# 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

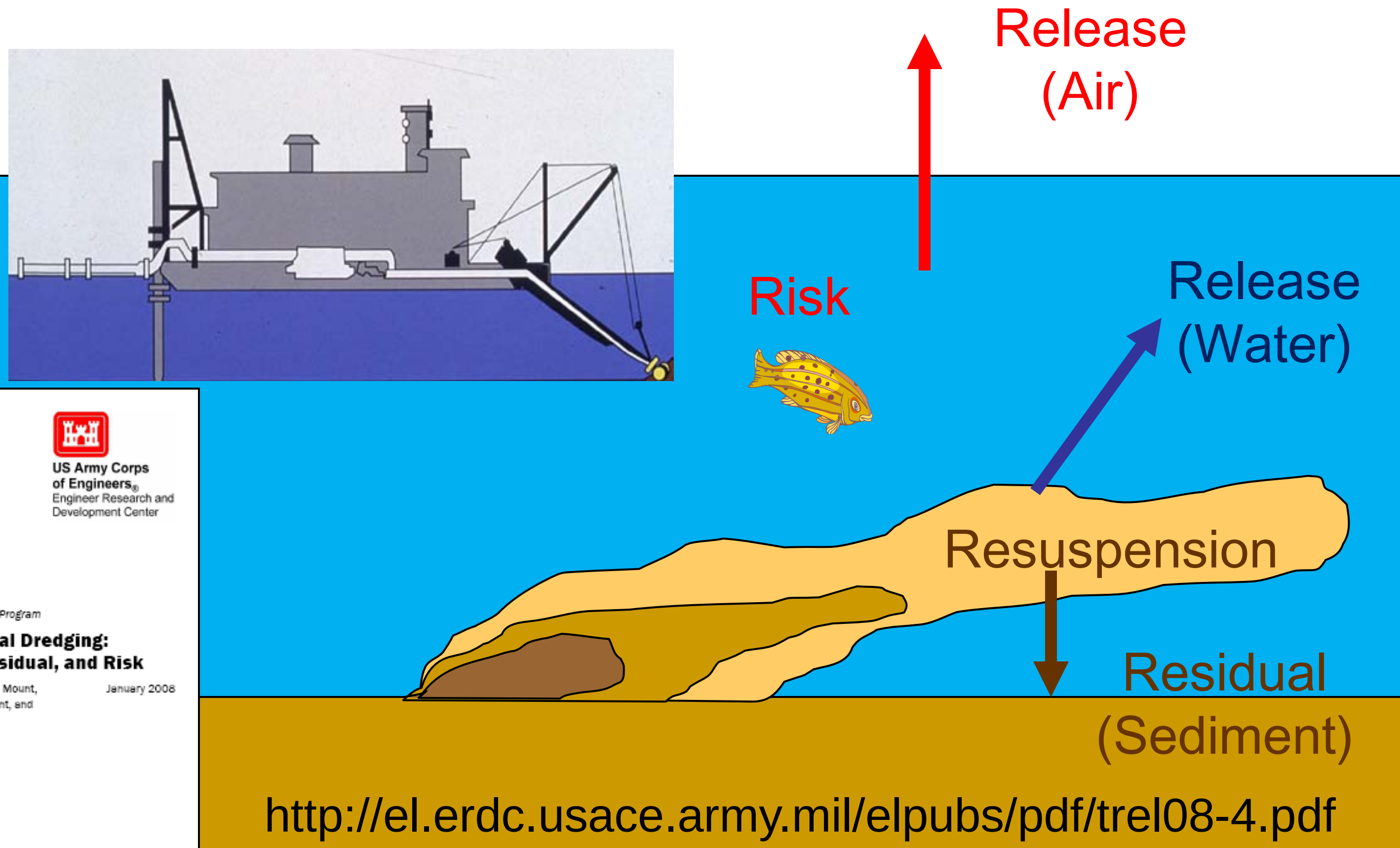
# The Medicine for the Malady

- A <u>disciplined</u> 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





ERDC/EL TR-08-4

US Army Corps of Engineers®
Engineer Research and Development Center

*Dredging Operations and Environmental Research Program*

**The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk**

Todd S. Bridges, Stephen Ells, Donald Hayes, David Mount, Steven C. Nadeau, Michael R. Palermo, Clay Patmont, and Paul Schroeder

