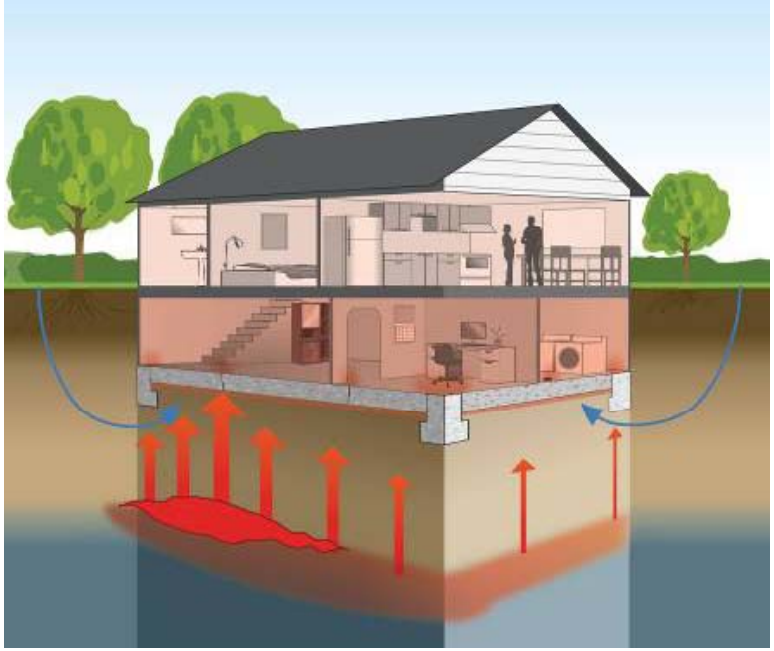

SOIL VAPOR INTRUSION FIELD RESEARCH PROGRAM - EVALUATION OF SOIL VAPOR ATTENUATION ABOVE RESIDUAL MGP IMPACTS AT SITE IN WISCONSIN

AWMA VI 2010 Conference Chicago, IL, September 29-30

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Outline

- Project Objectives
- Site Characterization Methods
- Overview of Site Characterization Results
- Capping Study
- Modeling Methods
- Modeling Results
- Conclusions

Project Objectives

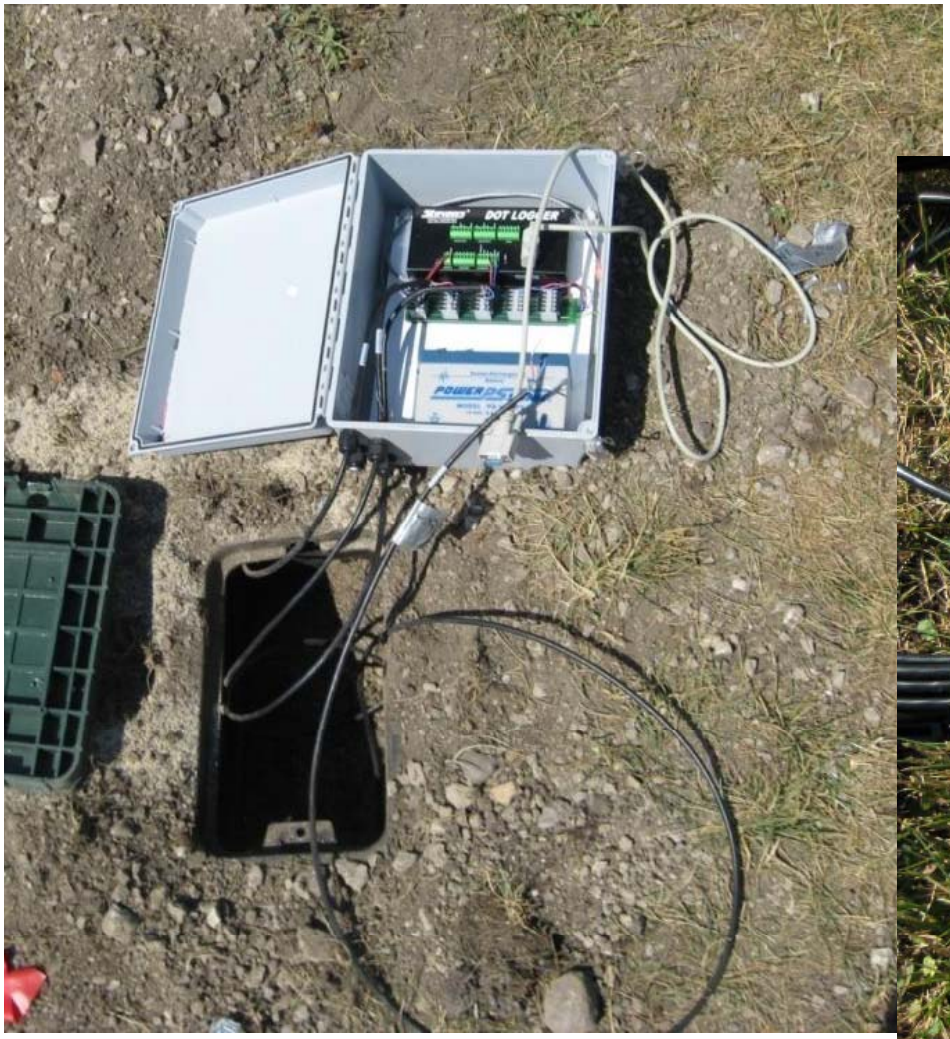
- Characterize the soil vapor intrusion (SVI) potential at remediated MGP sites with residual impacts
- Assess the significance of *vadose zone natural attenuation* (VZNA) for biodegradation of MGP chemicals
- Use site studies to evaluate alternative characterization methods to assess SVI for sites with buildings and sites with future development potential
- Assess approaches/methods for mitigation of SVI

