ACTIVE CAPPING FOR THE MANAGEMENT OF CONTAMINATED SEDIMENTS

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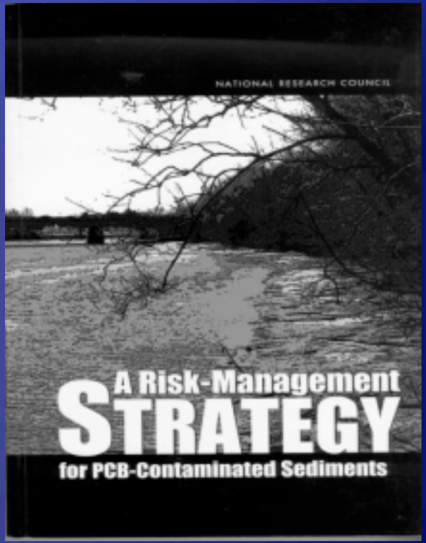
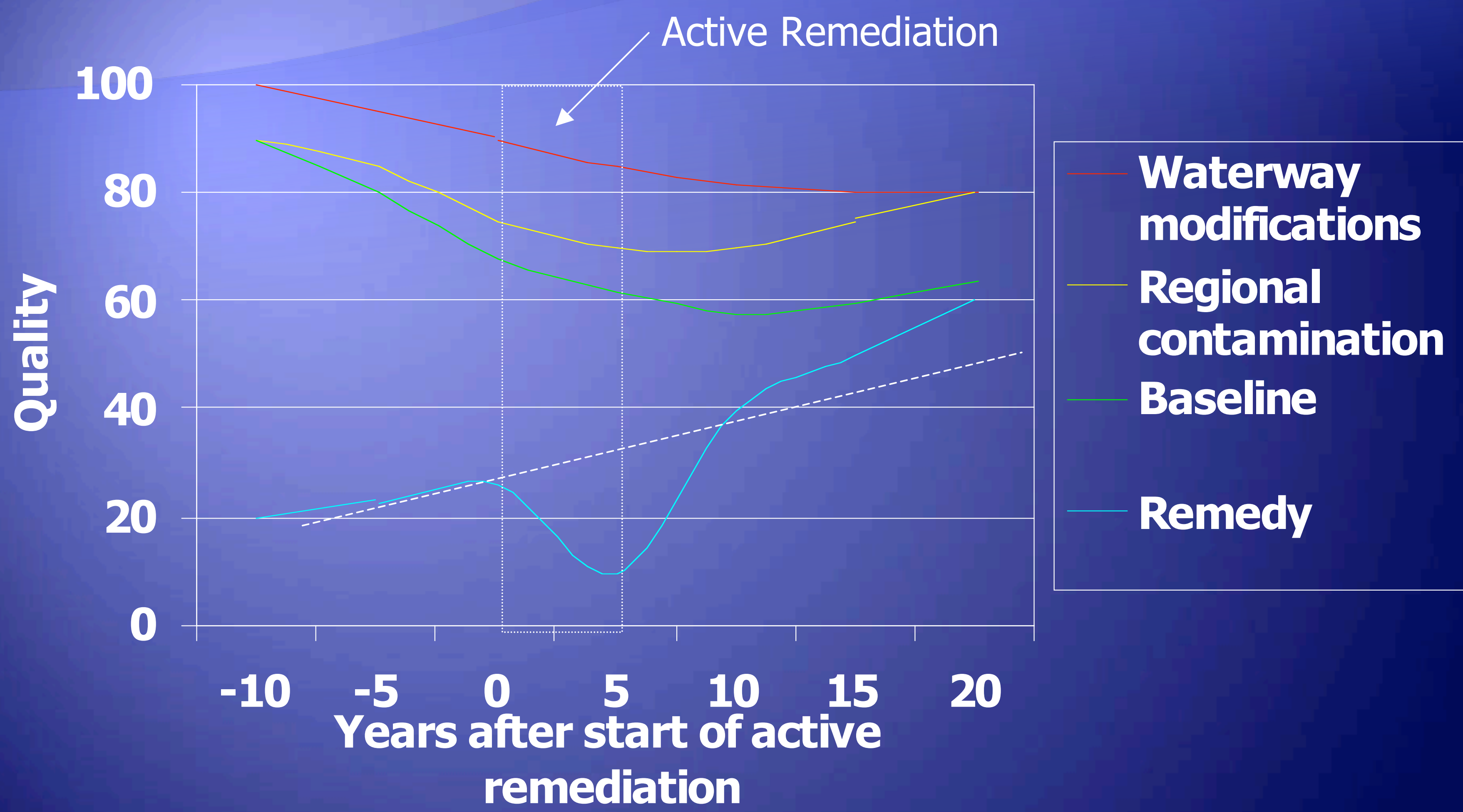
A Risk Management Strategy for PCB-Contaminated Sediments (NRC 2001)

"All remediation technologies have advantages and disadvantages when applied at a particular site, and it is critical to the risk management that these be identified individually and as completely as possible for each site…Thus, management decisions at a contaminated sediment site should be based on the relative risks of each alternative management action... For a site, it is important to consider "overall" or "net" risk in addition to specific risks." NRC (2001)

