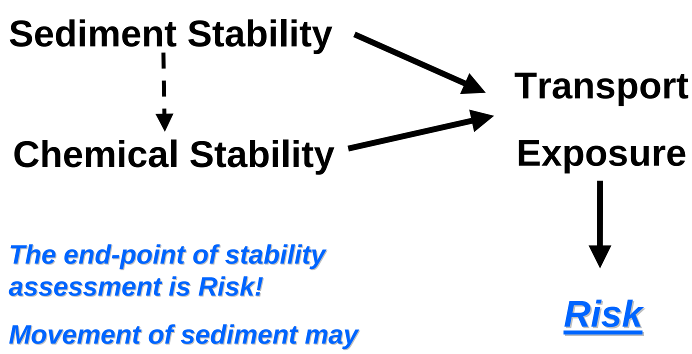
Stability Assessment - A Means to the End Point



The end-point of stability assessment is Risk!

Movement of sediment may not result in unacceptable risk.

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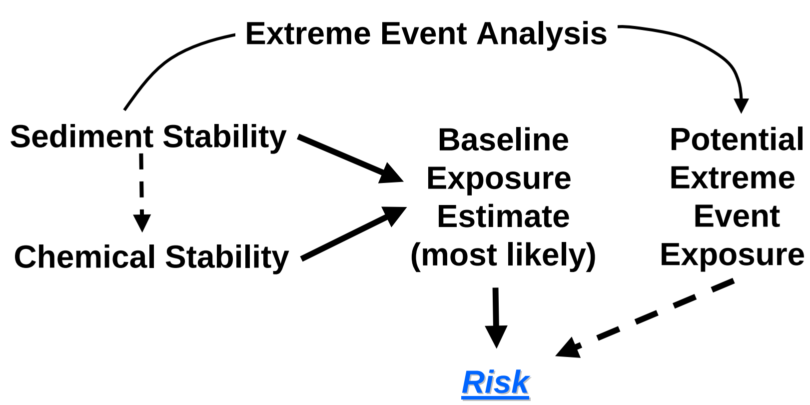
Evaluation of in-place Sediment Management (MNR, capping, residuals)

- **Physical bed stability determination required for evaluation of in-place management**
- **Chemical stability factors, process coefficients generally assumed constant during extreme events**

Key Question:

- **What is the *potential for increased risks* due to remobilization of buried contaminants during extreme events?**
- Focus should be on potential for elevated risk – not potential for movement of sediment

Integrated Stability Assessment (typically through fate and transport modeling)



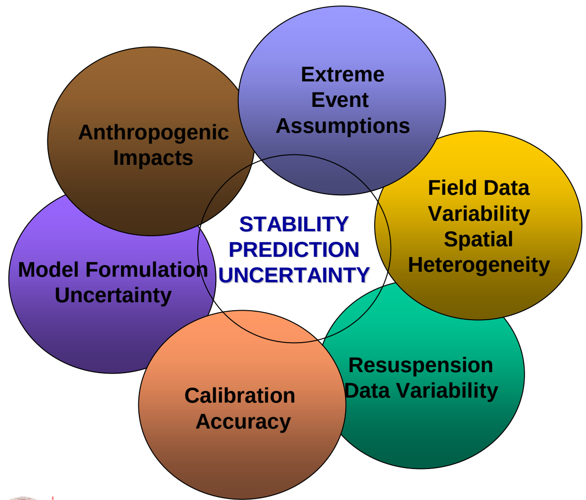
Utility of Models for Assessing Sediment and Chemical Stability:

- **Present-day exposure (risk) can be "measured"**
- **Key questions relate to future mobility/ exposure/ bioavailability**
- **End state of sediment and chemical stability (future exposure) requires some level of prediction**
- Conceptual
  Analytical
  Regression
  Numerical (0-D through 3-D)

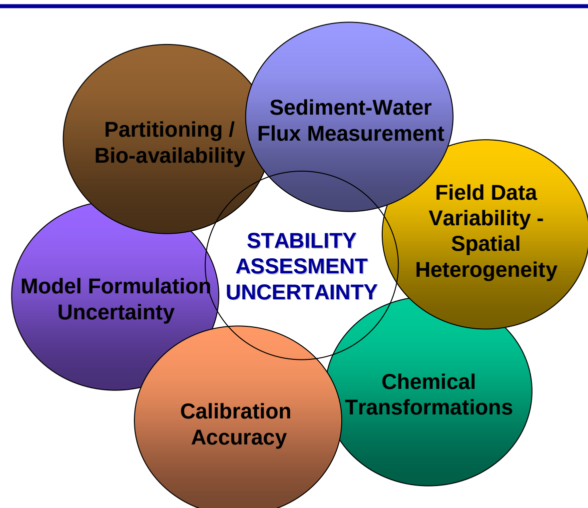
Managing Uncertainty Related to Sediment and Chemical Stability in the Sediment Bed

