AquaBlok® & Aquagate+

Technology & Application of Amendments and Low-Permeability Materials in Remediation & Geotechnical Applications

U.S. EPA – Region 10
April 2015

AquaBlok®
Composite Particle System

Presentation Outline

I. Background and Materials Technology Overview

II. Amendments – Regulatory Acceptance

III. East Branch Grand Calumet River – Project

IV. Activated Carbon – Updates

V. Case Studies

VI. Summary/Q & A

AquaBlok Ltd. Technology Platform

Delivery of High-Value Materials in Low Quantities

- Uniform Distribution
- Bulking Material Included / No Mixing or Separation
- Flexible/Rapid Installation (Low Cost)
- Custom Blends for Targeted Designs (Treatment)
- Can Vary/Control Permeability
- Placement through Deep Water
- Marine & Freshwater Blends

powder coating

+

aggregate core

=

AquaGate+ “composite particle”

Sequestration and/or Treatment

AquaBlok®

- Low Permeability Chemical Isolation Material
- Variable Particle Size & Densities
- High Shear Strength (Erosion Resistance)
- Proven Long-term Performance (Superfund Sites)

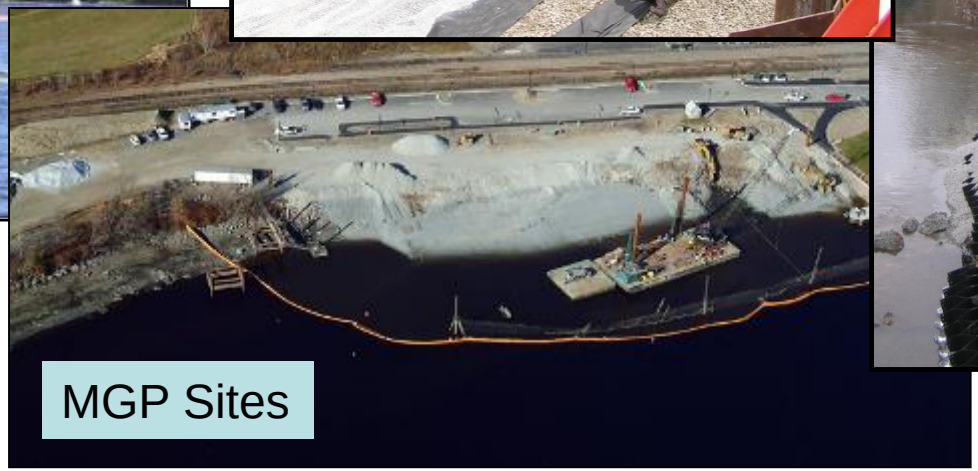
Aquagate+ PAC/Organoclay/Sorbster/Other

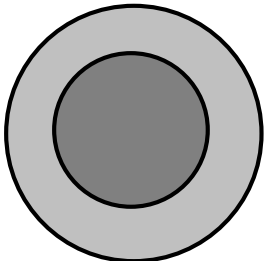
- Permeable (Variable)
- Powdered Treatment Amendments
  - Generally Increased Sorption Rate/Reduced Resident Time
  - Higher Surface area
  - Uniform Distribution at Low Levels
  - Targeted Placement within a Composite Cap

AquaBlok®
Composite Particle System

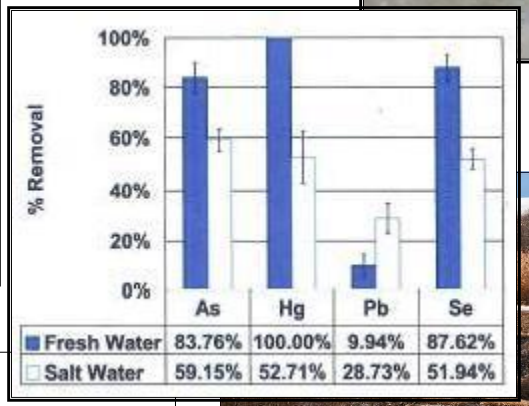
Low-Permeability for Sub-Aqueous Capping & Lining

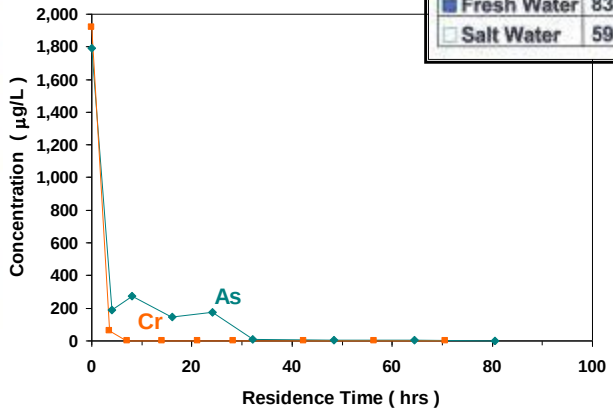
Applied *through*
standing water
or in the dry

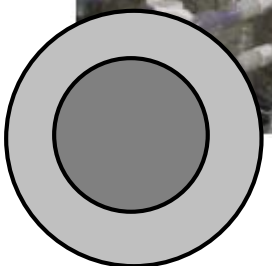




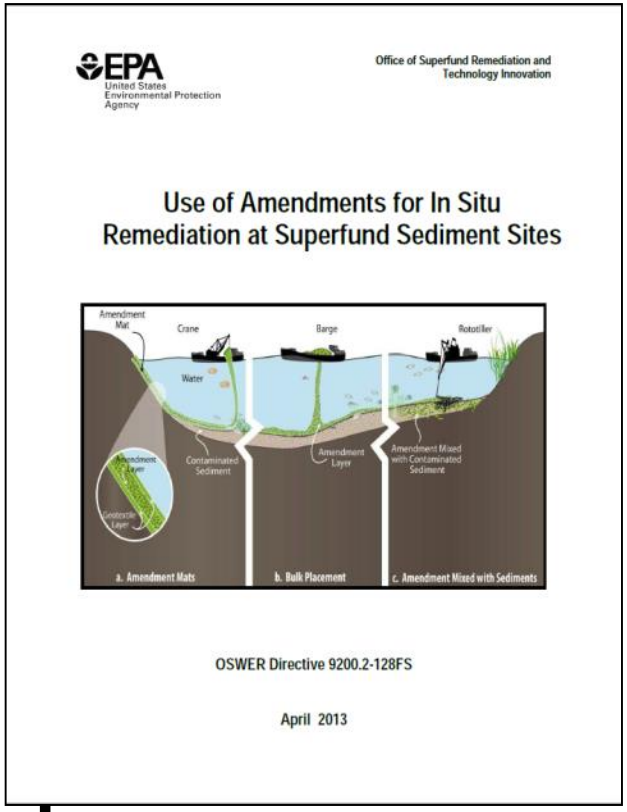
Permeable Materials for In-Situ Treatment & Remediation Applications

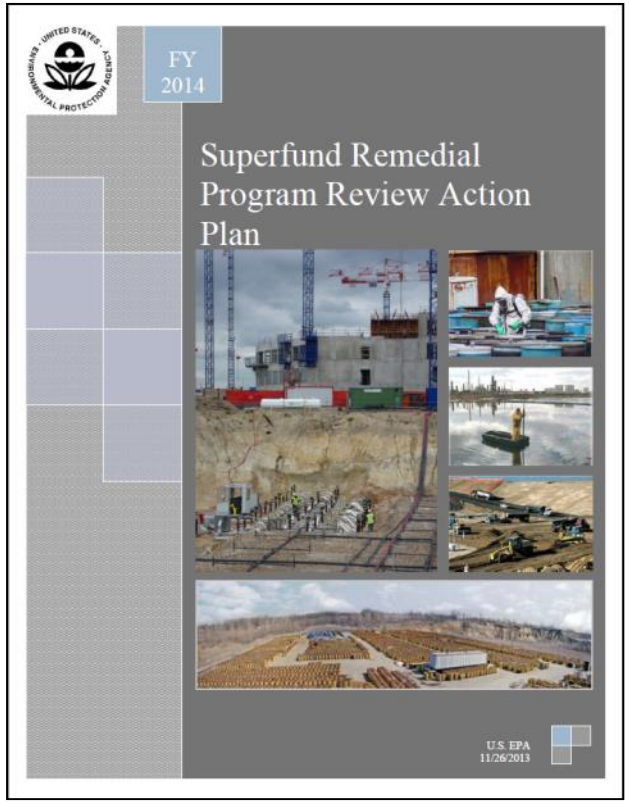






Amendments & Acceptance





"The appropriate use of amendments has much potential to limit exposure to contaminants and, thus, to reduce risks."

- Less obtrusive than dredging
- Focused on reducing bioavailability
- Shorten recovery time
- Less costly and more expedient

Grand Calumet River Legacy Act Cleanup

Grand Calumet River Area of Concern

Inland Steel Manufacturing Complex, circa 1909 – Looking to Lake Michigan

Grand Calumet River Legacy Act Cleanup

Grand Calumet River Area of Concern

East Branch (Zone B) of the Grand Calumet River:

