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Use of High Value Amendments to Address Contaminated Sediments in Sensitive Ecological Systems

John A. Bleiler, Upal Ghosh, Charles A. Menzie
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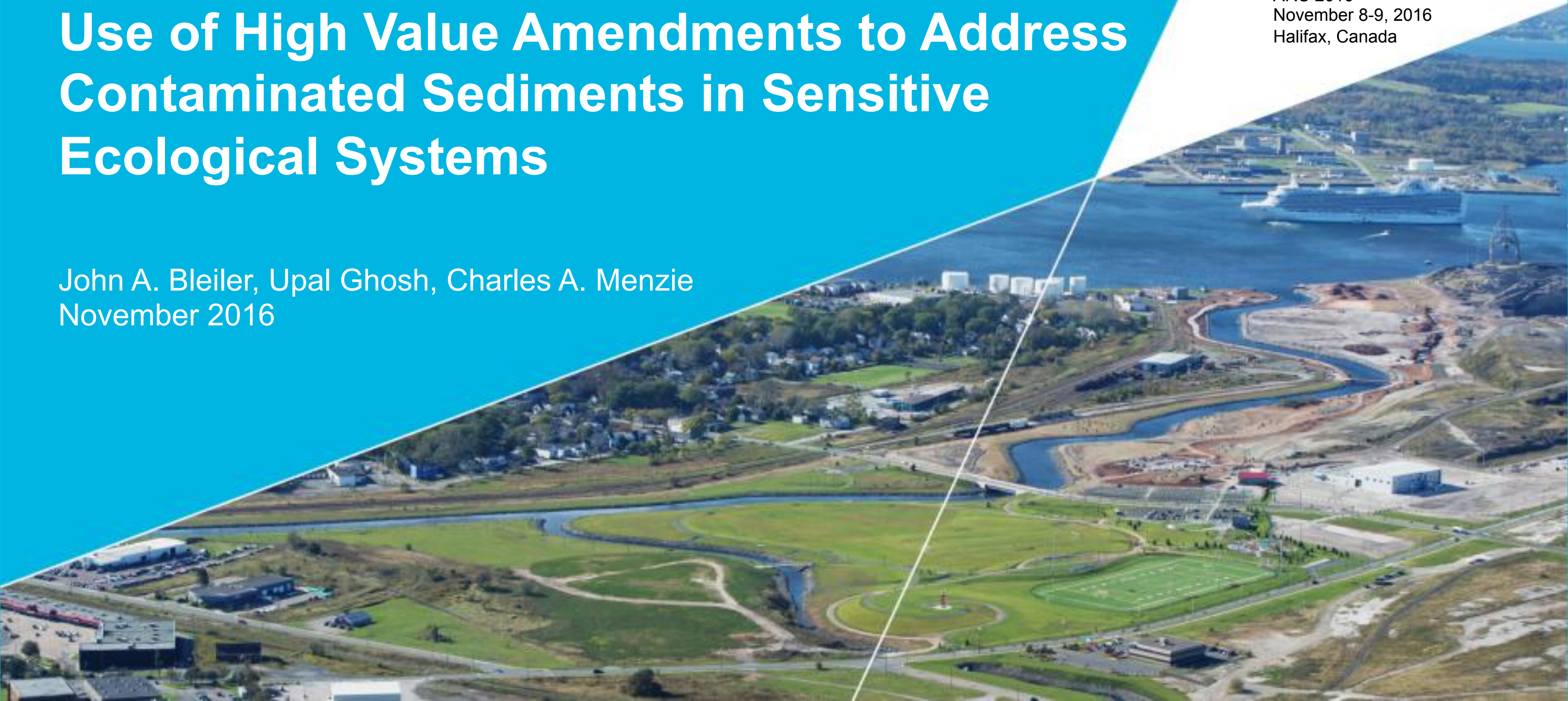

Overview

– Introduction
– Overview of Amendment Materials and Placement Methods
– Design Considerations
– Case Studies
    - Aberdeen Proving Ground, MD
    - Berry's Creek, NJ
    - Mirror Lake, DE
    - Pearl Harbor, HI
– Cost ($ and Ecological)
– Summary

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Contaminated Sediment Management

- Significant, wide-spread issue, yet remedial choices are limited:
  - Dredge
  - Cap
  - Monitored Natural Recover/Enhanced Monitored Natural Recovery
- Sediment and wetland remediation cleanup efforts will likely more than double in next 5 years
- Projects tend to be large and long-term
- Early in life cycle on many projects

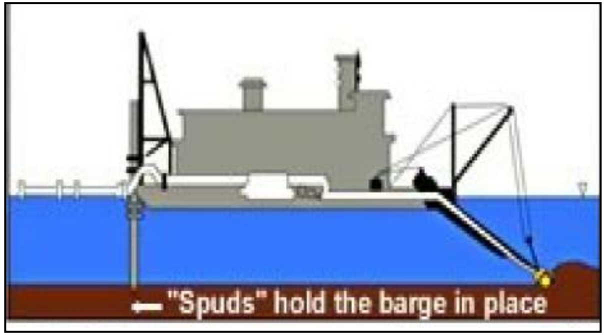
10% of USA sediment is contaminated (1.2b CY)!

