Subaqueous Sediment Capping from Field Investigation to Design with a Focus on Chemical Isolation

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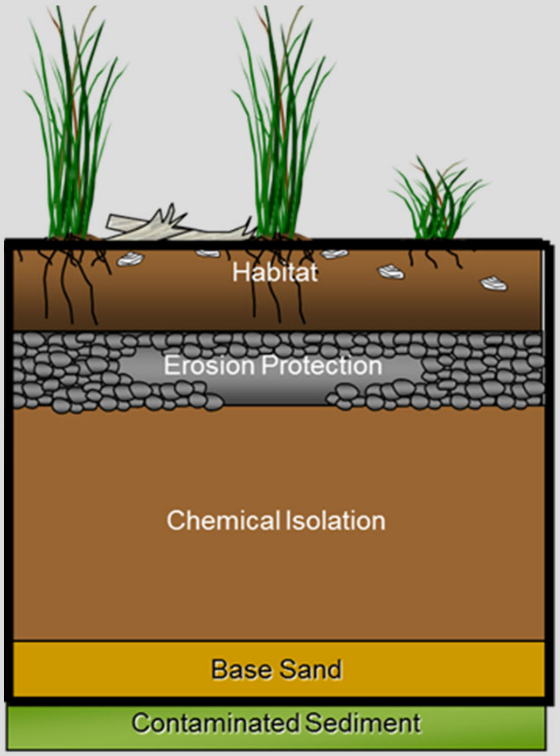
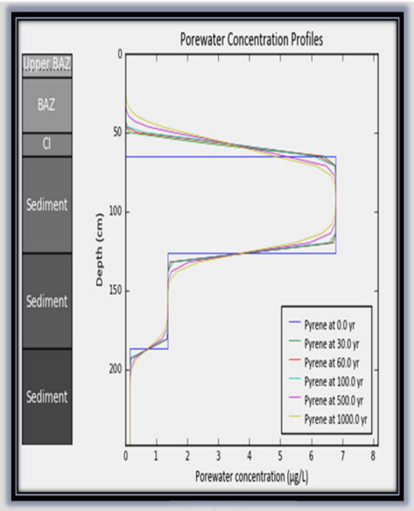
Sediment Capping Background

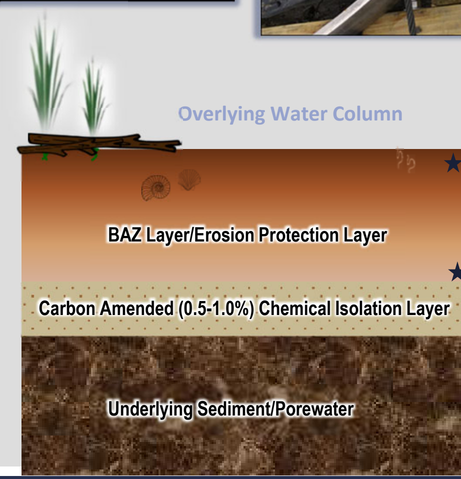
- Sediment capping is defined as the placement of a subaqueous covering or cap of clean materials over contaminated sediment.
- Sediment caps are engineered systems design to provide:
  - Physical isolation
  - Chemical isolation
  - Stabilization
- Conventional and amended caps have been applied at sites around the world to contain contaminated sediments.



Sediment Capping Advancements

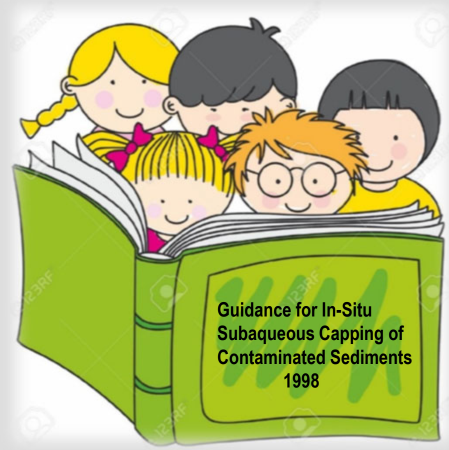
- Advancements over the last decade have included:
  - Demonstrated field investigation techniques and application of batch, column and other laboratory testing to aid in design evaluations
    - Porewater investigation and analysis
    - Groundwater upwelling
    - Site-specific lab and bench scale testing
  - Significant improvements in modeling tools
    - Increase in modeled fate and transport processes
    - User-defined or literature based input options
    - Chemical and material databases
    - Improve output graphics and profile definition
  - A better understanding of amendments and their application under varying site conditions
    - Ample lab, bench and pilot studies
    - Growing body of literature on application and performance





Key References for Sediment Capping

- Key documents
  - **Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (1998)**
    - Palermo, M., Maynord, S., Miller, J., and Reible, D. EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL.
  - **Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (2005)**
    - USEPA. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, OSWER 9355.0-85.
  - **Contaminated Sediments Remediation, Remedy Selection for Contaminated Sediments (2014).**
    - Interstate Technology & Regulatory Council. Washington, D.C.: Interstate Technology & Regulatory Council, Contaminated Sediments Team.
  - **Use of Amendments for In Situ Remediation at Superfund Sediment Sites (2013)**
    - USEPA. U.S. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation, Washington, DC, OSWER 9200.2-128FS.