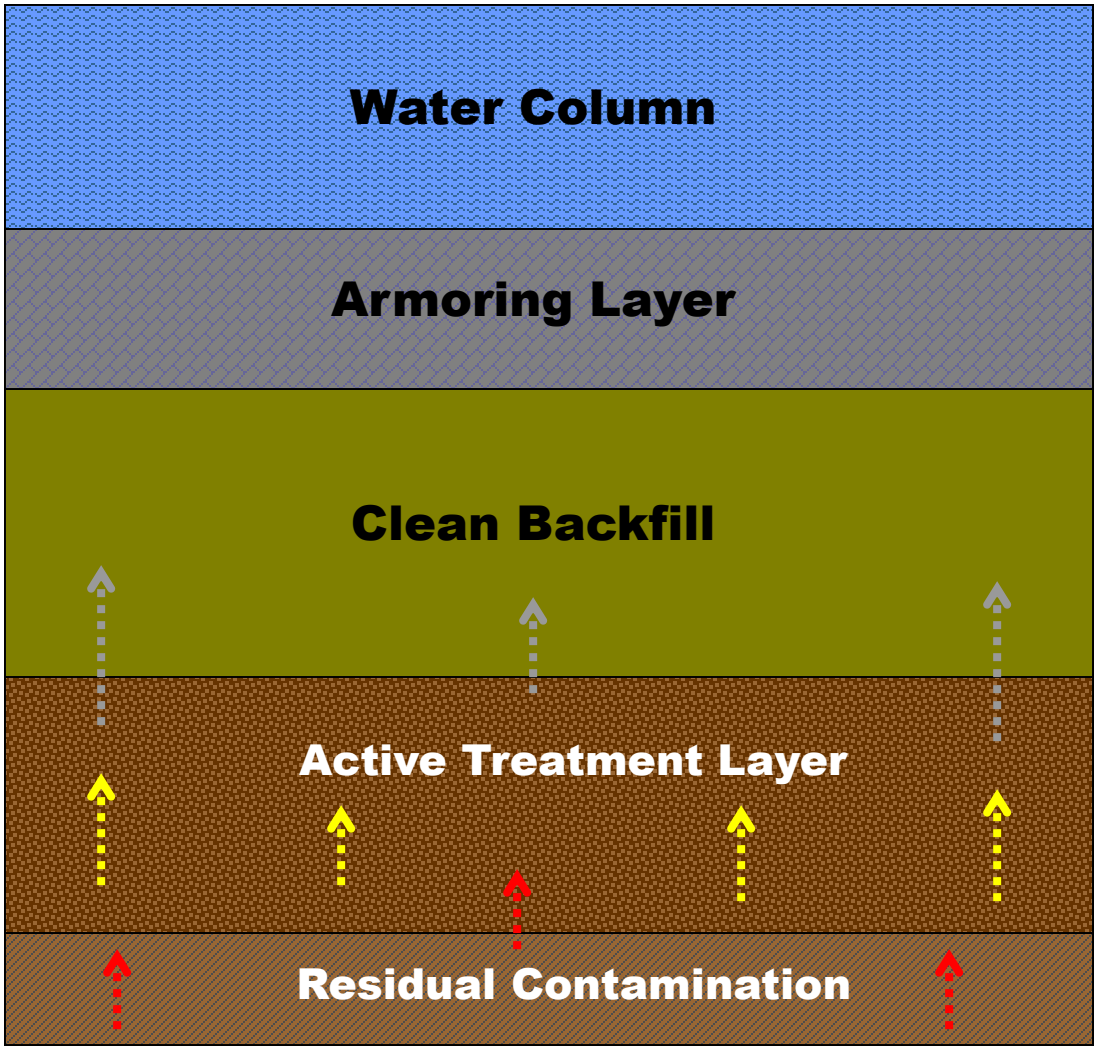
- **1.8-mile stretch of the river from Indianapolis Boulevard to Holhman Avenue**
- **350,000 cubic yards of sediment are slated to be removed**
- **A cap will be placed over the dredged sediment.**
- **Near shore habitats will be restored with native plants**
- **Completion expected in 2015.**

AquaBlok®
800-688-2649

www.aquablokinfo.com

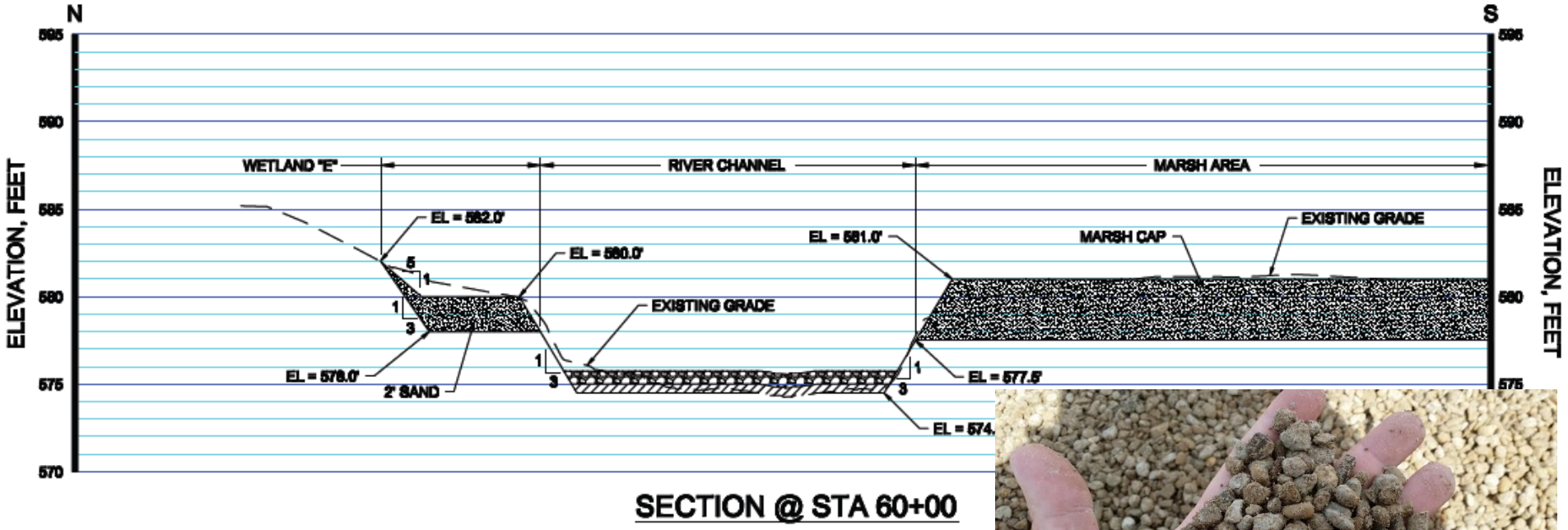
Critical Aspects of Reactive Cap Design: Treatment Through A Permeable Treatment Layer

- *Uniform Distribution* of Treatment Material within Layer is Most Critical.
- Increased Thickness is often Required to Provides More *Residence Time* for Adsorption AND *Capacity*
- Larger Quantity of Treatment Material is Often Required to Protect Against Breakthrough from Higher Concentration Areas or an *Isolated Seep Zone*
- Must consider potential for long-term *Reduction in Permeability*
- Use of Powder Materials *Improves Rate of Sorption* over Granular Material



not to scale

Reactive Cap Design

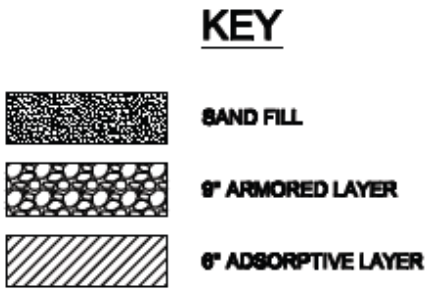


SECTION @ STA 60+00

Two Cap Designs:

1. **6-inch mixture of sand / AquaGate+Organoclay at a ratio of 2/3 Sand 1/3 AquaGate – in thickness**

2. **6-inch AquaGate+Organoclay layer**



Overview of Capping Material

Aquagate+ ORGANOCLAY™

Aggregate: Nominal AASHTO #8 (1/4-3/8") or custom-sized to meet project-specific need * Limestone or non-calcareous substitute, as deemed project-appropriate

Binder: Cellulosic polymer

Permeability: 1 x 10^{-2} to 1 x 10^{-5} cm/sec

Dry Bulk Density: 65 – 85 lbs/ft^3

Moisture: 10 – 20% (maximum)

REMEDIATION TECHNOLOGIES
Technical Data

CETCO

ORGANOCLAY® P
ORGANIC ADSORPTION MEDIA (POWDER GRADE)

Product Description:

Organoclay® P is a proprietary powder adsorption media effective in removing oils, greases other non-aqueous phase liquids (NAPL) and other dissolved high molecular weight/low solubility organic contaminants.

Characteristics:

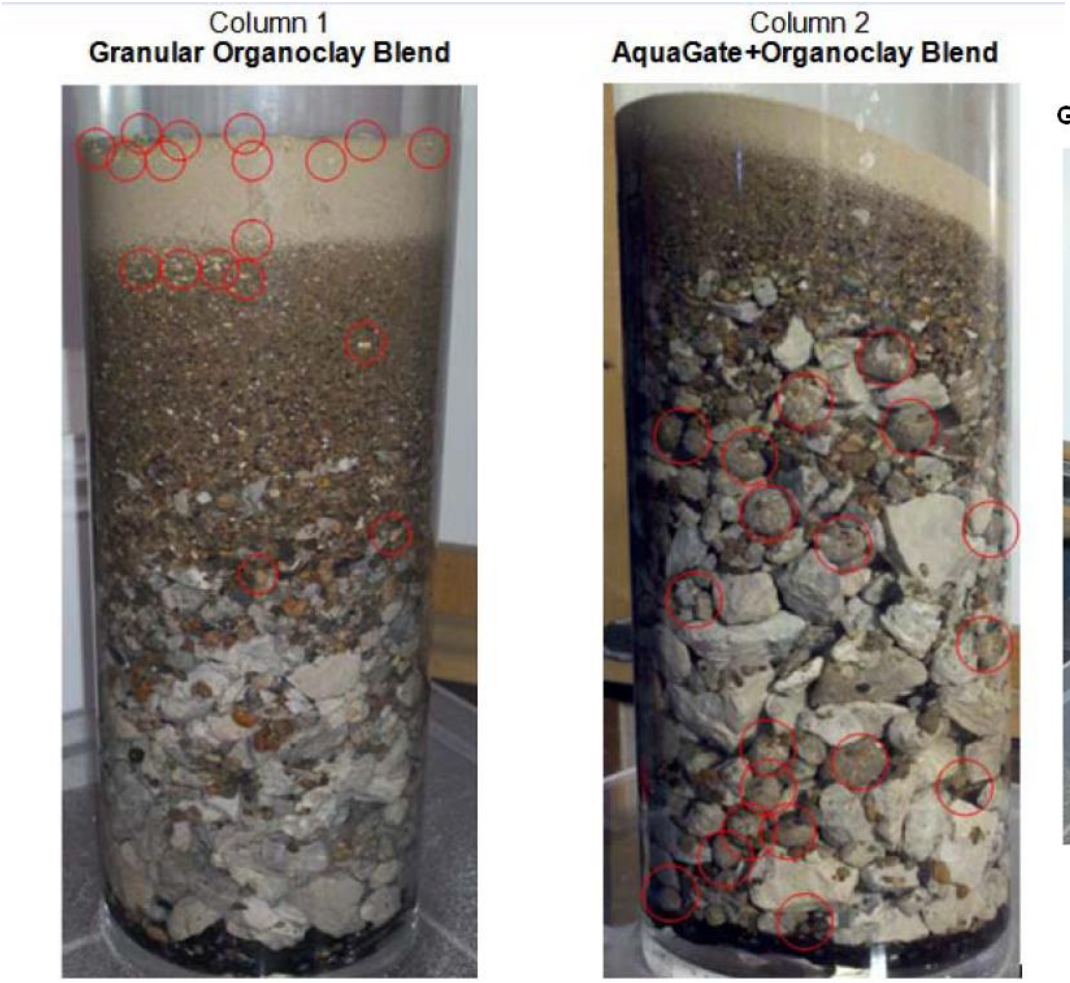
- Hydrophobic; will not absorb water or swell when wetted
- Non-toxic to marine and benthic organisms
- High adsorption capacity of oils, greases and other NAPL
- Demonstrates noncompetitive sorption—can sorb multiple contaminants