43% of US Navy cleanup budget focused on sediments in next decade

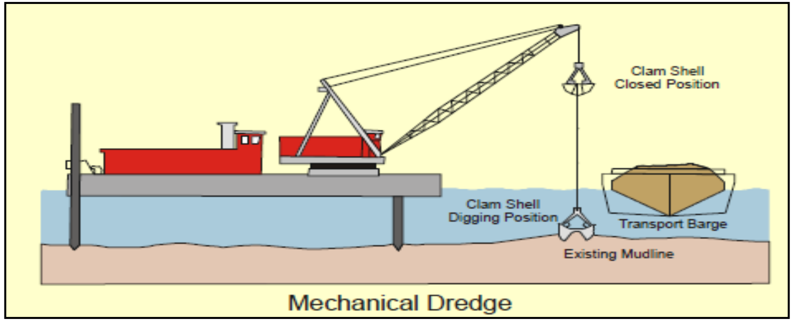
Innovation presents opportunities for 50% + savings on site remediation & restoration costs, and far lower Risk of Remedy

Types of Dredging

- Hydraulic
  - High disturbance
  - Substantial water treatment
  - No visual assessment

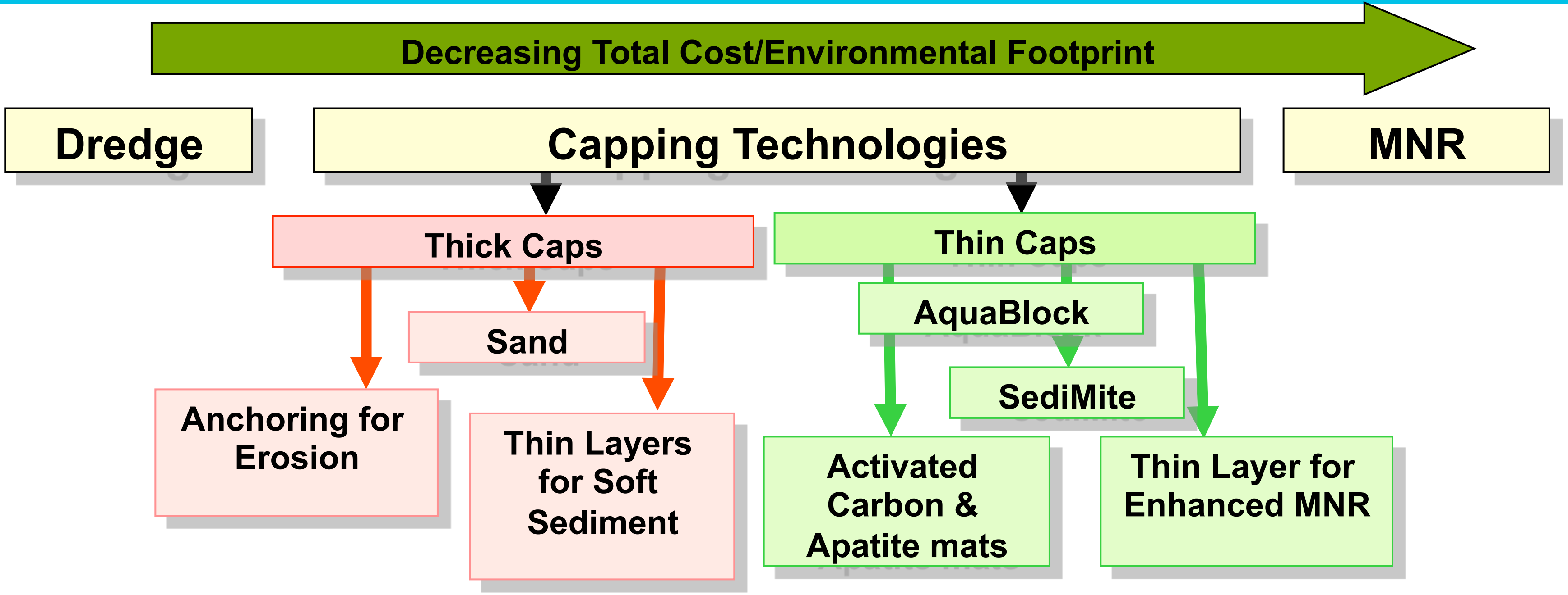


- Mechanical
  - High disturbance
  - Less water treatment
  - Visual assessment when performed in the dry



Key tool to address risk – when benefits of sediment removal outweigh habitat disruption

Range of Capping Technologies



Pros: effective, cost-effective isolation & exposure pathway elimination
Cons: reductions in flood storage & depth; can be compromised

Why Consider Amendments for In Situ Remediation?

- Establishing more environmentally friendly means to reduce risk from contaminated sediments is a regulatory priority
  - New remediation approaches are needed to supplement existing methods
  - Amendment treatment can reduce costs by more than 50% while reducing footprint of cleanups
  - Effective tool when sources are eliminated and newly deposited sediment is clean?

- Proven ability to reduced toxicity, mobility, and bioavailability = reduced risk

- Sorption capacity of amendment are well understood
  - Amendments have been used for years for groundwater and soil management
  - AC has large surface area, pore volume, and adsorptive capacity

> "*Amendments applied directly to the contaminated sediment may be particularly useful in areas where MNR, caps, or dredging are not likely to be effective in reducing risks*"   USEPA, 2013

Direct Amendment Addition Objectives and Challenges

Objectives

– Reduce or eliminate:
  - Bioaccumulation in benthos
  - Transfer to aquatic food chain
  - Flux of pollutants into water column

– Change the native sediment geochemistry without creating a new cap or new surficial substrate

Challenges

– How to deliver a thin layer application in dynamic aqueous environments?

– How to mix into bioactive zone?
  - Bioturbation
  - Mechanical equipment

– Treatment capacity?
  - Interactions with natural system
  - Long-term performance
  - Ongoing sources

– Risk profile

Examples of In Situ Sediment Amendments


Granular Activated Carbon


Zero-Valent Iron (ZVI)


Organoclay-MRM®


Biochar (wood charcoal)


Siderite (iron carbonate)


Elemental Sulfur


Sedimite™


Iron Sulfide


AquaGate +PAC +Sorbster™

Field Projects (AC and Biochar) (Source: Patmont et al., 2014)

