

Evaluation of Organoclay Permeable Adsorptive Barrier to Manage DNAPL and Dissolved PAHs in Groundwater Seepage

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CH2MHILL

Overview

The background of the slide features a blue-tinted photograph of a construction site. In the foreground, a large piece of heavy machinery, possibly a conveyor belt or a similar transport system, is visible. In the background, a worker in a white shirt and dark pants is standing on a flat surface, possibly a road or a construction site. The overall scene is industrial and focused on infrastructure development.

- **Objectives**
- **Project Background**
- **Bench Scale Study**
- **Results**
- **Conclusions and Observations**
- **Questions**

Objectives



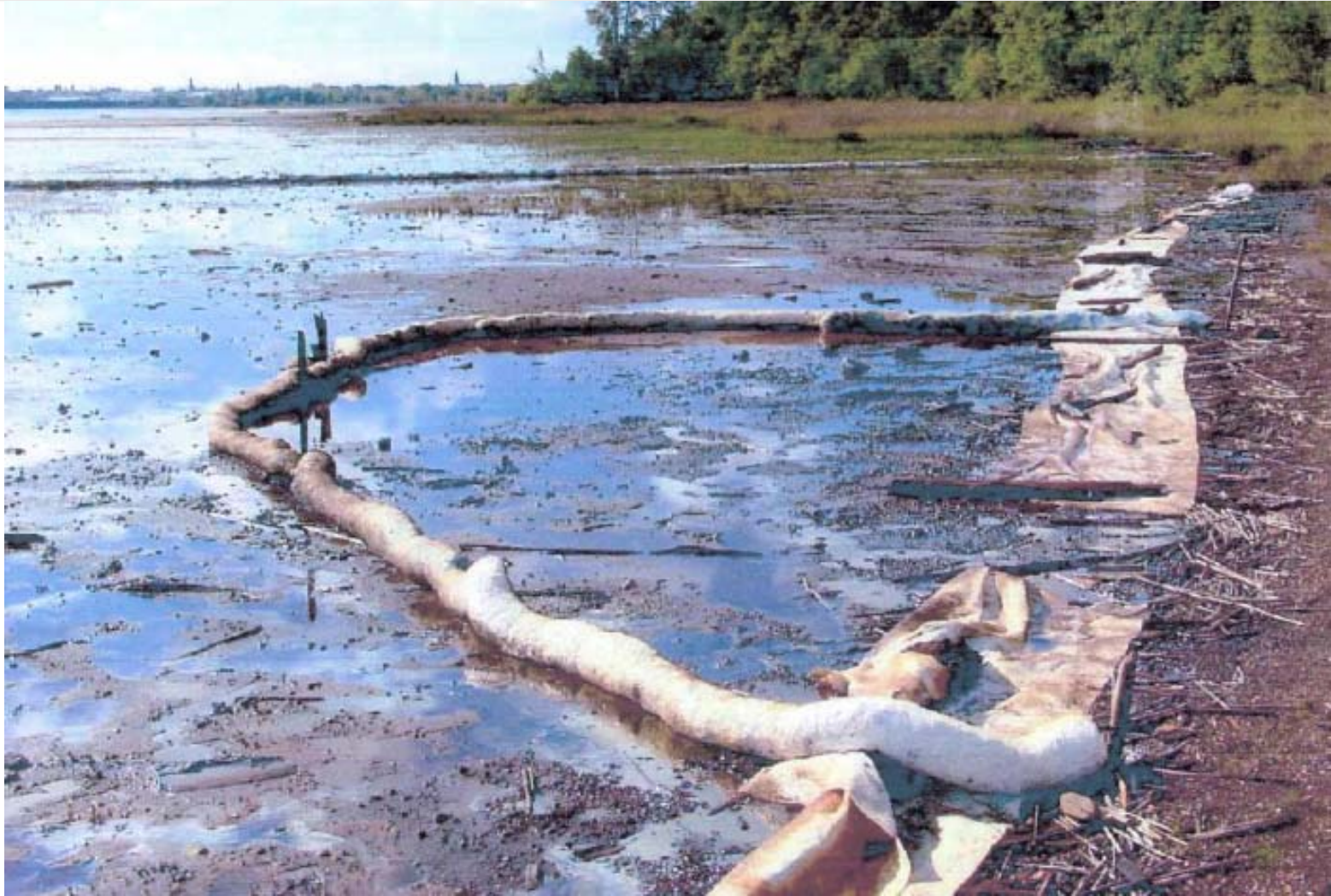
- **Evaluate existing interim organoclay permeable adsorptive barrier**
- **Test three types of organoclays for full scale implementation**
- **Predict performance of full scale adsorptive barrier**