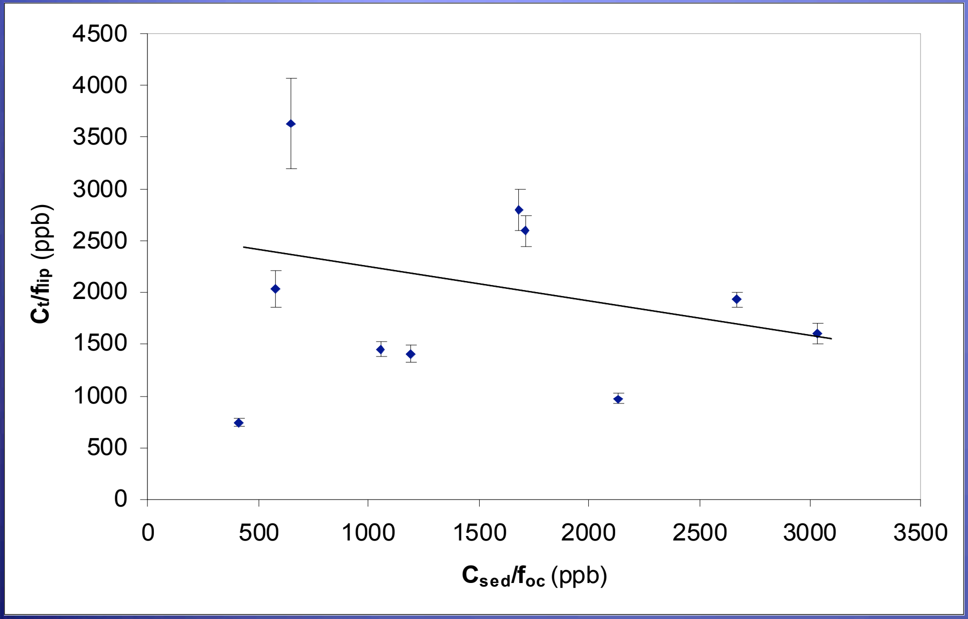


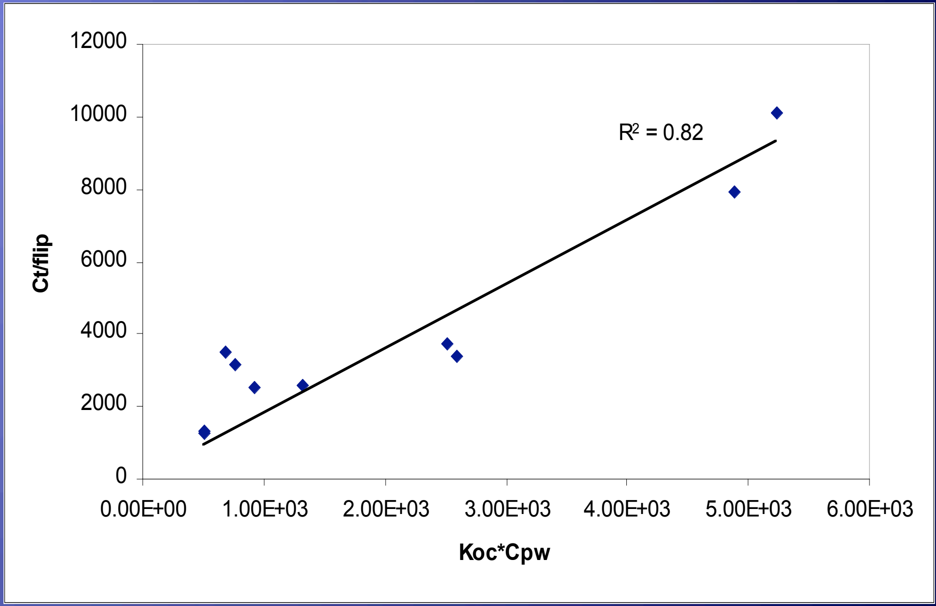
Ideal Recovery Scenario



Chemical measures of Risk Reduction Bulk Sediment or Interstitial Water?