January 2008

Environmental Laboratory

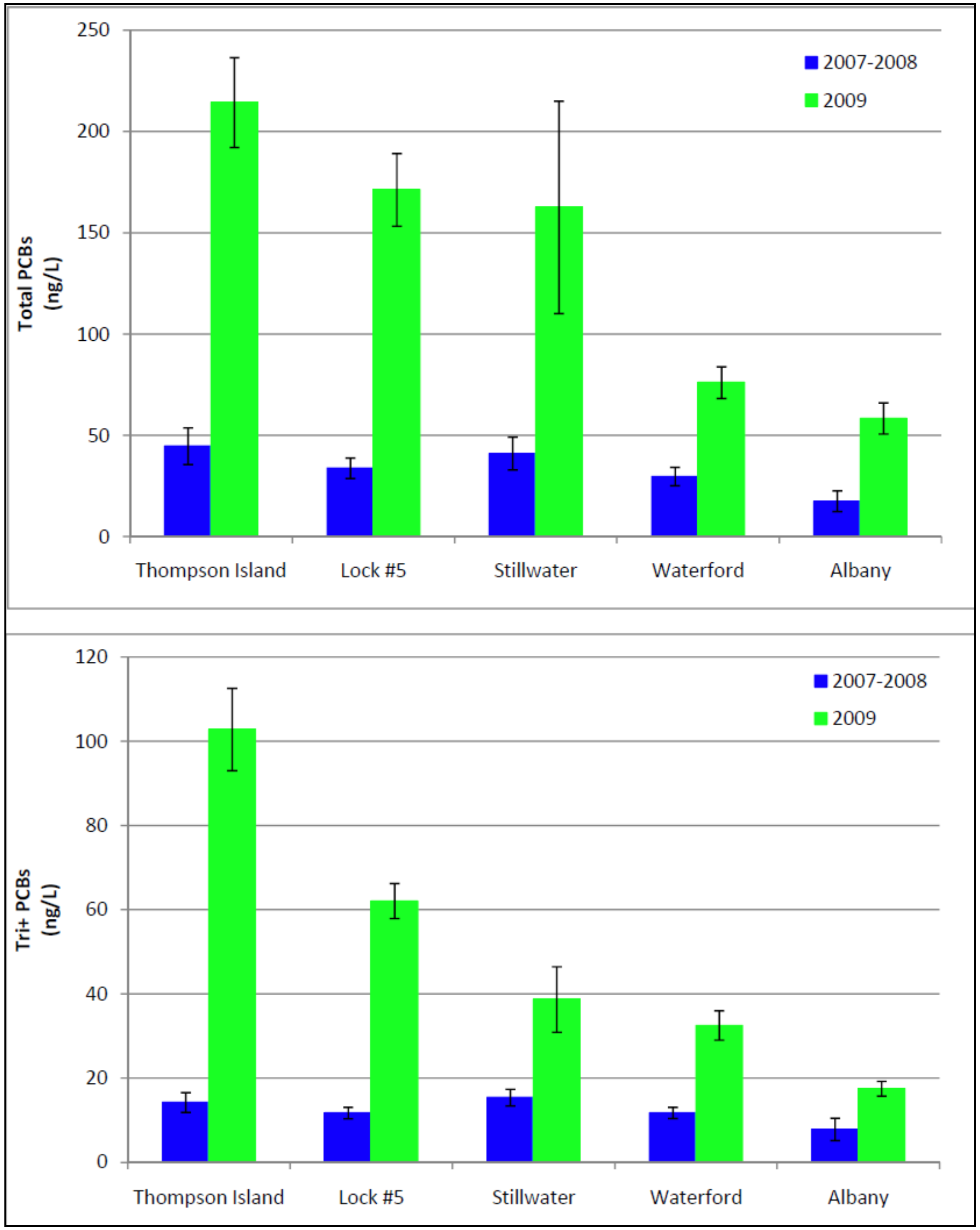
Approved for public release; distribution is unlimited.

T.S Bridges, K.E Gustavson, P. Schroeder, S.J. Ells, D. Hayes, S.C. Nadeau, M.R. Palermo, C. Patmont.  2010. Dredging Processes and Remedy Effectiveness: Relationship to the 4 Rs of Environmental Dredging.  *Integrated Environmental Assessment and Management* 6: 619-630.

# Hudson River Cleanup

- River contaminated with PCBs
- Cleanup design includes dredging > 2M $m^3$ 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/




Data Source: Anchor QEA and Arcadis (2010)

# Hudson River PCB Dredging Releases

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

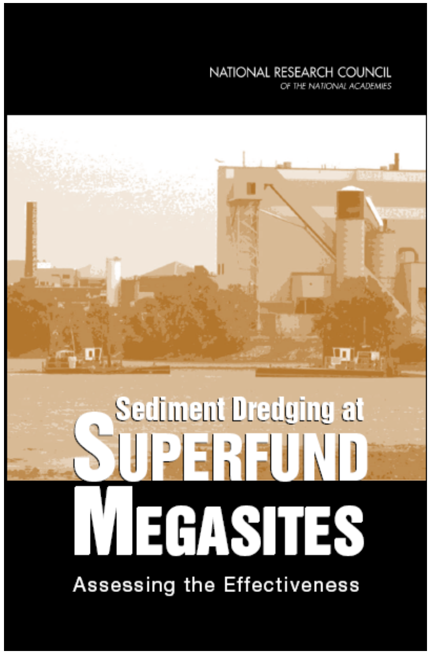
*Future Dredging Costs > $1 Billion*

# 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

# US National Research Council Review

- 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




THE NATIONAL ACADEMIES
*Advisers to the Nation on Science, Engineering, and Medicine*

Gustavson et al. 2008. Evaluating the Effectiveness of Contaminated-Sediment Dredging. *Environmental Science and Technology* 42:5042-5047.