Project Background

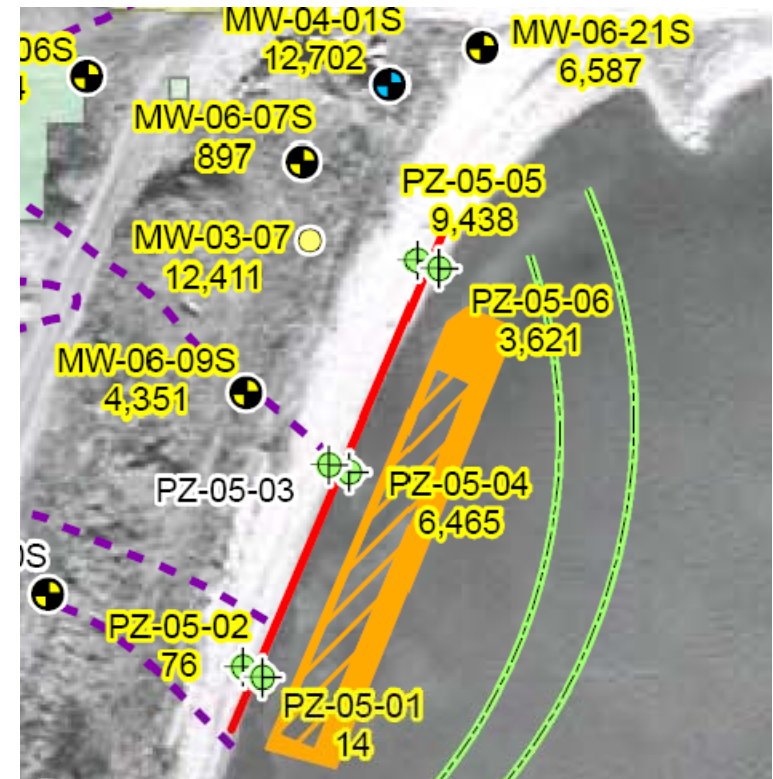
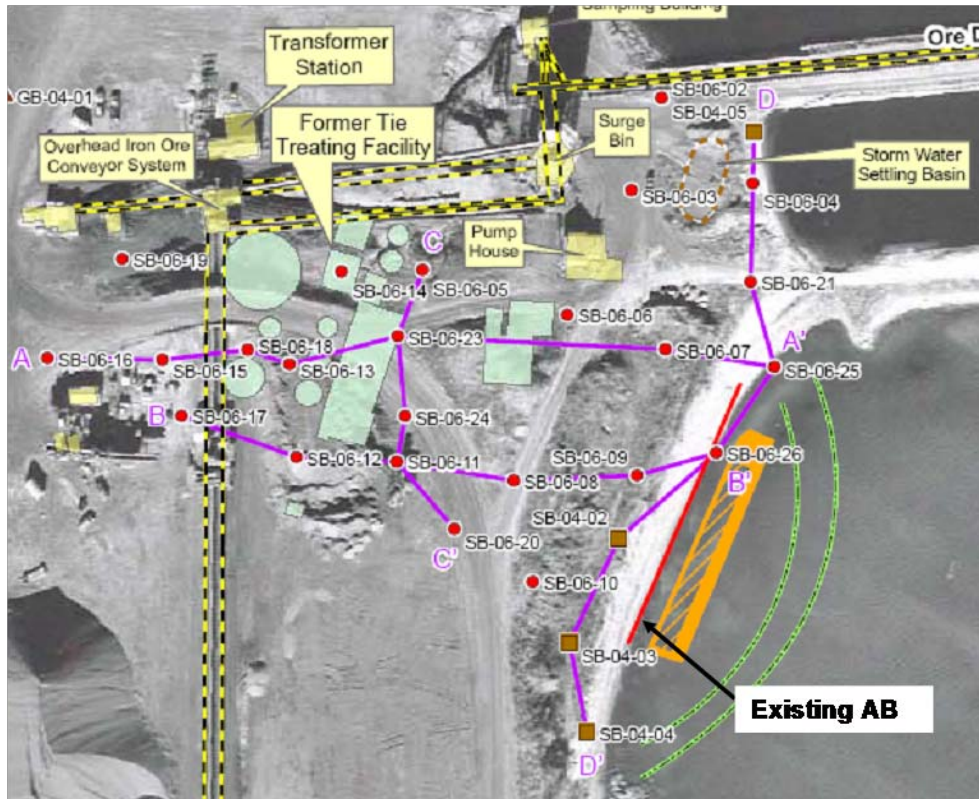


- **Site: Former Tie Treating Facility**
- **Location: Lake Michigan**
- **Phase: Evaluation of Remedial Options**
- **Project Issue: PAH DNAPL Seep along shoreline**
- **Objective: Mitigate migration of DNAPL and dissolved PAHs to surface water and sediment**