Site Characterization Methods

- Passive Gore Sorber survey
- Soil and groundwater quality testing
- High resolution soil gas profiling, and repeated sampling to obtain temporal data
  - Field analysis of O_2, CO_2, CH_4 by Landtec GEM-2000; Hydrocarbons by PID
  - Laboratory analysis TO-15, TO-17, Modified 8260

- Soil physical property testing
- Monitoring soil moisture using capacitance probe
- Real-time polymerase chain reaction (PCR) molecular testing

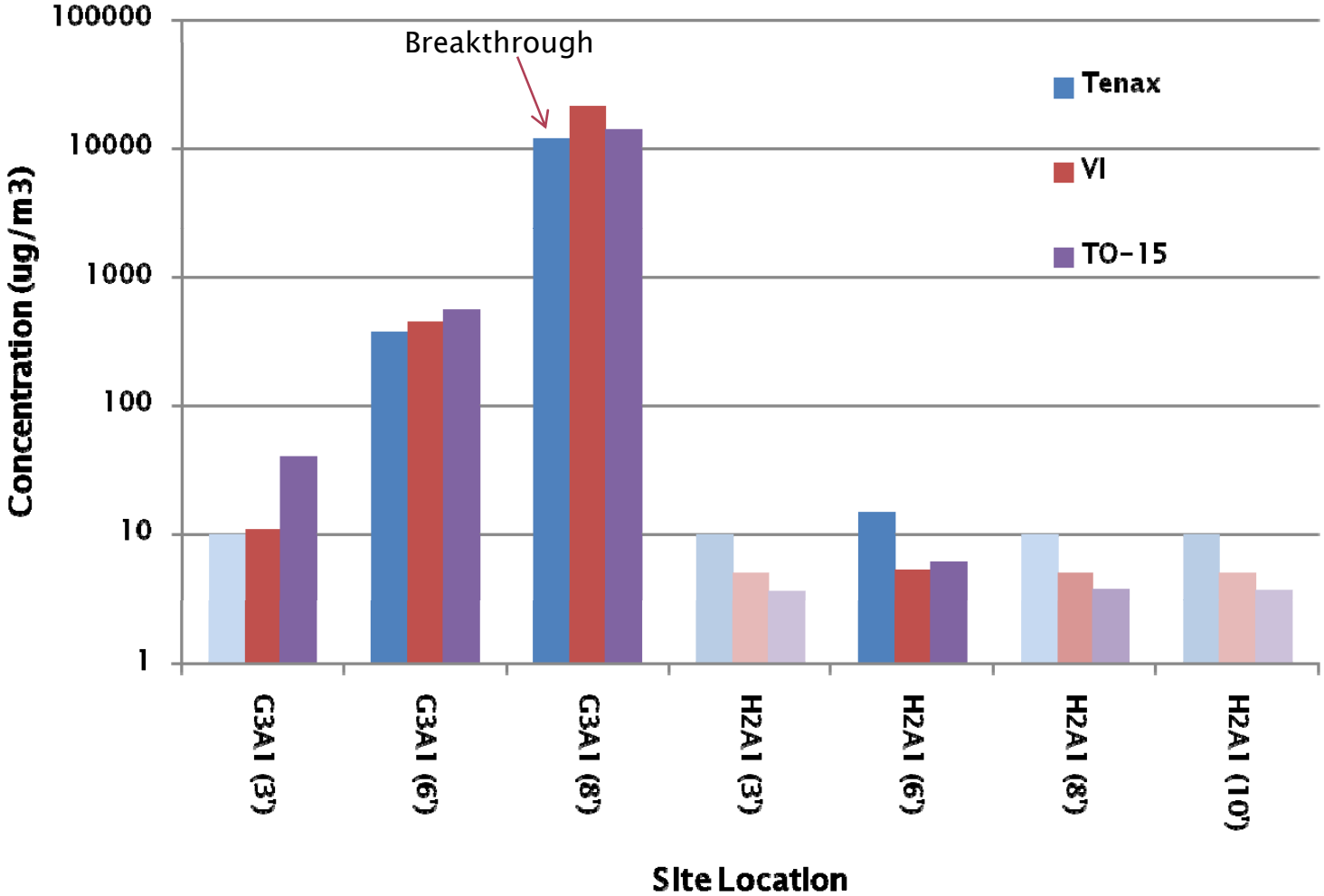
Soil Moisture Study



Study Area Characterization Results

- Depth to groundwater is approximately 10 ft.
- Localized residual NAPL near to water table
- Benzene and naphthalene groundwater concentrations equal to 2300 µg/L and 940 µg/L, respectively
- Vadose zone soils are dense clayey, silty sand fill (area excavated to ~12 ft.) with high water-holding capacity, localized deep gravel in one area; in-filled channel near study area with organic matter
- Anaerobic biodegradation in deep vadose zone, aerobic biodegradation (of MGP-vapors & CH_4) & rapid attenuation of hydrocarbon vapors between primarily 6 and 8 ft. depth
- PCR analysis indicated aromatic hydrocarbon-utilizing bacteria are locally present but not uniformly distributed

