Making Sensible Decisions: The Hardest Part of Sediment Management

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What do you call it when...

• You have a complex technical problem...
• That is rich with uncertainty...
• Where the person charged with solving the problem is overwhelmed by the technical issues and uncertainties...
• And the designated problem-solver is saddled with a large group of advisors and uninformed interested parties with widely divergent opinions?

A. A typical sediment problem
B. The makings of a very bad decision
C. Both A. and B.
The Status of Contaminated Sediment Remediation

• Complexity of contaminated sediment remediation currently exceeds our:
  - Collective scientific and engineering capabilities
  - Thoughtful regulatory frameworks
  - Deliberative and decision-making processes

• Evidence for this bold assertion:
  - Large remediation projects require decades
  - Projects continue to be dominated by uncertainty
  - “Re-dos” and are increasing
  - Increasing costs disproportionate to sketchy risk reduction benefits projected for distant future
Big Dollar Projects in the U.S.

- Hudson River, NY - >$1 B
- Fox River, WI - $875 M
- New Bedford Harbor, MA - $361 M
- Commencement Bay, WA – $197 M
- Silver Bow Creek, MT - $97 M
- Bayou Bonfouca, LA - $90 M
- Marathon Battery, NY - $84 M
- Triana/Tennessee River, AL - $80 M
- Coeur d’Alene Basin - ?
- Passaic River, NJ - ?
- Housatonic River, MA - ?
- Tittabawassee River, MI - ?
- Portland Harbor, OR - ?
- Others expected
A Diagnosis for the Disease

- Tendency to overestimate what we know (and can know) about contaminated sediments sites and risks
- Inclination to underestimate, or ignore, conditions that can affect remedy performance
- Unrealistic view of what engineering can and cannot achieve under real-world conditions
The Medicine for the Malady

• A **disciplined** scientific and engineering analysis of the site and potential remedy options
  – Quantifies relevant processes

• A deliberative process that structures decision making
  – Connects and relates the involved parties
  – Defines objectives

• An adaptive management process to guide remedy implementation
  – Monitoring of remedy effectiveness
Limited Option Set Simplifies the Problem

- In situ alternatives
  - Monitored Natural Recovery (MNR)
  - Capping
  - Enhanced MNR

- Ex situ alternatives
  - Dredging
    - Containment
    - Treatment ($$$)
Environmental Dredging and the 4 Rs


Hudson River Cleanup

- River contaminated with PCBs
- Cleanup design includes dredging > 2M m³ of sediment from 40 miles of the river
- First year of multi-year dredging occurred in 2009
  - Much greater release of PCBs to river than expected
- 9-month peer review process culminates in 100-page report recommending project modifications

http://www.epa.gov/hudson/
Hudson River PCB Dredging Releases

- 2009 dredging sent ~3% of dredged mass downstream
- Controls largely ineffective and caused other problems

Future Dredging Costs > $1 Billion

Data Source: Anchor QEA and Arcadis (2010)
Hudson River Sediment Debris

- Sediments contain large quantities of wood debris due to logging and saw mills
- Shallow bedrock and glacial clay also intermixed in the sediments due to past dredging activities
- Debris exacerbated resuspension and residual impacts
26 cleanup dredging projects reviewed

Dredging alone achieved desired contaminant-specific cleanup levels (CULs) at only a few of the reviewed sites

Longer-term benefits of dredging are not well understood or documented
  - Sparse or incomplete monitoring data were collected
  - Pre-remediation trends were not of sufficient duration to enable judging the effect of the remedial action

The committee was unable to establish whether dredging alone is capable of achieving long-term risk reduction

Capping

• Definition: The placement of clean sediment over contaminated sediment to reduce exposures
  • Physical separation
  • Reduce flux/transport
  • Dilute concentrations
• Euphemisms aren’t helpful
  • Backfill, residuals cover, etc.
Capping: Wishful Thinking

• Capping is not “entombment” ala Yucca Mountain

• The notions of “contaminant isolation” and “cap failure” are wholly inadequate concepts
  • It’s clearly a matter of degree, i.e., determining the effect on risk

• Capping comes with O&M obligations
Cap Performance Biological Endpoint: Eagle Harbor Flatfish Liver Lesions


Look before you leap!
Monitored Natural Recovery (MNR) involves leaving contaminated sediments in place and allowing ongoing aquatic, sedimentary, and biological processes to reduce the bioavailability of the contaminants in order to protect receptors.

NRC, 1997. Contaminated Sediments in Ports and Waterways

MNR... uses known, ongoing, naturally occurring processes to contain, destroy, or otherwise reduce the bioavailability or toxicity of contaminants in sediment.

MNR... includes... monitoring to assess whether risk is being reduced as expected.