Shoreline Seeps, October 2003



Site Plan View



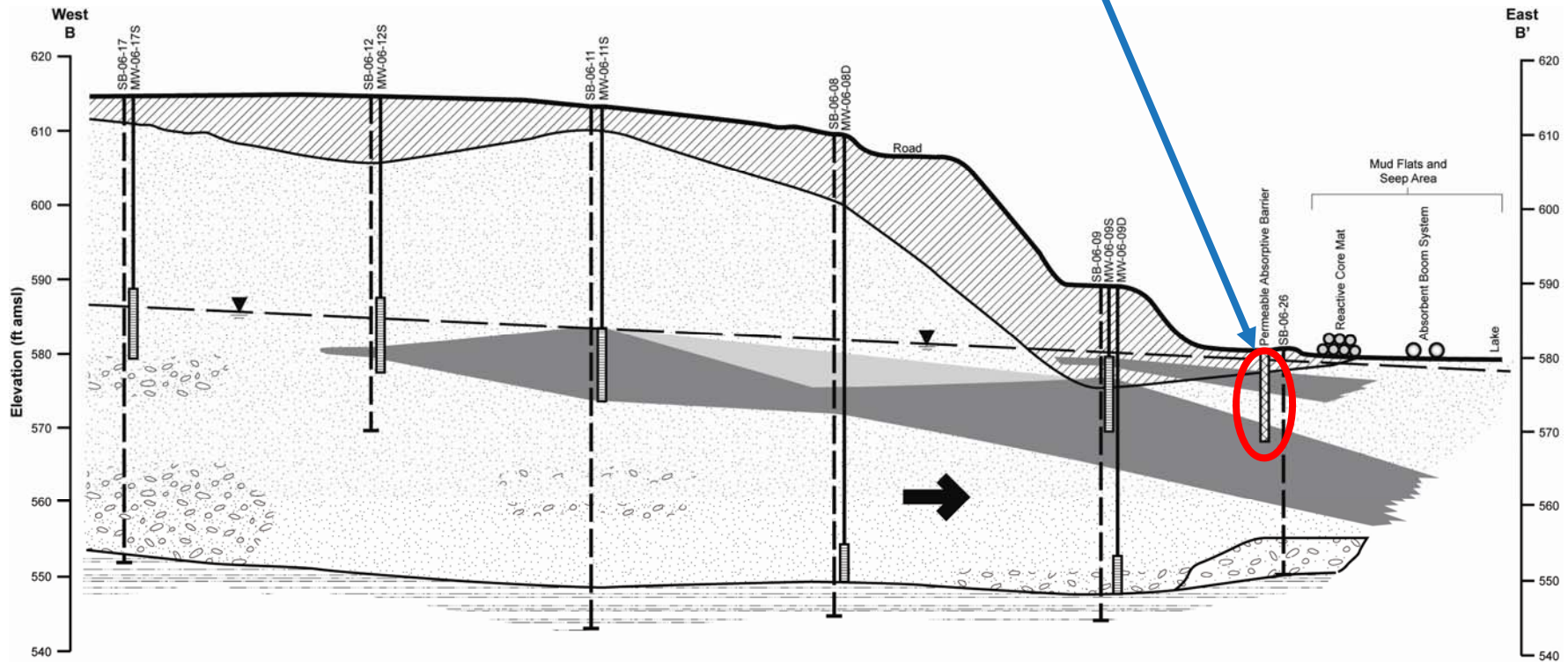
Distribution of dissolved PAH concentrations in groundwater around the existing AB. State generic cleanup criteria are 19 ug/L for acenaphthene, 13 ug/L for naphthalene, and 2.4 ug/L for phenanthrene

Cross-Section Parallel to Flow

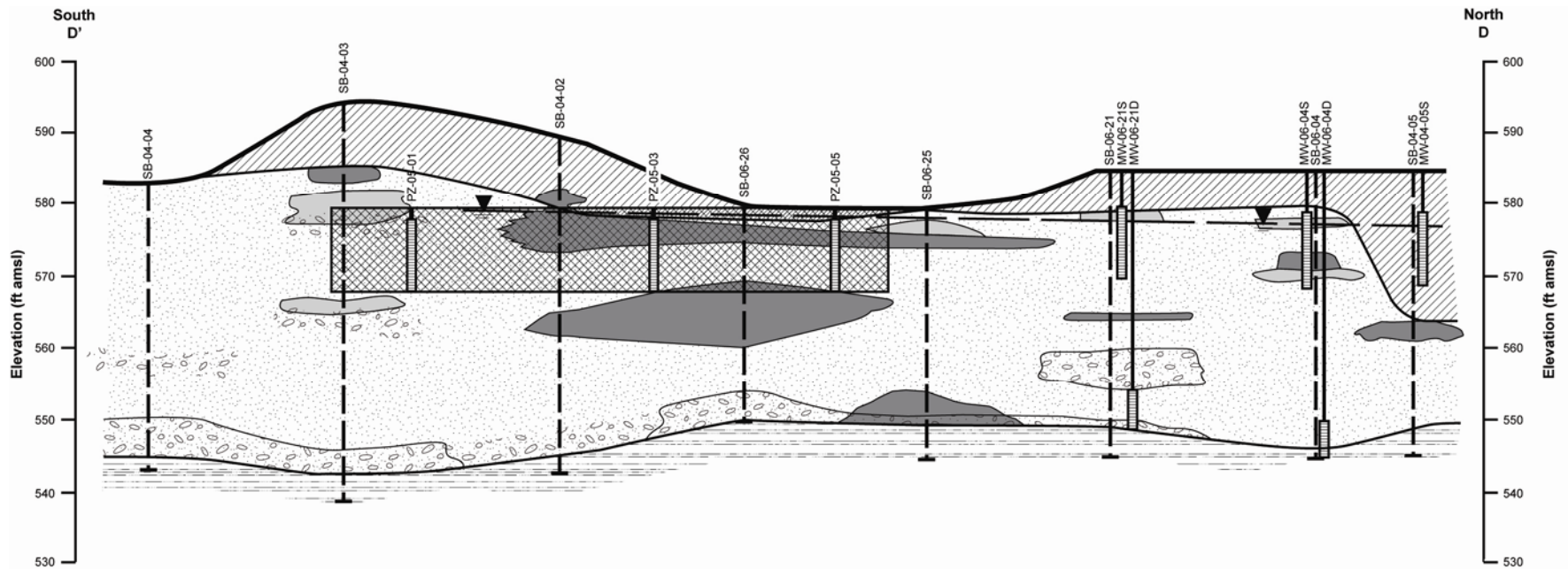
Source

Lake

Interim Barrier



Cross-Section Perpendicular to Flow (looking upgradient)



Interim Measure



Continuous Trencher

Interim Permeable Adsorptive Barrier Installation

- 82-meters long, 3.3-meters deep, 0.6-meter thick
- 25% Organoclay/75% granular backfill by volume