Benzene Soil Gas Comparison - April 2010



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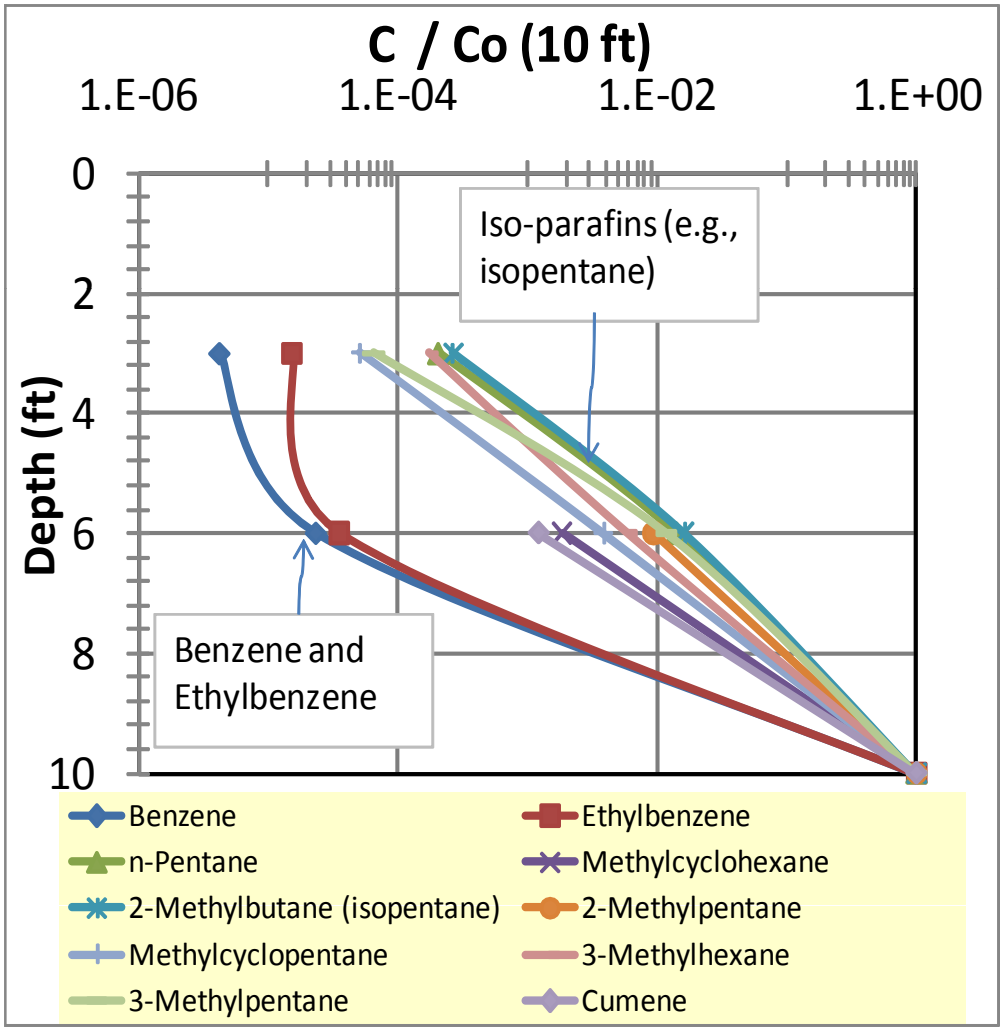
What is Vapor Composition and Relative Attenuation?



- Extended PIANO analyte list
- Aromatics ~67% (benzene highest concentration), aliphatics ~ 33%
- BTEX vapors attenuate to greater degree than iso-parafins (e.g., iso-pentane)
- Naphthalene concentration low even in deep vapor! (equal to or less than 200 ug/m^3)

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Capping Study

- Bioattenuation is a significant process under current conditions
- How might vapors change under future development scenario?
- Broader context are recent efforts to develop screening approaches for degradable hydrocarbons (e.g., exclusion factors based thickness of clean soil, attenuation reduction factors (e.g., 10X, 100X)
- How would this site fit this framework?

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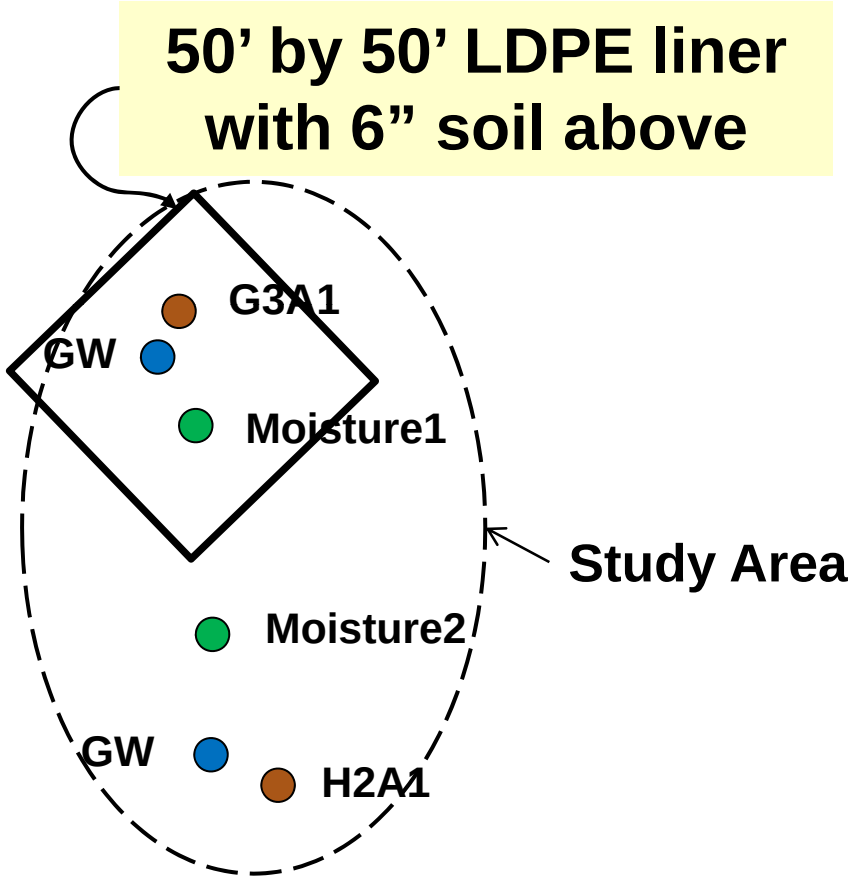
Capping Study