Representative Capping Projects

- **Important Precedence Projects**
  - Anacostia River, D.C.
  - Silver Lake, MA
  - Grand Calumet, IL
  - Onondaga Lake, NY
  - Wycoff-Eagle Harbor, WA
  - McCormick and Baxter, OR
  - Stryker Bay, MN
  - Grasse River, NY
  - Pine Street Canal, VT


https://clu-in.org/slovenia/download/Sediment_Remediation/Reible.pdf

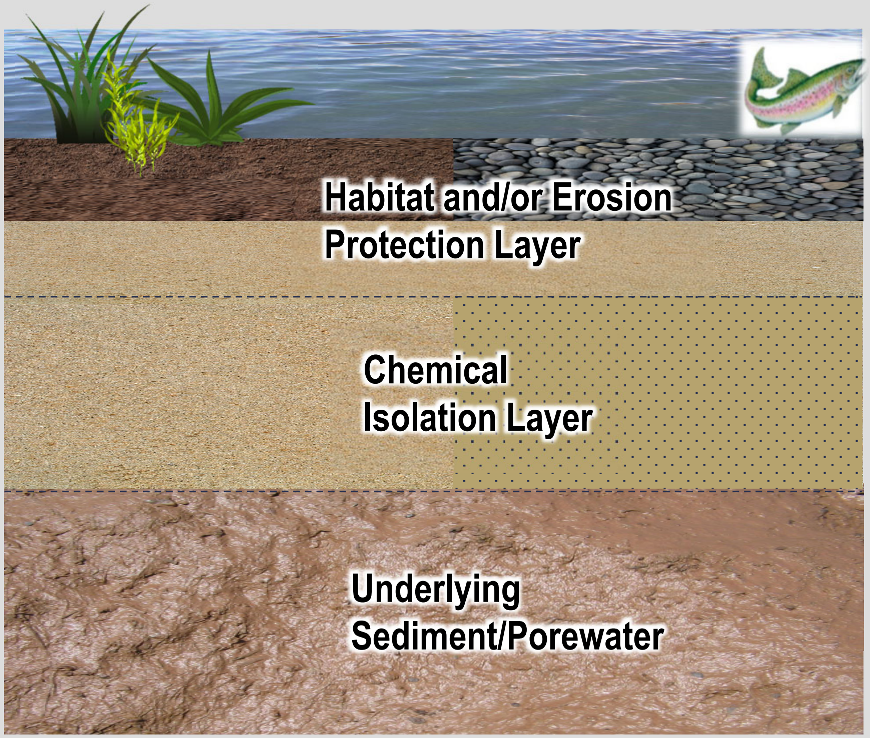

https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0901129

http://www.lakecleanup.com/about-the-cleanup/cleanup-areas/onondaga-lake/


https://sevenson.com/project/silver-lake-pilot-study-sediment-capping-project/

Cap Detail

Model Predicted Contaminant Concentration and Flux



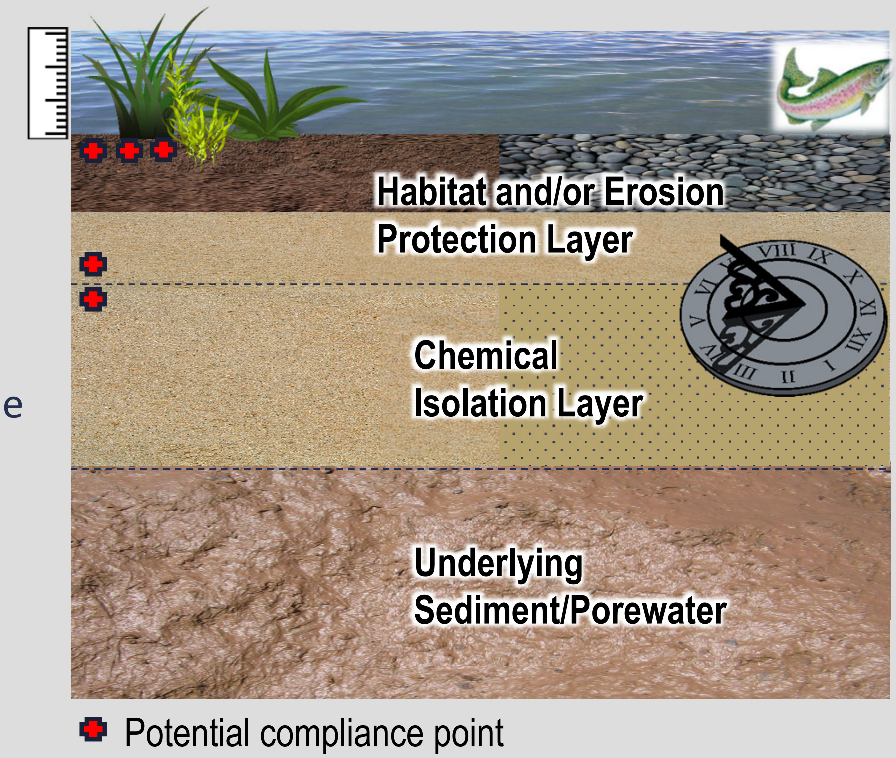
Cap Fate and Transport Processes

Bioturbation
Bioirrigation
Tidal Pumping
Adsorption (linear and non-linear)
Advection (groundwater)
Diffusion (molecular)
Dispersion
Biological Decay
Settlement Induced PW Expression

Cap Design Strategy

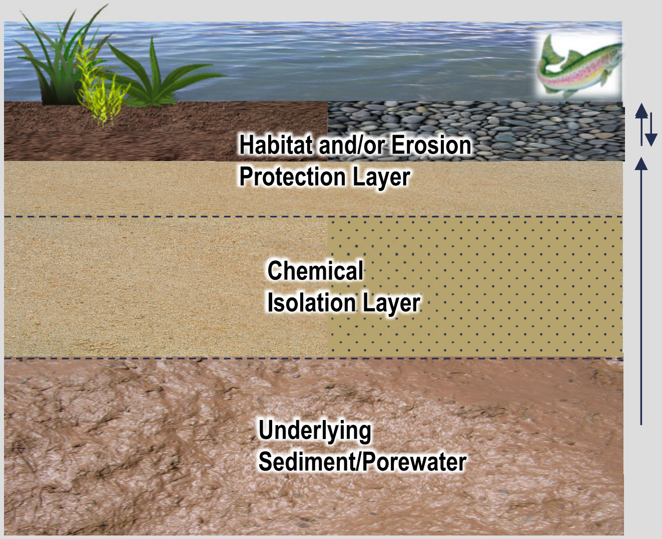
Cap Design Criteria

- Project goals and clean-up criteria
  - Chemical specific goal for sediment and/or porewater
  - Surface-weighted average concentrations
  - Surface water criteria
- Expectations for compliance points and/or design life
  - Bottom of habitat layer
  - Average throughout habitat layer/biologically active zone
  - Expectations on cap performance period
- Habitat and/or water depth requirements
  - Minimize water depth losses
  - Thicker layers required for habitat
  - Reduce potential for erosion