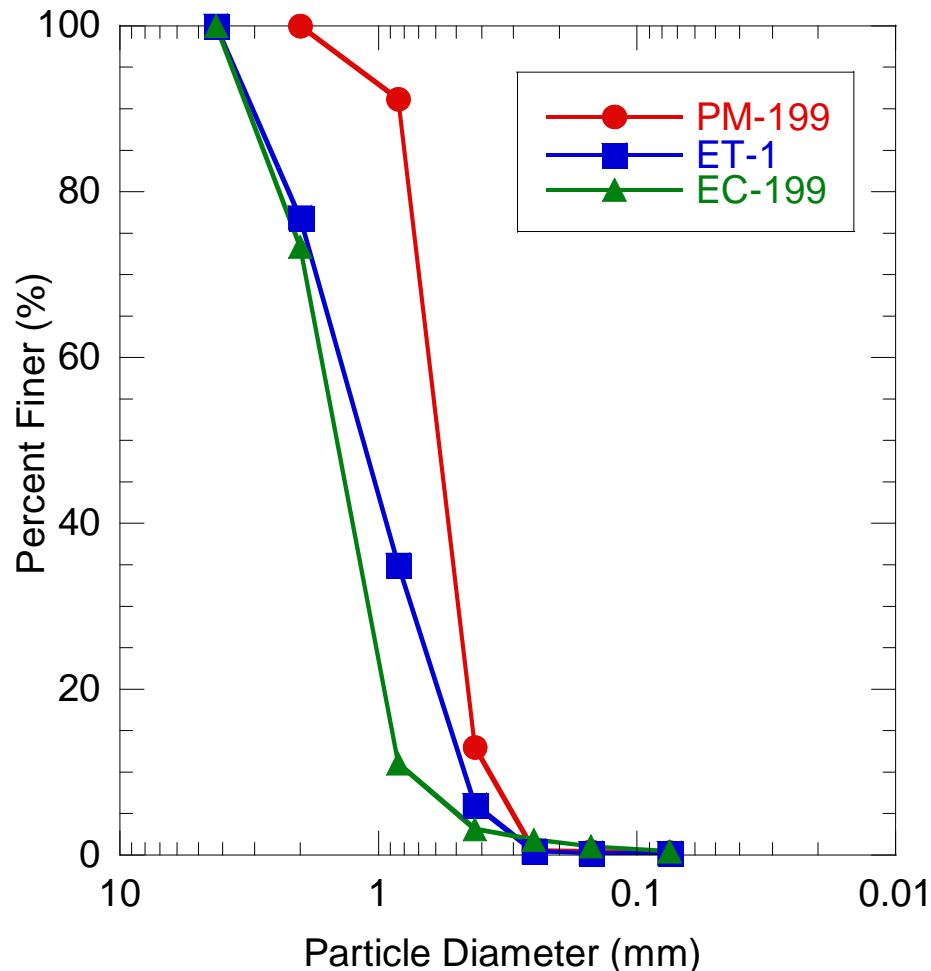
Interim Measure (continued)




- **No DNAPL observed migrating through the barrier after 4 years of operation**
- **Testing of organoclay material indicated very little reduction in adsorptive capacity**
- **No mounding of groundwater upgrade of the barrier suggests effective permeability to water**

Bench Scale Study

- **Testing of three organoclays (PM-199, ET-1, and EC-199)**
- **Organoclay physical properties**
- **DNAPL flow and transport**
- **Aqueous batch isotherm tests**
- **Aqueous column tests**

Physical Properties of Organoclay



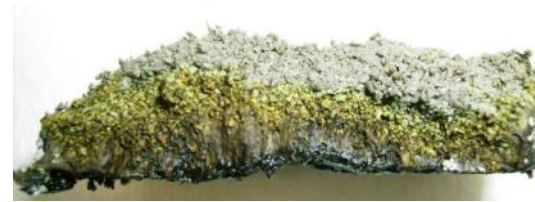
Organoclay		G_s	OC (%)	K_{sat} (cm/s)
PM-199		1.75	25.0	0.14
ET-1		2.00	15.5	0.12
EC-199		1.75	26.9	0.39

- **Very permeable to water**
- **Low G_s due to high organic carbon content**

DNAPL Flow and Transport



(a)