Benthic Tissue Accumulation of PAHs





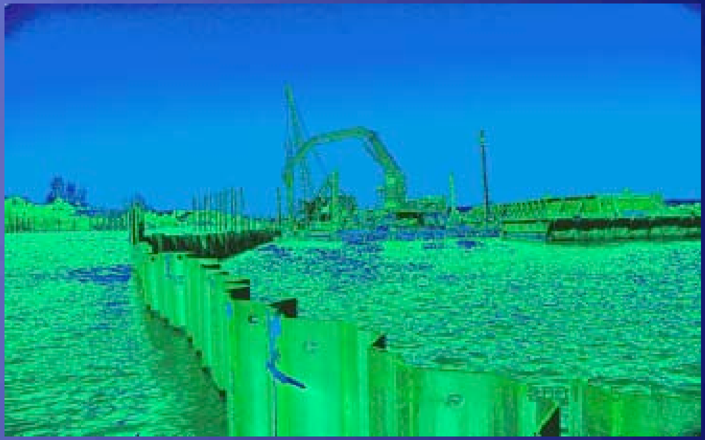
Bulk Sediment

Interstitial Water Concentration

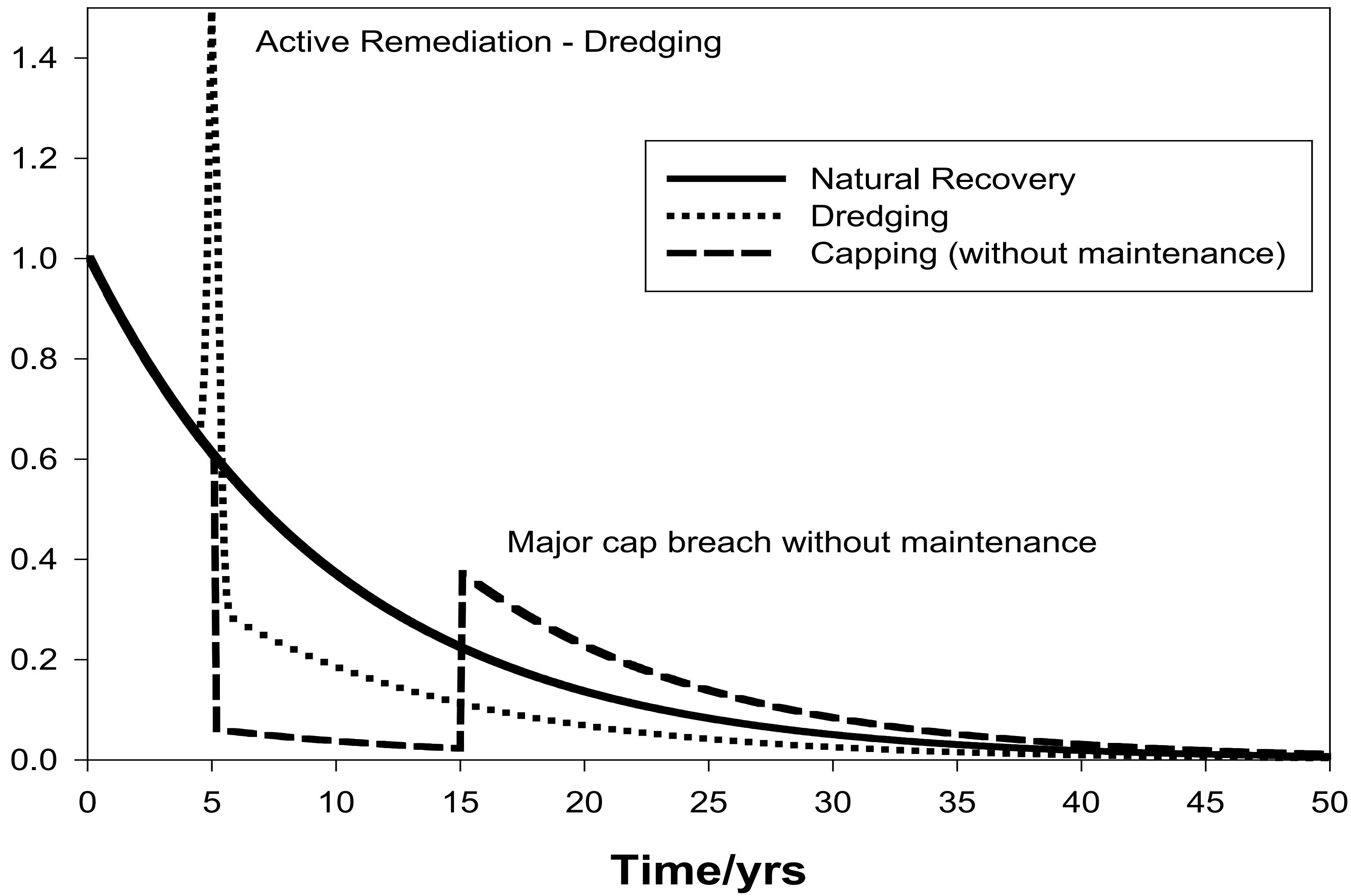
Anacostia River, Washington DC

Managing Risks What are the Options?

- Monitored Natural Recovery
  - Part of all remedies
  - May be an integral part of active remediation
- Dredging
  - Need to recognize impacts and limitations
  - Triggers a variety of onshore activities
- Capping
  - Clean sediment/sand layer over contaminated sediment
  - Can be rapidly implemented with minimal impact
  - Need to assess long-term protectiveness