Properties:

Property	Value	Test Method
Particle Size	70% Min. passing 200 mesh sieve	CETCO Test Method
Bulk Density	50-54 lbs/ft^3	CETCO Test Method
Oil Adsorption Capacity	0.5 lb/lb Min.	CETCO Test Method
Quaternary Amine Content	25% Min.	CETCO Test Method

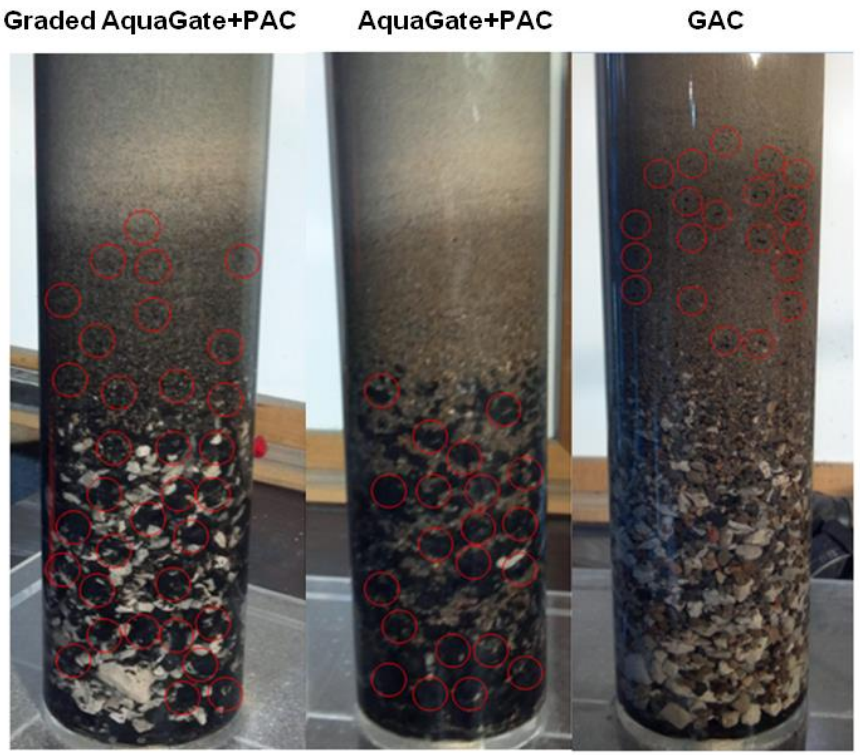
Uniform Distribution of a Small Quantity of Adsorptive Material Placed in a Single Lift

Column Test with Organoclay



Red Circles Indicate the Location of Organoclay within the Reactive Cap Layer

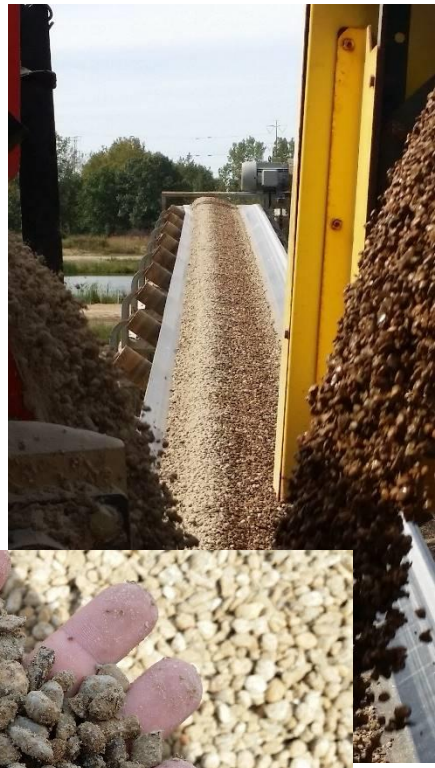
Column Test with Activated Carbon



Red circles indicate relative location of particles within the as-placed cap.
They do not denote the number of particles in a given location.

J.F. Brennan – Broadcast Capping System (BCS™)

- Able to accurately place over soft sediment with limited intermixing
- Limits resuspension of in-situ sediments
- Onboard tracking system records thickness, volume, and position of material placement
- Can accurately spread materials in very thin lifts, while achieving even distribution.



Production / Stockpile / Shipment

Manufacturing Facility: Swanton, Ohio

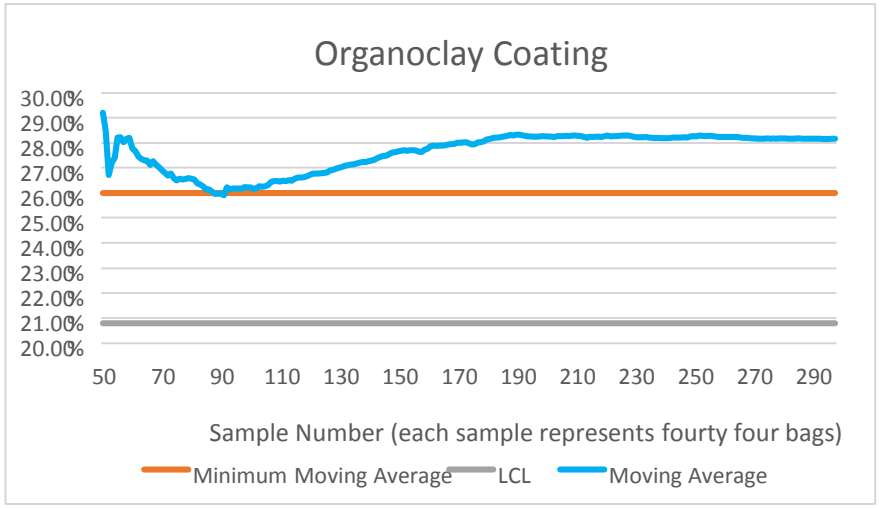
- Production initiated January 2014
- Due to On-Site issues – Temporary Delay in Manufacturing Occurred from End of April Until June
- Material Packaged in 2,500lb Bulk Bags
- Shipments Completed in November 2014
- Production = + ***16,600 tons***

Shipment / On-Site Stockpile

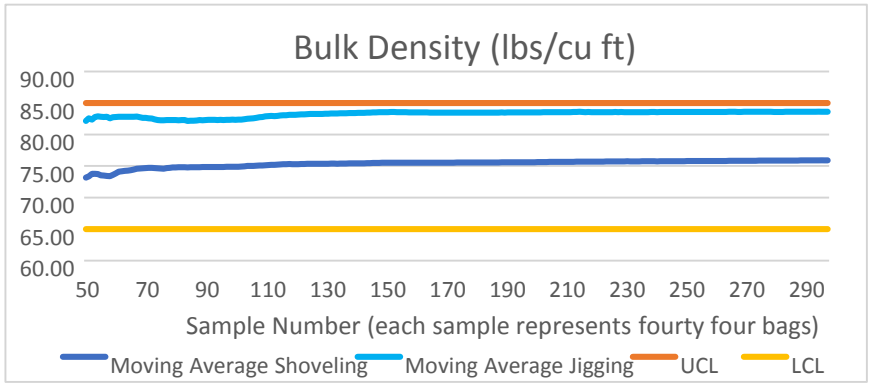
This Project is Believed to be the Largest Installation of an Organoclay-Based Active Cap for Contaminated Sediment Remediation

- Deliveries in 2,500lb Bulk Bags
- Approximately 4-5 Trucks/Day – at 22 tons
- Stockpile protected During Storage
- Placement Began in August – Completed November

Manufacturing & On-Site QA/QC



Bulk Density



- As-Manufactured Bulk Density
- As-Manufactured Moisture Content
- As-Manufactured Coating Content

B-Cap				
Bucket Number	ID #	Fines %	Ave. Fines	lb/cu ft
1	092514465	12.79% 15.87% 14.48%	14.38%	14.04
2	092614474	6.37% 4.91% 4.79%	5.36%	5.23
3	092914549	6.38% 7.34% 12.75%	8.82%	8.61
4	092914557	8.66% 7.67% 10.34%	8.89%	8.68
Average Fines			9.36%	
Target lb/cu ft			7.0 - 7.2	
Actual lb/cu ft			9.14	

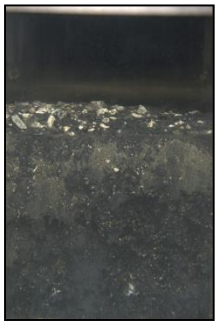
A-Cap				
Bucket Number	ID #	Fines %	Ave. Fines	lb/cu ft
5	100214689	39.63% 27.49% 26.12%	31.08%	25.64
6	100814783	25.78% 36.48% 31.18%	31.15%	25.70
7	110614534	28.10%		23.19
8	111114665	28.03%		23.13
9	111814798	26.78%		22.09
Average Fines			29.03%	
Target lb/cu ft			21.45	
Actual lb/cu ft			23.95	

- Core Samples and Buckets to Confirm Placement Thickness
- As-Placed Coating Content
- *Post-Placement Adsorption Testing Confirmed As-Placed Treatment Capacity*

Overview of Technology & Application of Activated Carbon (AC) Based Approaches for Remediation of Contaminated Sediments