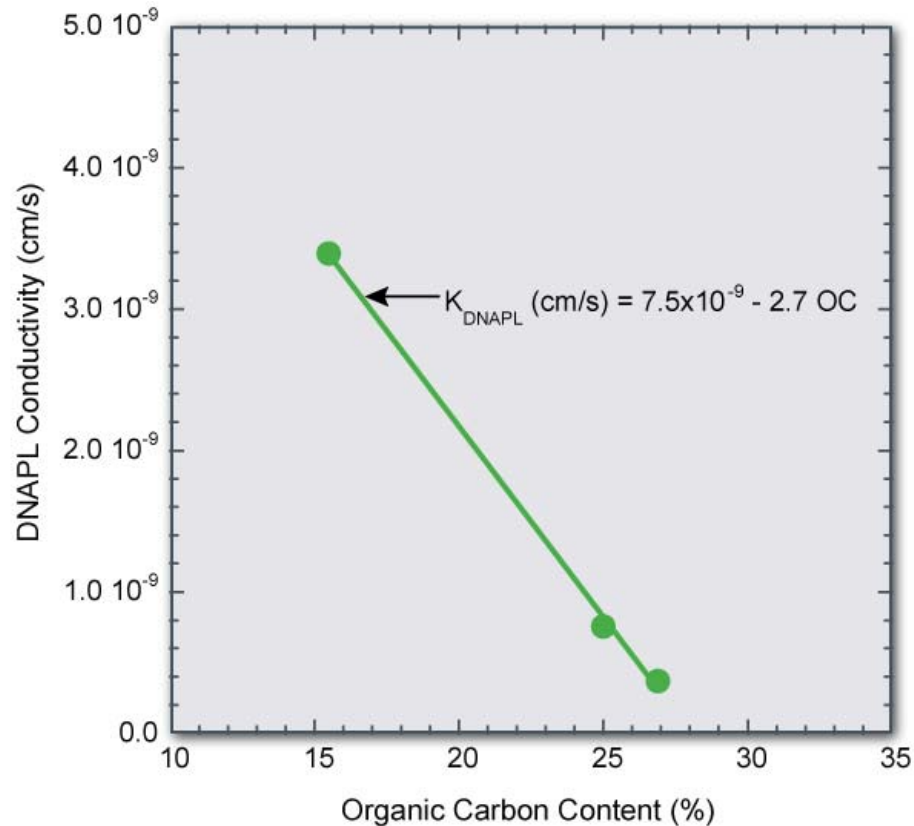


↑
Direction of flow

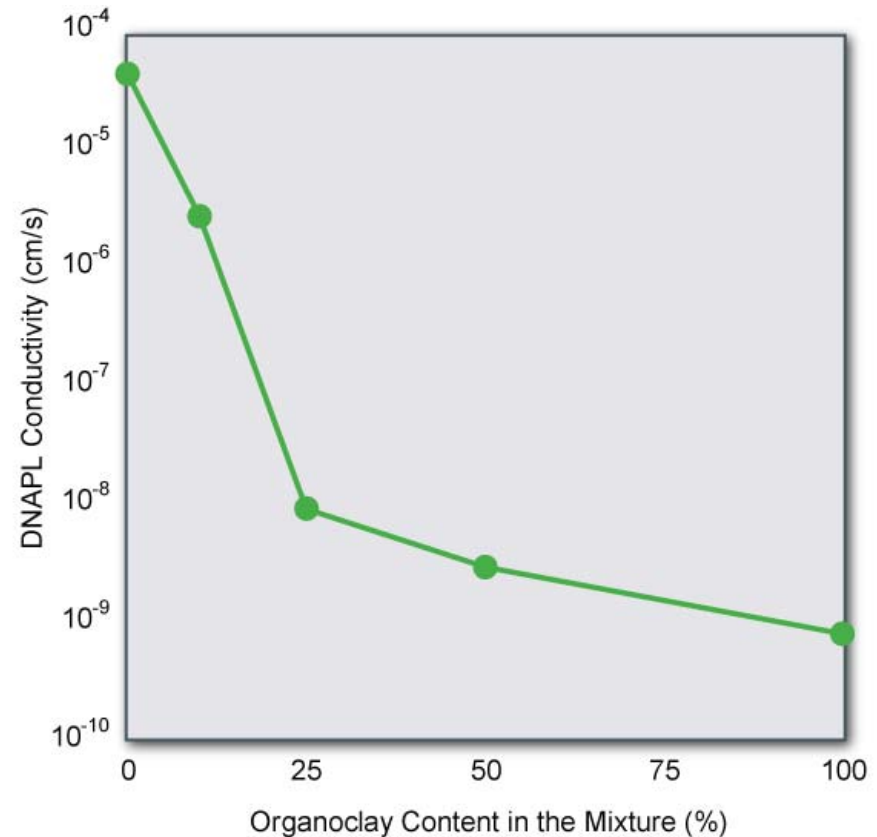
(b)

Side view (a) and cross-sectional view of influent end (b) of PM-199 after short-term column tests. Black zone at bottom in (b) is thin (1 mm) layer of gel-like organoclay solvated with DNAPL.

Effect of Organic Carbon and Clay Content (Organoclay-Sand Mixtures)