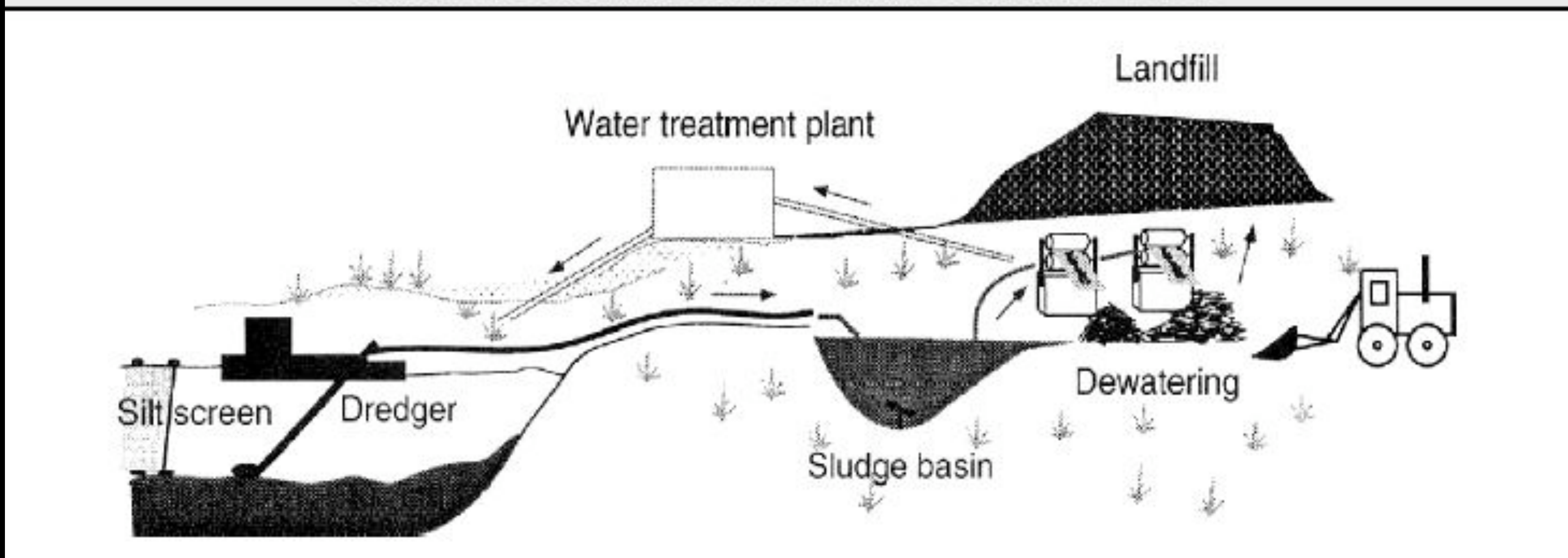
Response to Remedial Approaches



Dredging Treatment Train

- Dredging often <20% of effort and total cost
- Net risk reduction should consider entire process
- Flexibility in water/sludge treatment & disposal can dramatically change feasibility and

Highlight 6-8: Sample of Dredging Dewatering Process



NRC Evaluation of Dredging Effectiveness (2007)

- Operational goals (mass removal or dredging to elevation) established as cleanup levels were achieved at many sites.
- Dredging is effective at removing large volumes of contaminated sediments from the environment. This doesn't necessarily equate to risk reduction, but can be useful if those sediments are likely to be transported to less contaminated areas.
- Dredging alone achieved desired contaminant-specific cleanup levels at only a few of the reviewed sites; capping after dredging was often necessary to achieve cleanup levels. At some sites, dredging achieved cleanup levels and presumably contributed to declines in biota contaminant concentrations.

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NRC Evaluation of Dredging Effectiveness (2007)

- Difficulties arise primarily from dredging’s inherent limitations in fully removing contaminated sediments and site conditions that limit complete removal of contaminated sediments. The result is residual contamination that hinders the ability to achieve risk reduction.

- Dredging can cause releases of contaminants during operations that increase water column and fish tissue contaminant concentrations in the short term.

Liver Lesion Risk in English Sole

Eagle Harbor, 1983-May 2002

Randle Reef U.S. Steel (USS) Channel Capping

- Why choose capping?
    1. USS intake & outfall locations
    2. Presence of slag on channel bottom (not able to dredge)
    3. Existing USS dock wall stability concerns
    4. Mass of sediment contaminants in channel less than 1% of total mass of Randle Reef contaminants

- Capping Plan:
    - 30 cm thick layer of sand with silt and enriched TOC

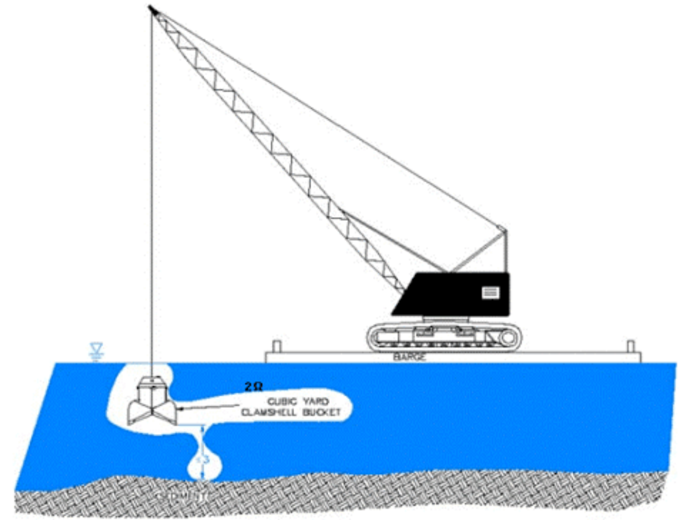
Randle Reef U.S. Steel (USS) Channel Capping

- Special Considerations:

1. Vessel berthing activities will continue along northern end of USS wall
   - Approx. 61 m length of the cap located at channel entrance will be armoured with 7.6 cm D50 stone placed over a geotextile

2. Small area adjacent to USS intake pipes
   - Capped with reactive core mats And armour mats to provide sediment Containment & scour protection