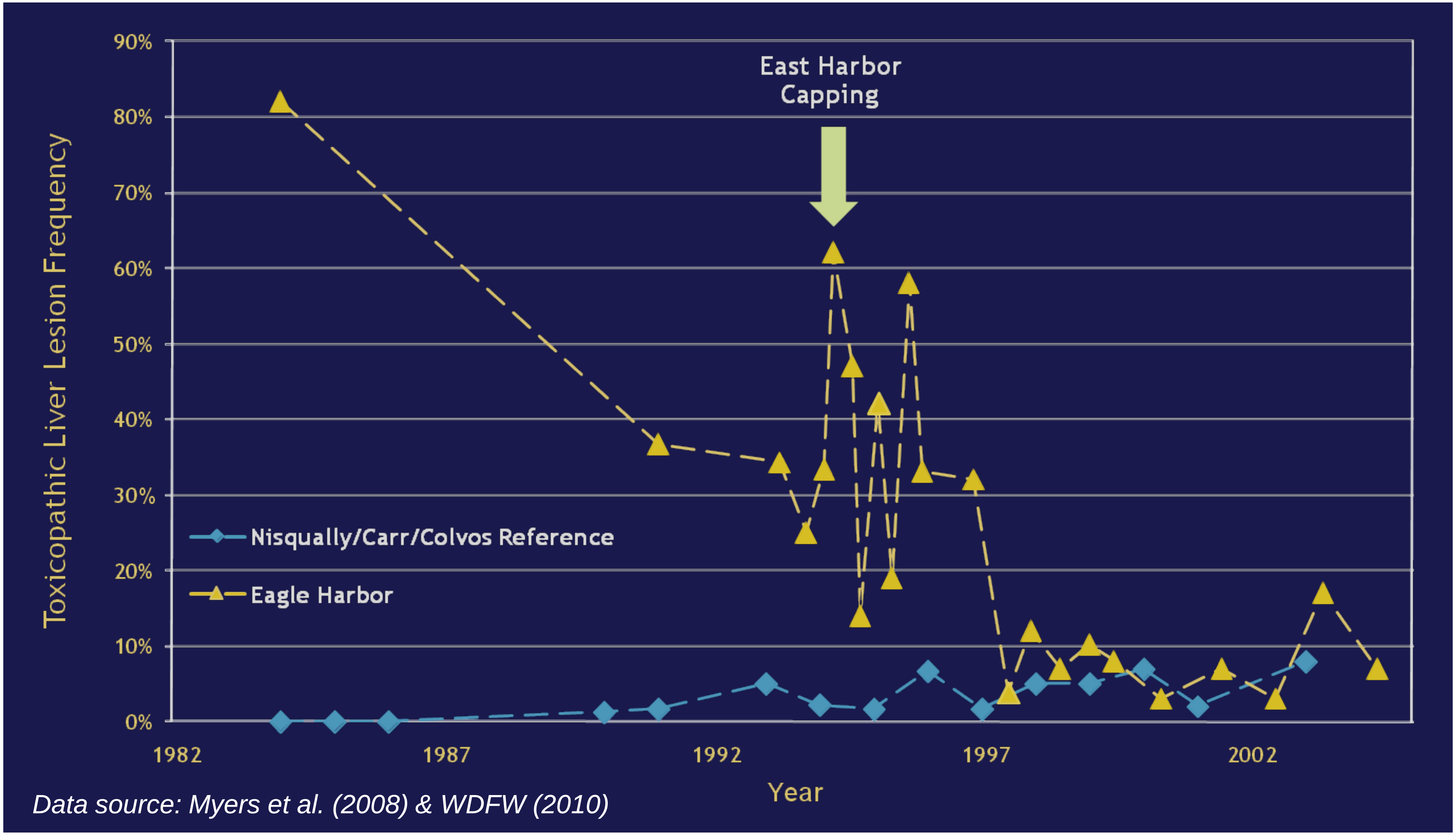
# Capping

- 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

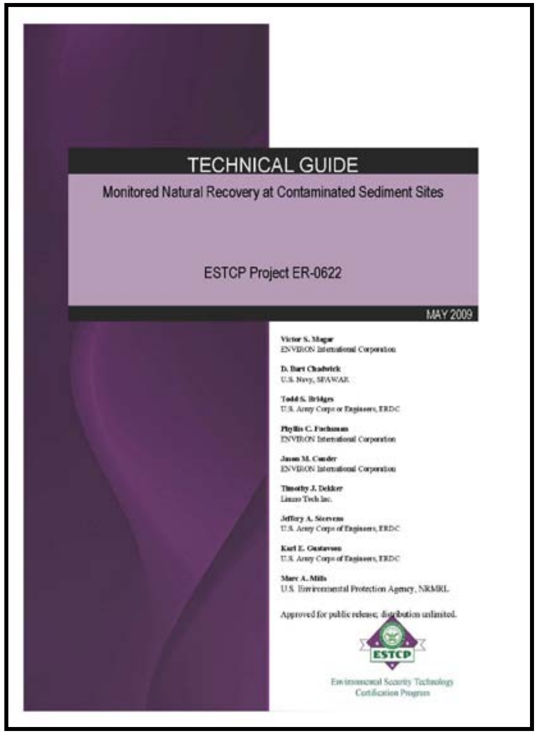



Look before you leap!

# Monitored Natural Recovery

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.

USEPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*

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

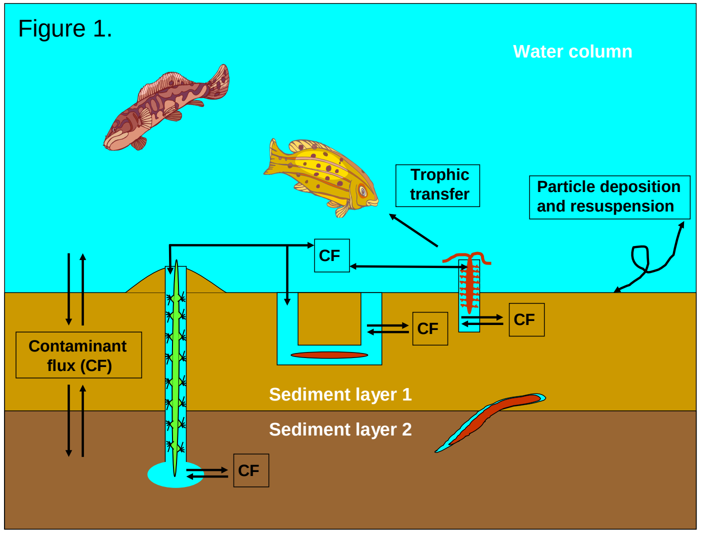
http://www.epa.gov/superfund/health/conmedia/sediment/documents.htm