Cap Design Strategy

- **Identify and Quantify Site Specific Cap Design Drivers**
  - **Primary contaminants and relative mobility**
    - **Porewater concentrations**
    - **Groundwater conditions**
  - Presence of NAPL
  - Potential for ebullition
  - Stability
  - Settlement
  - Site access, thickness restrictions, constructability or other site specific challenges



Cap Fate and Transport Processes
Bioturbation
Bioirrigation
Tidal Pumping
Adsorption
Advection
Diffusion
Dispersion
Biological Decay
Settlement Induced PW Expression

Lessons Learned:
- ✓Consider design strategy for the site and develop field investigation to quantify design drivers
- ✓Consider tiered approach to field investigation depending on existing data, conceptual site model, budget constraints and project schedule
- ✓Remediation drivers may not be the same as cap design drivers
- ✓Consider screening level modeling
- ✓Do not wait on more advanced testing such as bench or column testing

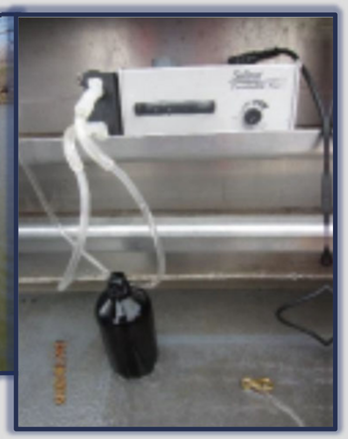
Data Collection for Cap Design - Porewater

- Characterize porewater concentrations immediately below cap
- Verify that detection limits are below performance criteria
  - Low level methods may be required for PCBs, metals, etc.
- Carefully consider volume limitations when choosing collection method
- Take care to maintain sample integrity
  - Be cognizant of surface water impacts and potential for draw down
  - Special handling and procedures may be required to maintain in situ conditions
- Information on TOC (sediment), DOC, pH, redox and other non-contaminant related parameters may be useful
- Photographic documentation of sampling

Sediment core collected for centrifugation

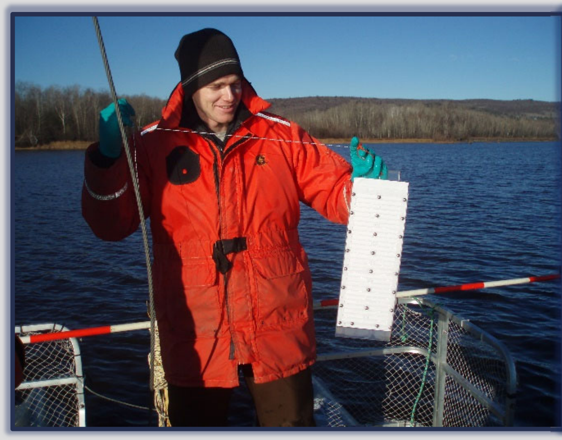
Data Collection for Cap Design - Porewater

- Peepers
- Suction devices
- Trident probes
- Centrifugation



Push-point samplers and on boat collection

Sediment core collected for centrifugation



Porewater sampling via peeper

Data Collection for Cap Design - Groundwater

- Characterize upland groundwater conditions
- Develop conceptual model of groundwater conditions across the site
  - Screening level evaluations and modeling
- Quantify upwelling velocities
  - Critical component of cap design
  - Can be challenging as velocities generally occur at a low rate and may be both seasonally and spatially variable
  - Decisions may be required based on cm/day, cm/month or cm/year
- Involve hydrogeologist and groundwater modeler during data collection planning and cap design
- Consider multiple lines of evidence to provide an appropriate level of confidence in estimates of upwelling velocities throughout the cap footprint.

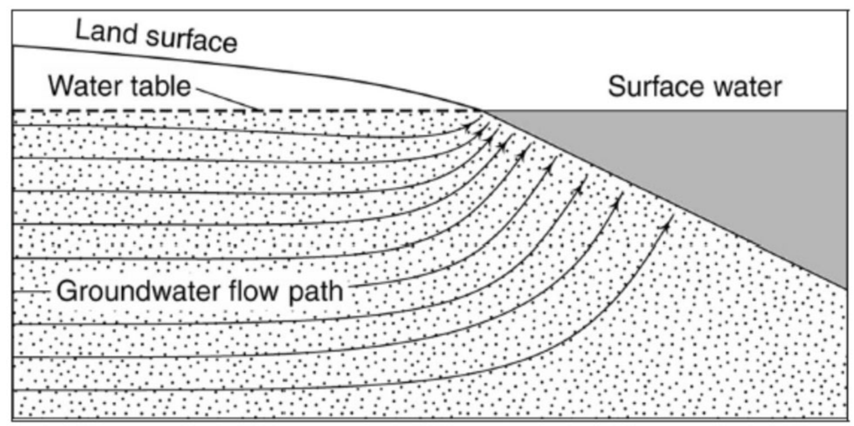


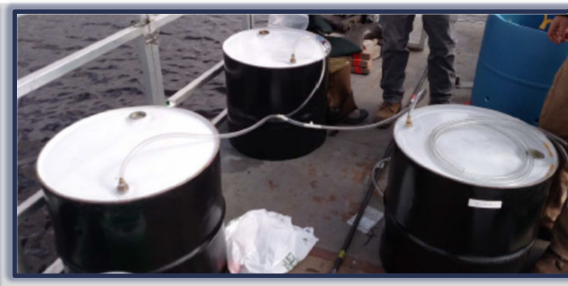
Figure 1. Groundwater inflow to surface water showing decreasing volumes of seepage with distance from shore. Modified from Pfannkuch and Winter (1984)

Subaqueous Capping and Natural Recovery: Understanding the Hydrogeologic Setting at Contaminated Sediment Sites. ERDC. July 2002.