Year Initiated	Site	Contaminant
Completed Field Projects		
2004	Anacostia River, Washington, DC	PAHs
2005	Hunters Point, CA	PCBs and PAHs
2006	Grasse River, NY	PCBs
2006	Trondheim Harbor, Norway	Dioxins/furans
2006	Spokane River, WA	PCBs
2009	De Veenkampen, Netherlands	NA (benthic study)
2009	Grenlandsfjords, Norway	Dioxins/furans
2009	Bailey Creek, VA	PCBs
2010	Canal Creek, MD	PCBs and Hg
Field Studies Underway		
2011	Onondaga Lake, NY	Chlorinated benzenes/PAHs
2011	South River, VA	Hg
2011	Sandefjord Harbor, Norway	PCB, TBT, & PAHs
2011	Bergen Harbor, Norway	PCBs and TBT
2012	Leirvik Sveis Shipyard, Norway	PCB, TBT, & metals
2012	Naudodden, Norway	PCB, PAHs, TBT, & metals
2012	Berry's Creek, NJ	Hg and PCBs
2012	Puget Sound Naval Shipyard, WA	Hg and PCBs
2012	Custom Plywood, WA	Dioxins/furans
2012	Duwamish Slip 4, WA	PCBs
2013	Mirror Lake, DE	PCBs and Hg
2014	Pearl Harbor, HI	PCBs and

Canal Creek Wetland Restoration Demonstration Project

- Can *in situ* technologies be used to sequester contaminants in wetlands without negatively impacting the ecology of these sensitive systems?
- Metrics for success
  - Ecological impact
  - Risk reduction
  - Cost-effectiveness
  - Regulatory acceptance
  - Sustainability
- USA funded DoD demonstration/ validation projects
  - PCBs
  - Mercury

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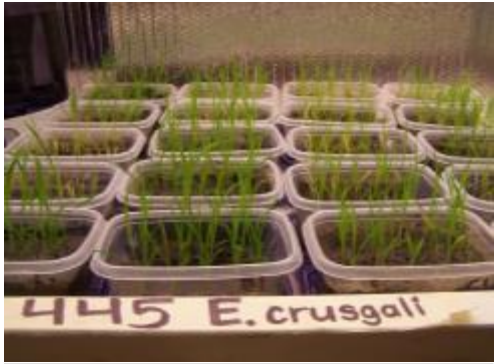
Demonstration of *In Situ* Sediment Treatment Technologies

SediMite®

AquaGate™

Pelletized Carbon

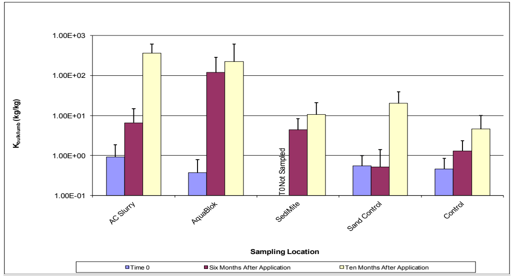


Laboratory Studies

Monitoring

Carbon Slurry Delivery

Dry Broadcasting



Reporting

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Test Design – Field Application

Carbon Slurry

Dry Broadcast

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SediMite® Applications: Blowers and Spreaders (source Menzie 2013)

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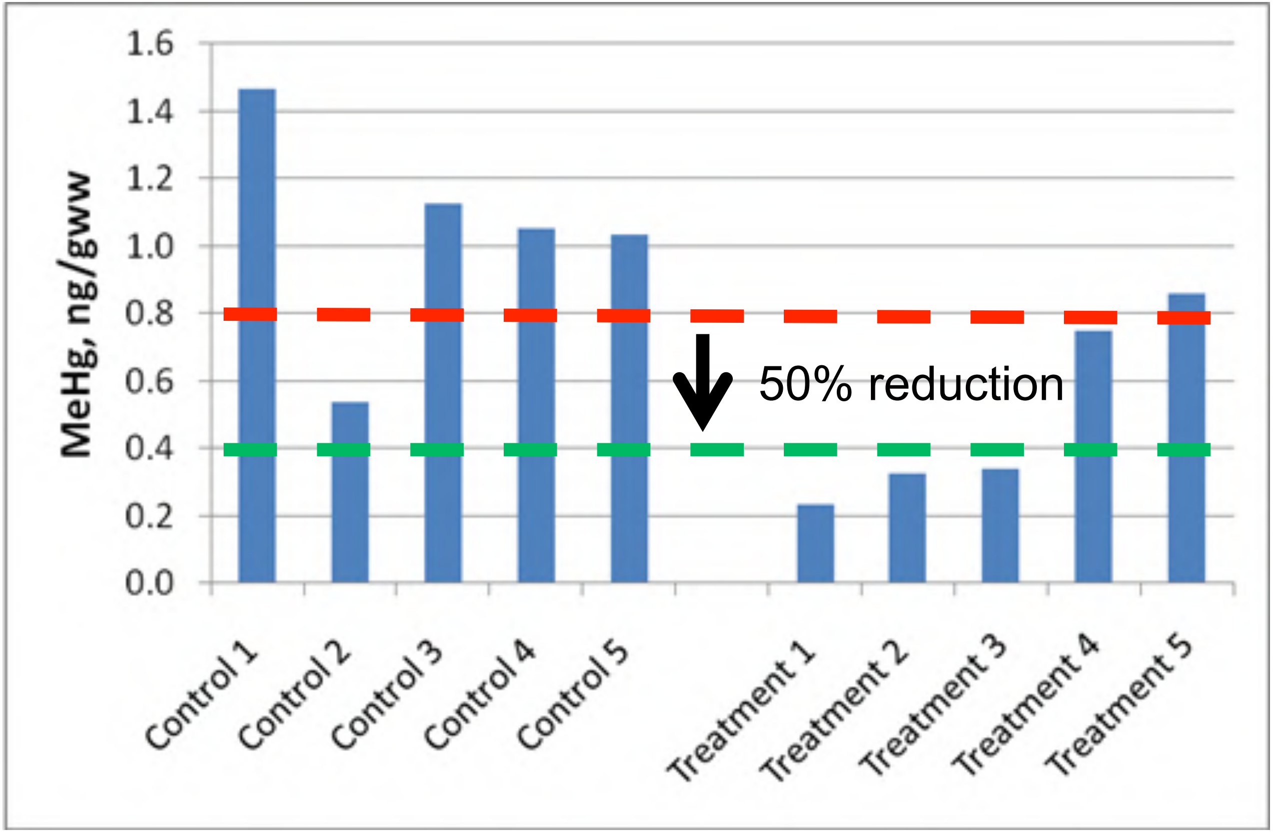
MeHg in worm tissues: 1-year post-application sampling



