USGS science for a changing world

Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies; Miami, Florida (May 22-25, 2017)

Field Application of Dual-Biofilm Barriers for In Situ Remediation of Chlorobenzenes in Groundwater and Wetland Sediments

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Superfund Application and Collaborative R&D

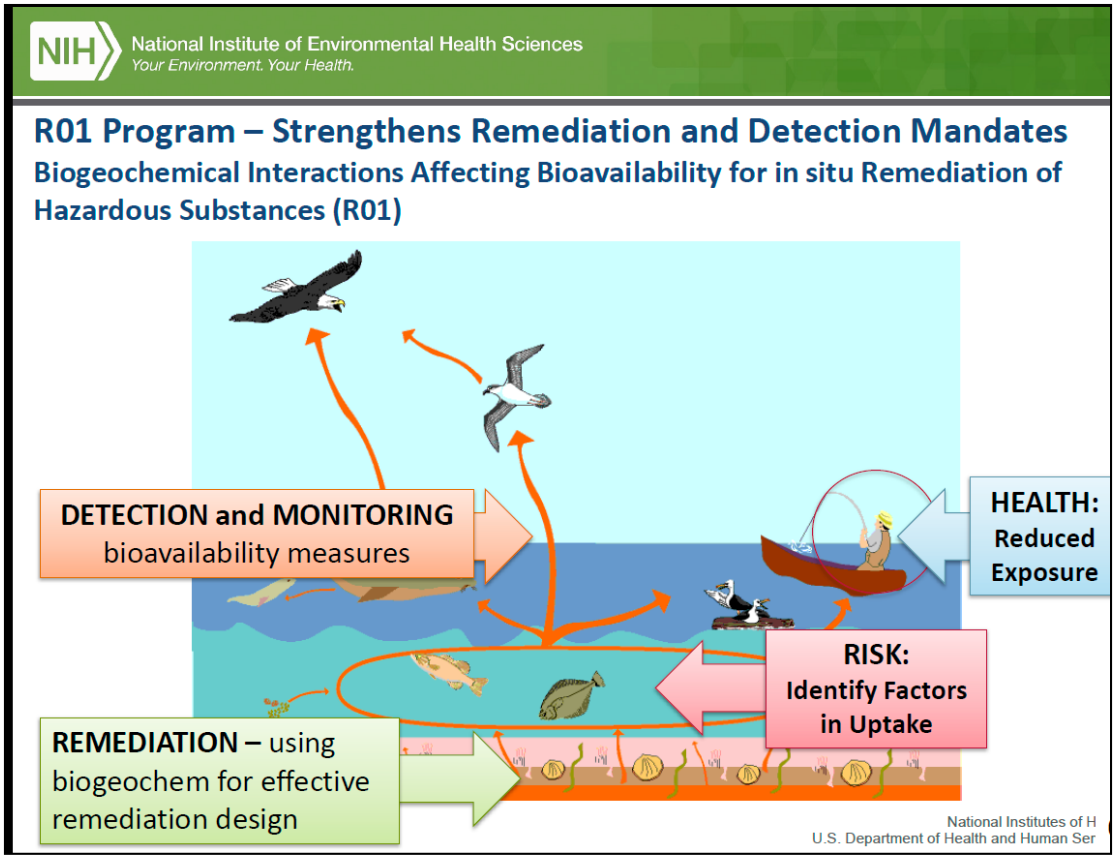
Funded by

- USEPA, Region III
- NIEHS, Superfund Research Program

United States Environmental Protection Agency

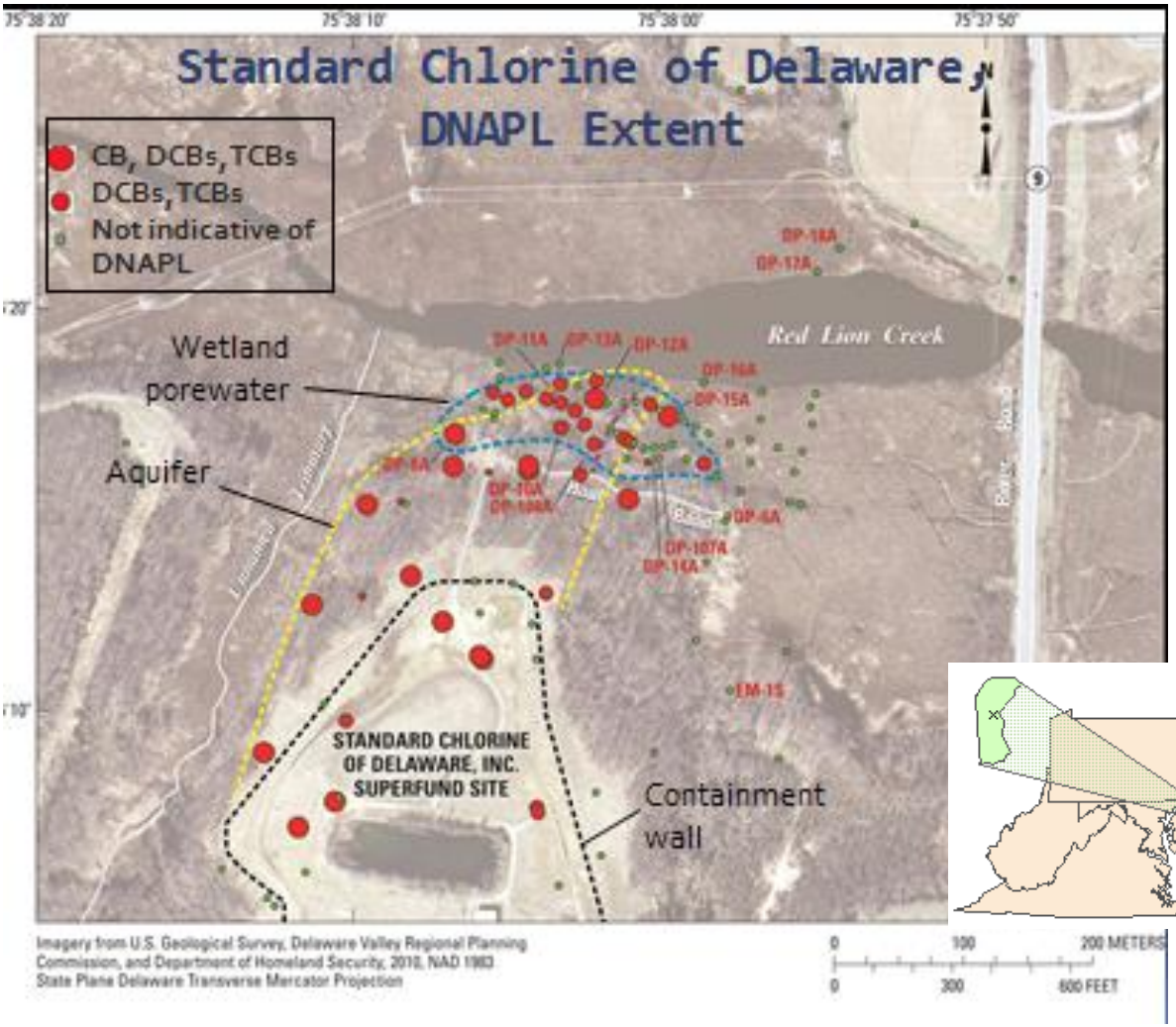
Collaboration between JHU, USGS, and Geosyntec

- Interdisciplinary team
- Problem-solving mechanistic research
- Research outcomes are directly applicable
- Fundamental science to inform risk assessment
- Engage end-users



Project Site

- Chemical plant 1966-2002
- Over 500,000 gal CBs in one spill



Source: USGS, EPA

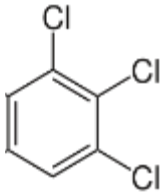
Biodegradation

Anaerobic (reductive dechlorination)

- CB serves as terminal electron acceptor
- Separate e- donor required
- rate decreases with decreasing number Cl

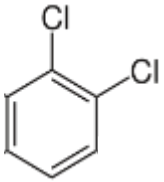
Aerobic (oxidation)

- O_2 required as electron acceptor
- CBs utilized as C and e^- donor



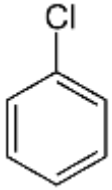
70 (124TCB)

Trichlorobenzenes*
135TCB,124TCB, 123TCB



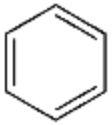
75 (14DCB)