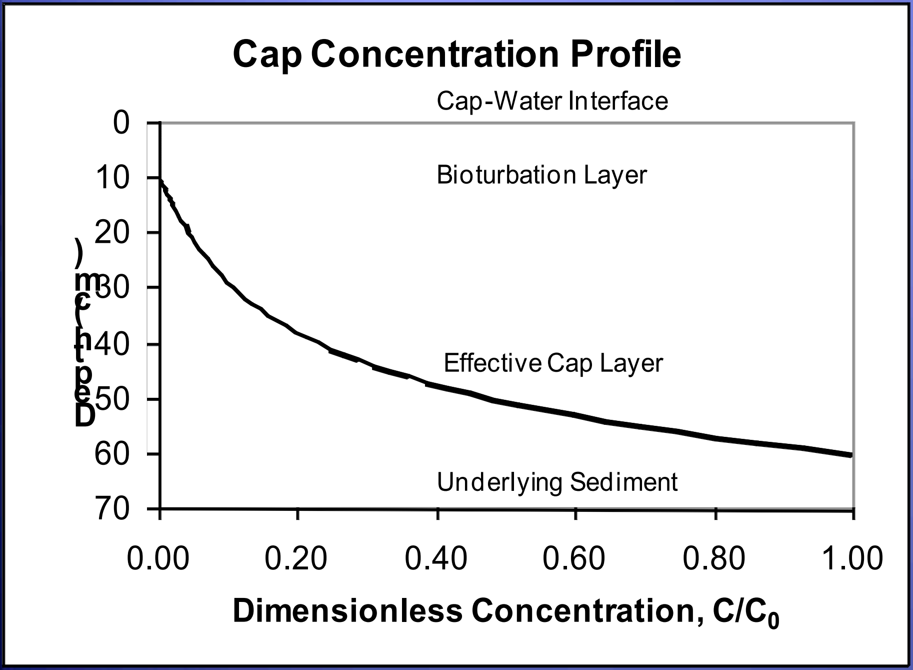
Schematic of Subsurface Clamshell Application

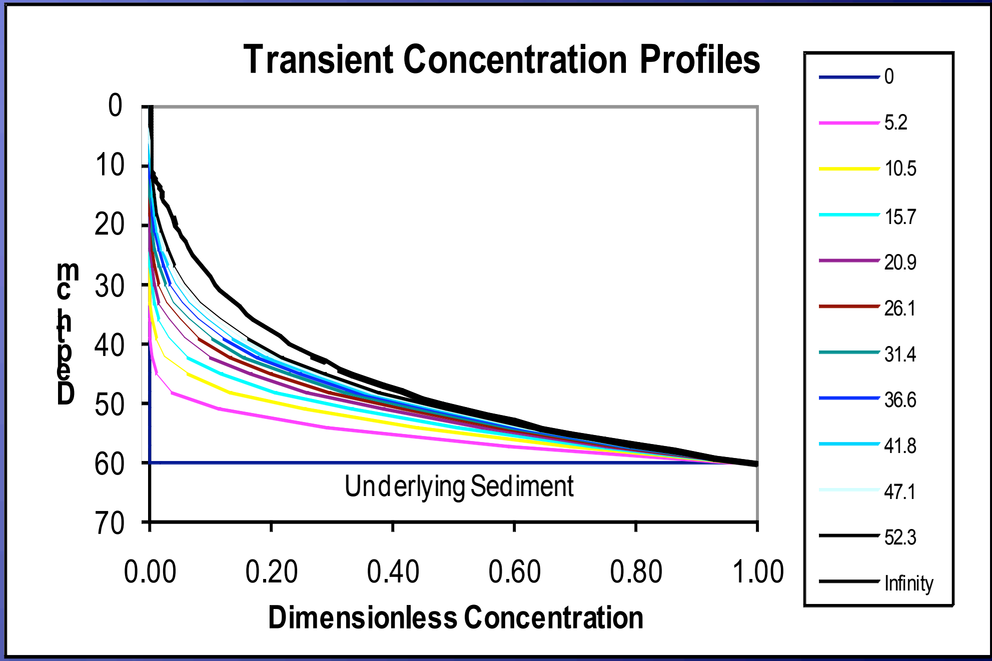


When is Conventional Sand Capping Effective?

- Sources controlled
- Strongly solid associated contaminants
  - Minimal mobile fraction
  - Elimination of ingestion exposure pathway
- Hydraulic control achieved or attainable
  - Upwelling velocities typically in 1-10 cm/yr or less
  - Controlled with groundwater withdrawal, interception or sheet piling