- **How do we reduce uncertainty in conclusions concerning future exposure / bioavailability?**

Sources of Uncertainty in Sediment Stability Assessment



Sources of Uncertainty in Chemical Stability Assessment



Options to Reduce Uncertainty

Improve Science

- Field Measurement Technologies
- Process measurement technologies
- Mathematical models
- Process understanding

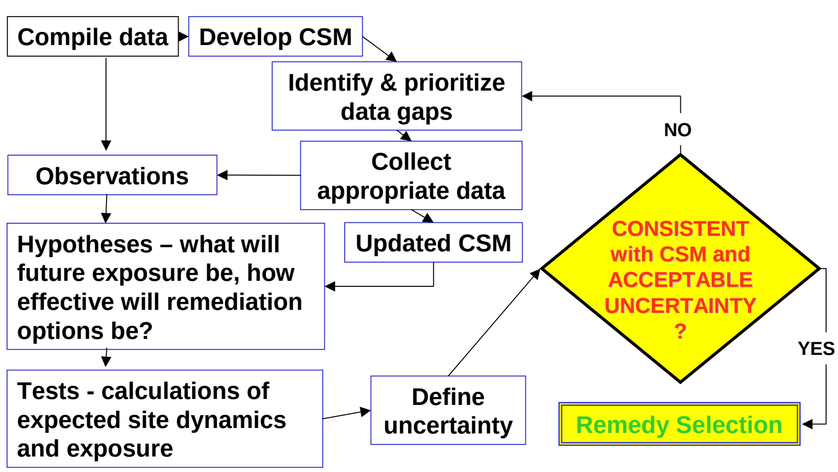
Use Multiple Lines of Evidence

- Identify independent lines of evidence
- Test consistency of all lines of evidence with CSM

Collect Additional Data, as Appropriate

- Field observations
- Process data
- Pre/post extreme event data

Iterative Assessment to Reduce Uncertainty



Increasing Acceptability of Predictions

- Start simple
- Use multiple lines of evidence to develop CSM
- Formulate conclusions regarding stability/risk relationship
- Quantify range of outcomes, bracket results with uncertainty
- Test significance of uncertainty on conclusions - hypothesis testing – does it matter? Are risks acceptable?
  – Subjective, requires key stakeholders

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Reducing Uncertainty – To What Extent?

- **Weigh study complexity, uncertainty vs. cost of error**
  – **Unnecessary remediation cost / Impacts due to over-use of "Precautionary Principal"**
  – **Magnitude of risk from wrong conclusion**

- **Pursue appropriate weight of evidence**

"Weight-of-evidence"
needed depends on
"weight of decision"

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Lines of Evidence (LOEs) for Sediment Stability Assessment

- Components

Historical Review	empirical	
Geomorphology assessment		
Sediment core profile analyses		
Bathymetric analyses		
Sedimentation / erosion measurements		predictive
Sediment transport predictions		

- Applicable to large and small sites

Sediment Stability Assessment (SSA), Step 1: Compile data, develop initial CSM and LOEs:

- **Identify, compile, and review available data/expertise**
  - Bathymetric data (USACE, NOAA, etc)
  - Geomorphologic data (USGS, universities)
  - Event records (USGS, local authorities)
  - Watershed Usage (county records)
  - Water quality/TSS (sanitation district)
- **Gather local experts for support**
- **Review previous, similar studies**
- **Develop a Conceptual Site Model (CSM)**

Sediment Stability Assessment, Step 2: Identify/prioritize data gaps, collect data:

- **Determine additional data requirements**
- **Data collection**
  - Should support refinement of the CSM or development of LOEs
  - Develop data collection plan using screening level models, local expertise, and historic data
  - Identify Data Quality Objectives (DQO) with consideration of impact on uncertainty in conclusions

Sediment Stability Assessment, Step 3: Data Analysis and Refinement of CSM, LOEs

- **Data analysis – further develop each LOE**
  - Bathymetric and morphologic change
  - Geochronology and geomorphology
  - Sediment stratigraphy
  - Contaminant concentration and distribution
  - Sediment budget analysis
  - Hydrodynamic measurements
  - Predictive modeling
- **Refine Conceptual Site Model**

Step 4: State and Test Hypotheses (typically based on study question statements)

- **Hypothesis examples**
  - Resuspension during a 100-year flood will not cause unacceptable increases in exposure
  - Sediment cap integrity will be maintained during an ice-dam event
  - A 100-year flood event will not significantly increase total transport of contaminants
- **Tests**
  - **All available LOEs, and CSM**

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Step 5: Assessing Uncertainty in Sediment and Chemical Stability LOEs:

- **Must relate uncertainty quantified for specific processes / assumptions to uncertainty in conclusions**
- **No standard methods available**
- **Bracket predictive results based on model uncertainty**
- **Identify agreement / differences in LOEs**
- **Form conclusion statements based on all LOEs**
- **Identify uncertainty range on potential exposure**

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