Dichlorobenzenes*
14DCB, 13DCB, 12DCB



100

Chlorobenzene*



5

Benzene *

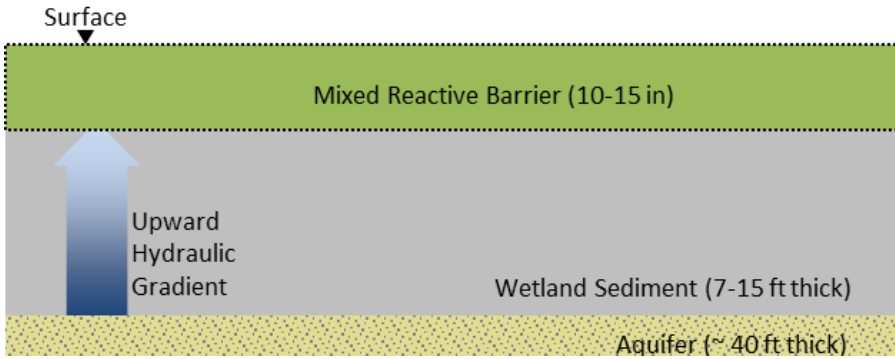
CO_2, CH_4

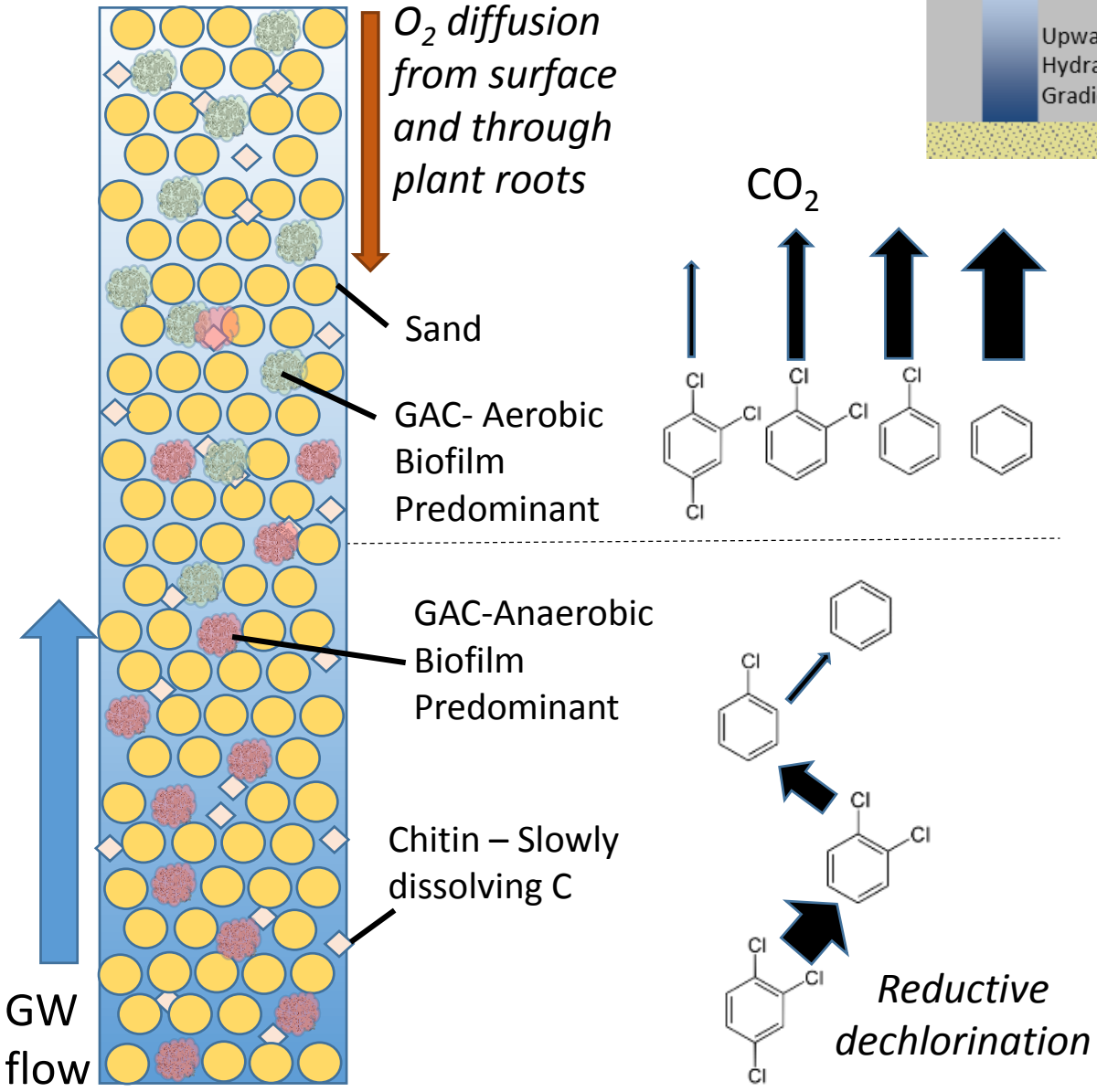
Drinking Water MCL µg/L

Aerobic CO_2, HCl

* Parent contaminant

Reactive Barrier Concept

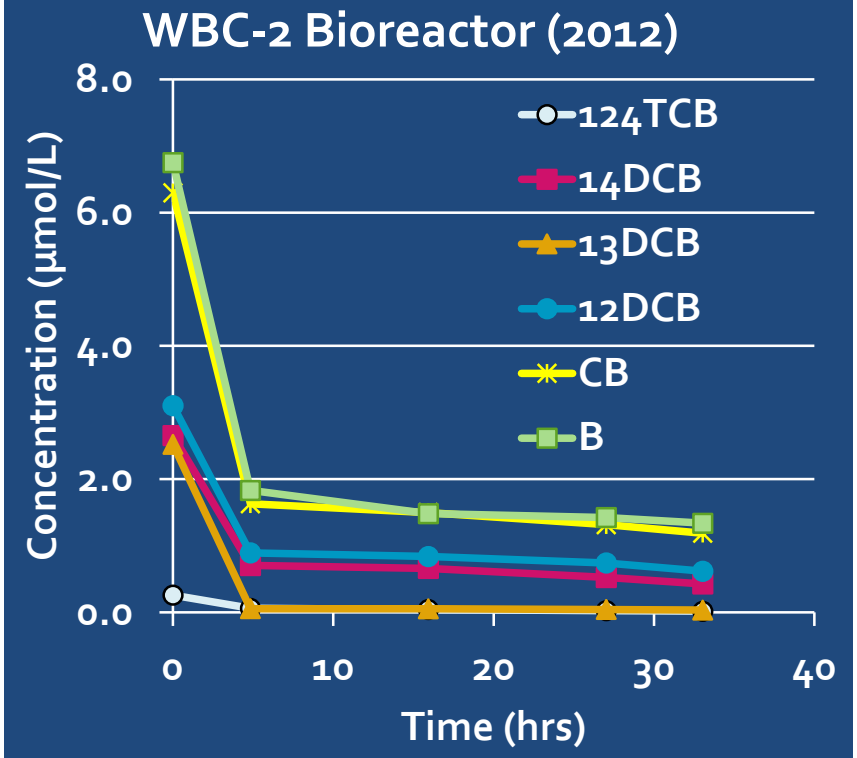




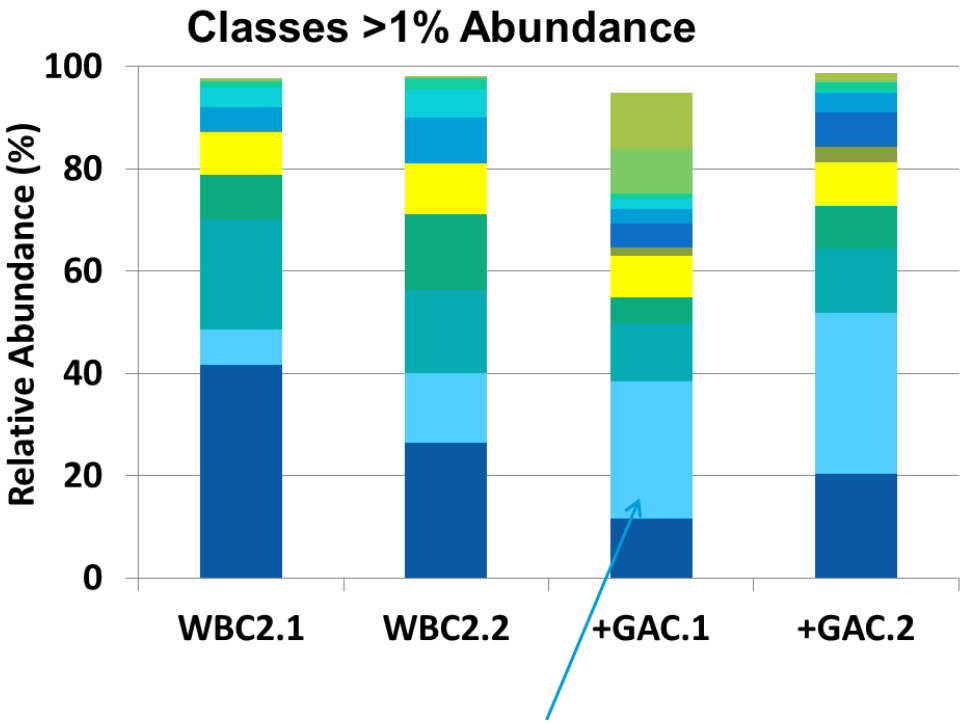
Reductive dechlorination

- **GAC (3-5 % by dry weight) sequesters >95% contaminants**
- **GAC decreases bioavailability but not total sediment concentrations**
- **Biofilm-GAC decreases the total concentrations through biodegradation**
- **Biodegradation rejuvenates GAC (self-sustaining)**

Anaerobic Culture WBC-2



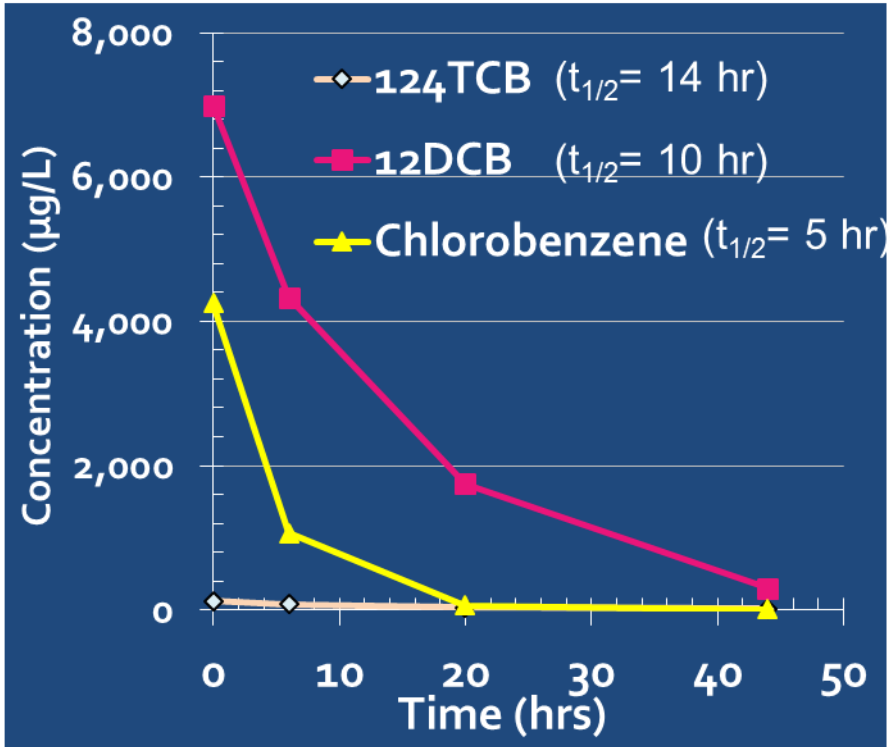
- Enriched from wetland sediment at APG to degrade chlorinated VOCs
- Sediment-free culture since 2002
- Readily available in large quantities