- Would attenuation change with cap simulating building slab?!
- Cap constructed July 2009
- July 2009 – present
  - Field analysis (O2, CO_2, CH_4, PID)
  - Lab analyses (TO-15, TO-17)
- Soil moisture monitoring using capacitance probe and data logger



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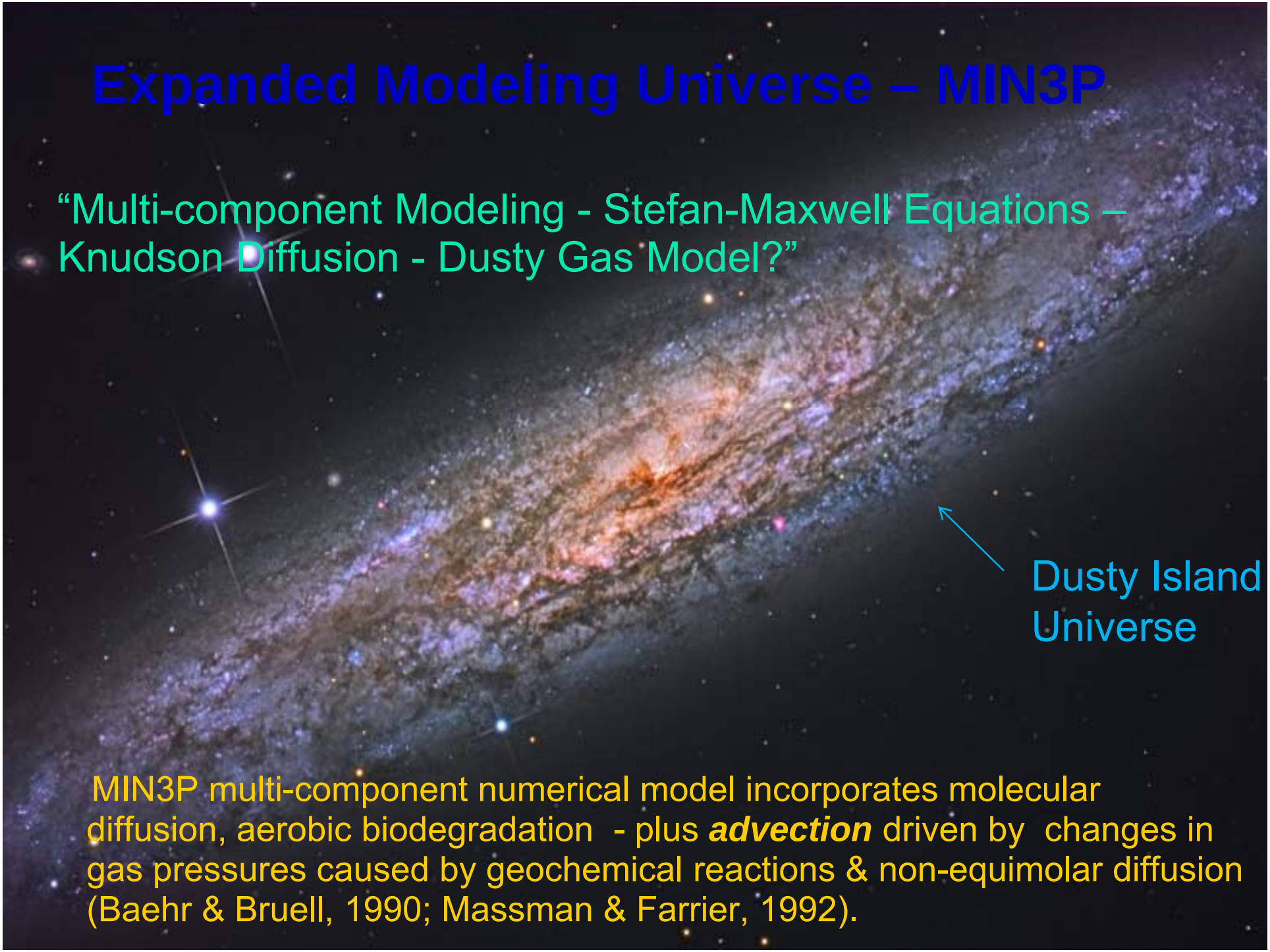
Vapor Transport Modeling

- Conventional vapor transport models generally simulate:
  - Molecular diffusive transport,
  - Aerobic first-order biodegradation, and
  - Soil gas advection through an external pressure gradient (e.g., depressurized building, barometric pumping)