DoD 2009 Technical guide: Monitored natural recovery at contaminated sediment sites. ESTCP-ER-0622.

http://www.epa.gov/superfund/health/conmedia/sediment/documents.htm
Example Sites that Selected MNR

• Kepone, James River (VA)
  - Active remediation estimated at $3 to $10 billion
  - Active remediation would disturb existing habitat
  - Sediments likely to be buried, or diluted by flushing and mixing

• Lead, Interstate Lead Company Superfund site (AL)
  - Historical trends indicated a general decline in sediment lead concentrations,
  - No evidence of damage to existing ecosystem
  - Active remediation would damage existing ecosystem
  - Natural recovery would result in minimal environmental disturbance

• PCBs, Lake Hartwell Superfund site (SC), 1994 ROD
  - Active remediation technically impracticable or too costly
  - EPA and public agreed that fishing advisories could adequately reduce risk
  - Source control was implemented at the former Sangamo-Weston plant
  - 1-D (HEC-6) model predicted recovery to 1 mg/kg within a reasonable time
**Enhanced MNR**

- Engineering actions taken to accelerate processes contributing to risk reduction
  - Thin layer capping can accelerate surface sediment concentration reductions, and achievement of cleanup goals
  - Use of novel materials (e.g., carbon, nutrients, etc.) used to stabilize and/or degrade contaminants

![Figure 1.](image)
Remedial Investigation and Risk Assessment: Lower Willamette River, OR

• 10 years of detailed field investigations
• Total expenditures of over $80 MM prior to FS
• Wishful thinking about how much we can know about sites
• An alternative:
  • Solution-focused risk assessment
  • Active adaptive management
Value of Information (VoI)

- Information has value if it might alter the determination of which alternative is optimal
- VoI analyses are undertaken to:
  - Determine if the decision is sensitive to a particular source of uncertainty
  - Identify which uncertainties should be resolved first
  - Determine how much to invest in eliminating or reducing the uncertainty

Based on a review of ~120 peer-reviewed journal articles
A. Passive Adaptive Management

Goals → Management Strategy → System Modeling → Implementation → Monitoring → Evaluation

adaptive learning

B. Active Adaptive Management

Goals → Management Strategy → Hypothesis Generation → System Modeling → Implementation 1 → Implementation 2 → Implementation N → Monitoring → Evaluation

hypothesis testing

adaptive learning

“Today's scientists have substituted mathematics for experiments, and they wander off through equation after equation, and eventually build a structure which has no relation to reality.” Nikola Tesla, Modern Mechanics and Inventions, July, 1934
The Current, Messy Process

**Decision-Maker(s)**

- **AD HOC Process**
  - Include/Exclude?
  - Detailed/Vague?
  - Certain/Uncertain?
  - Consensus/Fragmented?
  - Iterative?
  - Rigid/unstructured?

**Tools**

- Risk Analysis
- Modeling / Monitoring
- Cost or Benefits
- Stakeholders’ Values

Quantitative?  Qualitative?
A Risk and Decision Analytic Process

A Sediment Example

Manufactured Soil
Cement Lock

In-place Soil

KEY:
- Dredged Material
- Effluent
- Manufactured Liner
- Dike Wall
- Cap
- Standard Landfill Waste


Decision Criteria: NY/NJ Harbor

Contaminated Sediment Management Decision

- Cost: $/Cubic Yard
- Footprint: Impacted Area / Capacity
- Human Health: 
  - # of complete human exposure pathways
  - Largest Cancer Risk calculated for any one pathway
  - Estimated Fish COC Concentration / Hazard Level
- Ecological Impacts: 
  - # of complete ecological exposure pathways
  - Largest Ecological Hazard Quotient (HQ) calculated for any one pathway

Source: NY/NJ Dredged Material Management Plan and Expert Opinion

Source: Kane Driscoll et al. (2002).
## Criteria Levels for Each DM Alternative

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<th>Footprint (acres / M CY)</th>
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**Blue Text: Most Acceptable Value**

**Red Text: Least Acceptable Value**
## USACE/EPA Survey Results: Criteria Weights (%)

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10 Risk Management Principles

1. Risk management is a scientific enterprise
2. Risk management assumes a forward-looking posture
3. Specific and measurable objectives are developed in a transparent and rigorous manner
4. Risk management is accomplished through open, transparent and deliberative processes
5. Uncertainties are acknowledged and addressed through quantitative analysis
6. Risk management investments are commensurate with the magnitude of risks and uncertainties
7. Risk management is a system-scale activity
8. Risk reduction is most reliably achieved through the use of an integrated network of multiple remedial technologies and actions
9. Risk communication is integral to effective risk management
10. Risk management is achieved through formal application of adaptation management
Todd’s last presentation at SedNet 2011 is now concluded!