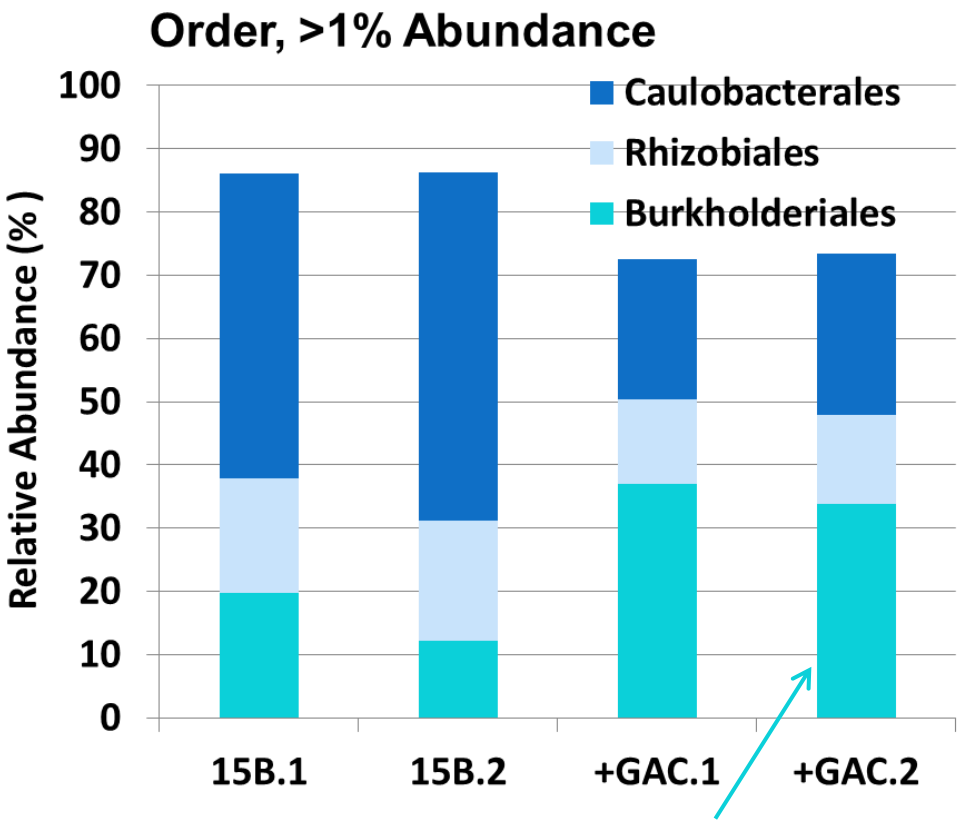
Significant increase in Dehalococcoidales on GAC.

f__Dehalococcoidaceae;g__Dehalococcoides
f__Dehalococcoidaceae;g__Dehalogenimonas

Aerobic Culture 15B



- Wetland groundwater from SCD
- Tryptone-yeast extract media
- Fed with CB, 12DCB, 14DCB, and 124TCB
- Incubated aerobically on shaker



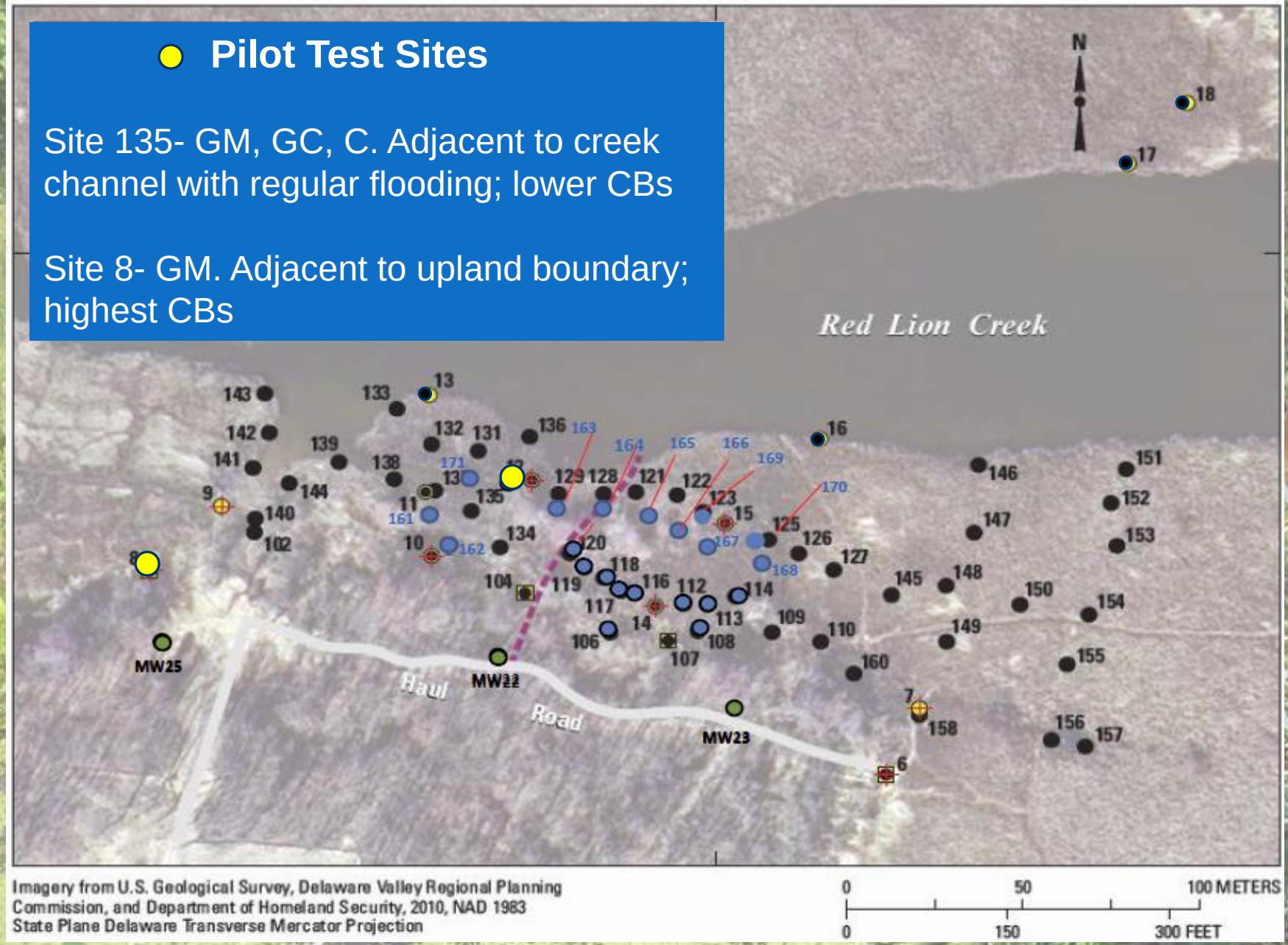
Significant increase in Burkholderiales on GAC.

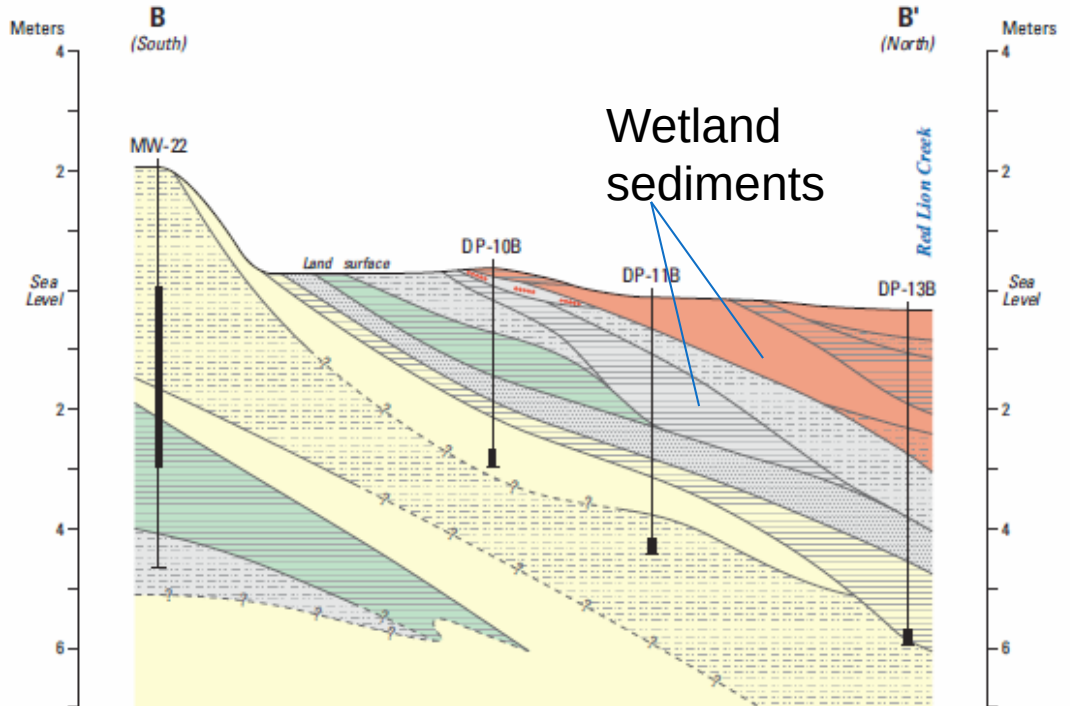
f__Alcaligenaceae;Other
f__Alcaligenaceae;g__
f__Comamonadaceae;g__Comamonas