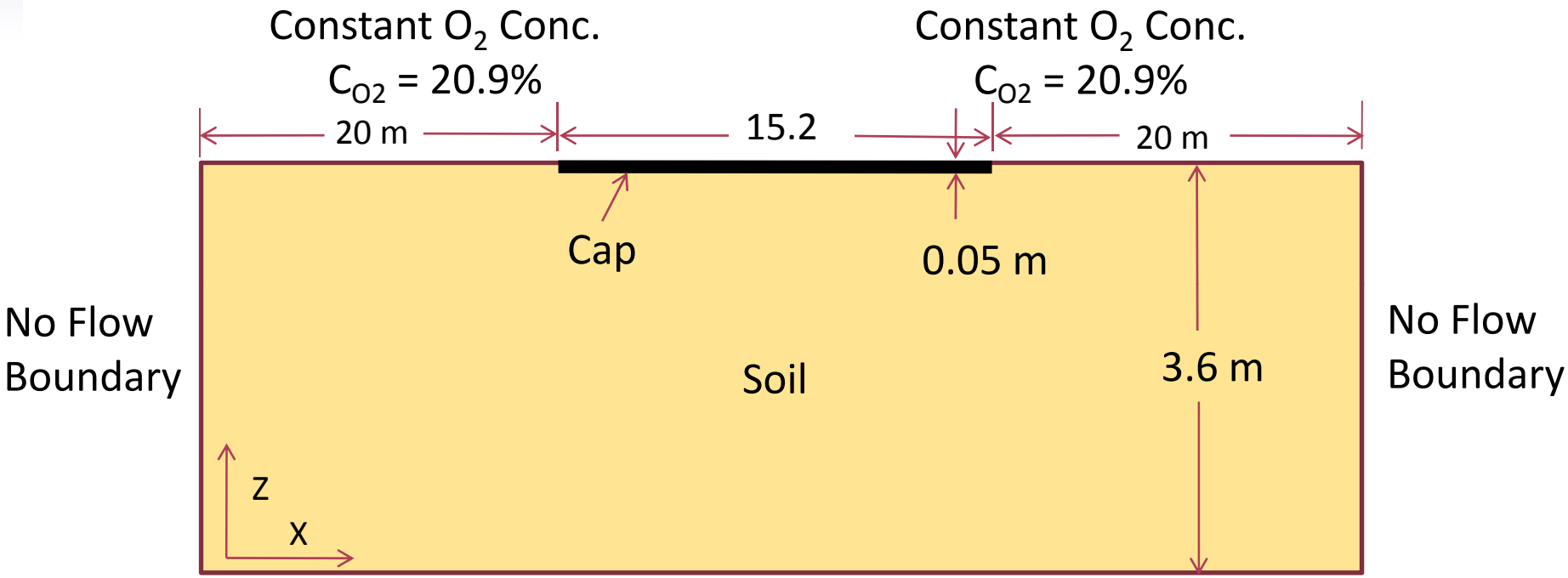
Expanded Modeling Universe – MIN3P

"Multi-component Modeling - Stefan-Maxwell Equations – Knudson Diffusion - Dusty Gas Model?"



MIN3P multi-component numerical model incorporates molecular diffusion, aerobic biodegradation - plus ***advection*** driven by changes in gas pressures caused by geochemical reactions & non-equimolar diffusion (Baehr & Bruell, 1990; Massman & Farrier, 1992).

Modeling Study – Set up



Constant Hydrocarbon Concentration C_{HC}

Two components:

Hydrocarbon = 0.5 mg/L (~0.15%) (Most model runs assume all vapors are benzene)

Methane = 6%

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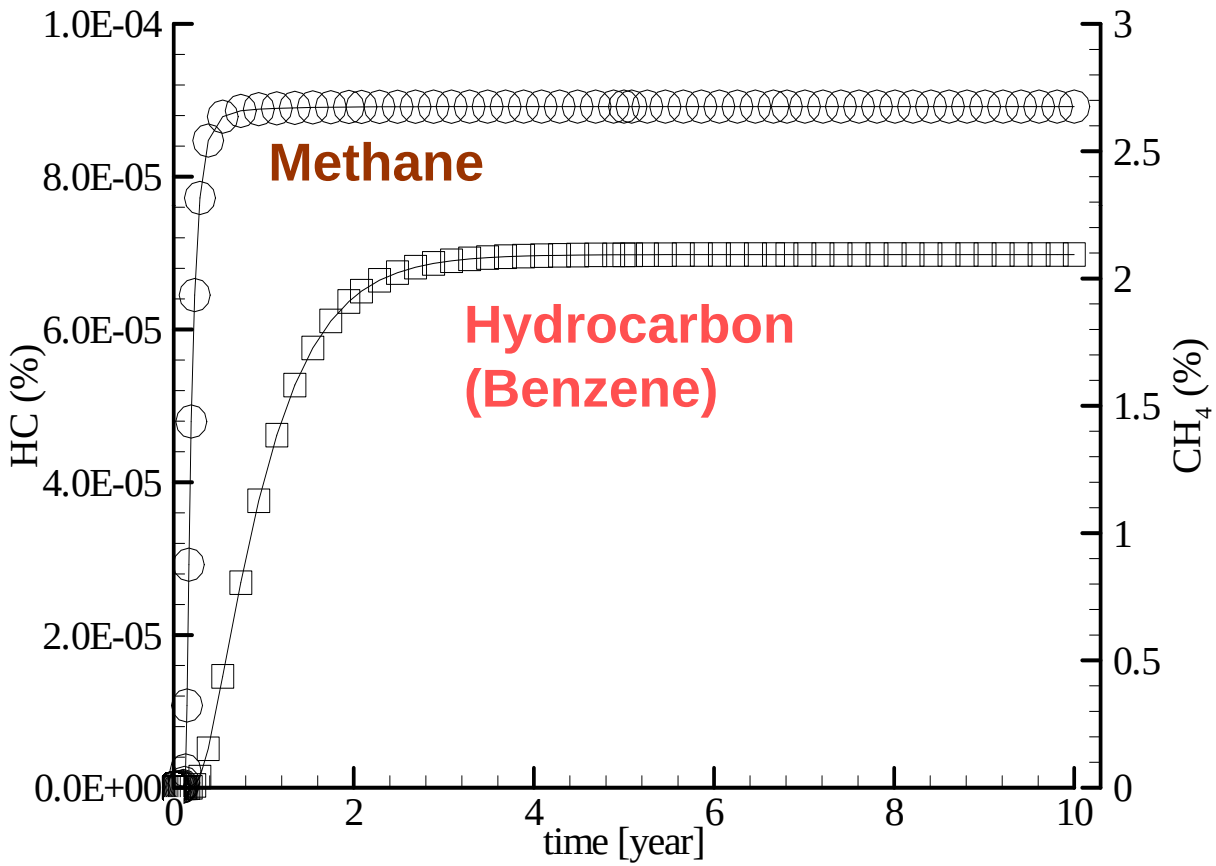
Modeling Study – Transient Results Just Below Center of Cap