# 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

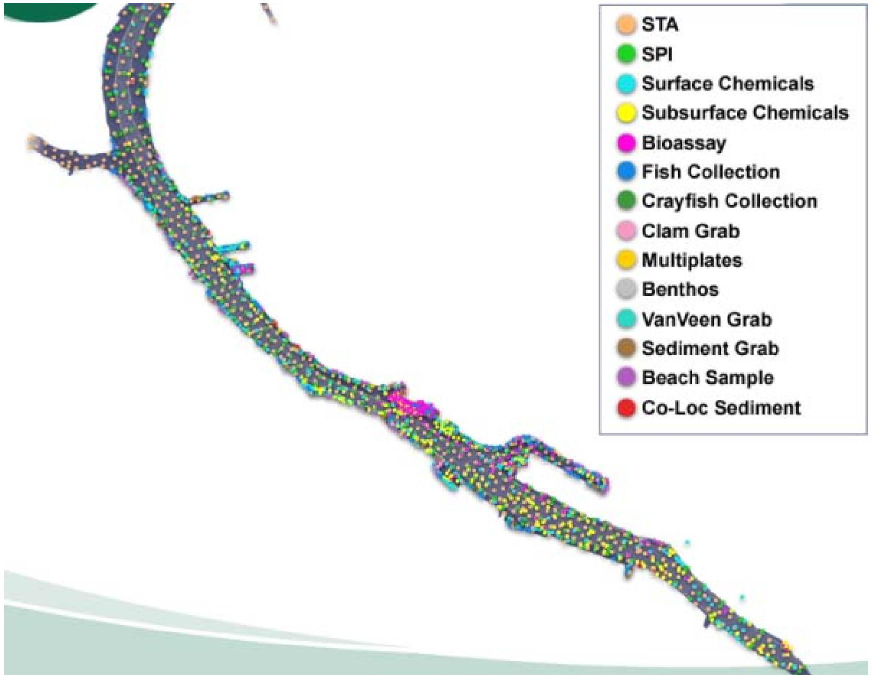
# Enhanced MNR

- 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



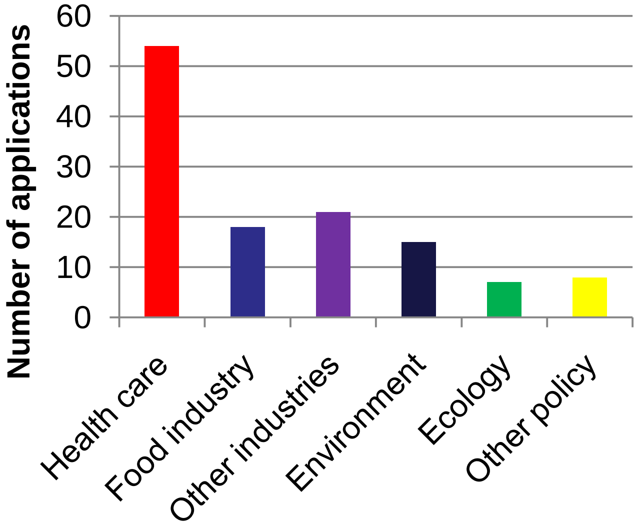
# Remedial Investigation and Risk Assessment: Lower Willamette River, OR

- 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



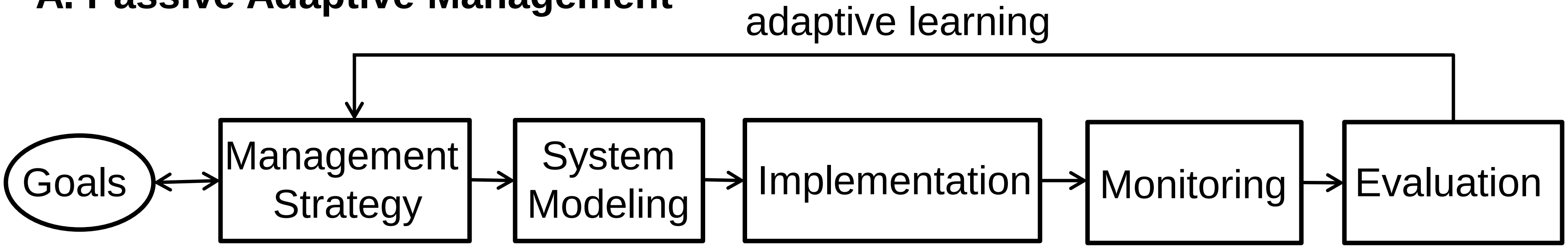
# Value of Information (VoI)