Pilot Test Sites

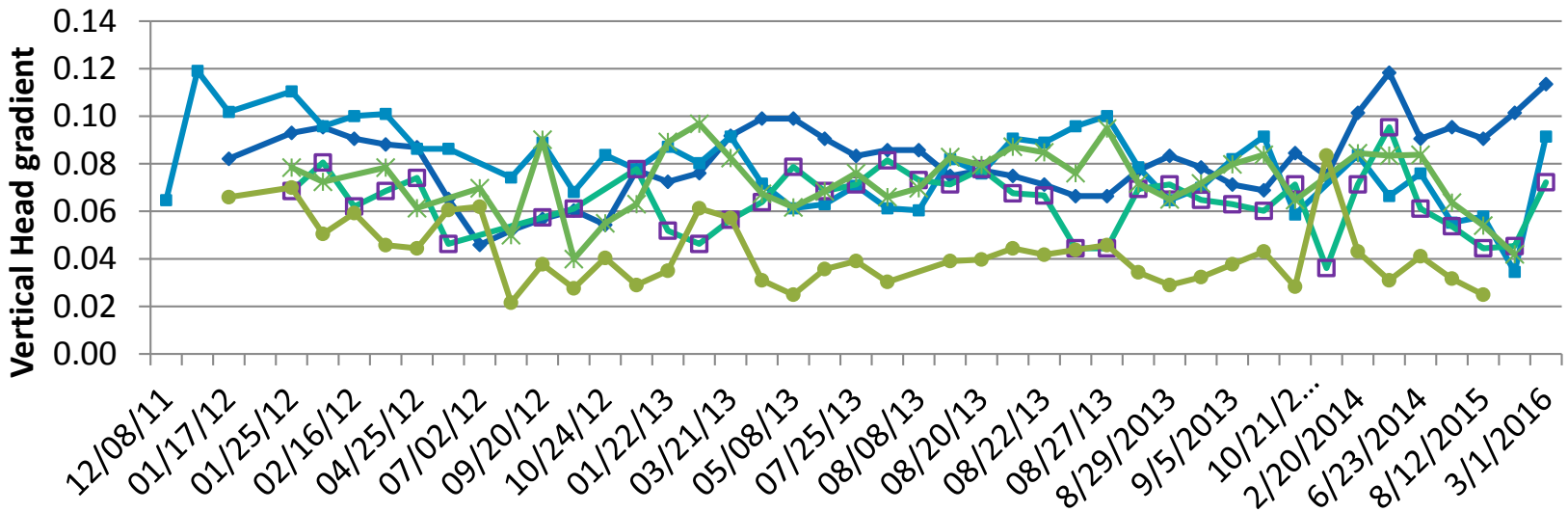
Site 135- GM, GC, C. Adjacent to creek channel with regular flooding; lower CBs

Site 8- GM. Adjacent to upland boundary; highest CBs

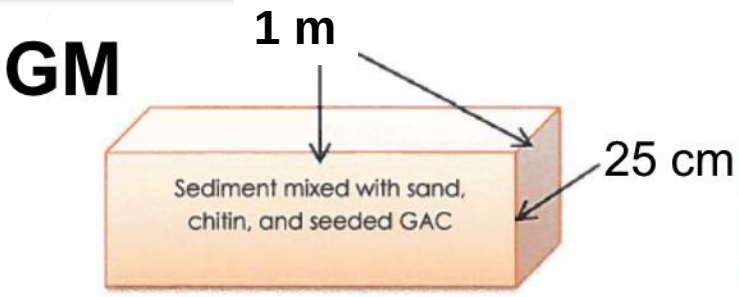


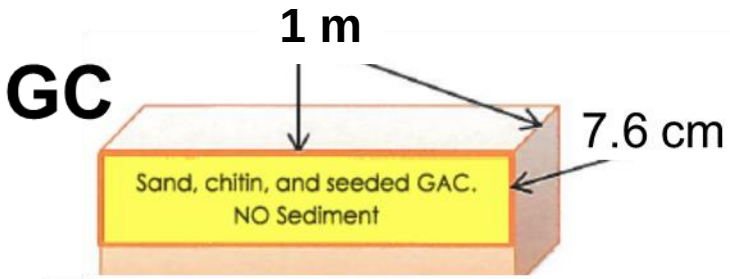


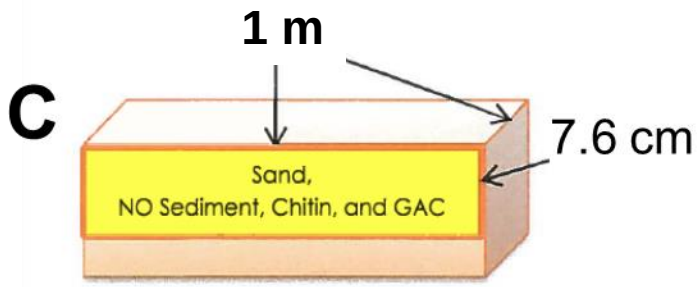
Vertical head gradients in wetland piezometers have remained upward during 2011-16.



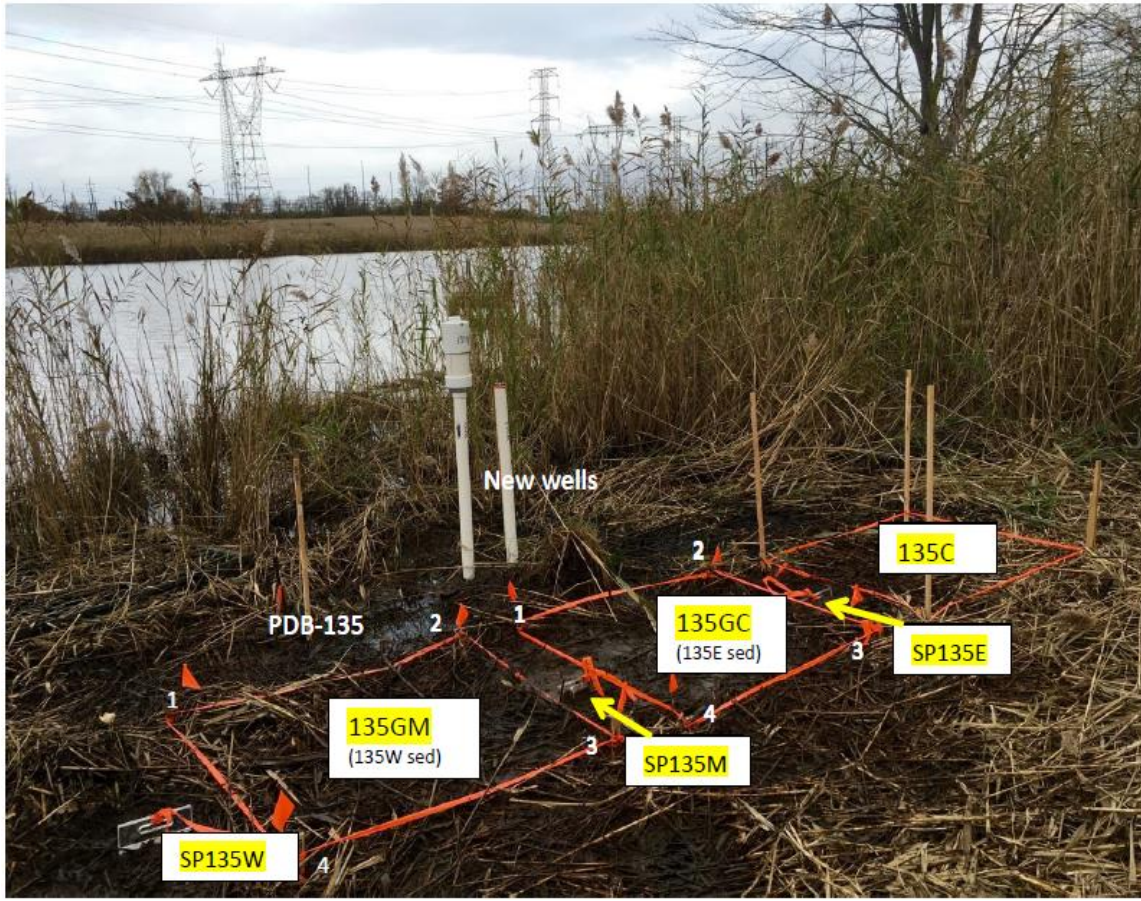
Reactive Barrier Pilot Test Plots







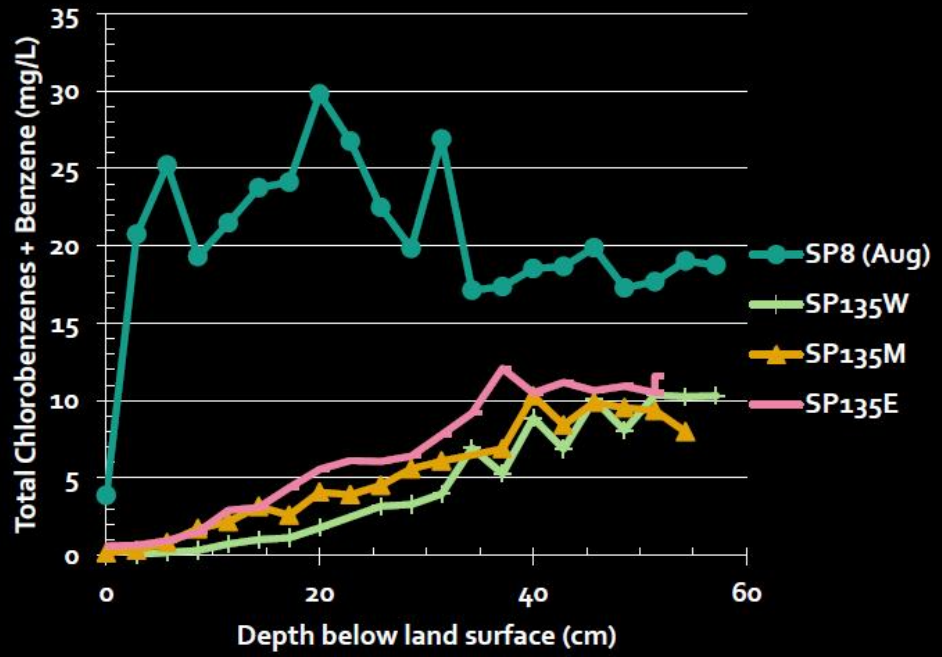
Vol %	GAC	Chiten	Sand
GM	5	3	12
GC	5	3	92
C	5	3	100



Site 135- GM, GC, and C test plots and pre-installation sampling.