Sand Cap Effectiveness Weak Upwelling



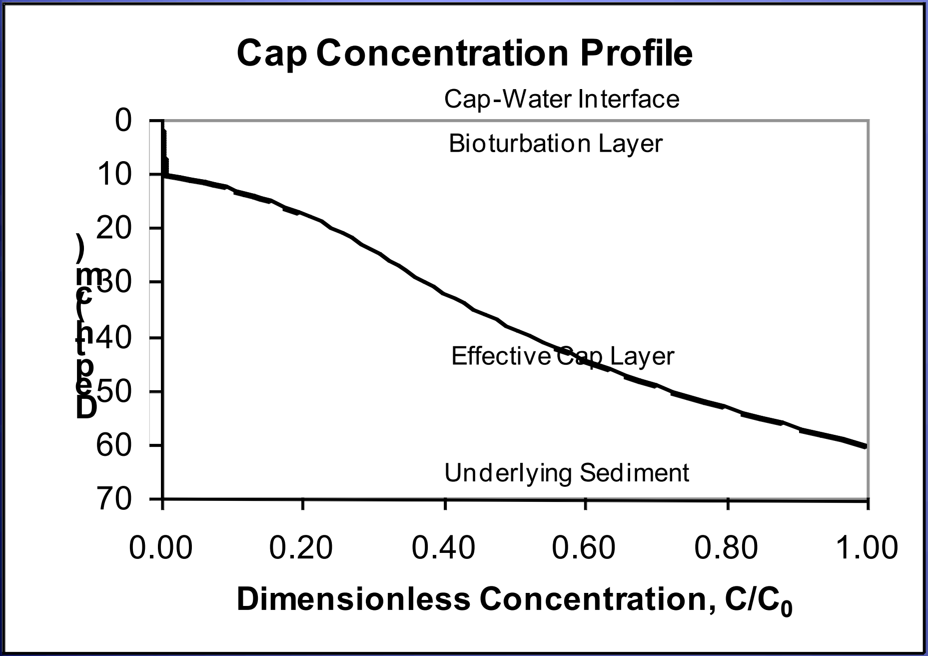


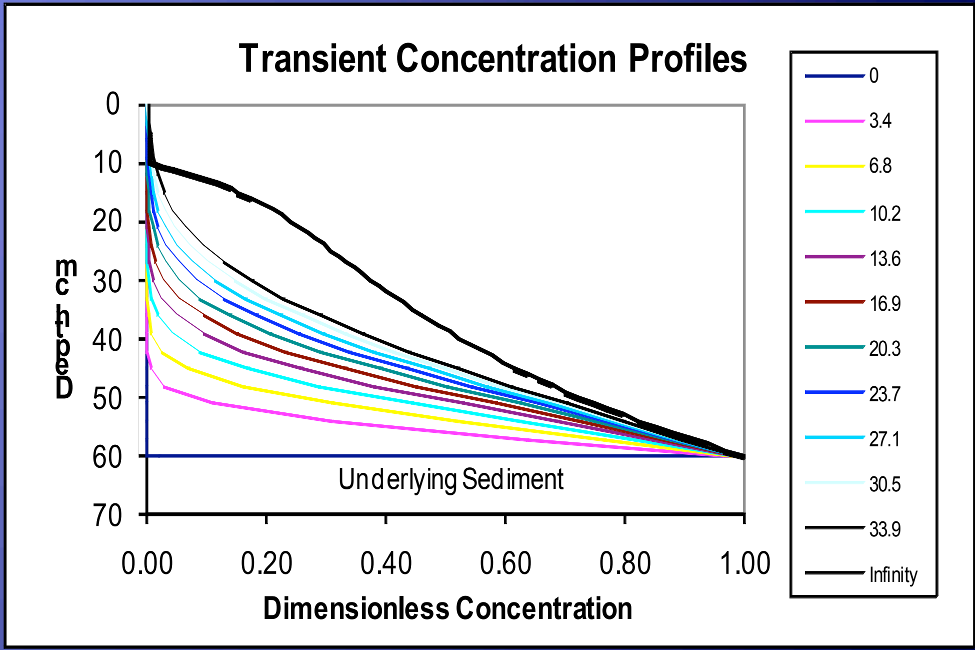
Steady State Concentration Profile

Transient and Steady Profiles

Phenanthrene – 1 cm/yr

Sand Cap Effectiveness Moderate Upwelling



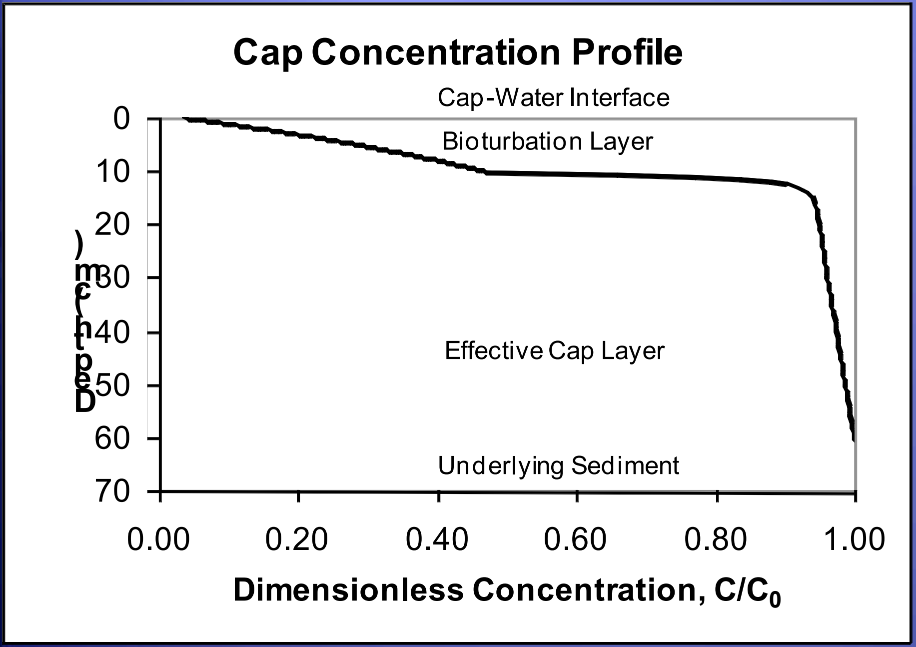


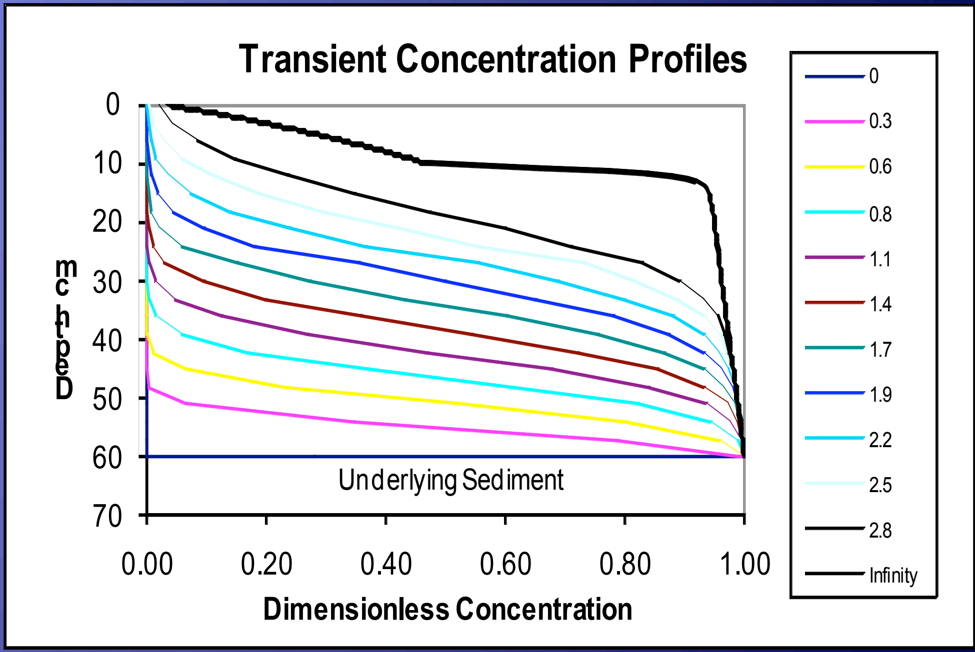
Steady State Concentration Profile

Transient and Steady Profiles

Phenanthrene – 1 cm/month

Sand Cap Effectiveness Strong Upwelling





Steady State Concentration Profile

Transient and Steady Profiles

Phenanthrene – 1 cm/day

Active Capping

- Potentially greater effectiveness than with sand can be achieved with "active" caps
  - Encourage fate processes such as sequestration or degradation of contaminants beneath cap
  - Discourage recontamination of cap
- Feasible if high value components are placed in thin layer in a controllable manner
- Effective if time/capacity of active cap sufficient to manage finite mass of contaminants
- Significant stakeholder acceptance advantage

Goals of Active Capping

- Permeability Control
  - Discourage upwelling through contaminated sediment by diverting groundwater flow
- Contaminant Migration Control
  - Slow contaminant migration, typically through sorption related retardation