- 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

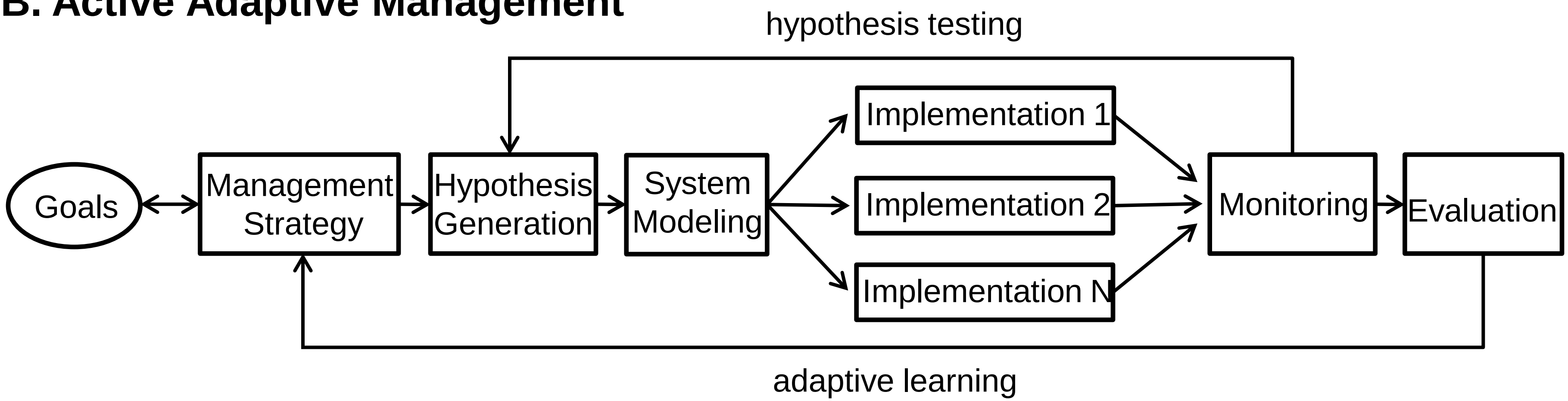



Based on a review of ~120 peer-reviewed journal articles

## A. Passive Adaptive Management

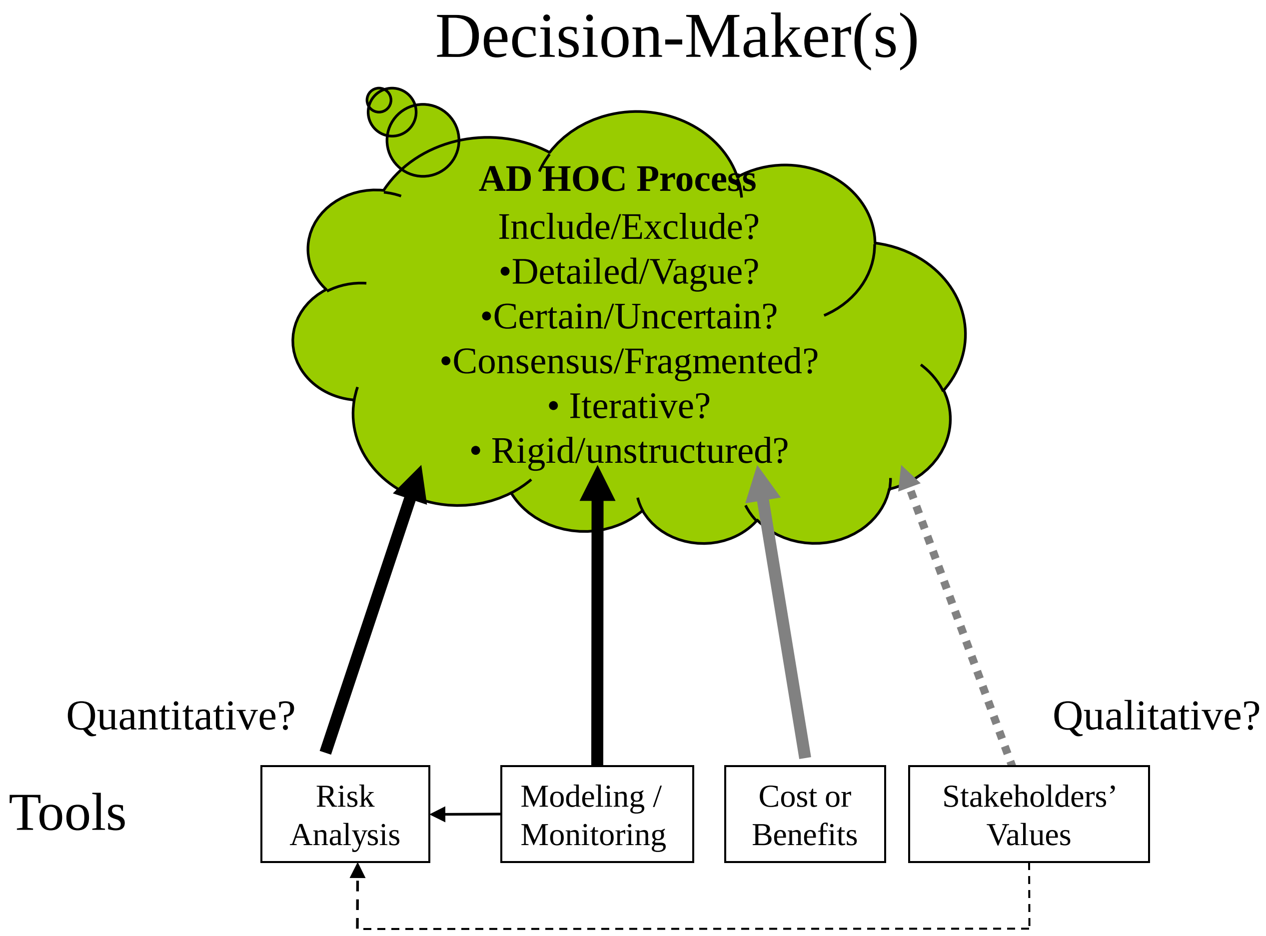



## B. Active Adaptive Management

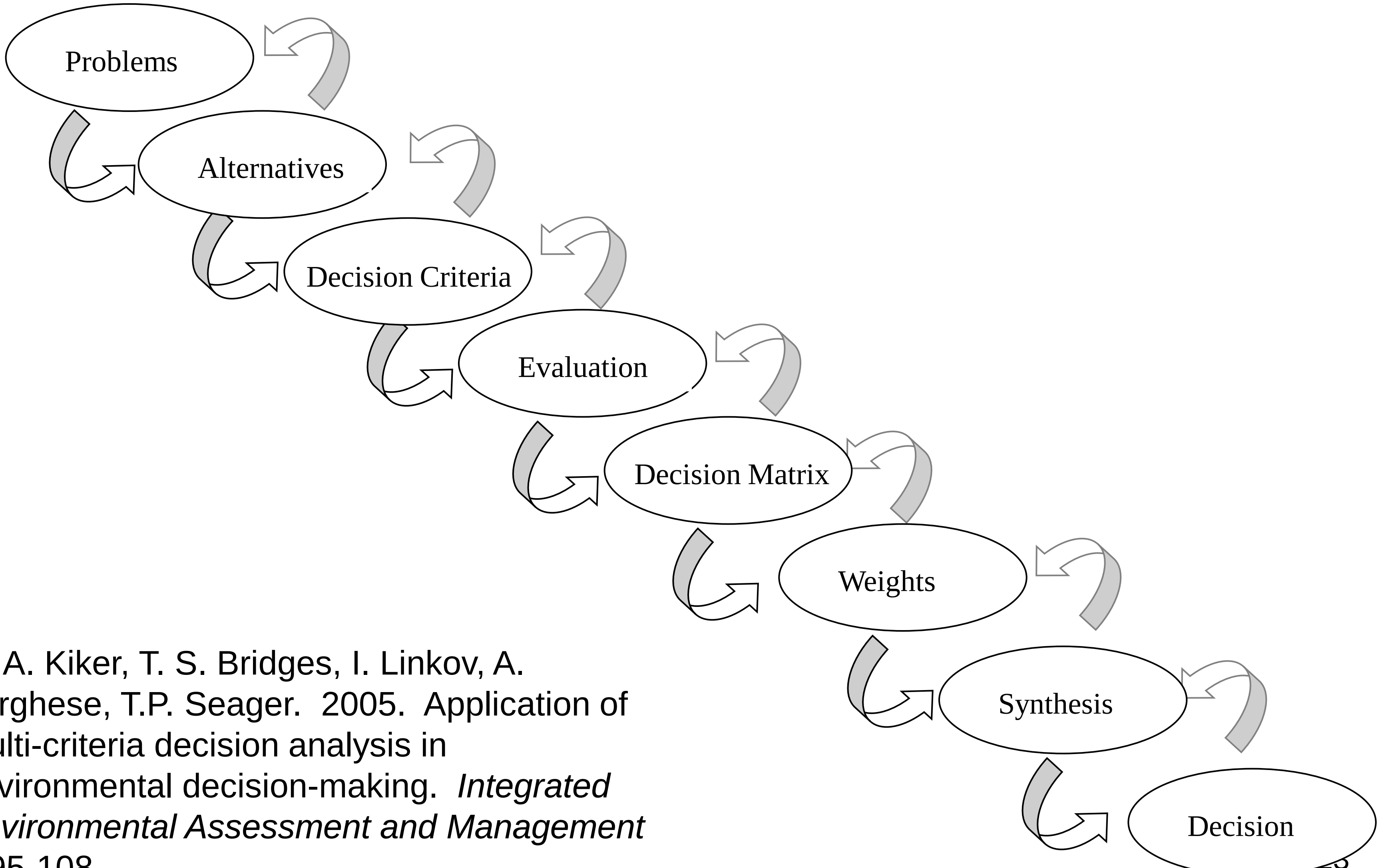



“Today's scientists have substituted mathematics for experiments, and they wander off through equation after equation, and eventually