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Canal Creek Summary

1. Overall results suggest that addition of AC *may* be effective in wetland setting
   a. PCB and Hg heterogeneity
   b. Small sample sizes
   c. Slow mixing of placed carbon
   d. Migration of placed carbon
   e. Sample and monitoring program design
   f. Methyl mercury dynamics

→ Confounding Factors

2. Bench scale testing confirmed PCB and Hg sequestration and reductions in bioavailability
3. Equipment to deploy carbon readily available and implementable

Overall results are encouraging, but additional field monitoring is necessary to demonstrate the efficacy of using activated carbon

Berry's Creek Superfund Site, NJ

1. Can activated carbon or other amendments reduce the bioavailability of Hg, MeHg, and PCBs?

2. What factors control and limit bioavailability and update?

   - Urban watershed
   - 416 hectares
   - Hg and PCBs in tidal marshes
   - Laboratory and marsh pilot study
   - Hg speciation

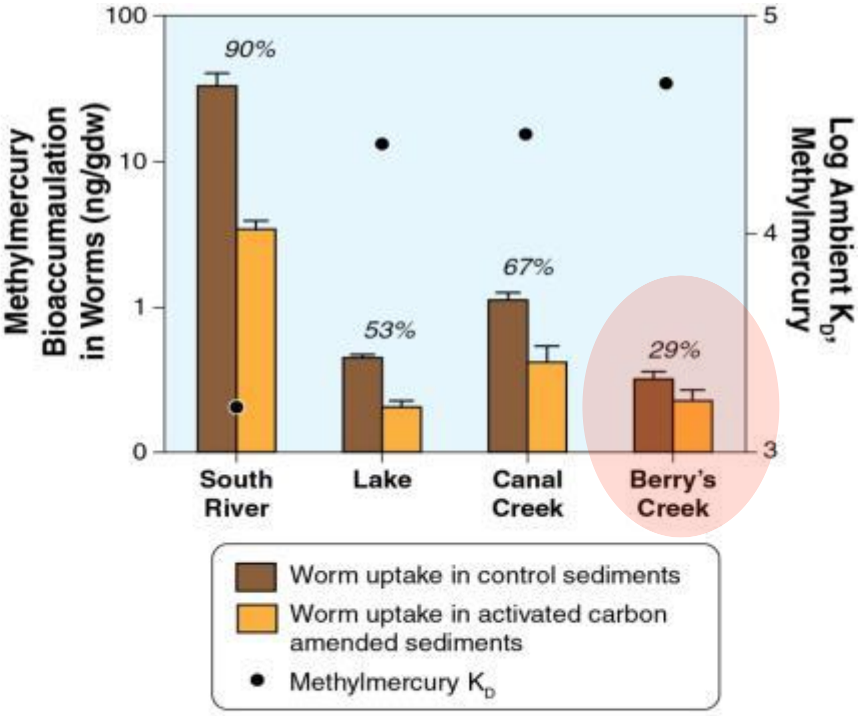
Work conducted by Dow/Morton and Partners

Berry's Creek Superfund Site: Proof of Concept

– Sediment slurry studies demonstrated that AC reduced concentrations of PCBs, Hg, and MeHg in porewater

- MeHg in pore water reduced by 45 to 90% relative to controls
- MeHg in test organisms reduced by 30 to 90% relative to controls

– Amendments were most effective in sediments with low native sediment: water MeHg partition coefficients



Source: Adapted from Gilmour et al., 2013.

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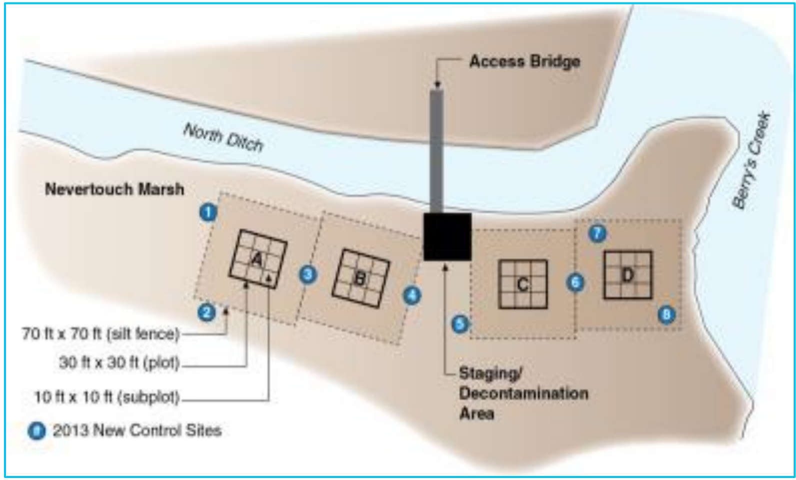
Berry's Creek Superfund Site: Field Pilot Study

- Various AC applications at 5% by dry weight (top 10 cm)
  - Amendments survived major storm events (Superstorm Sandy/Hurricane Irene)
  - AC penetrated 3 cm+ surficial sediments (3 plus years)
- PCBs
  - Reduced porewater concentrations and uptake in field-caged and laboratory organisms
  - Reduced concentrations in surficial detritus
- Hg
  - THg in pore water and caged biota ~50% in AC (Sedimite™) plots compared to controls
  - MeHg dynamics complex, but similar reductions observed in some treatments (complicated by elevation and tidal inundation dynamics)