- Model predicts ~ 3 years for steady state conditions for benzene to be achieved

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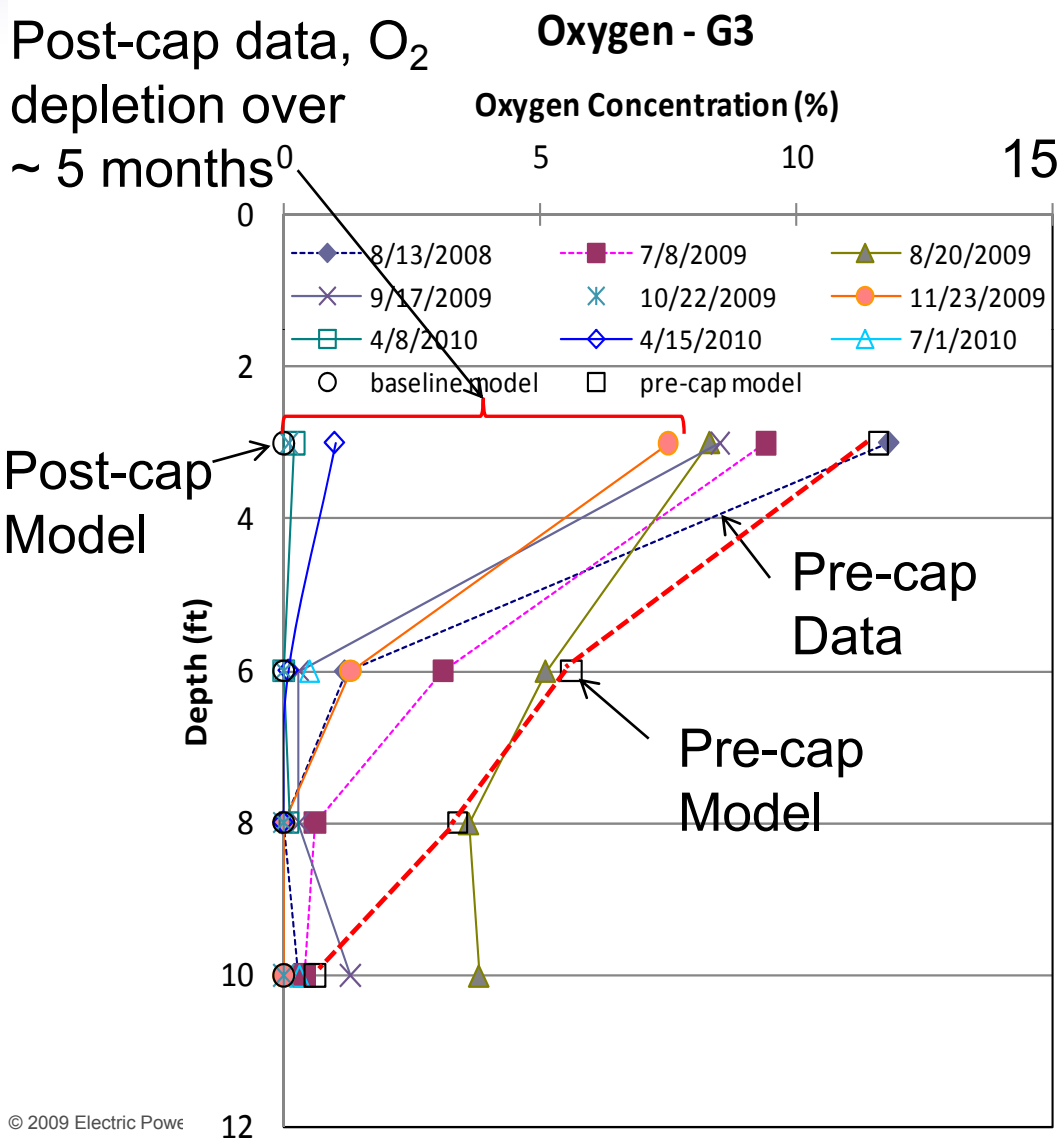
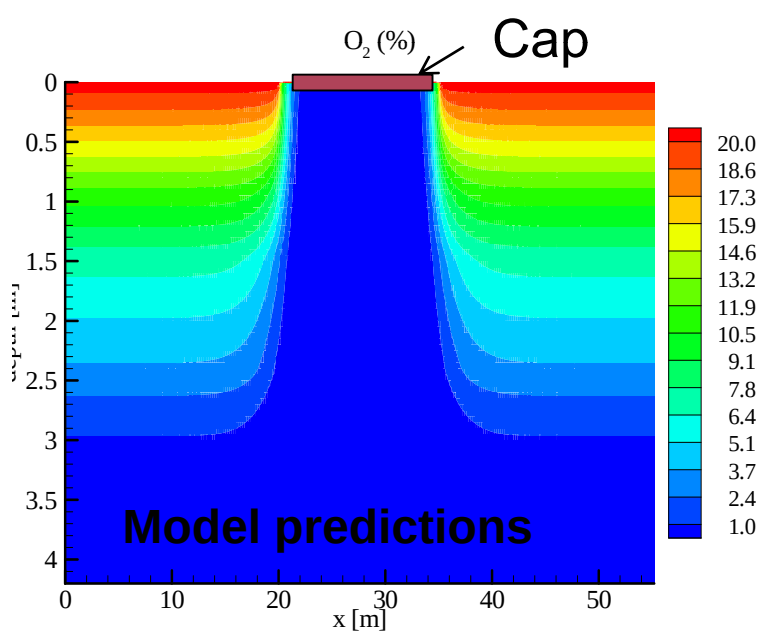
Modeling Study – Oxygen