build a structure which has no relation to reality.” Nikola Tesla, *Modern Mechanics and Inventions, July, 1934*

# The Current, Messy Process

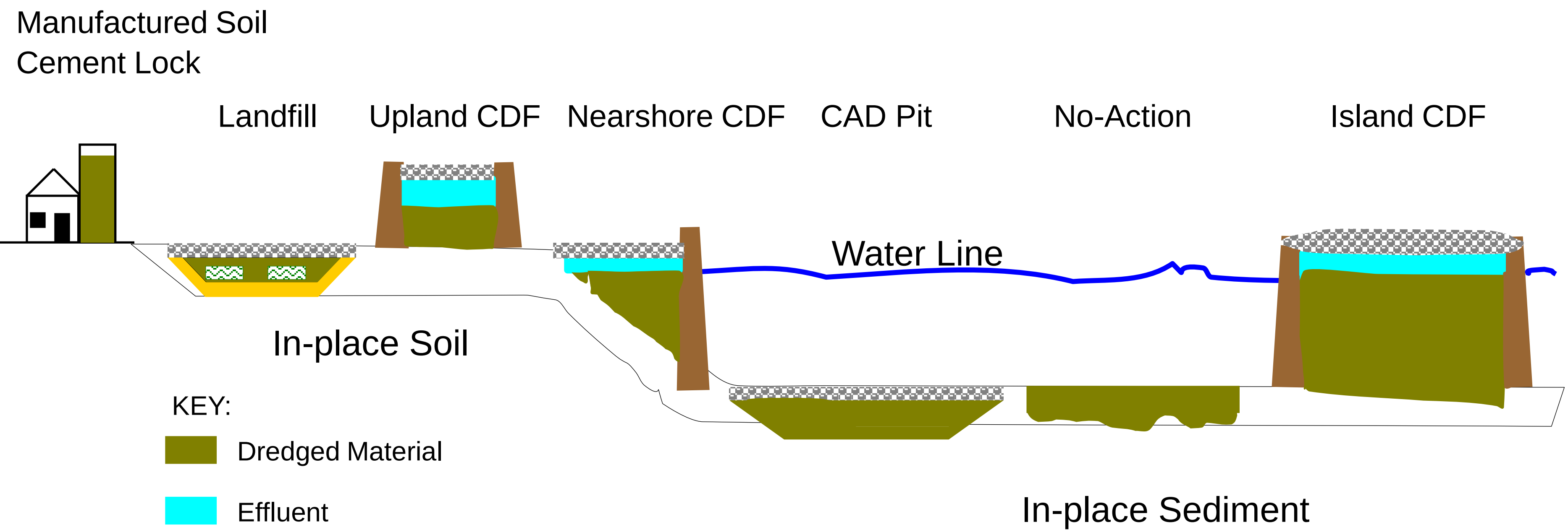


# A Risk and Decision Analytic Process




G. A. Kiker, T. S. Bridges, I. Linkov, A. Varghese, T.P. Seager. 2005. Application of multi-criteria decision analysis in environmental decision-making. *Integrated Environmental Assessment and Management* 1:95-108