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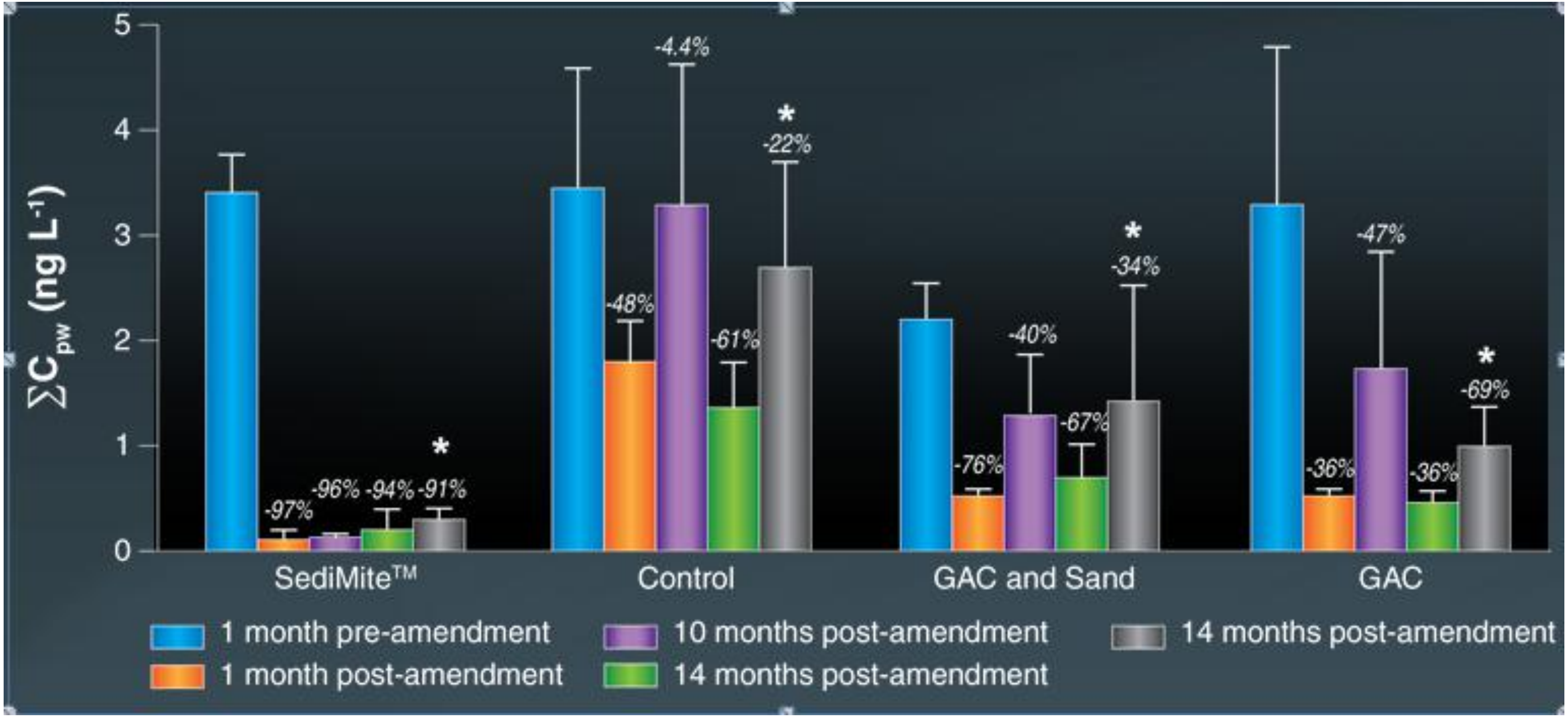
Berry's Creek: Concentrations of PCBs in porewater substantially decreased in treated plots relative to control, with largest reduction (97%) in SediMite™ Plot



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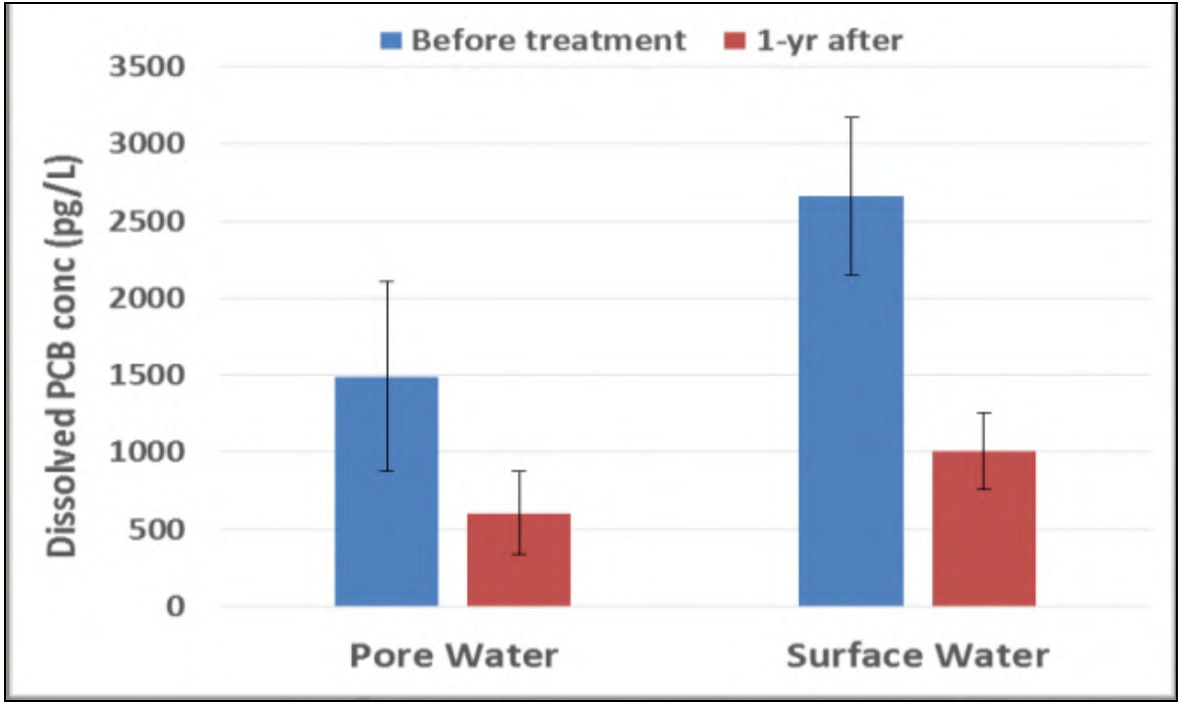
Mirror Lake, DE