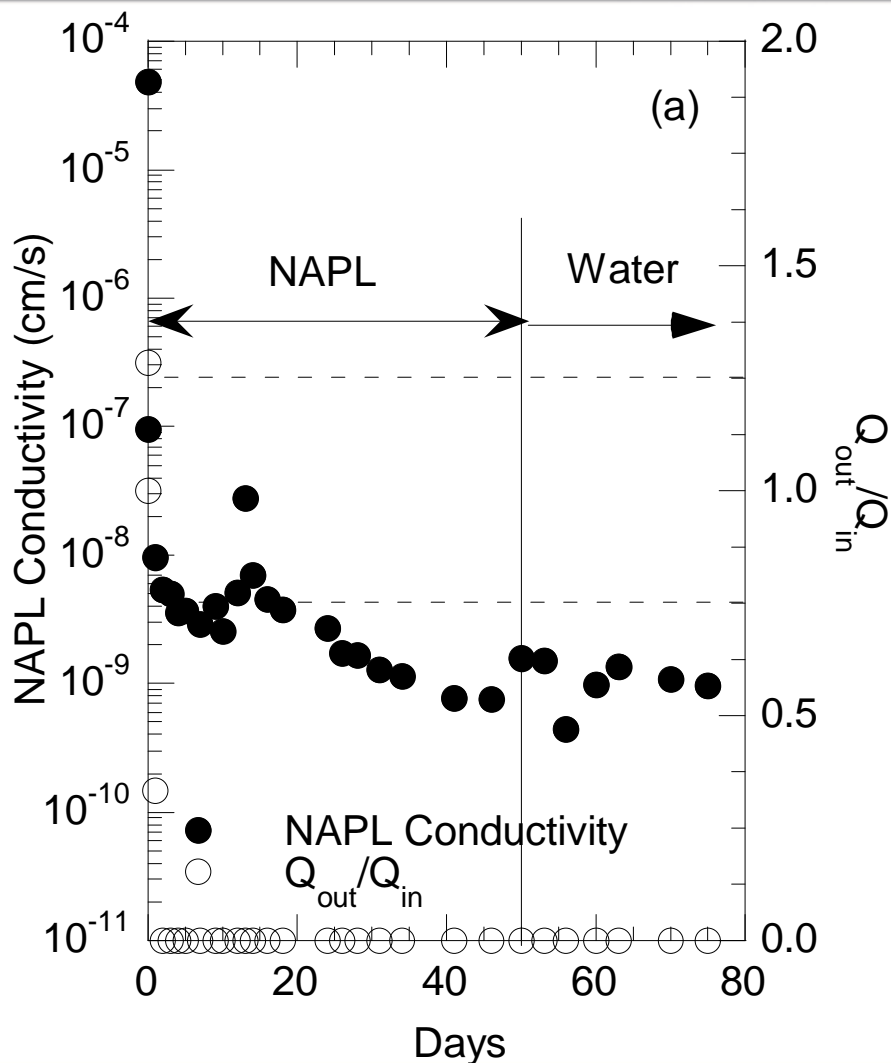


Greater organic carbon loading yields lower conductivity to DNAPL



Very low K with 25% to 50% organoclay

Summary of Hydraulic Conductivities



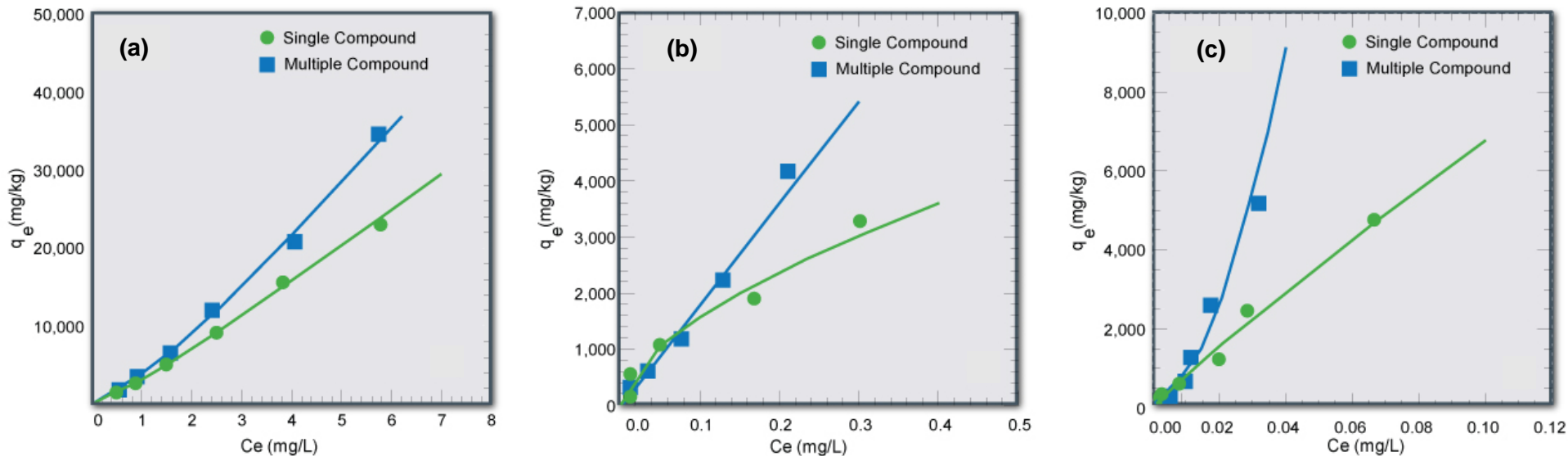
Material	Hydraulic Conductivity (cm/s)
PM-199	7.6X10 ⁻¹⁰ (for DNAPL) 9.6X10 ⁻¹⁰ (for water)
ET-1	3.4X10 ⁻⁹
EC-199	3.7X10 ⁻¹⁰ (for DNAPL) 1.1X10 ⁻⁹ (for water)
0% PM-199	4.1X10 ⁻⁵
10% PM-199	2.6X10 ⁻⁶
25% PM-199	8.6X10 ⁻⁹
50% PM-199	2.8X10 ⁻⁹

- Nearly impermeable to DNAPL, but varies by clay
- Can obtain similar low K with a sand-organoclay blend

Aqueous Phase Tests

- **Understand how PAHs dissolved in groundwater migrate through an organoclay adsorptive barrier**
- **Batch tests:**
 - **Naphthalene, acenaphthene, and phenanthrene selected for testing**
 - **Evaluate adsorption of PAHs onto organoclay**
 - **Kinetics and equilibrium condition**
 - **Fast and simple experiments, but may not replicate flow through condition**
- **Column tests:**
 - **Evaluate transport of PAHs in organoclay under flow through conditions**