# A Sediment Example

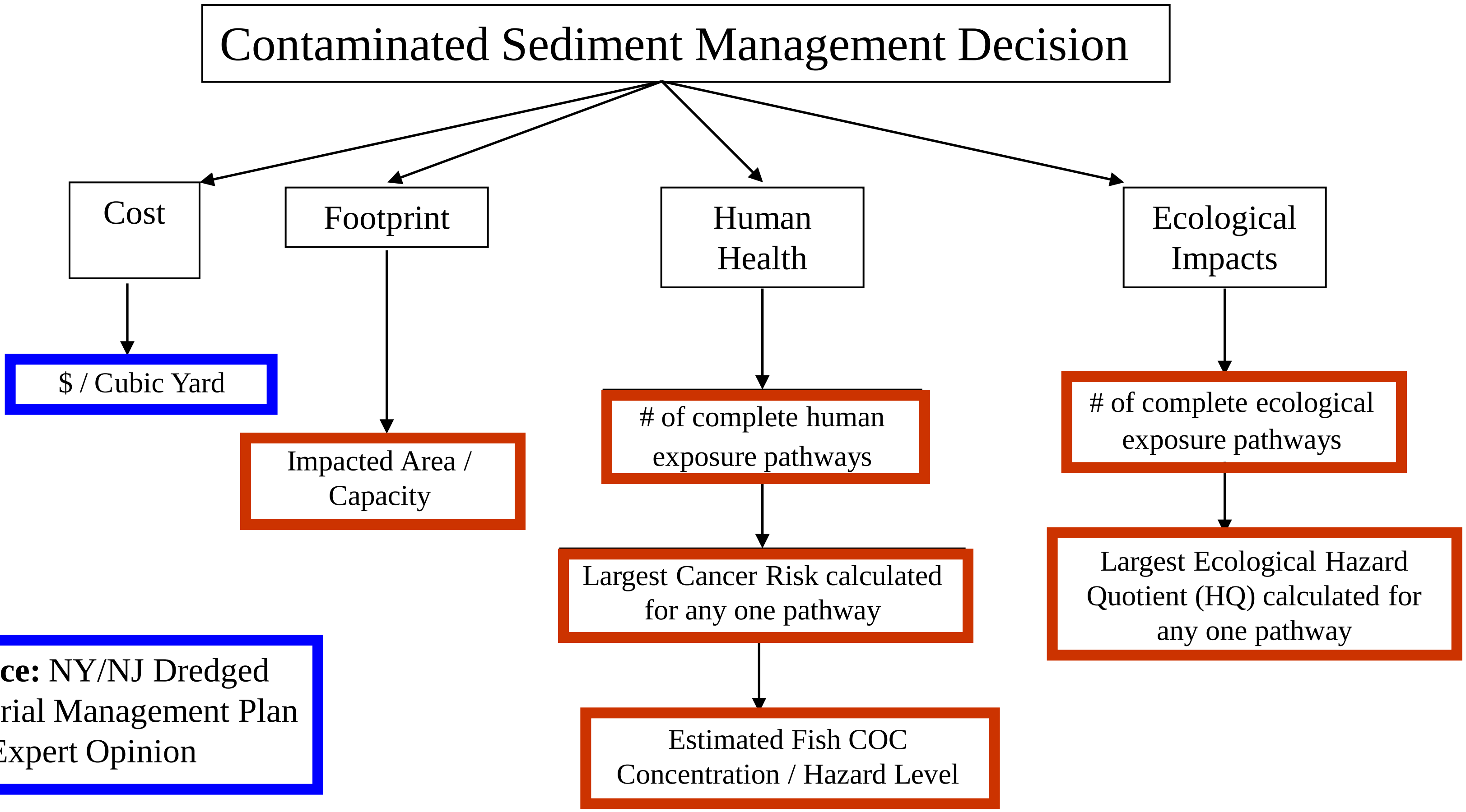





**Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. *International Journal of Human and Ecological Risk Assessment* 8: 603-626.**

**G. A. Kiker, T. S. Bridges, J. B. Kim. 2008. Integrating Comparative Risk Assessment with Multi-Criteria Decision Analysis to Manage Contaminated Sediments: An Example From New York/New Jersey Harbor. *Human and Ecological Risk Assessment* 14:495-511.**

# *Decision Criteria: NY/NJ Harbor*




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

**Source:** Kane Driscoll et al. (2002).

# Criteria Levels for Each DM Alternative

| DM Alternatives | *Cost* | *Footprint* | *Ecological Risk* | | *Human Health Risk* | | |
|---|---|---|---|---|---|---|---|
| | ($/CY) | Impacted Area/Capacity (acres / MCY) | Ecological Exposure Pathways | Magnitude of Ecological HQ | Human Exposure Pathways | Magnitude of Maximum Cancer Risk | Estimated Fish COC / Risk Level |
| **CAD** | 5-29 | 4400 | 23 | 680 | 18 | 2.8 E -5 | 28 |
| **Island CDF** | 25-35 | 980 | 38 | 2100 | 24 | 9.2 E -5 | 92 |
| **Near-shore CDF** | 15-25 | **6500** | 38 | 900 | 24 | 3.8 E -5 | 38 |
| **Upland CDF** | 20-25 | **6500** | 38 | 900 | 24 | 3.8 E -5 | 38 |
| **Landfill** | 29-70 | 0 | 0 | 0 | 21 | 3.2 E –4 | 0 |
| **No Action** | **0-5** | 0 | **41** | **5200** | 12 | 2.2 E –4 | **220** |
| **Cement-Lock** | **54-75** | 0 | 14 | 0.00002 | **25** | 2.0 E -5 | 0 |
| **Manufactured Soil** | 54-60 | 750 | 18 | 8.7 | 22 | **1.0 E –3** | 0 |