- First full-scale placement of AC in US
- 2-hectare urban pond
- Goals
  - Enhance the sorptive capacity of native sediment
  - Reduce PCB bioavailability and uptake without altering the existing sediment bed
  - Reduce or eliminate fish advisory

- Planning
  - Extensive stakeholder engagement and public outreach efforts
- Implementation
  - 79 tons of SediMite™ delivered over 10 days
  - Ca. $1M including planning, design, construction, and 3-year monitoring
- Monitoring
  - Bulk sediment
  - Water
  - Fish tissue
  - Passive samplers
  - Bioaccumulation studies
  - Sediment cores

Mirror Lake Passive Samplers

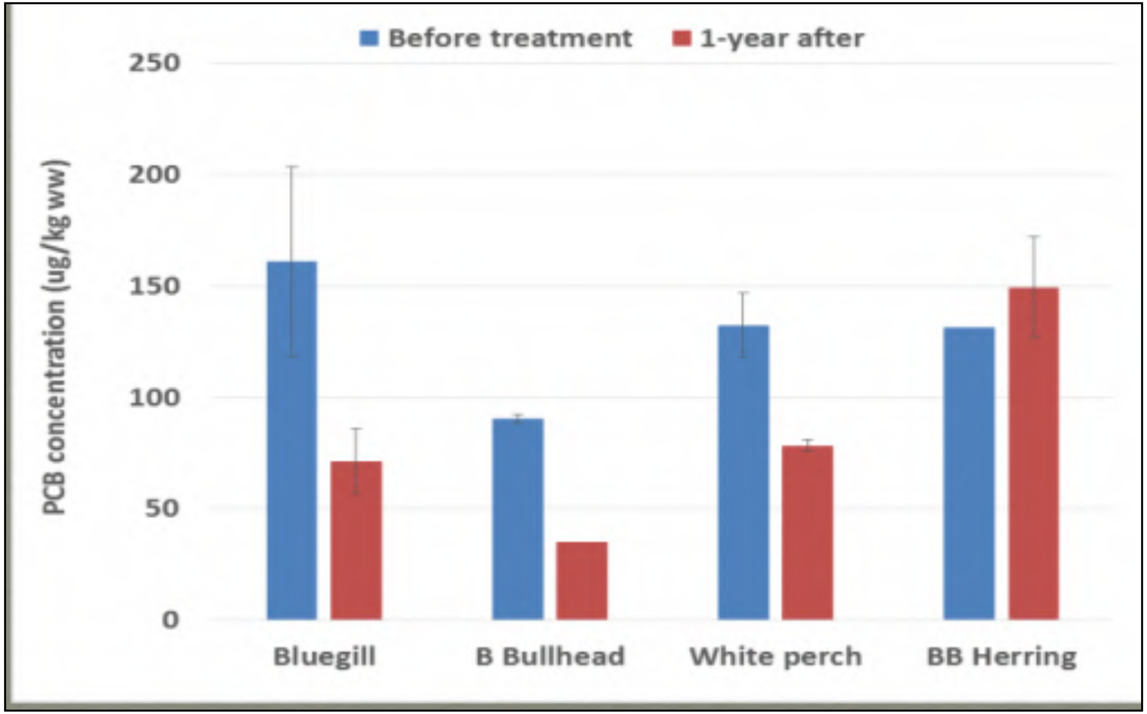
60 percent reduction in porewater and water column 1 year post-treatment



Source: Cargill, 2015

Mirror Lake Fish Tissue Monitoring

50 to 60 percent reduction in PCBs in resident fish (0 to 40% in migratory fish)



Source: Cargill, 2015

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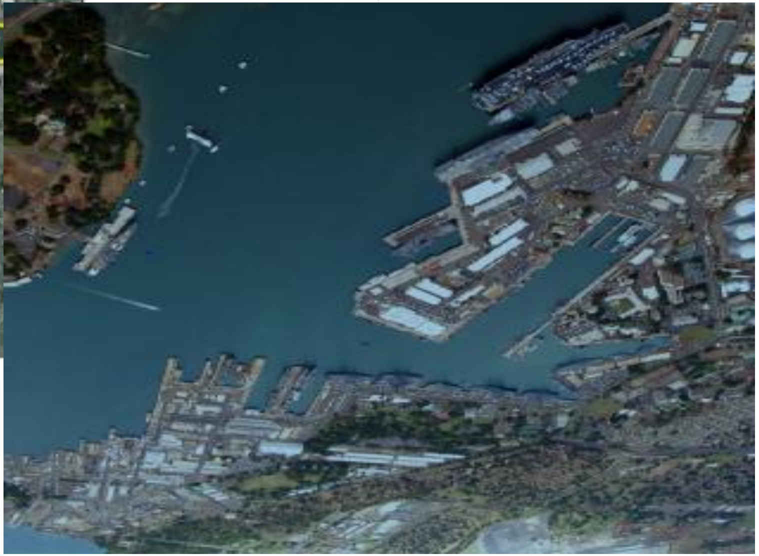
Pearl Harbor Under Pier AC Treatment Studies

Test Area



- PCBs and Hg in surface sediment
- Soft sediment under piers
- Active submarine berthing and repair area