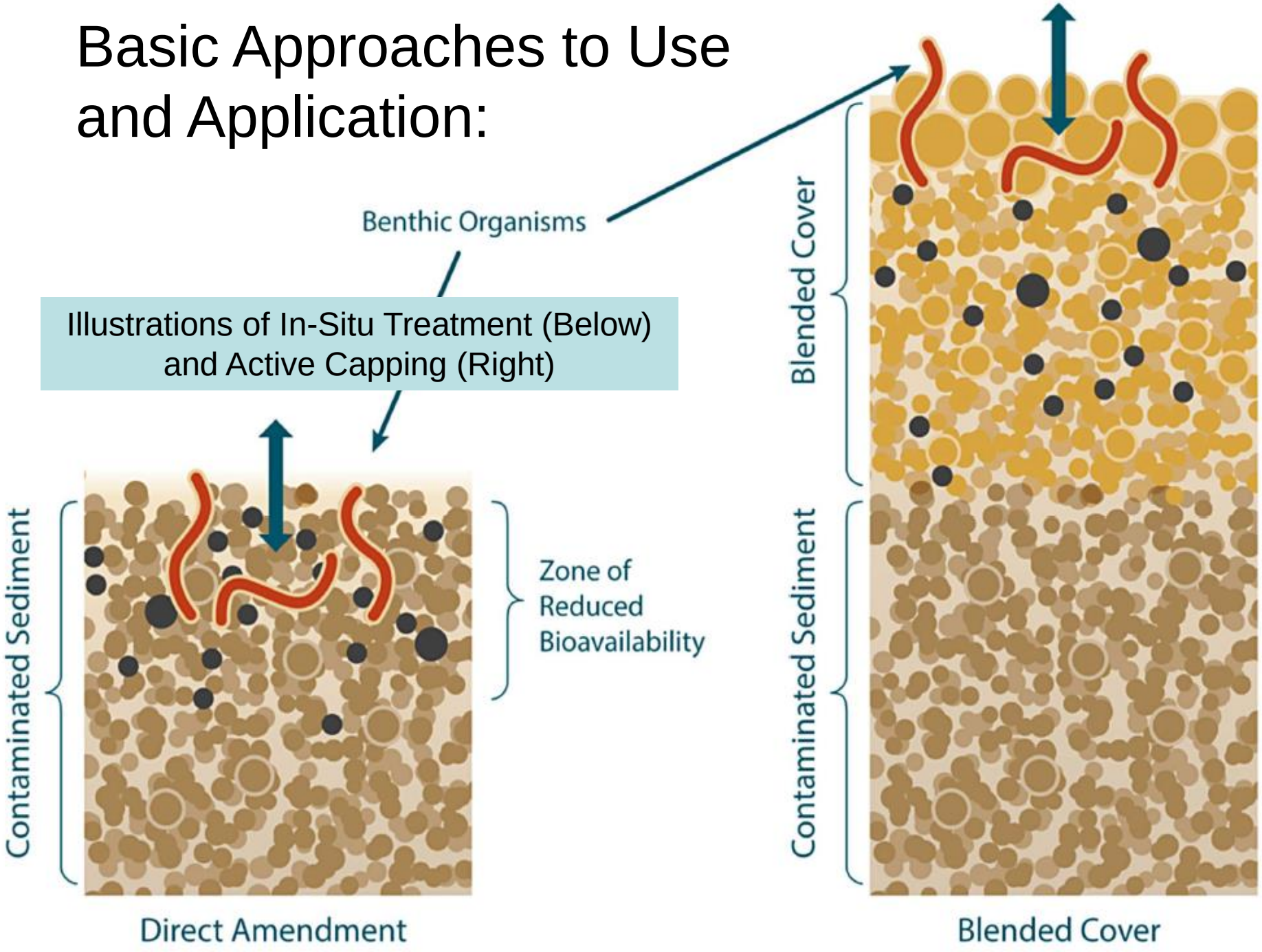
- Basic Approaches to Use & Application
- Forms & Physical Characteristics of Materials
- Performance Considerations – Powder vs. Granular
- Toxicity & Ecological Considerations
- Issues and Considerations for Placement
- AquaGate+PAC Case Study



Basic Approaches to Use and Application:

Illustrations of In-Situ Treatment (Below) and Active Capping (Right)



Primary Forms & Physical Characteristics of Activated Carbon

Granular

Typical Size:
20x80 mesh
(0.42-0.84mm)

Powder

Typical Size:
200-325 mesh
(0.074-0.044mm)

Activated Carbon – Bulk Density	20lb/cu.ft	0.32g/cm^3

AquaGate+PAC™

Typical Size:
3/8” Minus
(9.5 mm)

Sedimite™

Typical Size:
1/4” Minus Diam.
Length Varies
(6.7 mm diam.)

Bulk Densities -	75-80lb/cu.ft	45lb/cu.ft.

Performance Considerations: Powder vs. Granular Forms of Activated Carbon

Evaluation of Powdered vs Granular Forms of Amendments for In Situ Sequestration of Sediment Contamination

Matt Vanderkooy, Tom Krug – Geosyntec Consultants
John Hull, John Collins – AquaBlok, Ltd.
Jeff Roberts – SiREM Laboratories

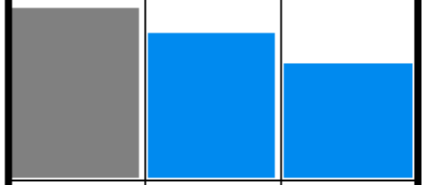
Activated Carbon Testing:
Granular vs. Powder Forms

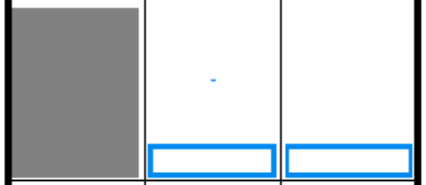
- TOC → 6,900 mg/kg → f_{oc} = 0.0069
- Total PCBs in Sediment → 12,000 µg/kg
  - Aroclor 1248 - 11,000 µg/kg
  - Aroclor 1260 - 1,700 µg/kg
- Total PCBs in Water
  - All Aroclor 1242

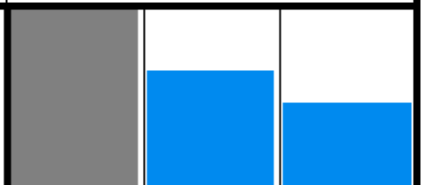
Note: 862 g dry sediment per 2-L jar

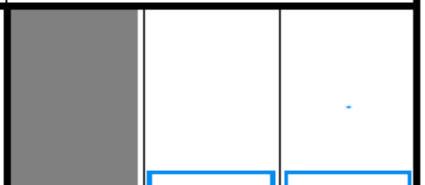
Mass GAC (g)	--	43.1	129.4
Dose GAC (%)	--	5%	15%
Treatment	Control	GAC	

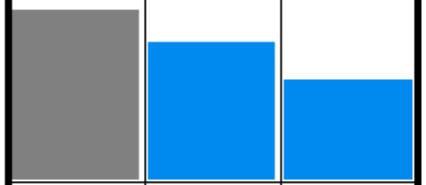
Mass PAC (g)	--	43.1	129.4
Dose PAC (%)	--	5%	15%
Treatment	Control	PAC	

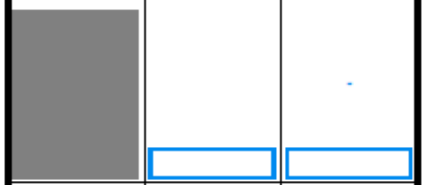
Time	Contact Time - 1 week		
Median PCB Concentration (µg/L)			
	0.27	0.23	0.18

Time	Contact Time - 1 week		
Median PCB Concentration (µg/L)			
	0.27	<0.05	<0.05

Time	Contact Time - 3 weeks		
Median PCB Concentration (µg/L)			
	0.31	0.21	0.16

Time	Contact Time - 3 weeks		
Median PCB Concentration (µg/L)			
	0.31	<0.05	<0.05

Time	Contact Time - 10 weeks		
Median PCB Concentration (µg/L)			
	0.27	0.22	0.16

Time	Contact Time - 10 weeks		
Median PCB Concentration (µg/L)			
	0.27	<0.05	<0.05