Data Collection for Cap Design - Groundwater

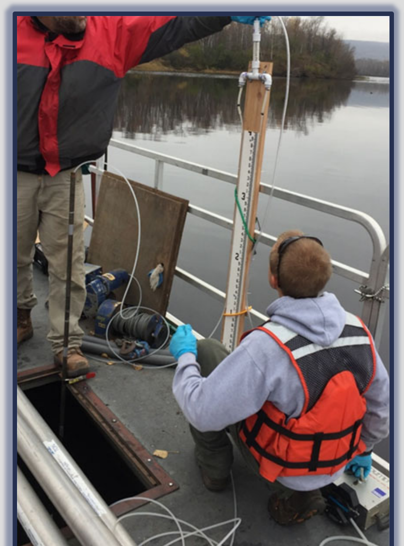
- Field Techniques
  - Screening tools
    - Piezometers
    - Manometers
  - Seepage Meters
  - Ultra Seep Meter
- Modeling

Screening Transects

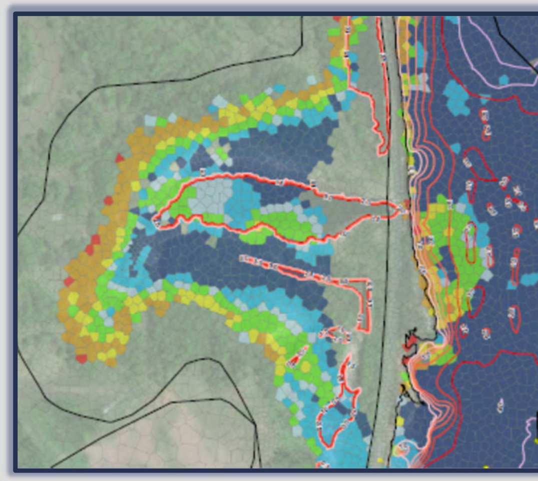


Seepage meters

Ultra Seep Meter



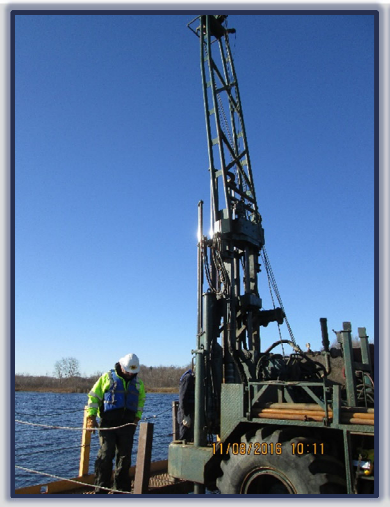
Manometer Screening



Groundwater Model Output - Darcy Velocity

Data Collection for Cap Design - Sediment

- Chemical
  - Sediment Concentrations
  - TOC
- Physical and Geotechnical
  - Grain size
  - % solids
  - Specific gravity
  - Atterberg limits
  - Consolidation
  - Shear strength - field vane shear test, laboratory triaxial compression test
- Other
  - Presence of NAPL
  - Evidence of Ebullition
  - Bioturbation extent
  - Deposition rates

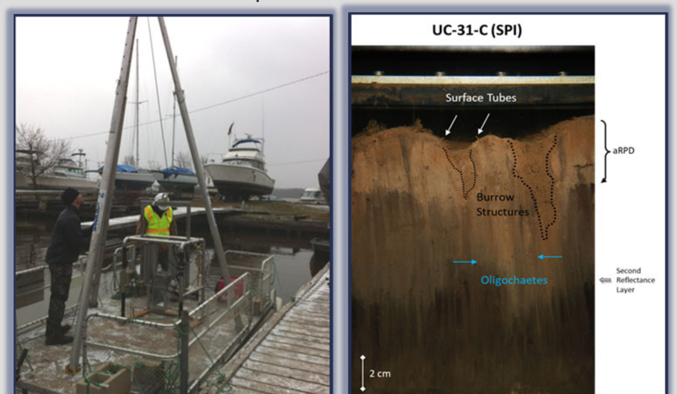


Sediment Core via Drill Rig

Modified Van Veen Surface Sample

Lessons Learned:
- ✓Site-specific measurements of surficial sediment conditions may provide insight on post-cap conditions
- ✓Geotechnical data collection required for all areas where cap stability and sediment may vary based on conceptual model

Vibracore Sampler



SPI Device and Image

Laboratory Testing for Cap Design

- Fate and Transport Evaluations
  - Column studies
- Amendment Evaluation
  - Batch and Column Studies
  - Carbon Isotherms
  - Partitioning Studies
- NAPL Mobility
- Biological Decay
- Ebullition