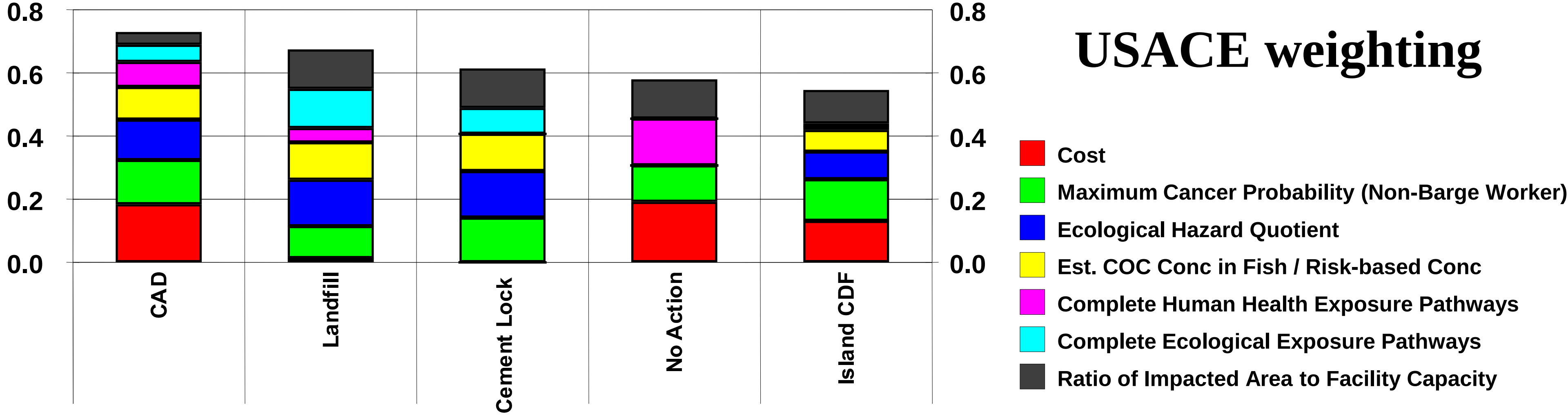
**Blue Text: Most Acceptable Value**

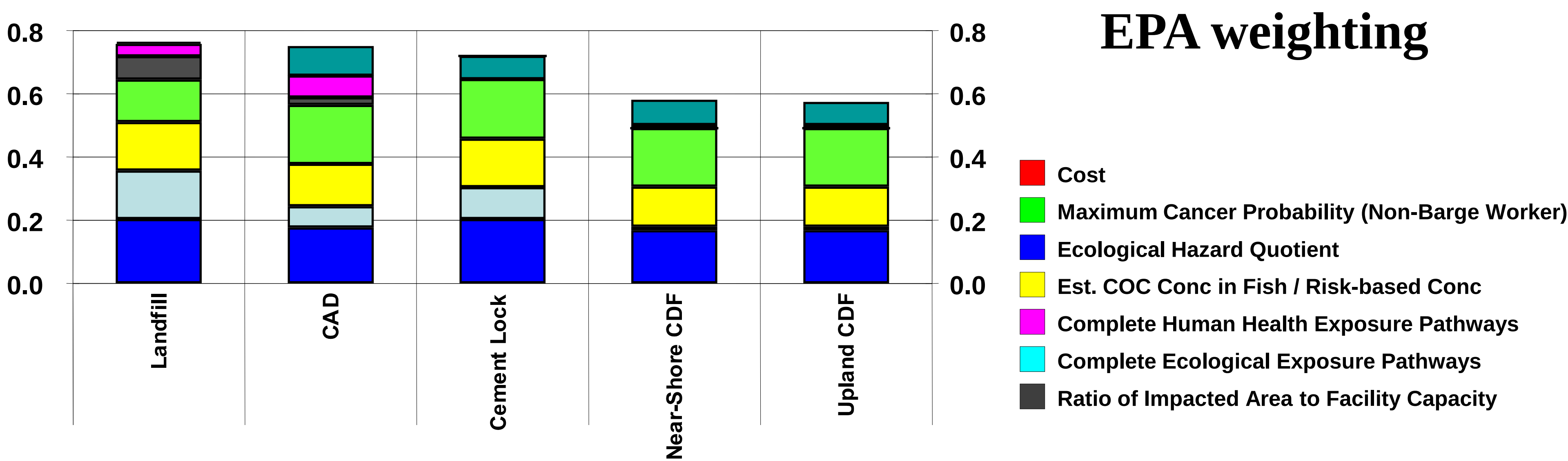
**Red Text: Least Acceptable Value**

# USACE/EPA Survey Results: Criteria Weights (%)

| | EPA | USACE |
|---|---|---|
| Footprint | 7.4 | 12.5 |
| Ecological Health | 35.6 | 27.1 |
| Human Health | 47.0 | 40.7 |
| Cost | 10.0 | 19.7 |

# MCDA Rankings



# 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!