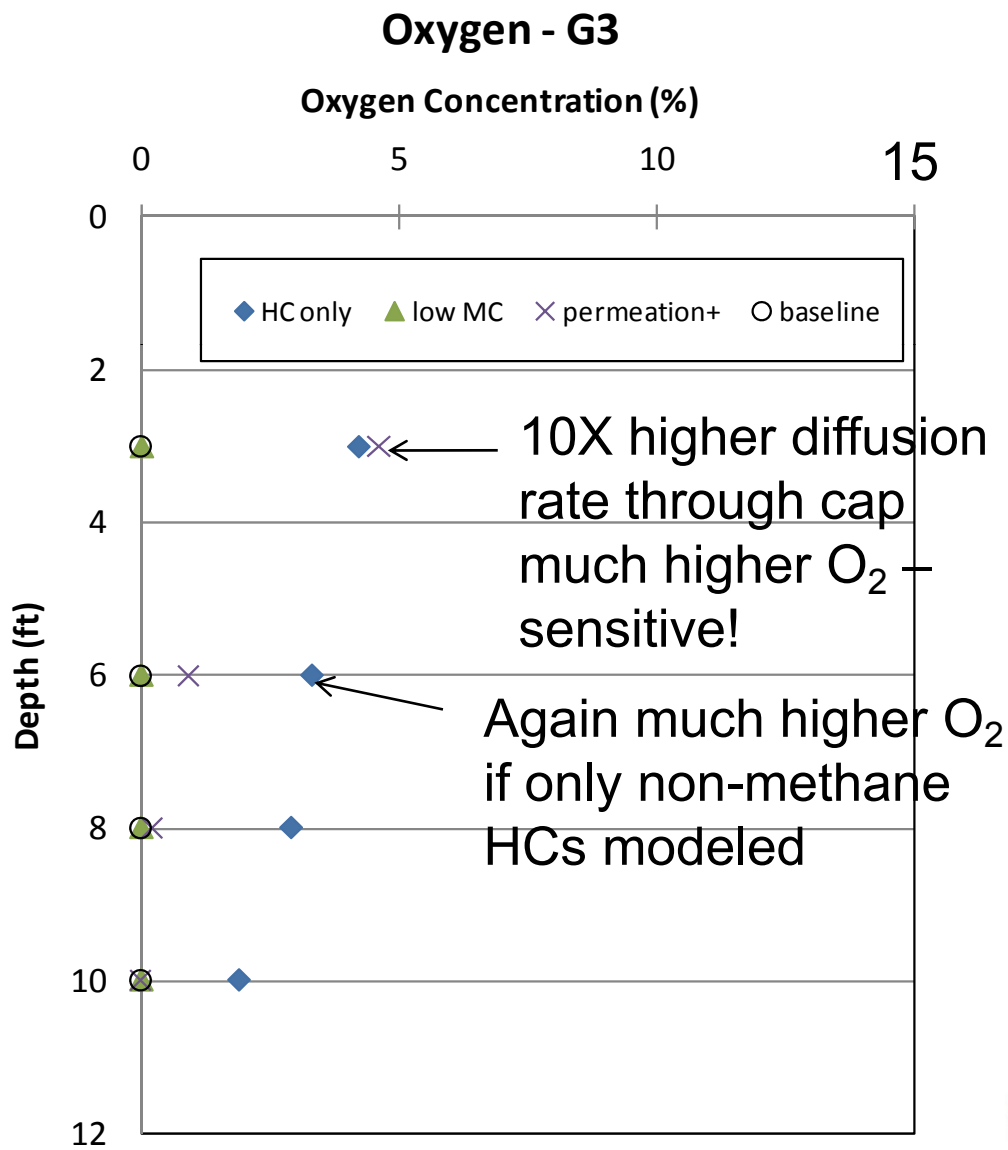
Post-cap data, O_2 depletion over ~ 5 months