Mass GAC (g)	--	43.1	129.4
Dose GAC (%)	--	5%	15%
Treatment	Control	GAC	

Time	Contact Time - 1 week

Mass PAC (g)	--	43.1	129.4
Dose PAC (%)	--	5%	15%
Treatment	Control	PAC	

Time	Contact Time - 1 week

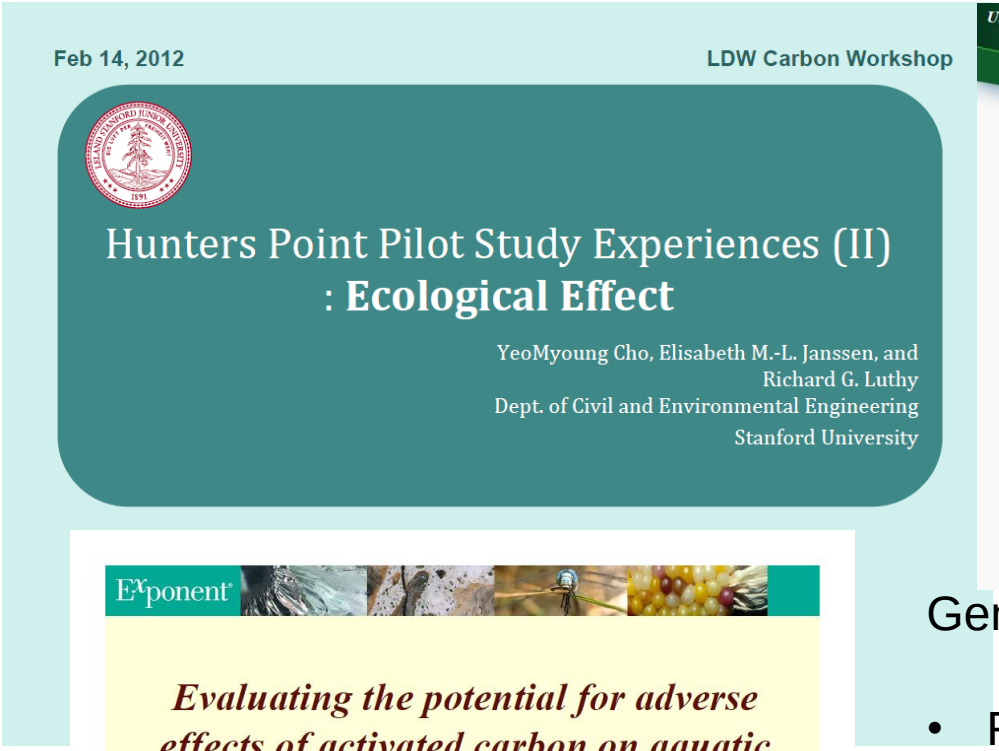
Activated Carbon & PCBs

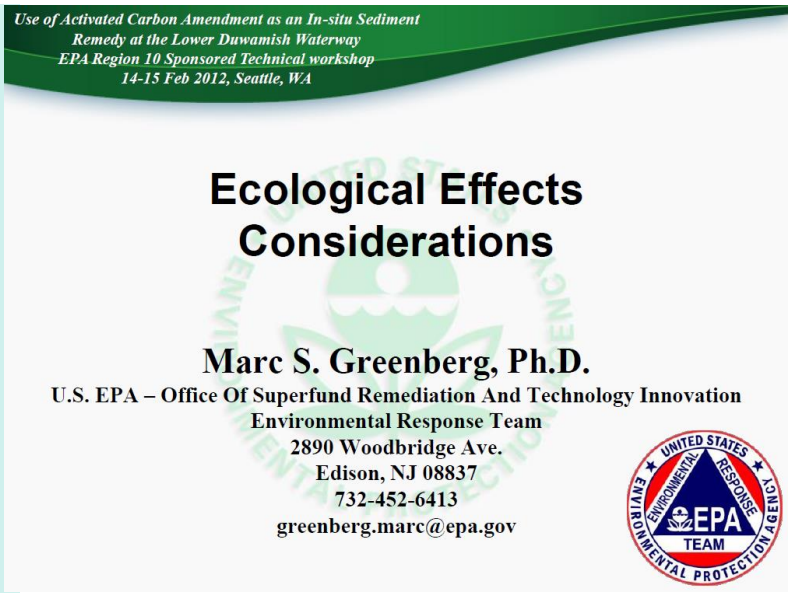
- PAC faster sorption rate than GAC
- PAC reduced concentrations to detection limits
- GAC, no additional removal over 10 weeks
- On scale of years relative performance not measured

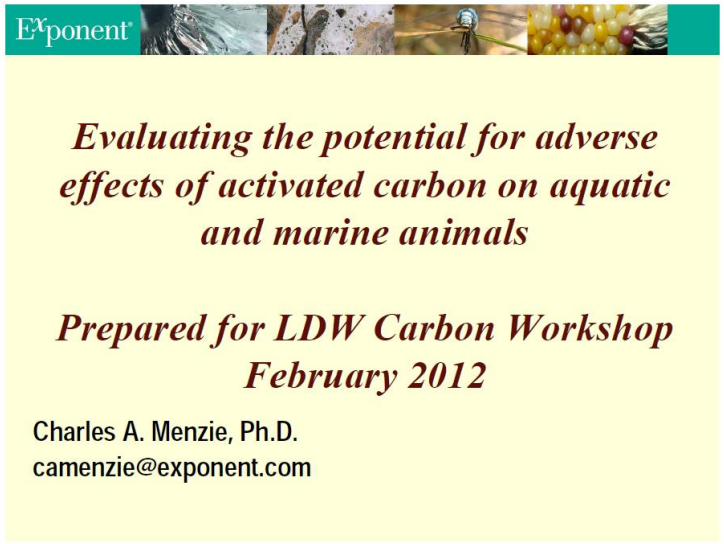
Median PCB Concentration (µg/L)			
	0.27	0.22	0.16

Median PCB Concentration (µg/L)			
	0.27	<0.05	<0.05

Toxicity & Ecological Effects of Activated Carbon in Sediments







General Conclusions:

- Following carbon addition, benthic community returned quickly and was similar to baseline structure and function
- It has been demonstrated that less than a 5% dose of carbon in the BAZ will have little or minimal adverse impact.

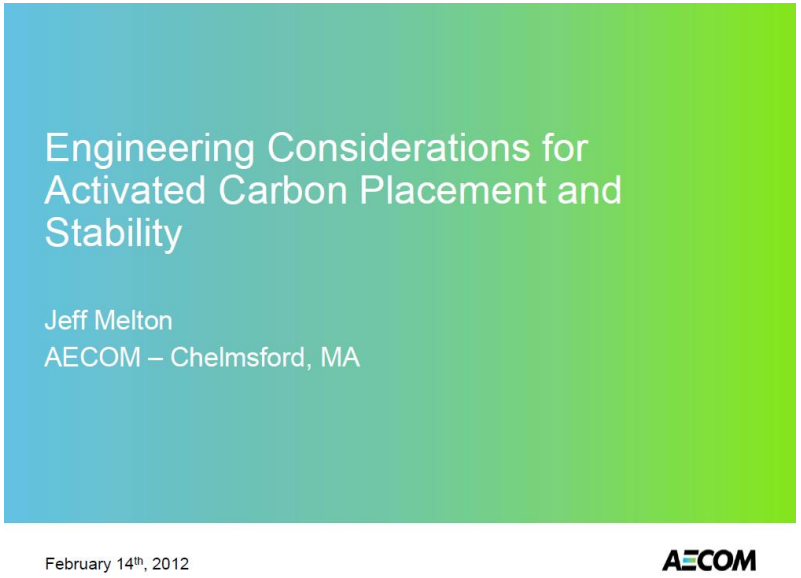
Issues & Considerations for Placement / Installation

Key Issues:

- Bubbles in the pores of granular material increase buoyancy, decrease settling rate in the water column: *Granular AC particles are likely to drift with the current, missing delivery area.*

- Mixtures of GAC with other materials are likely to segregate, *causing GAC to settle on top of other materials*. Can be overcome by placing many thin lifts and over-placement of GAC.

- If successfully placed, AC still *susceptible to currents, propwash and wave action which would result in*
- *re-suspension and subsequent drift/loss of treatment material*.

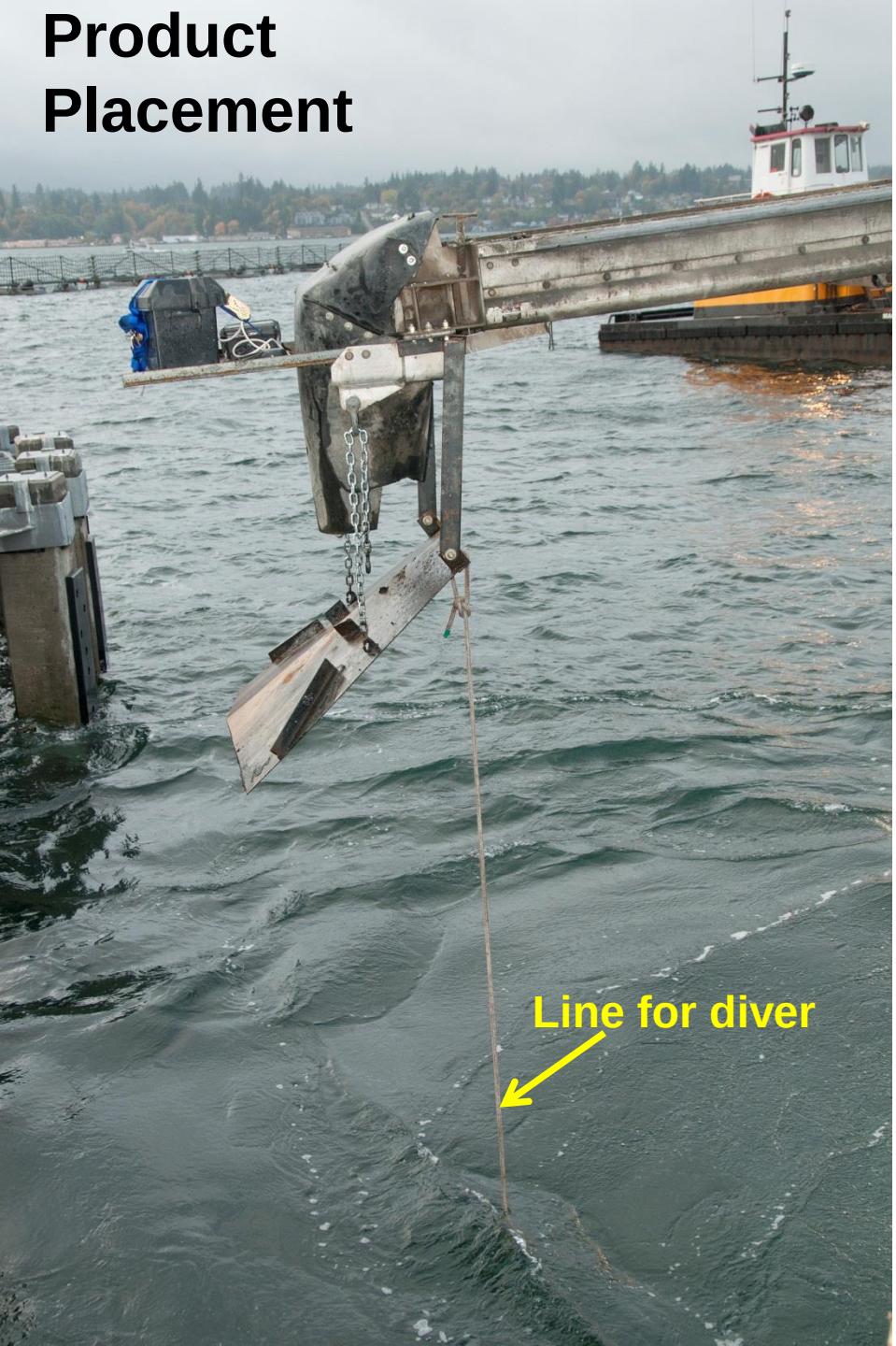


Different treatment areas due to different factors:

- Natural (floods, currents, waves, plants and animals)
- Vessel Traffic (large ships, tugs, pleasure craft)
- Structural (pipe lines, electric lines, piers, foundations)
- Human Use (fishing, clamming, bird watching, recreation)