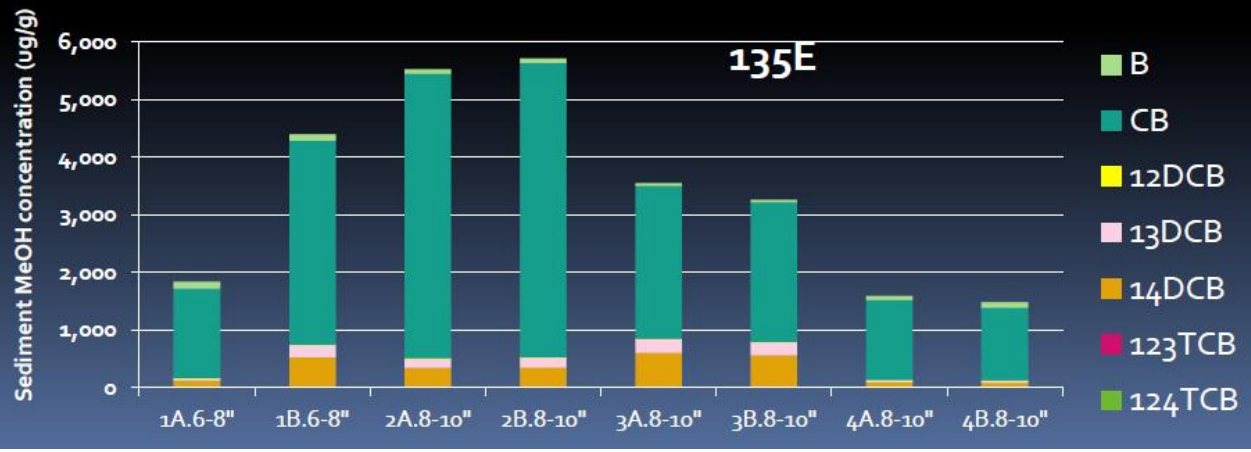
Pre-Installation Sampling

Peepers for porewater sampling



200 screws per peeper

Sediment VOC analysis by methanol extraction at four corners of each test plot



Pilot Test Installation- GAC Preparation

Bacteria transported to site in trailer along with a nitrogen tank for WBC-2.

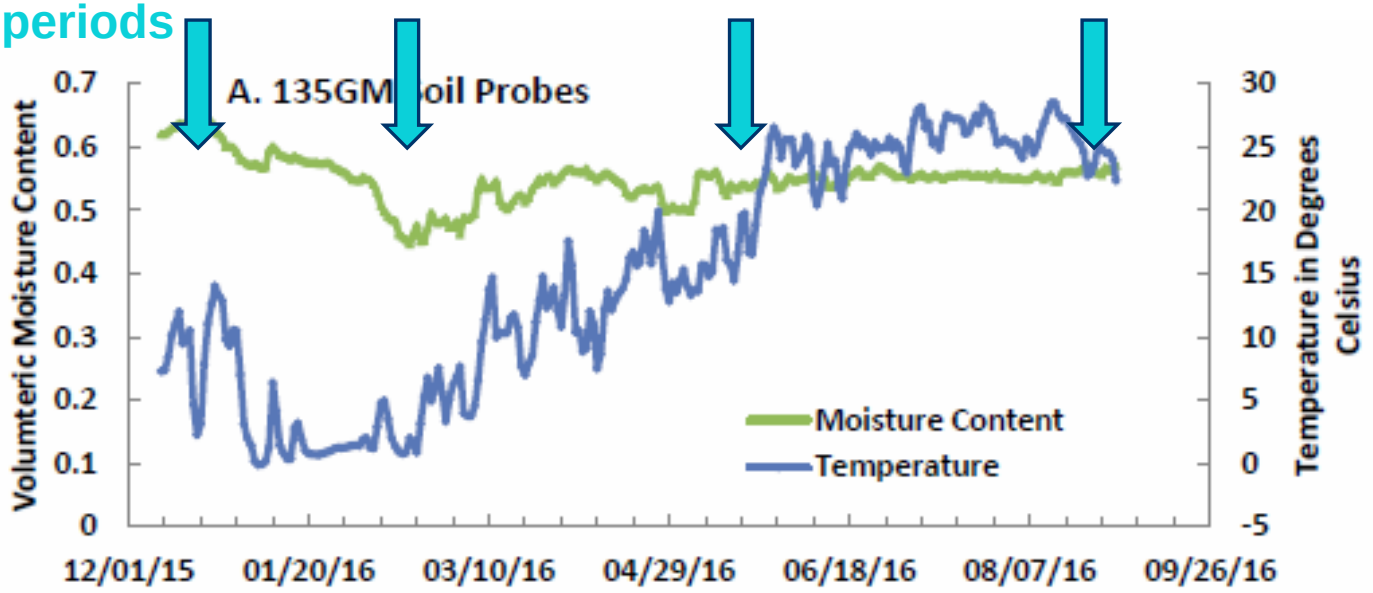
WBC-2 seeded GAC in mesh bags transferred for seeding with 15B aerobes

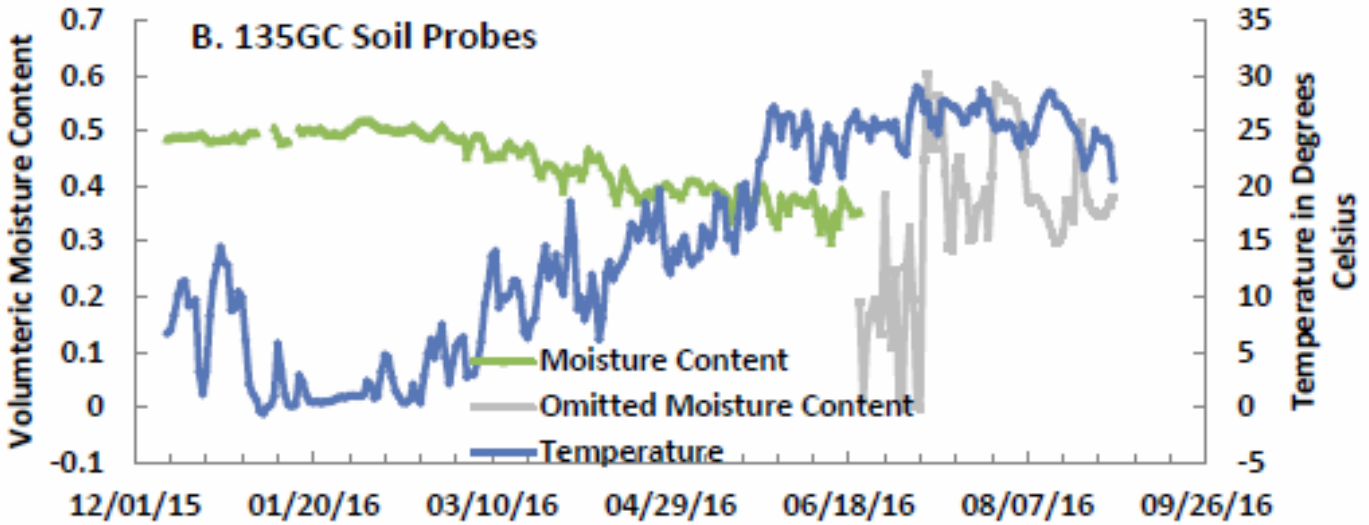
Pilot Test Installation

Buckets of pre-measured sand-chitin-seeded GAC dumped in plot and mixed into sediment to depth of 10 inches with small auger or “egg-beater” attachments on drill.