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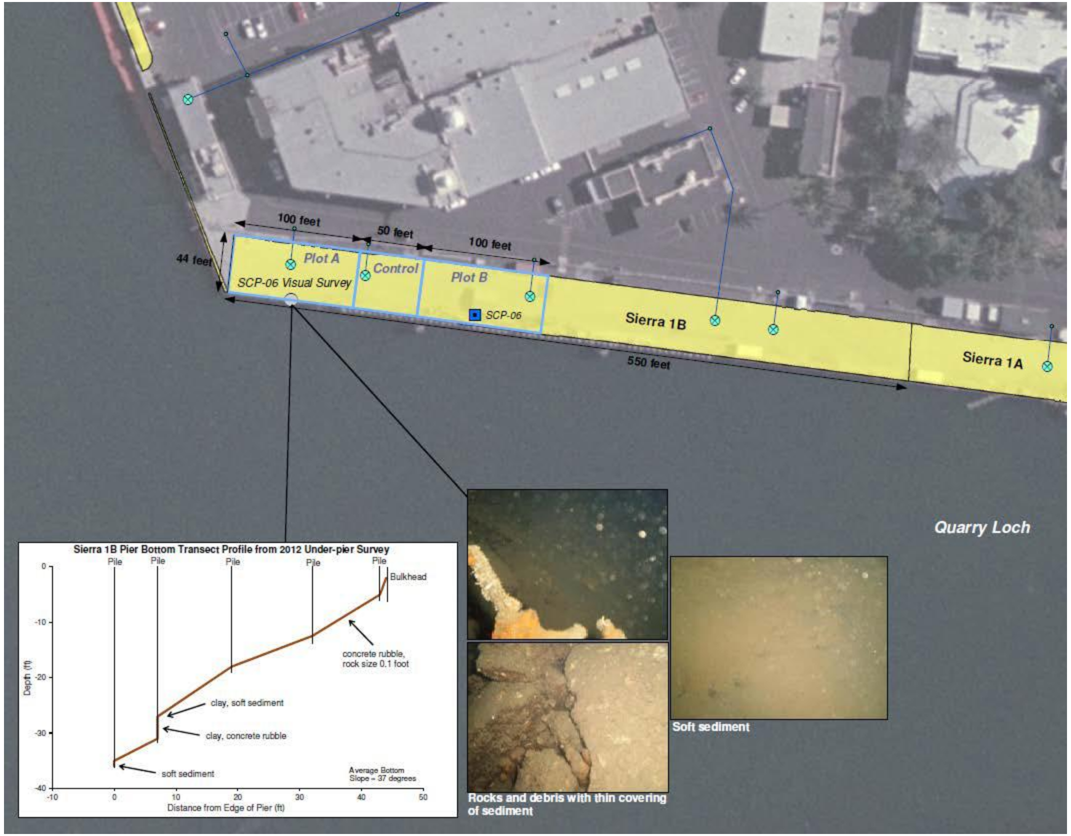
Treatability Studies Under Sierra 1 Pier, Pearl Harbor



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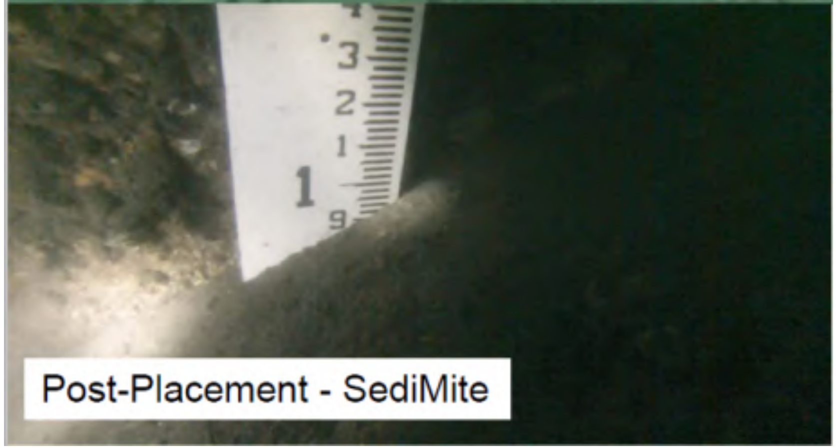
Pearl Harbor Under Pier AC Treatment Studies

- Primary Criteria
  - Thickness placement depth
  - AC maintained at designed dose (2.5%)
  - Minimum 50% reduction in porewater and tissue PCB concentrations
- Secondary Criteria
  - Mixing of AC in the biologically active zone
  - Efficient placement techniques identified
  - Presence of infauna following AC placement