Installing an Activated Carbon Sediment Amendment at the Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Bremerton, WA

Product Placement



Results

Battelle Eighth International Conference on Remediation and Management of Contaminated Sediments

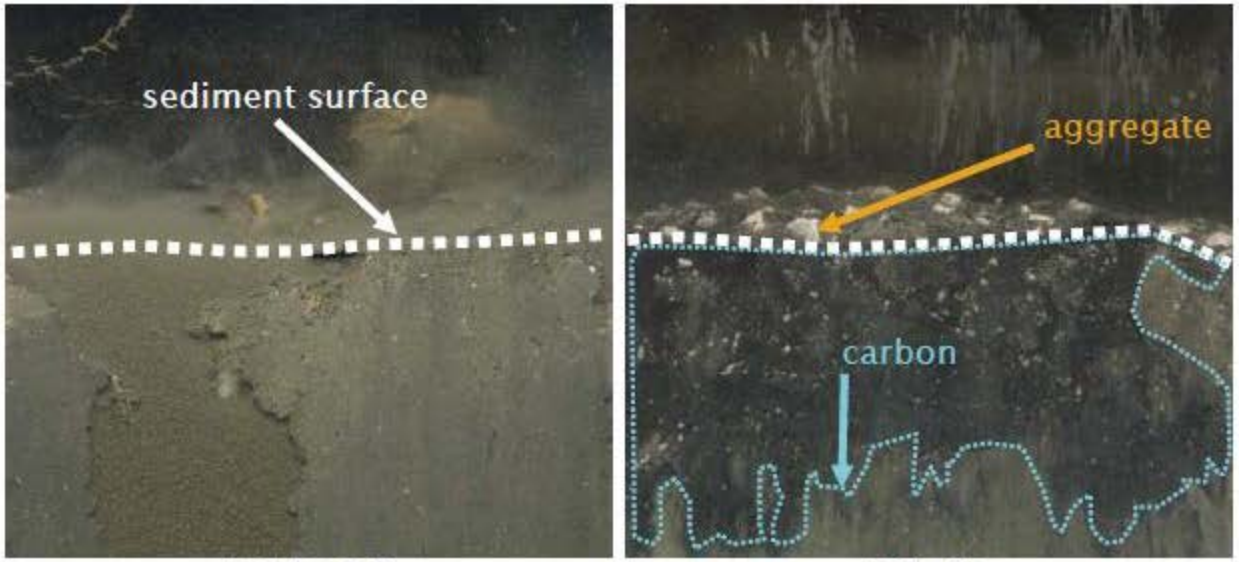
Jason Conder[1]
Melissa Grover[2]
Gunther Rosen[3]
Victoria Kirtay[3]
D. Bart Chadwick[3]
Victor Magar[4]

[1] ENVIRON International Corporation, Irvine, CA*
[2] ENVIRON International Corporation, San Diego, CA
[3] SPAWAR Systems Center Pacific, San Diego, CA
[4] ENVIRON International Corporation, Chicago, IL
* Current affiliation: Geosyntec Consultants, Huntington Beach, CA

NAVFAC
SPAWAR
Systems Center PACIFIC
ESTCP
ENVIRON

AquaGate + PAC™ Amendment

- Targeted 5-cm (2-inch) amendment layer
- Increase in Total Organic Carbon observed in top 10 to 15 cm (measured via analysis of core samples)
  - Baseline = 4%, After amendment = 8%

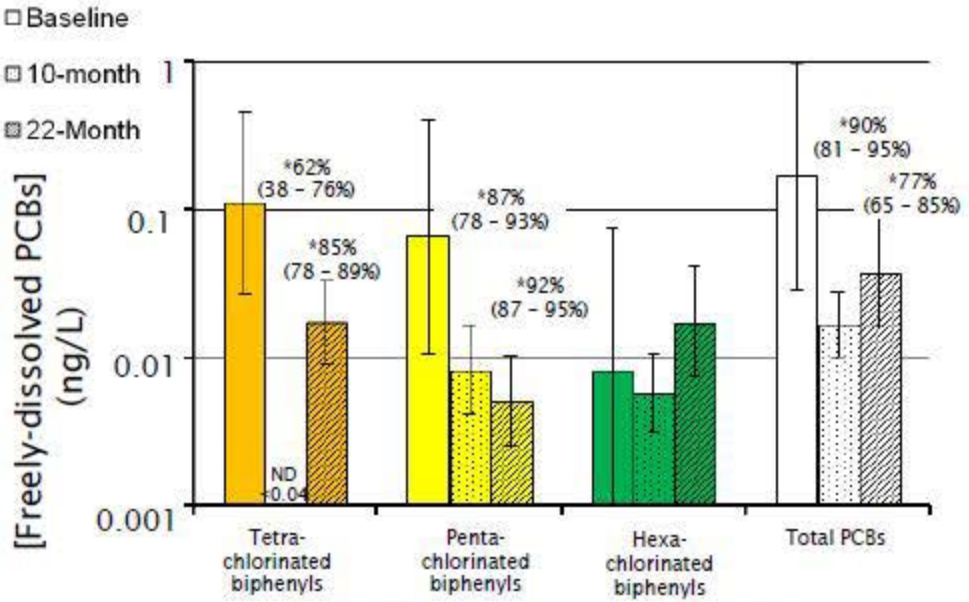


BEFORE AFTER

Concentrations of PCBs in Sediment Porewater

SPME fiber

- Total PCBs decreased by 90% and 77% in 10- and 22-month monitoring events, respectively
- Significant decrease in all homologs except
  - Hexachlorinated biphenyls

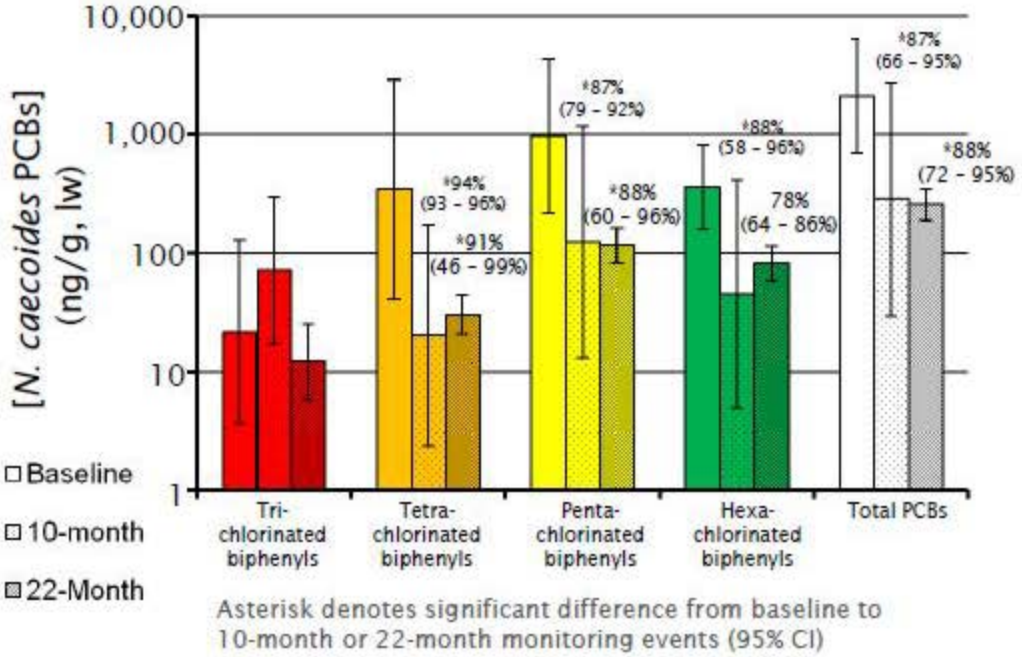


Asterisk denotes significant difference from baseline to 10-month or 22-month monitoring events (95% CI)

Concentrations of PCBs in Polychaete Tissue

Nephtys caecoides

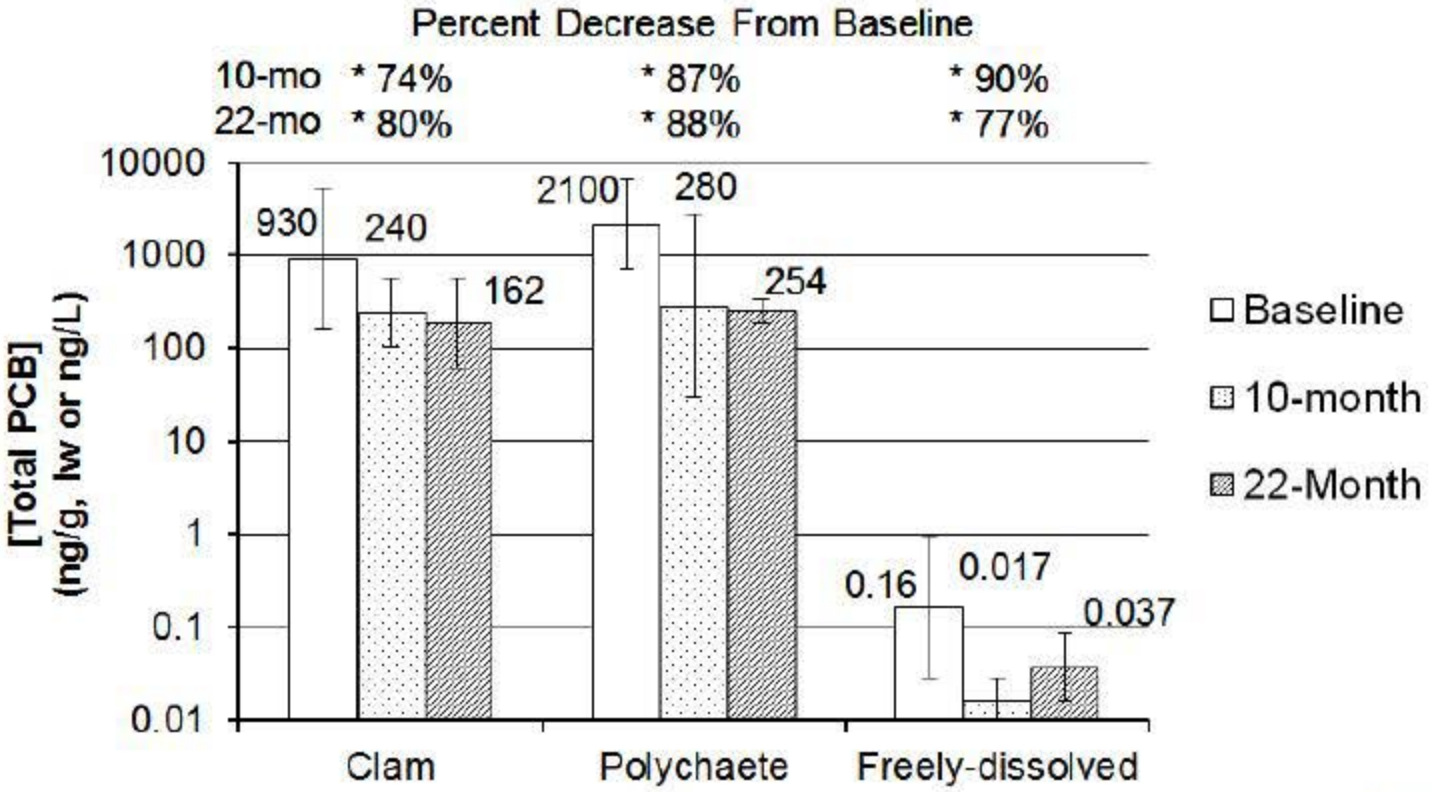
- Total PCBs decreased by 87% and 88% in 10- and 22-month monitoring events, respectively
- Significant decrease in all homologs except
  - Trichlorinated biphenyls
  - Hexachlorinated biphenyls in 22-month monitoring event