- Contaminant Degradation Aid
  - Less well developed, contaminant specific but designed to encourage contaminant fate processes

Potential Active Cap/Treatment Materials

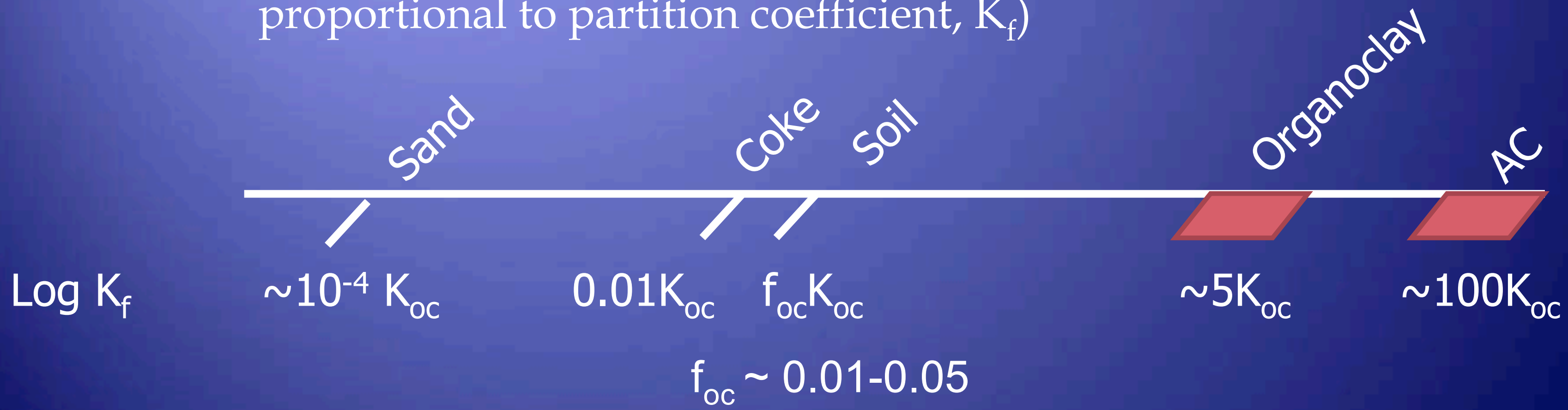
Demonstrated

- Clays for permeability control
- Activated Carbon or other carbon sequestration agent
- Organoclays for NAPL control
  - Demonstrated (e.g. McCormick and Baxter)
  - Significant swelling and permeability reduction with NAPL
  - Design balancing capacity with permeability reduction
- Phosphate additives for metals
  - Rock phosphate (e.g. apatite) demonstrated
  - Phytic acid salts, injectable into sediments
- Siderite (FeCO3) for pH control
- Zero valent iron
- Oxygen or hydrogen release compounds/technologies
- Biopolymers
  - Can sorb metals and organics
  - May provide erosion control and suitable surficial substrate
  - May provide carbon source to enhance microbial activity

Speculative

Sorbents for Sequestration and Bioavailability Reduction

- Effectiveness of Activated Carbon, Coke, and Soil as cap amendments
  - PAHs/PCBs sorbed to AC and coke is less bioavailable (Talley et al. 2002, McLeod et al. 2004)
  - Expect retardation/bioavailability reduction proportional to porewater concentration (inversely proportional to partition coefficient, K_f)