Aqueous Batch Test Results

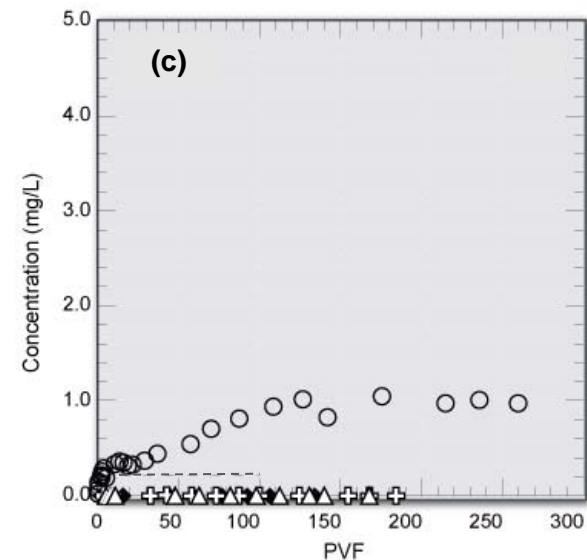
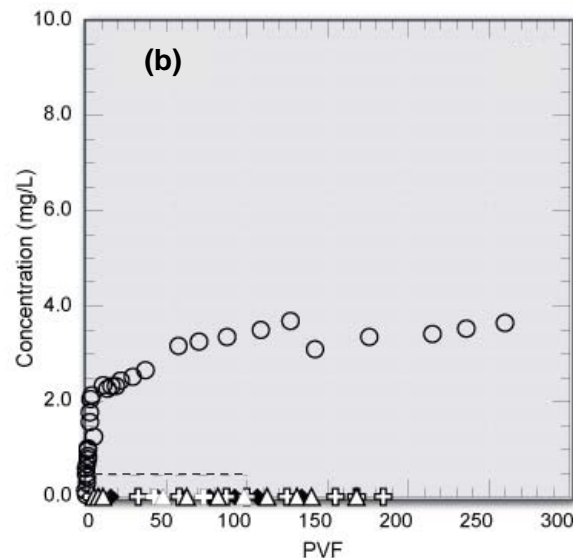
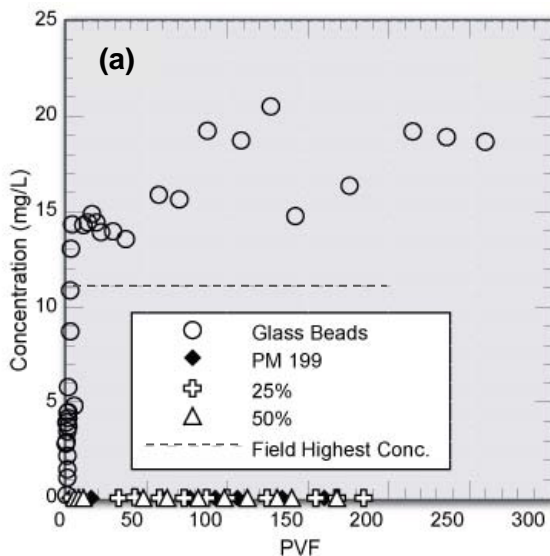


Adsorption isotherms of PM-199 for naphthalene (a), acenaphthene (b), and phenanthrene (c) with fits of Freundlich model for solutions containing a single PAH or multiple PAHs

PAH Adsorption Isotherms

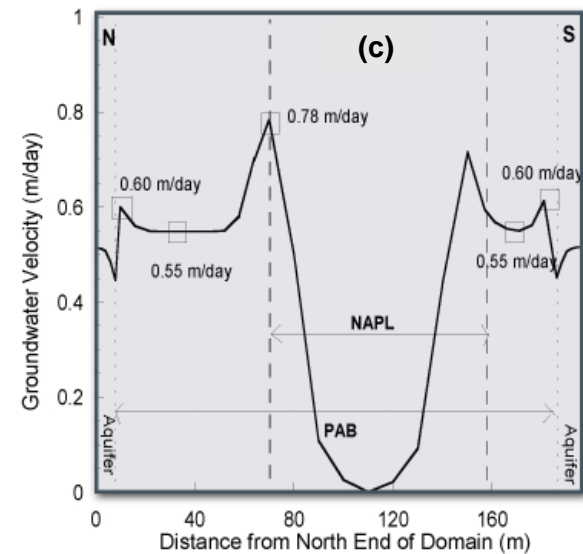
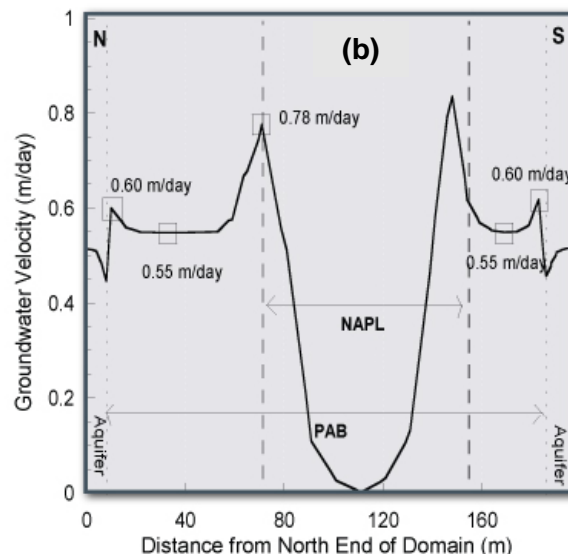
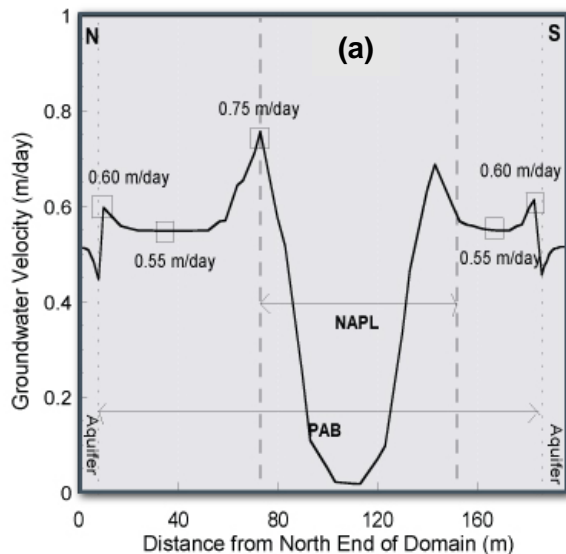
Organo-clay	PAH	K (L/kg)		n		R ²	
		Single	Mixed	Single	Mixed	Single	Mixed
PM-199	Naphthalene	3285	3888	1.13	1.23	0.99	0.99
	Acenaphthene	6236	20497	0.60	1.06	0.97	0.99
	Phenanthrene	57478	3257617	0.93	1.83	0.98	0.90
		Mixed		Mixed		Mixed	
ET-1	Naphthalene	361		1.23		0.59	
	Acenaphthene	1749		1.02		0.93	
	Phenanthrene	13431		1.19		0.98	
EC-199	Naphthalene	1876		1.28		0.98	
	Acenaphthene	10629		1.04		0.97	
	Phenanthrene	263451		1.56		0.77	