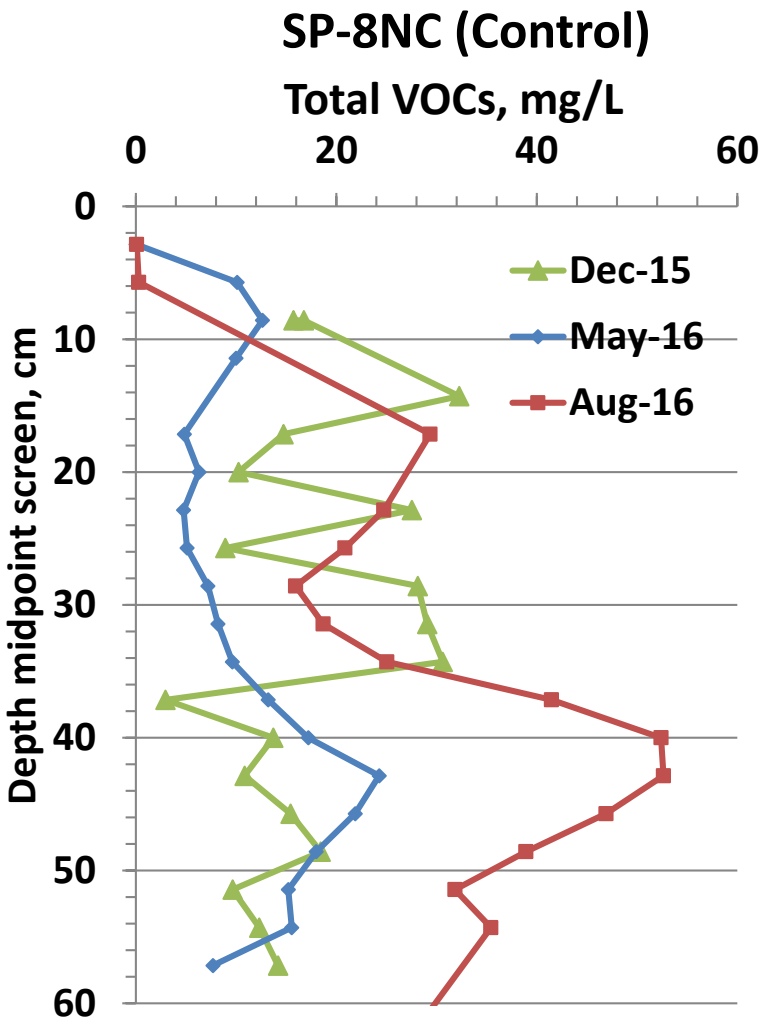
Sampling periods

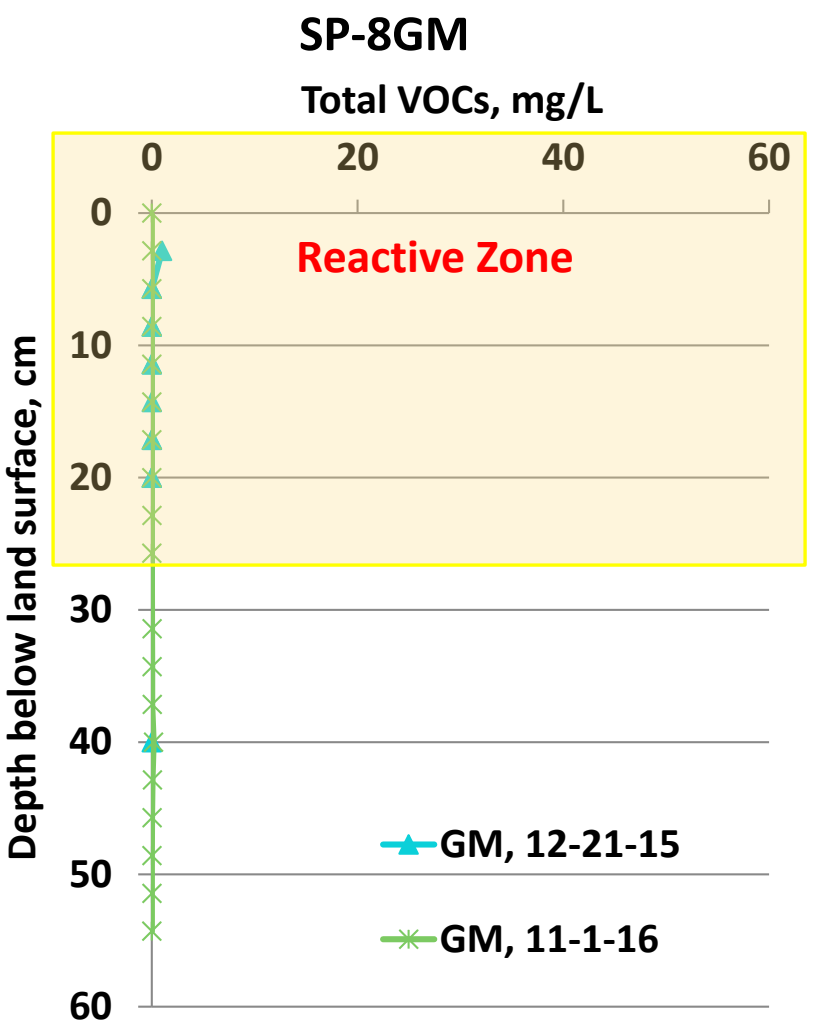
Moisture content in sand cap (GC) was variable compared to mixed plot (GM).



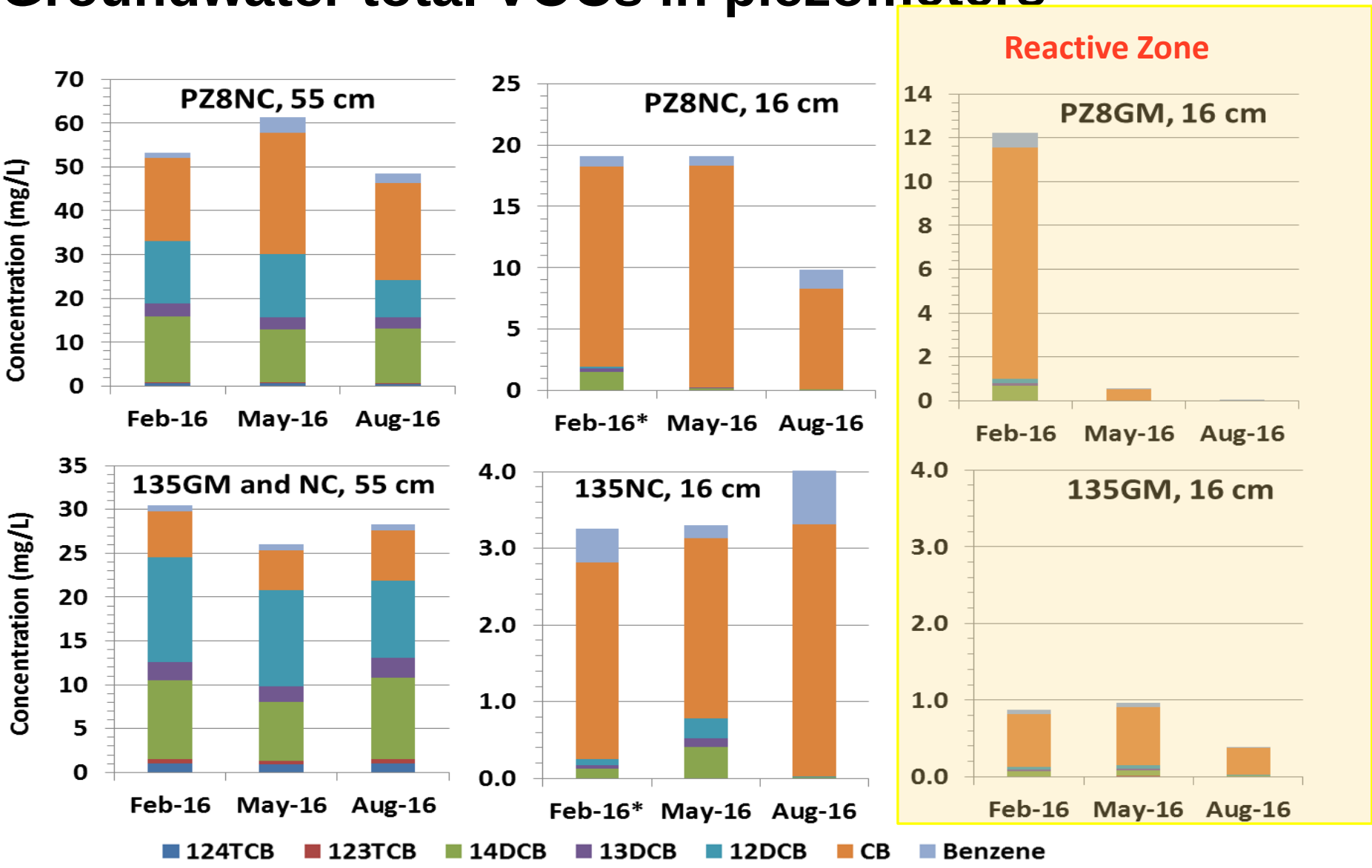


Groundwater total VOCs in peepers





Groundwater total VOCs in piezometers

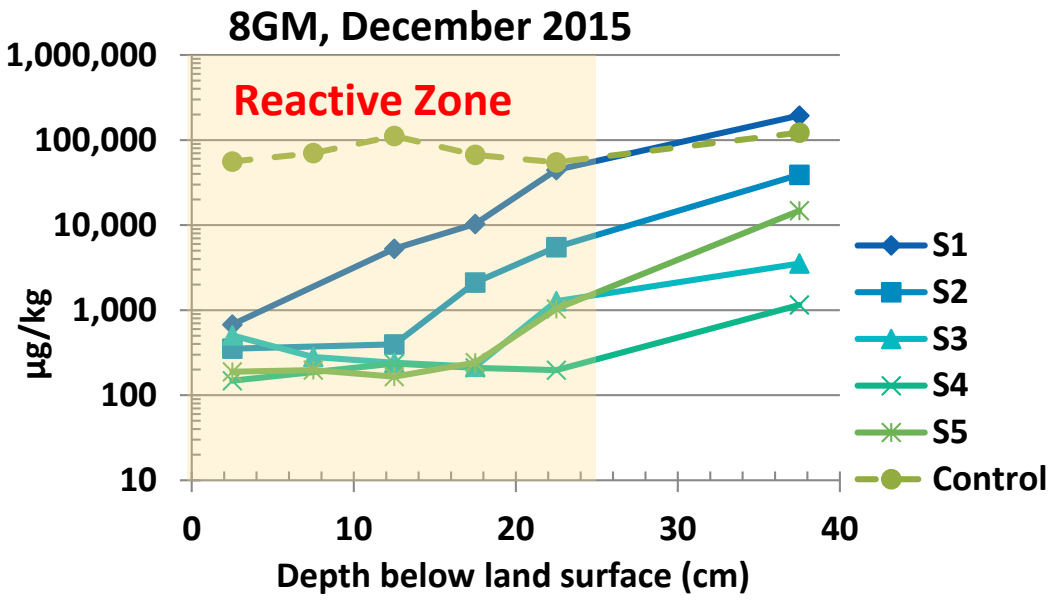


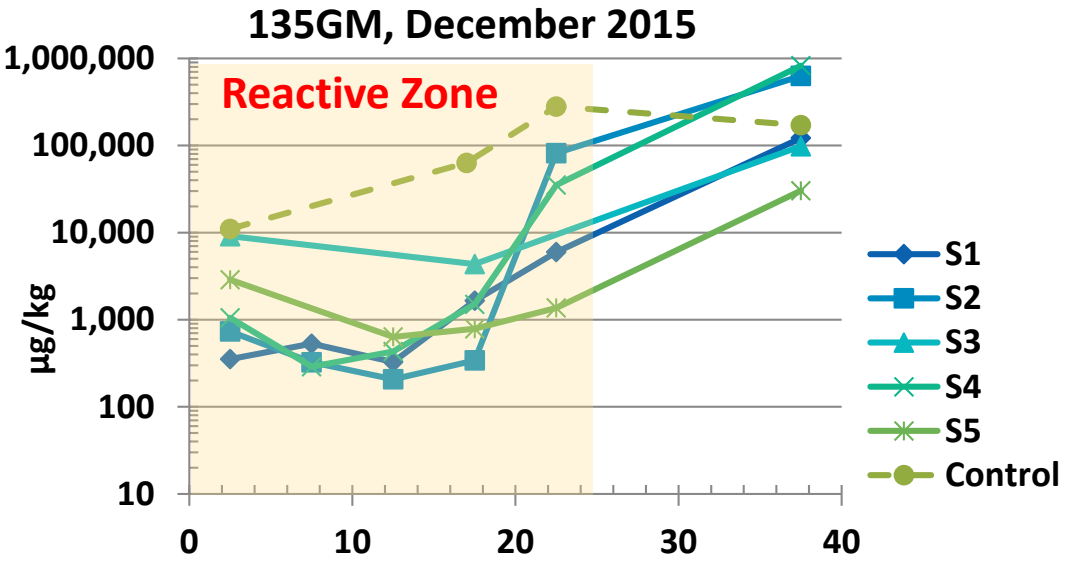
Sediment total VOCs- 12 days post-install 18 pore volumes