Active Capping Organics

- NAPL present - Organoclays
  - Capacity of O(1 g NAPL/g organoclay)
  - Placement within a laminated mat for residual NAPL or to allow replacement if capacity exceeded
  - Placement in bulk for significant NAPL volumes
  - Multiple organoclay layers or organoclay/activated carbon layer for both NAPL and dissolved contaminant control
- Dissolved contaminants only - Activated carbon
  - Placement in mat may be necessary to allow easy placement
  - Placement as amendment also possible
  - Activated carbon typically more subject to fouling than organoclay

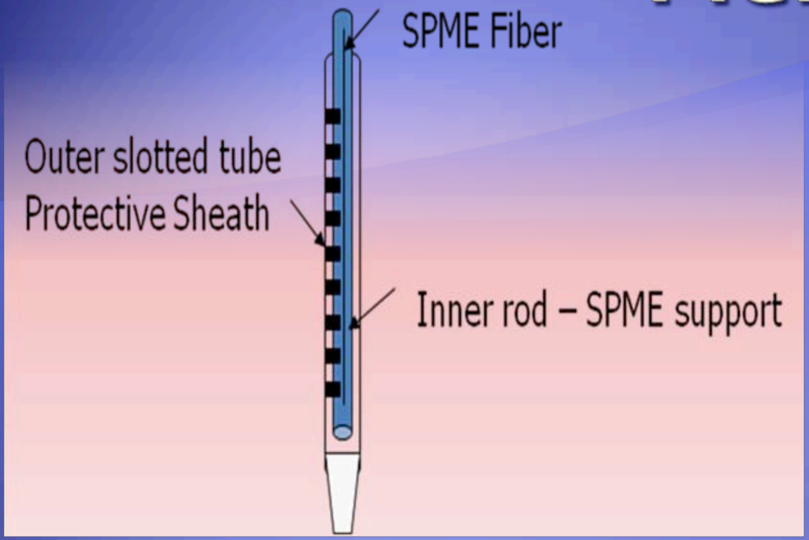
Capping Summary

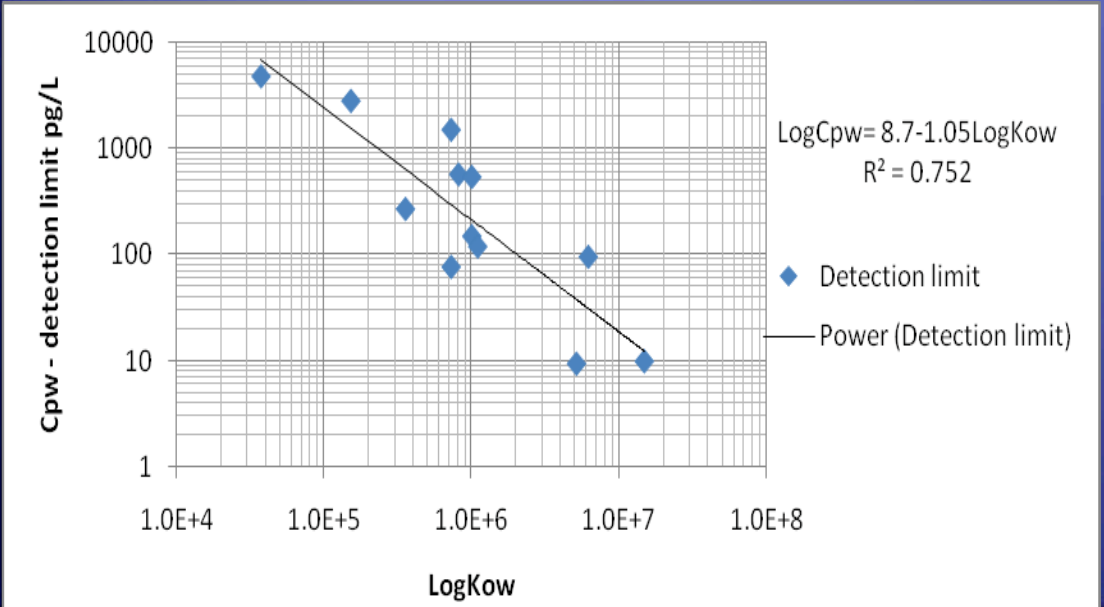
- Conventional sand caps easy to place and effective
  - Contain sediment
  - Retard contaminant migration
  - Physically separate organisms from contamination
- Methods are available for key design needs
  - Cap erosion and washout
  - Cap and sediment consolidation
  - Chemical containment
  - Assessment of exposure and risk
- There are existing and developing alternatives when a conventional cap is not sufficiently protective (e.g. organics)
  - Organoclay if NAPL present or expected, either alone in bulk or as a mat or with an activated carbon layer for excellent dissolved control
  - Activated carbon if only dissolved contaminant

Monitoring at Sediment Sites

- Monitoring is not an add-on activity for satisfying scientific curiosity; it's an essential part of the remedy.
- Monitoring is necessary to establish that the remedial action had its intended effects. If remedial actions did not achieve desired goals, then the monitoring information should be used to modify and optimize the performance of the remedy.
- A robust conceptual site model is needed to guide selection of monitoring endpoints that are linked to risk from sediments and capable of detecting changes in that risk.
- While ultimately monitoring must be focused on the risk being remediated (e.g. fish tissue concentration), interim measures are critical to the evaluation of success

Field Deployable SPME





SPME Measured Porewater Concentration Profile – Anacostia River

1- 2 orders of magnitude change in upper 25 cm!
Not reflected in bulk sediment concentration
How do we define and manage the risk?