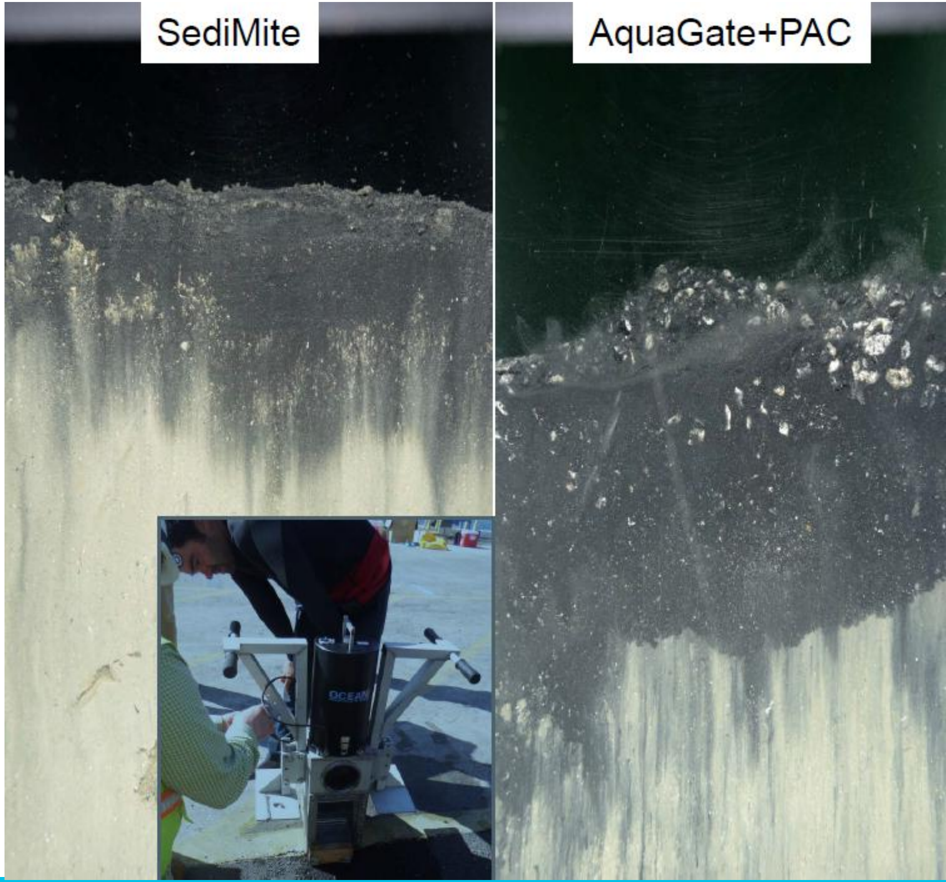
Pre-Placement - SediMite



Post-Placement - SediMite

Pearl Harbor Sediment Profile Imaging

- SPI conducted at 26 locations
- All locations displayed presence of amendment
- Some over-application observed
- Native sediment layers observed
- Material persisted 6 months following application
- Evidence of benthic activity after 6 months



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6-Month Sampling Preliminary Results: Bulk Sediment and Porewater Chemistry

– Sediment Porewater Chemistry

- Decreased porewater PCB concentrations in test plots
- Higher percent decrease with Aquagate+PAC

Average Change in Sediment Porewater PCB Concentration	
Activated Carbon Amendment Type	Total NOAA-18 PCBs % Change
SediMite™	-36%
Aquagate+PAC	-71%

6-Month Performance Evaluation (Preliminary Evaluation)

Performance Criterion		Criterion Met?	
		Sedimite	AquaGate+PAC
Primary	Achieve minimum design thickness	Yes	Yes
	Average black carbon content ≥ baseline level + 2.5%	No	Close
	Average TOC ≥ baseline level + 2.5%	Yes	Yes
	50% reduction in porewater COC concentration over the Treatability Study duration	No	Yes
Secondary	Mixing of AC amendment in the BAZ	Yes	Yes
	Presence of benthic infauna post-emplacement	Yes	Yes

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Summary of Cost

- Conventional wetland remedial costs
  - Often exceed $1M million per hectare
  - Restoration alone can be $250K/hectare + depending on the type of wetland habitat for even shallow excavations
- Costs for application of in situ AC remediation
  - ~ $150K to $500K/hectare typical in literature (AC, field placement, monitoring)
- Cost drivers
  - Mobilization/Demobilization (for small applications)
  - Site preparation (for sites with challenging access)
  - Long-term monitoring (tissue sampling, congener analysis, 30-year duration, etc.)
  - Expectation that costs may drop eventually with technology acceptance

Additional Concerns

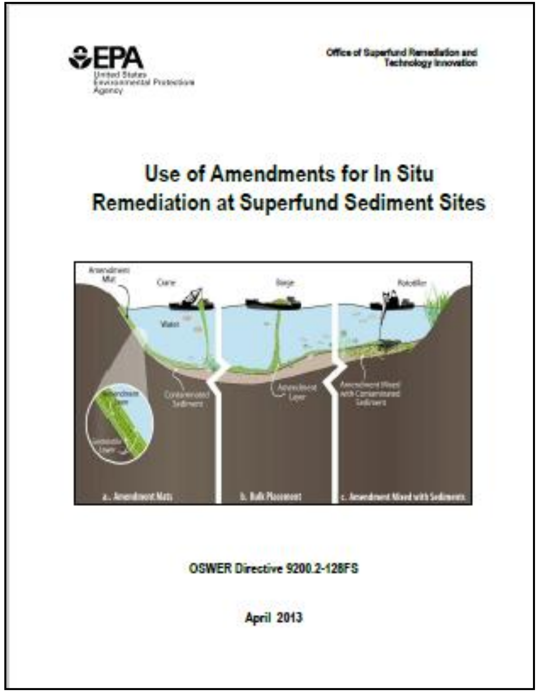
1. **Is the material toxic?**
   a. Limited toxicity or biological effects testing in field
   b. Potential effects minimized when AC doses are low (<4%)

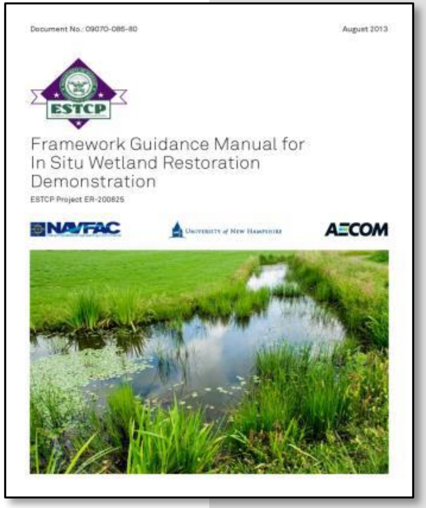
2. **Long-term success?**
   a. Longer term studies show promise (Grasse River, Hunters Point, etc.)
   b. Increasing database (5 to 10 years) suggests material effectiveness increases with time

3. **Regulatory acceptance**
   a. Permits have been issued
   b. Mirror Lake Delaware is agency-driven

4. **Monitoring Needs?**
   a. Technology (materials and placement) generally costs less than conventional remedies…but
   b. Complex long-term monitoring can be costly

Guidance





Framework Manual in Press

1. Introduction
2. Site Characterization and Monitoring
3. Technology Descriptions
4. Technology Considerations
5. Pilot Scale, Design, and Full Scale Implementation
6. Post-Implementation Evaluation and Monitoring
7. Cost Analysis

Conclusions

In situ treatment technologies represent a viable option at some sediment sites

- AC can rapidly address key exposures
- Placement with range of conventional construction equipment possible
- Not appropriate when contaminants are present in unstable environments (Dredging or Capping preferable)
- Represents a sustainable technology to consider in sensitive environments
- Potentially useful at sites where combination of technologies are applied

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Thank You!

John.Bleiler@aecom.com