Asterisk denotes significant difference from baseline to 10-month or 22-month monitoring events (95% CI)

Conclusions

- Activated carbon amendment resulted in a significant reduction in available total PCBs



Asterisk denotes significant difference from baseline to 10-month or 22-month monitoring events (95% CI)

On-Site Production and Operations

Full-Scale Remote Manufacturing Performed at Multiple Locations

Manufacturing & Project Experience

Aquagate+pac

Projects Completed or Scheduled:

United States:
- Aberdeen, MD Proving Grounds – Pilot
- Bremerton, WA Navy Shipyard – Pilot
- Norfolk, VA (Little Creek) – Full Scale
- Pearl Harbor, HI (Sub Base) – Pilot
- Passaic River (RM10.9) – Full Scale
* Hunters Point, CA (Navy) – Pilot
* Menomonee River, WI – Full Scale
* Columbia River, OR - Pilot

International:
- Sandefjord Harbor, Norway – Pilot
- Bergen Harbor, Norway – Pilot
- Leirvik Sveis Shipyard, Norway – Full Scale
- Naudoddan, Farsund, Norway – Full Scale

* Scheduled for 2015/2016

Tons of Material:

United States: 4,402 Tons
International: 1,500 MT

Note: Total Production of all AquaGate Products Exceeds 25,000 tons, including the above

AC Sediment Cleanup Remedy Costs

- AC placement throughout a 10-acre site to achieve a 4% AC dose after bioturbation into top 4 inches

Component	Low-Range Unit Cost	High-Range Unit Cost
Activated Carbon	$20,000/acre	$40,000/acre
Mixing in Binding Agent[a]	$0/acre	$30,000/acre
Mixing in Sediment or Sand[a]	$0/acre	$40,000/acre
Field Placement	$30,000/acre	$70,000/acre
Long-Term Monitoring	$10,000/acre	$50,000/acre[b]
Total	**$60,000/acre**	**$200,000/acre**

Notes:

[a] Mixing in a binding agent or sediment/sand (typically not both) may be required in some applications depending on site-specific conditions and project designs.

[b] High-end monitoring cost of $50,000/acre reflects prior pilot projects and likely overestimates costs for full-scale remedy implementation.

"In-Situ Sediment Treatment Using Activated Carbon: A Demonstrated Sediment Clean-up Technology"; Clayton Patmont, et al, 2014

Case Studies

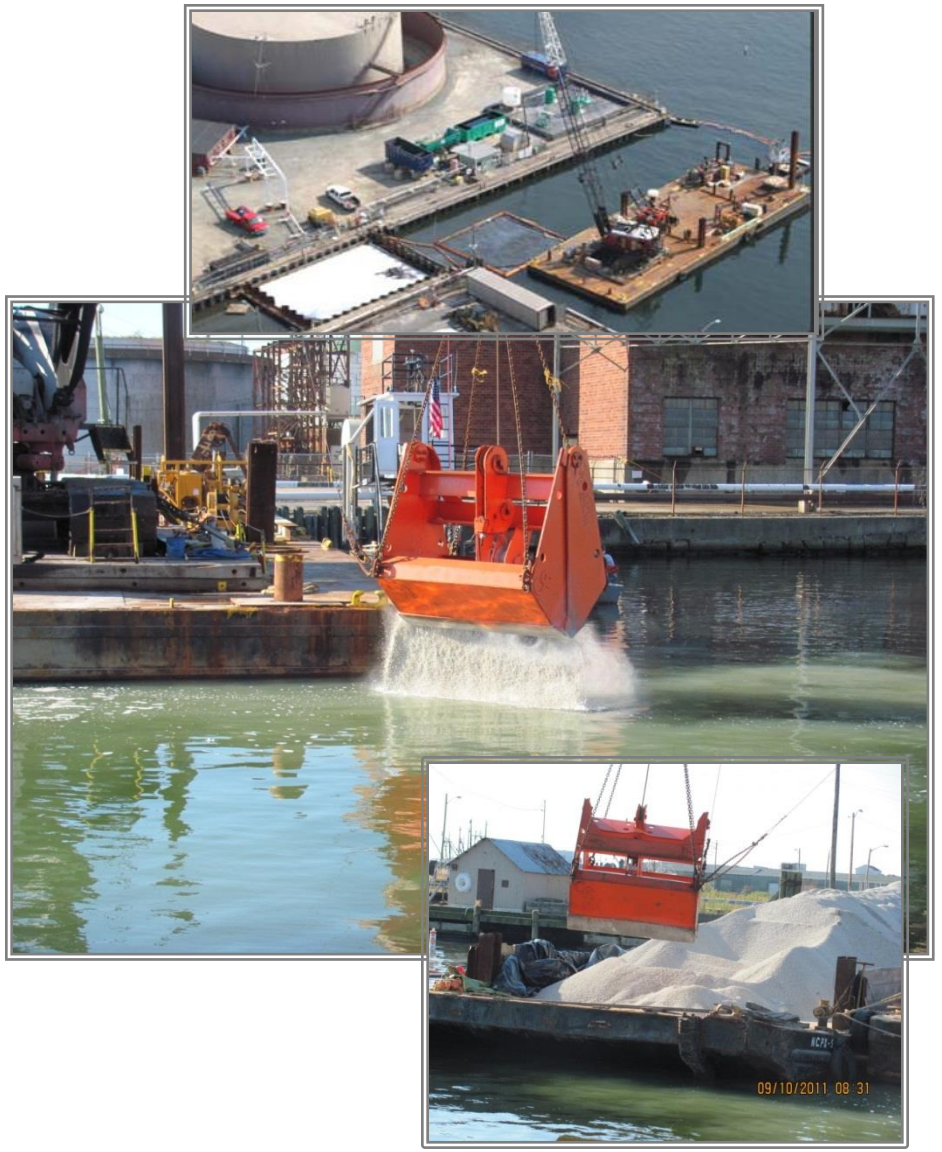
Examples of AquaBlok and AquaGate Applications at Contamination Sites

Site Location: *U.S. EPA Region 1*

NSTAR – New Bedford Harbor, MA

Project Status:
Completed October 2011

- **Setting/Purpose:** MPG Site – Slip. Low permeability encapsulation of residual contaminants in sediments following excavation - provide seal against bulkhead.
- **Contaminant(s) of Concern:** Coal Tar associated with historic MGP site.
- **AquaBlok Cap Design/Site Area:** Multi-layer comprising a sand consolidation layer followed by a six inch layer of AquaBlok 3070SW#8 saltwater formulation AquaBlok. A graded aggregate for armoring protection was placed over the AquaBlok.
- **Method of AquaBlok Placement:** Barge-based excavator



AquaBlok®
800-688-2649

www.aquablokinfo.com

Site Location: British Columbia, Canada

Fraser River, Burnaby B.C. (Near Vancouver)

- **Setting/Purpose:** Encapsulation of contaminated sediments, within the context of a wetland restoration project.
- **Contaminant(s) of Concern:** Organic (DNAPL Creosote-related)
- **AquaBlok Cap Design/Site Area:** One meter-thick gas vent layer with vent piping secured to the sheet pile walls. AquaBlok ~12-15 inches, followed by sand/gravel bedding layer of 12 inches.

- **Method of Placement:** Crane with Concrete Bucket

AquaBlok® 800-688-2649

Site Location: ***U.S. EPA Region 10***
Saltwater Trench Cap/Dam, Shoreline, Washington

Project Status:
Completed November 2008

Trench Seal and Cap of Pipeline to Isolate From Contaminated Soil

- **Setting/Purpose:** Full strength saltwater application - prevent establishment of preferential pathways.
- **Contaminant(s) of Concern:** PAHs, Refinery Property
- **AquaBlok Cap Design/Site Area:** Pipe of 7' in diameter capped and trench dams placed at two locations along length of pipeline
- **Method of AquaBlok Placement:**

  Stone Slinger/Conveyor.