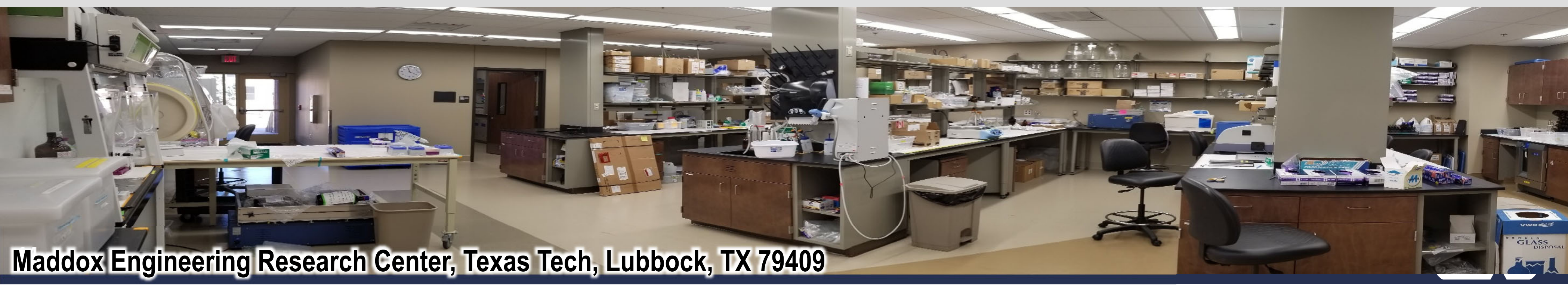
Lessons Learned:

✓Useful for unique site conditions

✓Requires upfront planning and coordination, may require method development

✓Consider schedule implications and test durations

✓Exceptional institutions capable of executing this work, wide-body of literature documenting state-of-the science



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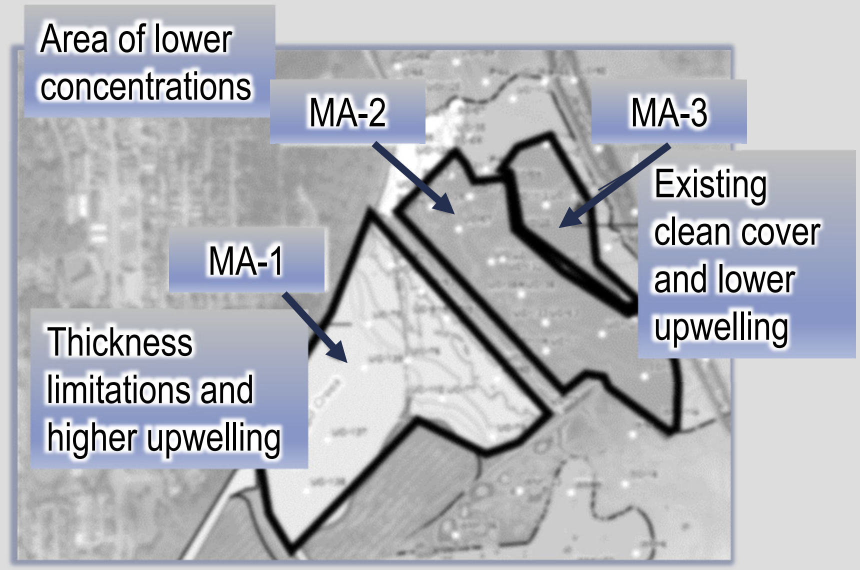
Chemical Isolation Layer Modeling

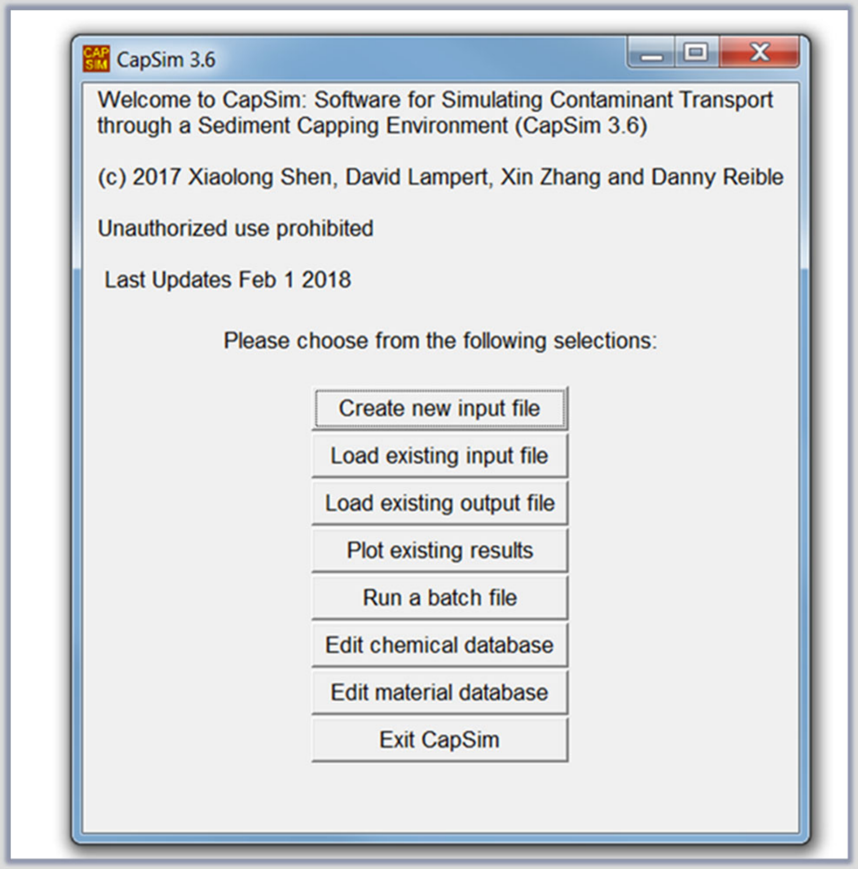
- Goal
  - Cap thickness
  - Cap material
  - Cap performance over lifetime
- Approach
  - Develop table of model input parameters
    - Establish values and potential range of values
    - Identify source – empirical or literature based
    - Summarize basis for modeled condition
  - Establish modeling framework based on site conditions
- Evaluate results with respect to design criteria and performance goals
- Challenge in developing appropriate design input over life of cap