- Methanol extraction of sediment samples
- 1-3 orders of magnitude decrease in reactive zone in GM (mixed) test plots at both sites

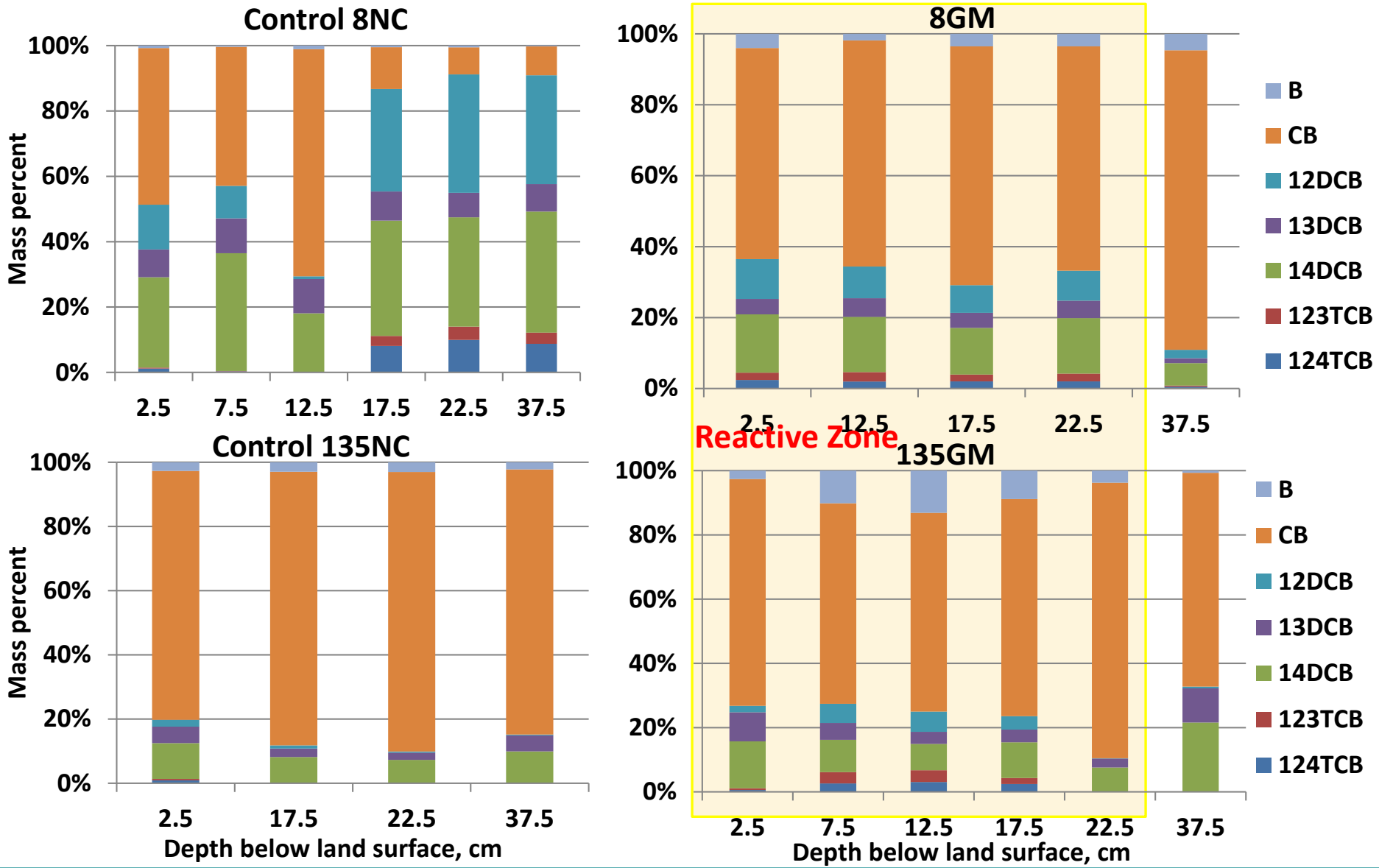
	cm									
	10	20	30	40	50	60	70	80	90	100
10										
20										
30			S1					S2		
40										
50					S5					
60										
70										
80			S4					S3		
90										
100										

Sediment core sites in reactive barrier test plot



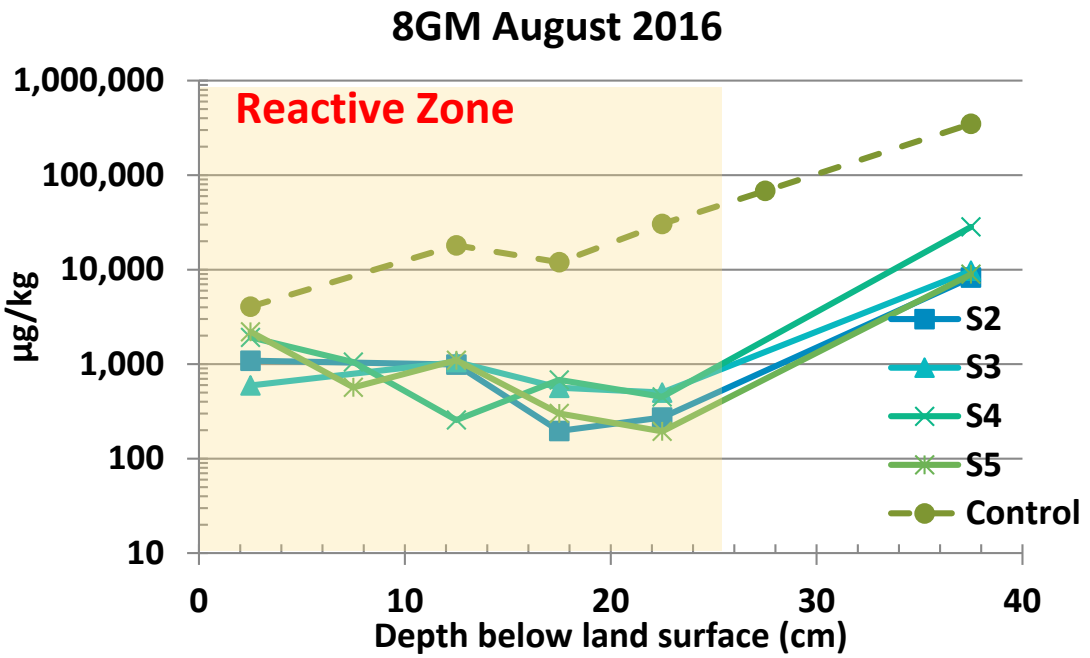


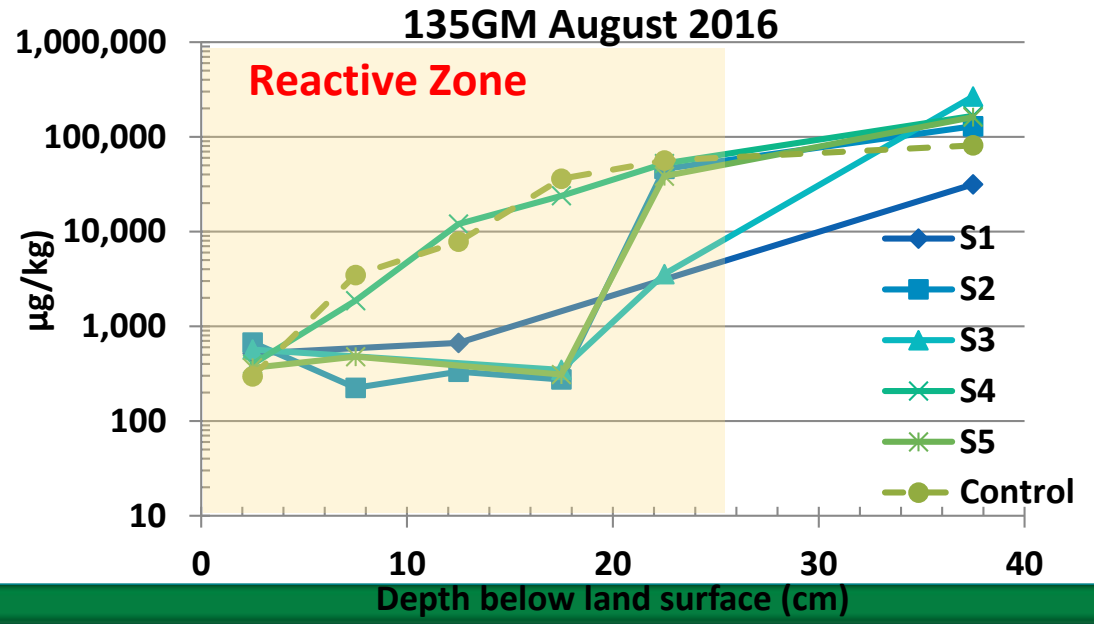
Sediment VOC Composition- 12 days post-install (18 PV)



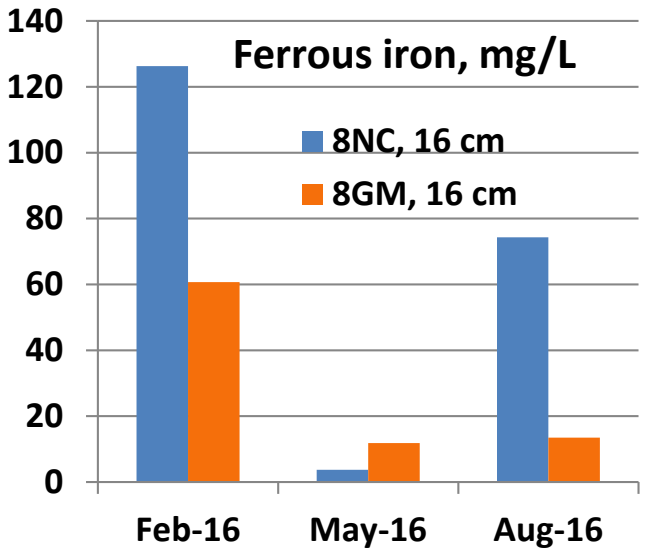
Sediment total VOCs- 256 days post-install 400 pore volumes