AquaBlok®
800-688-2649

Site Location: ***U.S. EPA Region 2***
Confidential Site – New York State MGP

Project Status:
Completed February 2008

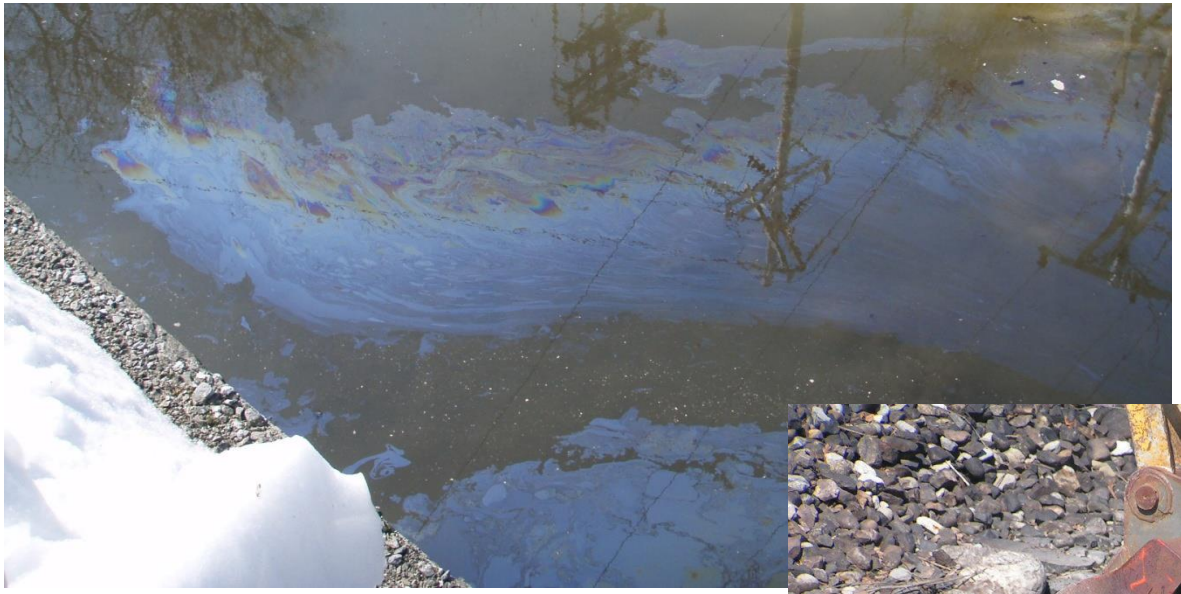
Horizontal Funnel & Gate with AquaGate+ORGANOCLAY To Isolate & Adsorb Coal Tar

- **Setting/Purpose:** Canal/River (freshwater). MGP Site – Prevent Sheens. Site area was approximately 4,000 square feet.
- **Contaminant(s) of Concern:** Coal Tar associated with historic MGP site.
- **AquaBlok Cap Design/Site Area:** Funnel & Gate layer design comprised of a one inch basal layer AquaBlok+ORGANOCLAY covered with a 6” hydrated layer of AquaBlok. The cap was then armored with a two-inch layer of AASHTO #2 stone.
- **Method of AquaBlok Placement:** Shore-based excavator

Placement of stone armor over AquaBlok low permeability capping material

Completed Cap with Armor and rip rap on slope

Site Location: ***U.S. EPA Region 2***
Confidential Site – New York State, Con't.

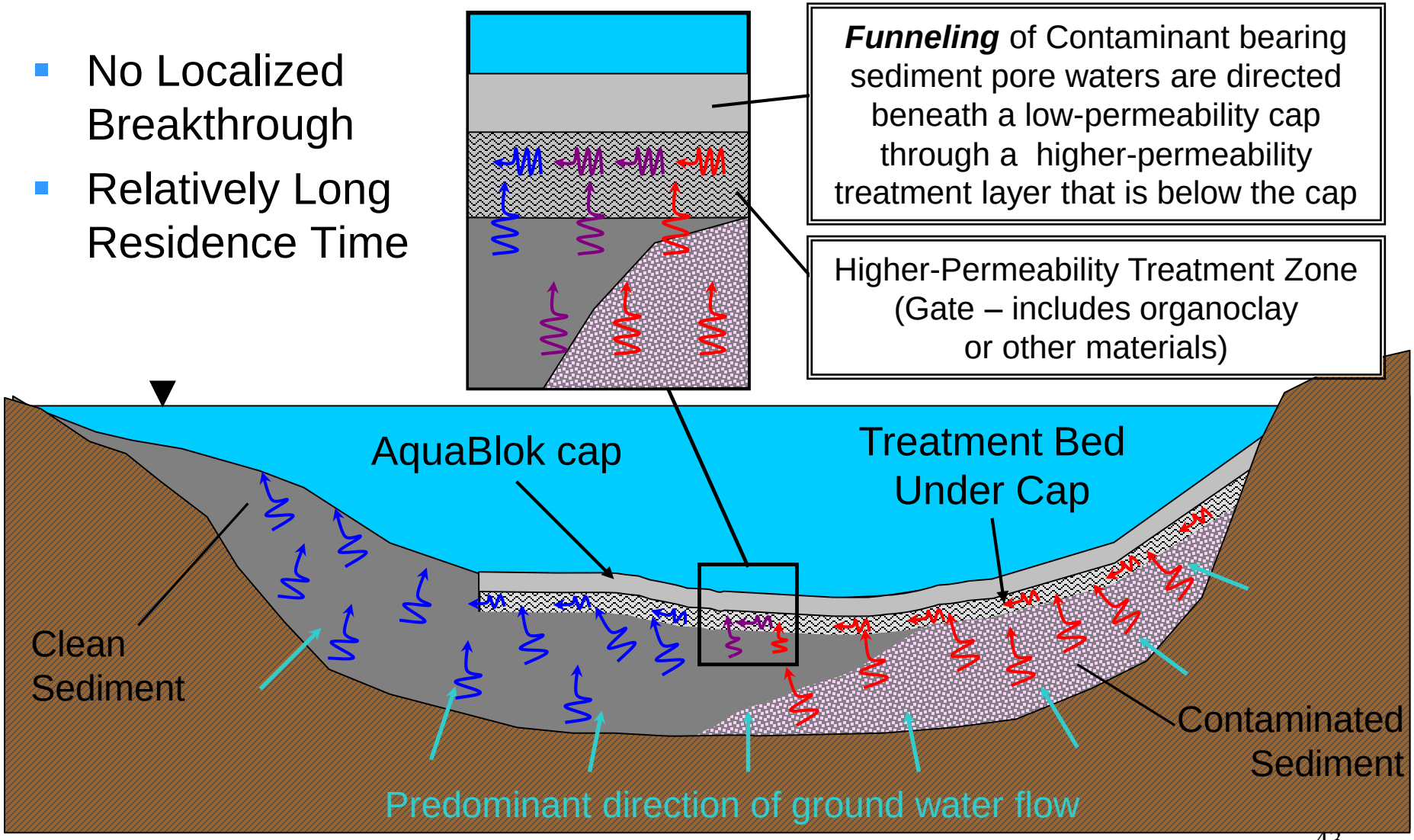


Left: Example of Sheen

Below and Below Left: View of Organoclay Being Applied & Close up View in Place

Site Location: ***U.S. EPA Region 2***
Confidential Site – New York State (Cont'd)

- No Localized Breakthrough
- Relatively Long Residence Time



not to scale

Site Location: *U.S. EPA Region 5*
Ohio DOT Project, Toledo, Ohio

Project Status:
Completed September 2012

- **Setting/Purpose:** Highway construction resulted in a release (seep) of arsenic bearing water.. Objective is to direct seep to adsorptive treatment materials in to limit the potential migration of residual to a nearby river.

- **Contaminant(s) of Concern:** Arsenic from historic accumulation of fill material.

- **AquaBlok Design / Site Area:** The approach utilizes a “funnel & gate” treatment design with AquaGate+EHC-M reactive, treatment materials to address a seep zone. A low-permeability AquaBlok layer directs the residual seep downward to the base of the slope through the permeable treatment zone. (EHC®-M is a proprietary treatment material supplied by FMC Environmental)

Use of AquaGate+EHC-M for Treatment of Arsenic Seep Zone

RCRA Metals	Before	June13'	Aug13'	March14'
Arsenic	**60 mg/L**	**ND mg/L**	**ND mg/L**	**ND mg/L**
Barium	0.15 mg/L	0.12 mg/L	ND mg/L	0.1mg/L
Cadmium	0.0033 mg/L	ND mg/L	ND mg/L	ND mg/L
Chromium	0.067 mg/L	ND mg/L	ND mg/L	0.043 mg/L
Lead	0.17 mg/L	ND mg/L	ND mg/L	ND mg/L
Selenium	0.81 mg/L	ND mg/L	ND mg/L	ND mg/L
Silver	0.0034 mg/L	ND mg/L	ND mg/L	ND mg/L
Mercury	ND mg/L	ND mg/L	ND mg/L	ND mg/L

Site Location: ***U.S. EPA Region 5***
MGP Impacted River – Ann Arbor, MI

Project Status:
Completed 2012

Implementation of NAPL Trapping Cap* for Control of Ebullition

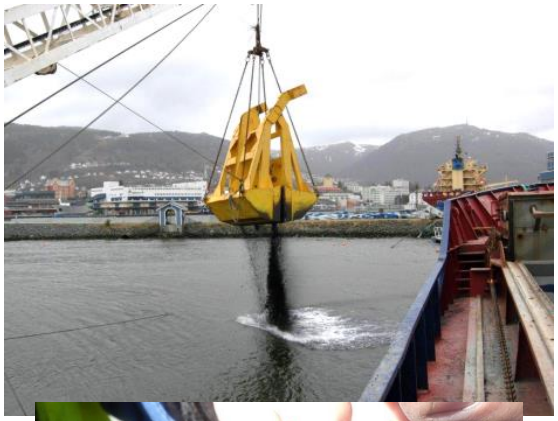
* NAPL Trapping Cap was designed by RMT/TRC

International Installations/Activity

Norway:

Australia:

Kirkebukten, Bergen Harbor, Norway, 2011, Caps with PAC



Leirvik Sveis Shipyard, Norway, 2012, Caps with PAC

Sydney Harbor, State Property Authority (SPA), NSW

Summary – Q&A

AquaBlok as a Low-Permeability Material for Remediation & Geotechnical Applications:

Permeable Treatment Material for Remediation Applications:

Permeable Treatment Material for Sediment Remediation Applications

- Provides Uniform Delivery of Small Quantities of a High Value Treatment Material
- Use of Powder Treatment Materials = Faster Adsorption Rates
- Creates Thicker (uniform) Layers with Less Material Usage
- Ability to Mix Treatment Materials with other Granular Capping Materials and Provide Uniform Delivery in a Single Lift - Less Risk of Material Separation Wide Range of Treatment Materials

- **Rapid Installation – Using Conventional Equipment**
- **Proven Full-Scale Production – On-Site Manufacturing**