Model Area Development

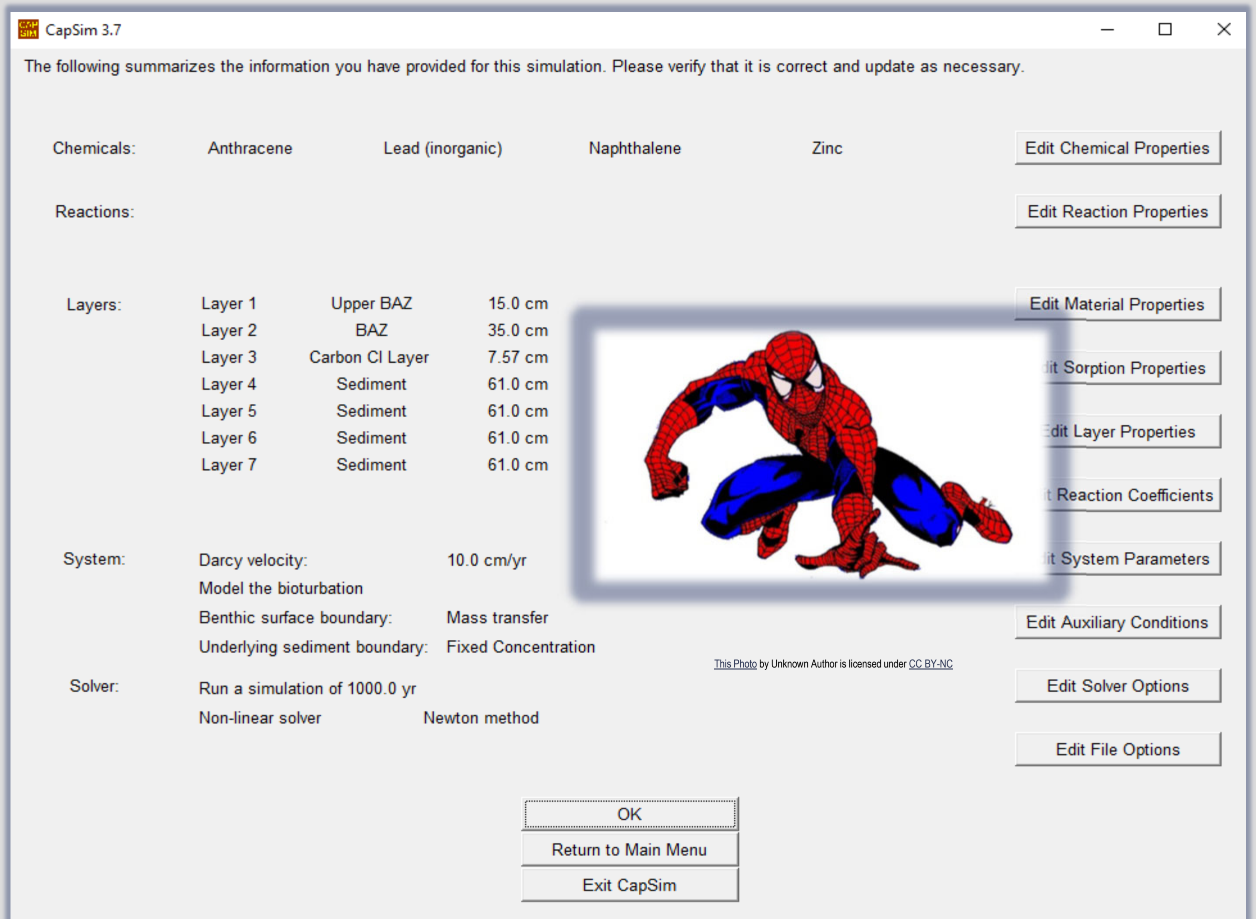
Chemical Isolation Layer Modeling

- CapSim
  - Simulates contaminant transport in sediments and sediment caps
  - Basis dates back to the early 90's
  - Current version is an extremely robust tool
    - User friendly interface
    - Database of chemical and material properties
    - Quick start instruction manual
    - Includes extensive options for fate and transport processes
    - Useful graphic capabilities
    - Detailed results output



CapSim Model Start-up Screen

Chemical Isolation Layer Modeling

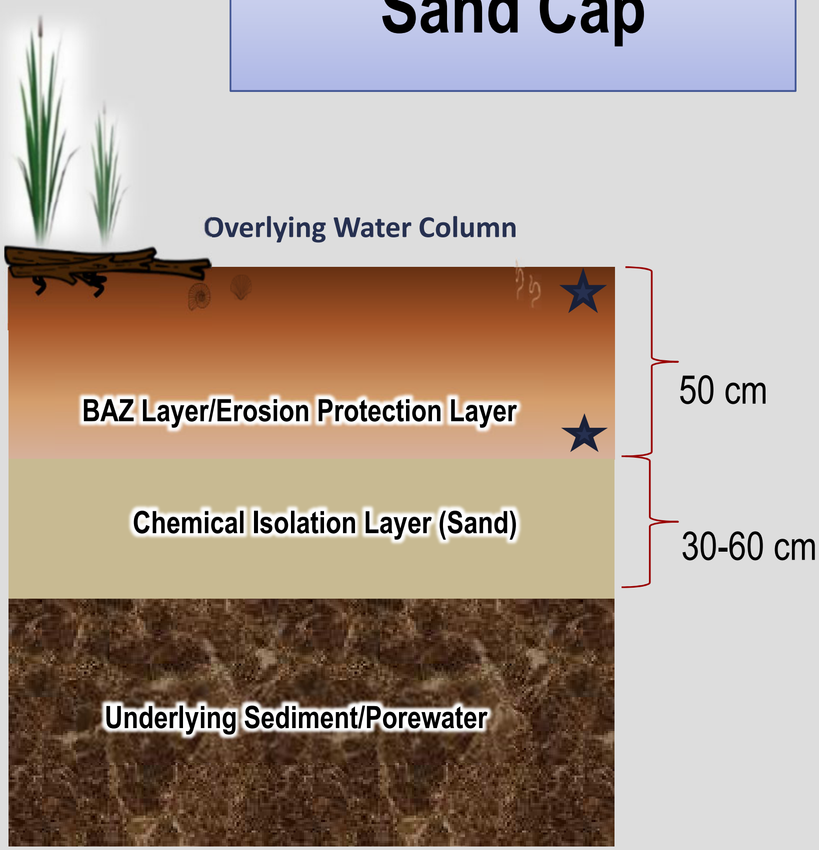


CapSim Model Summary Screen

Lessons Learned:

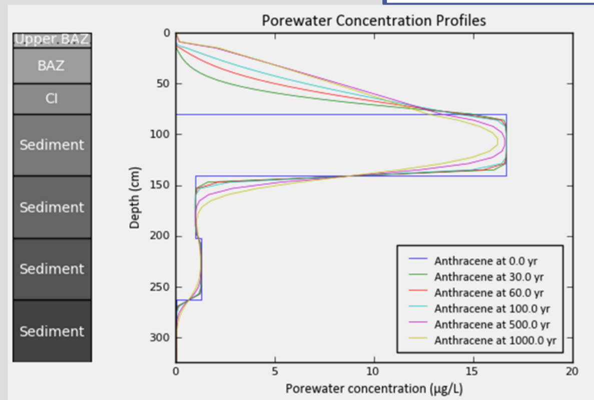
- ✓Invest time upfront in developing model input parameters and range of conditions, compliance points and durations of interest
- ✓Use site-specific data where possible especially for parameters that drive design
- ✓Model output requires post-processing and presentation framework for results communication and evaluation against design performance criteria
- ✓It is critical to review output profiles and conduct some form of sensitivity evaluation to validate results
- ✓Consider long-term monitoring requirements and ability to verify cap performance, this may influence modeling results interpretation and presentation

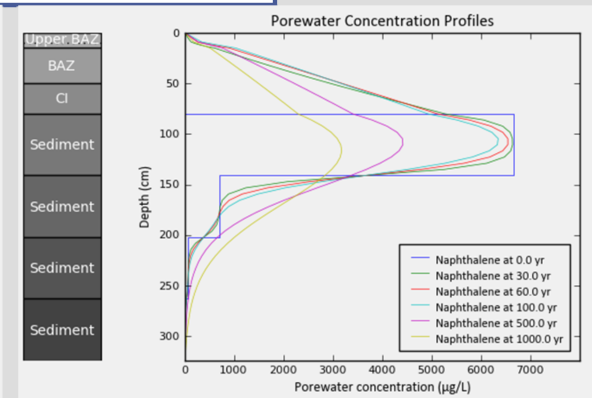
Model Area with Sand Cap



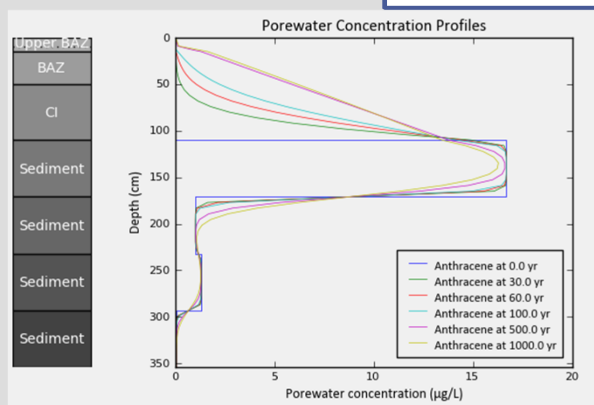
★Cap compliance point

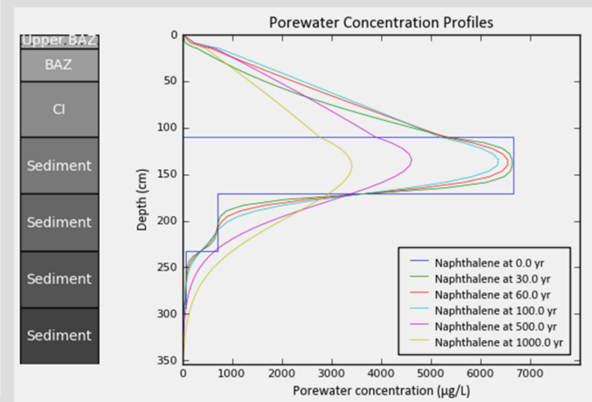
0.1cm/yr Darcy Velocity, 30 cm



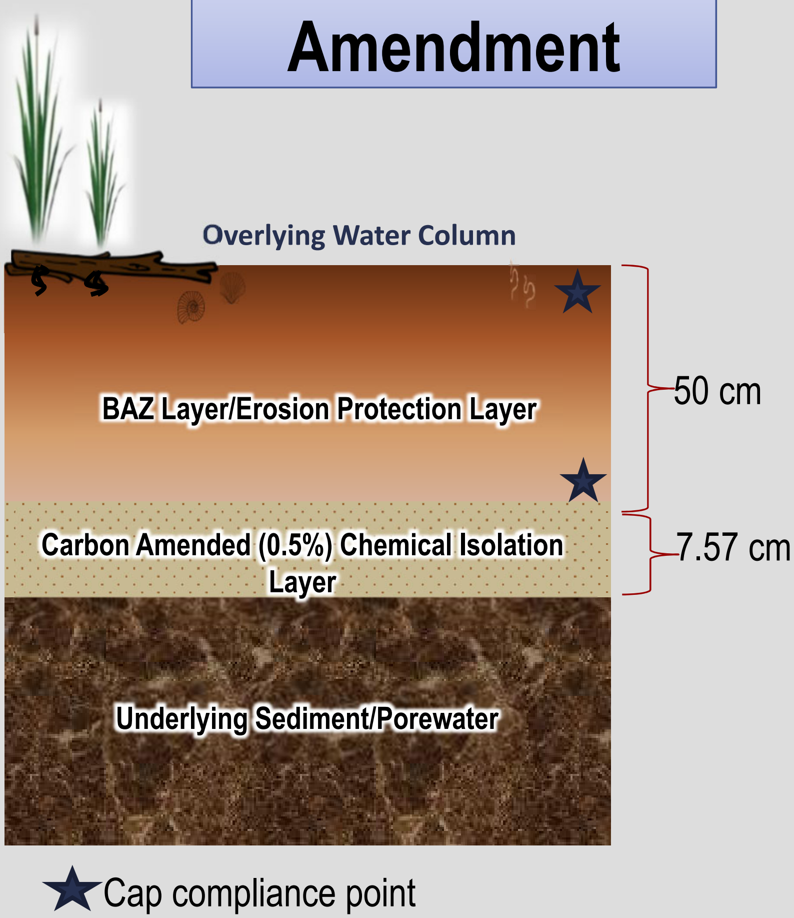


0.1cm/yr Darcy Velocity, 60cm

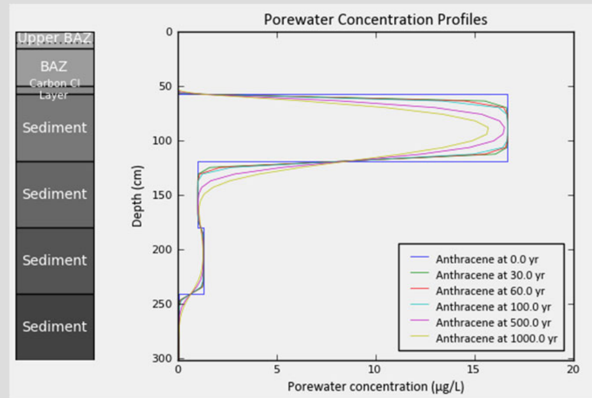


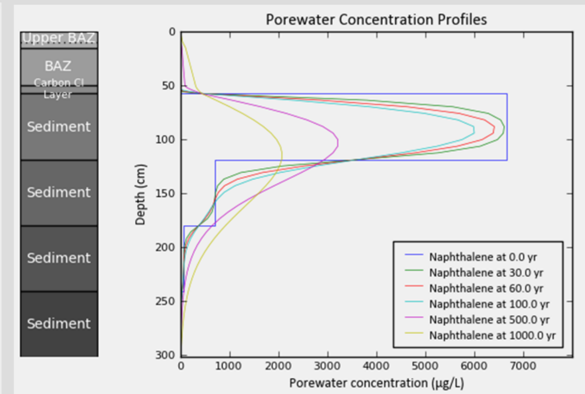


Model Area with Carbon Amendment

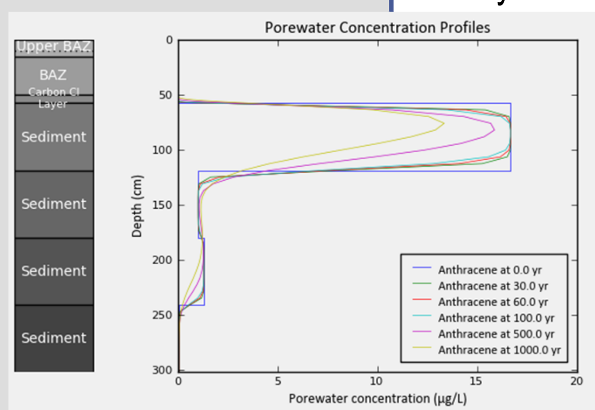


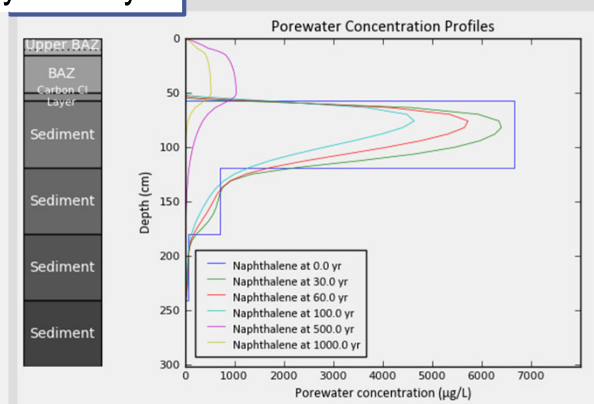
0.1cm/yr Darcy Velocity





10cm/yr Darcy Velocity





What have we learned?

- Site Characterization for Cap Design
  - Porewater characterization and quantification of groundwater rates are essential
  - Field investigation should attempt to characterize site characteristics that drive the design to the extent practical, upfront investment in data collection will help to streamline modeling and design
  - Unique site conditions and/or amendment applications may require phased field investigation, lab bench scale and/or pilot testing
- Cap Modeling
  - Advances in modeling tools streamline the modeling process; however, it remains essential to understand the fate and transport processes and contaminant profiles in the cap layers
  - A well thought out modeling strategy and model input table help communicate basis for design
  - Dividing the site into areas with specific characteristics helps to focus modeling evaluations
  - Allow time for post processing and consideration of effective results presentation
- Cap Design
  - Key guidance documents and experience documented at numerous sites provide useful references for design evaluations
  - Multiple line of evidence approach may be required to design for long-term
  - Consider how long-term monitoring requirements will be used to verify design criteria have been accomplished
  - Critical to continue to document, present and share lessons learned on capping projects (especially amended caps) to continue advancing the science, design and long-term performance assessment

Thank You!

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