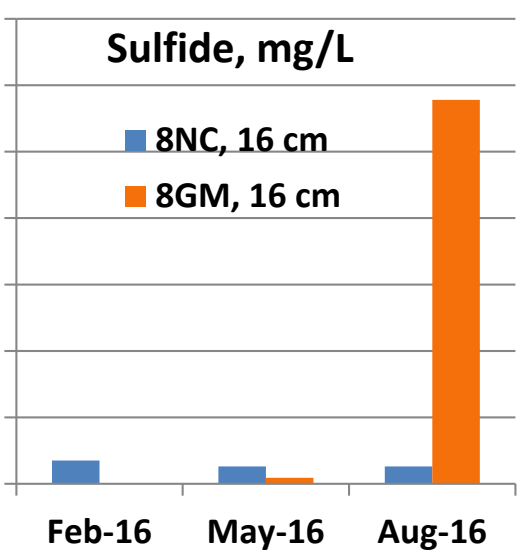
- Methanol extraction of sediment samples
- Consistent removal of total VOCs in sediment
- More loss in control sediment in August near surface (high root mass)

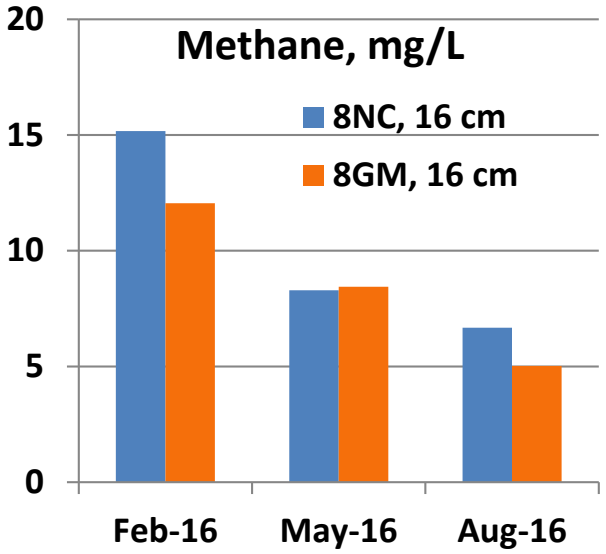


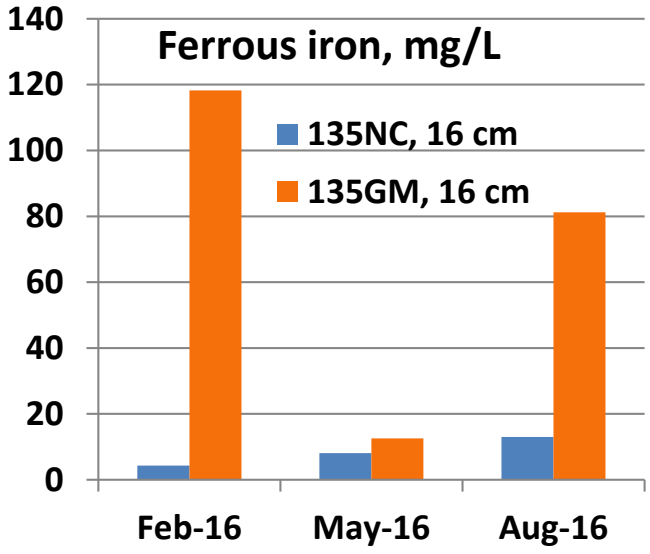


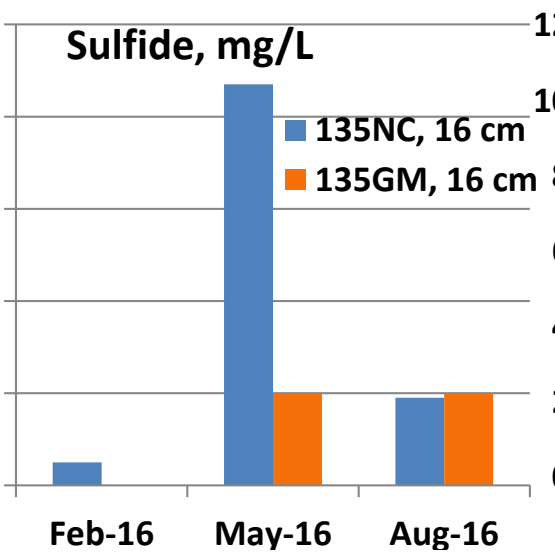
Groundwater Redox: Control and Reactive Barrier, 16 cm

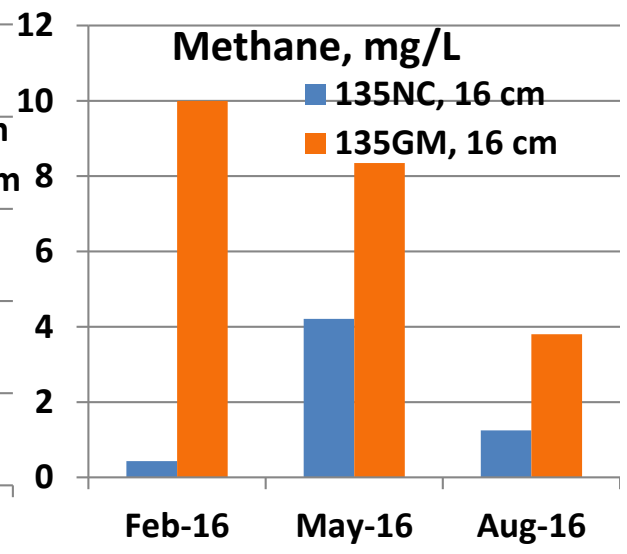






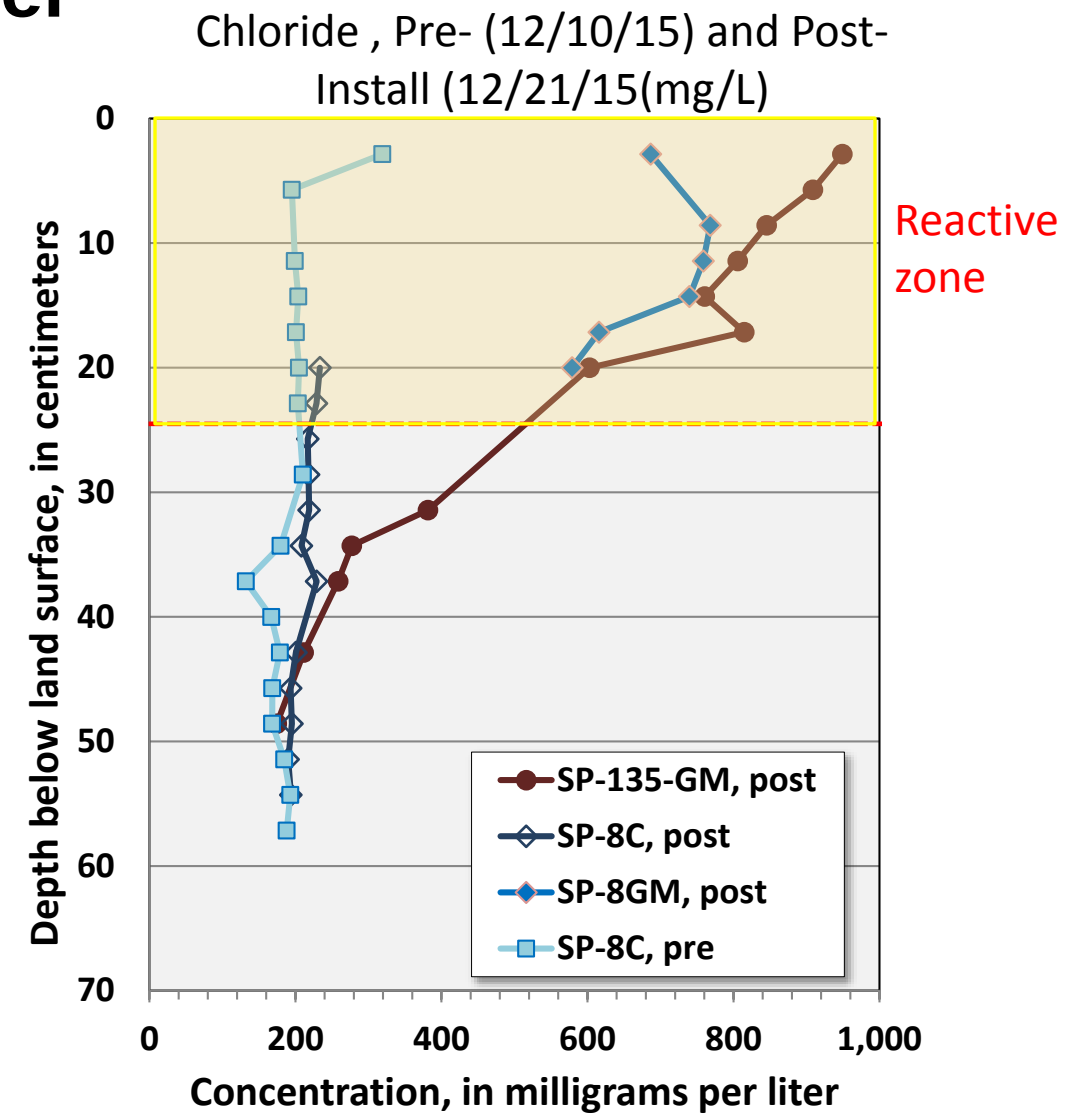






Chloride in porewater (peepers)

- Chloride concentration increases by **factor of 3 to 5** in reactive zone compared to pre-install samples and to beneath reactive zone
- Indicates degradation of CBs in porewater and sorbed to sediment.
- Chloride still elevated in August 2016



Questions?