Aqueous Column Test Results



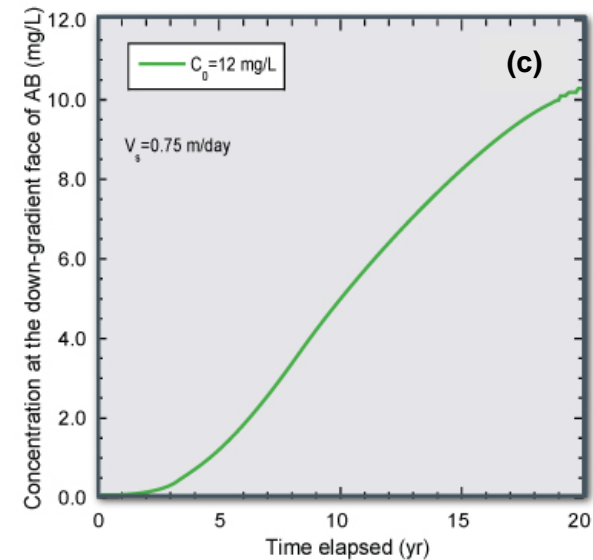
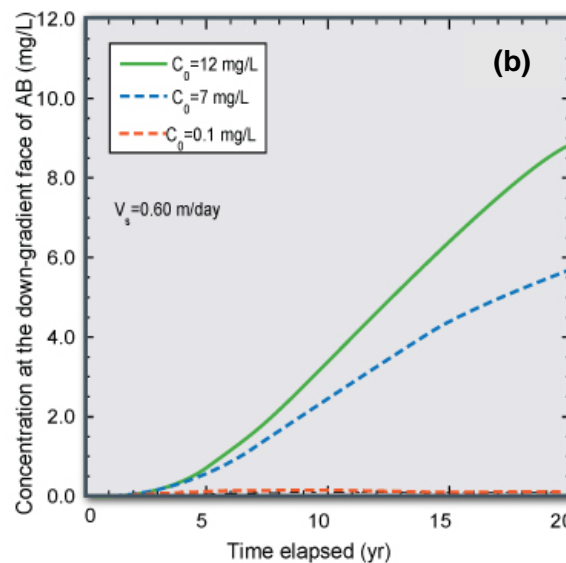
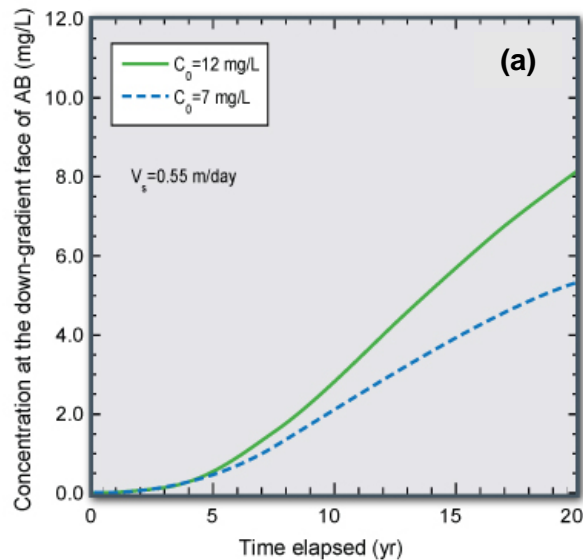
Effluent concentration of naphthalene (a), acenaphthene (b) and phenanthrene (c) from columns containing PM-199, 25% organoclay-sand mixture, and 50% organoclay-sand mixture.

Groundwater Velocity Scenarios



Groundwater velocity profile along alignment of the AB immediately after contact between DNAPL and organoclay (a), 1 year after contact (b), and 2 years after contact (c).

Predicted Breakthrough Scenarios



Naphthalene concentration at the effluent face of a 0.6-m-thick AB using a Freundlich isotherm model for a groundwater velocity of 0.55 m/d (a), 0.60 m/d (b), and 0.75 m/d (c).

Conclusions and Observations

- **Organoclays can create a dual function adsorptive barrier: relatively impervious to DNAPL, highly permeable to water, and effective in treating dissolved phase PAHs.**
- **Organoclay solvation with DNAPL can result in flow blockage and lateral movement of DNAPL.**
- **DNAPL conductivity is strongly correlated to organic carbon content of organoclay.**
- **Organoclays have high affinity for PAHs.**
- **Adsorption of PAHs was greatest for PM-199, followed by EC-199, and ET-1.**

Conclusions and Observations (cont'd)

- Sorption was greater in mixtures of PAHs than in solutions with single compounds.
- No naphthalene breakthrough was observed in 10 months using PM-199 and organoclay-sand mixtures.
- Predictive modeling is useful in evaluating adsorptive barrier thickness, breakthrough criteria, and service time.
- Variable groundwater velocity distribution can prevail along adsorptive barrier.
- Higher groundwater velocities will affect breakthrough.
- Periodic monitoring and passive DNAPL removal can prolong breakthrough and reduce O&M cost.

Questions?

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