Relatively good match modeled and measured data



Modeling Study – Oxygen Sensitivity Post-capping



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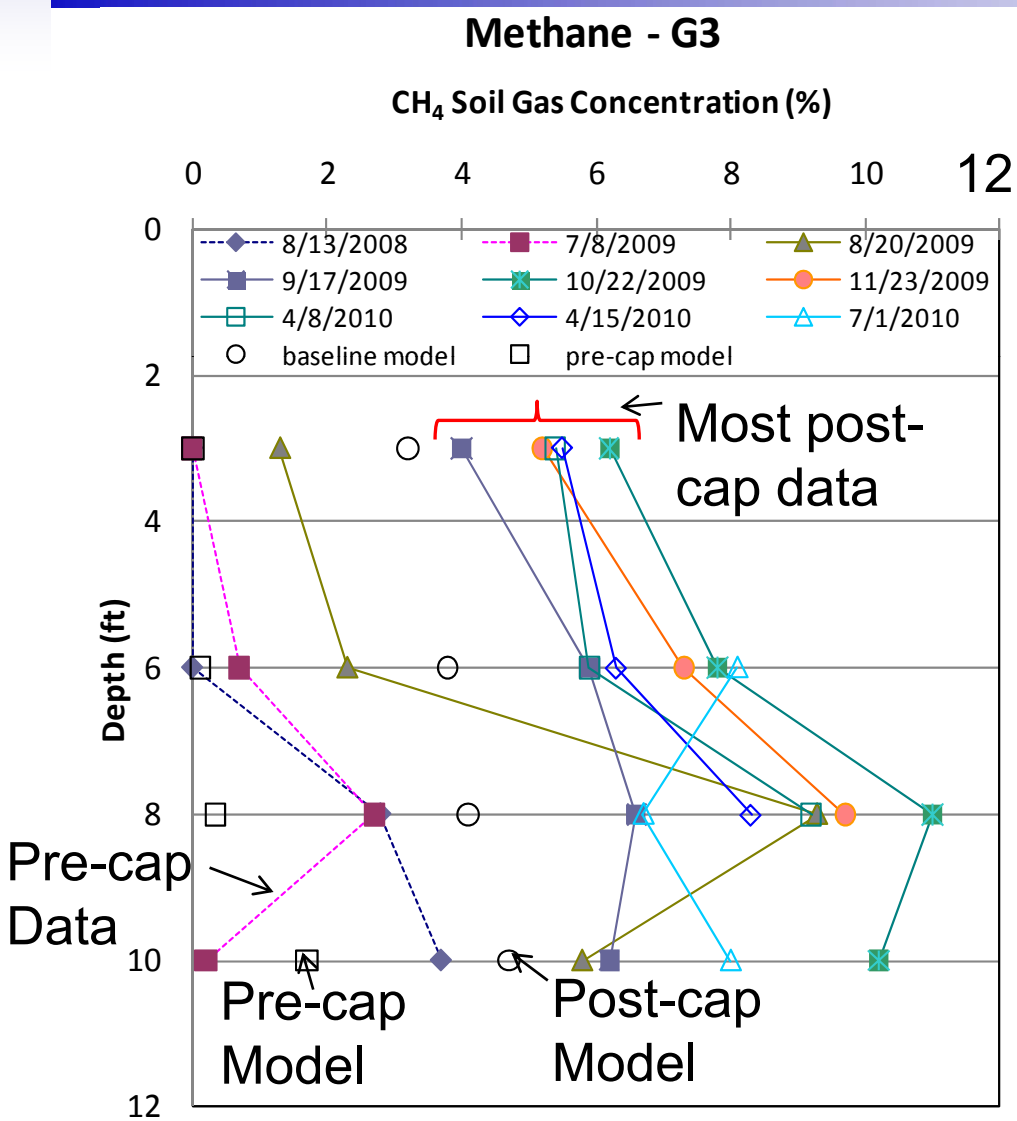
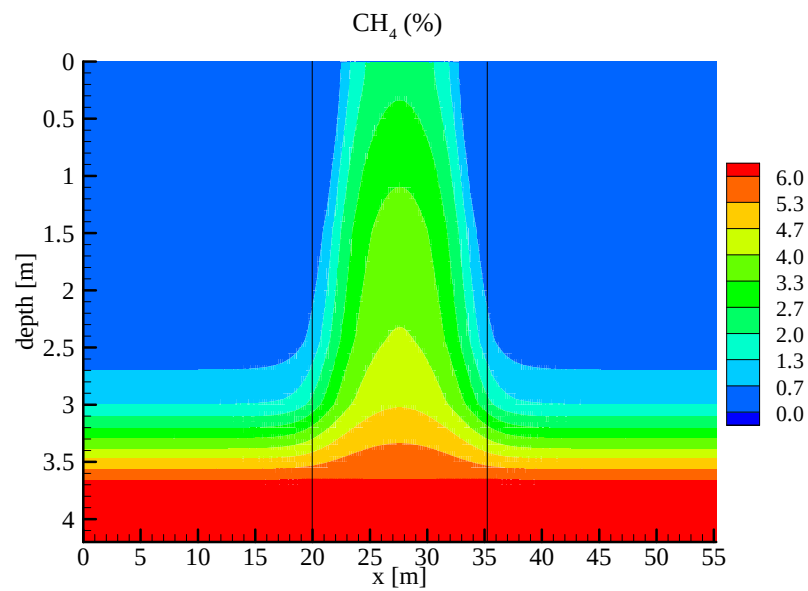
Modeling Study - Methane



Methane concentrations slightly underpredicted



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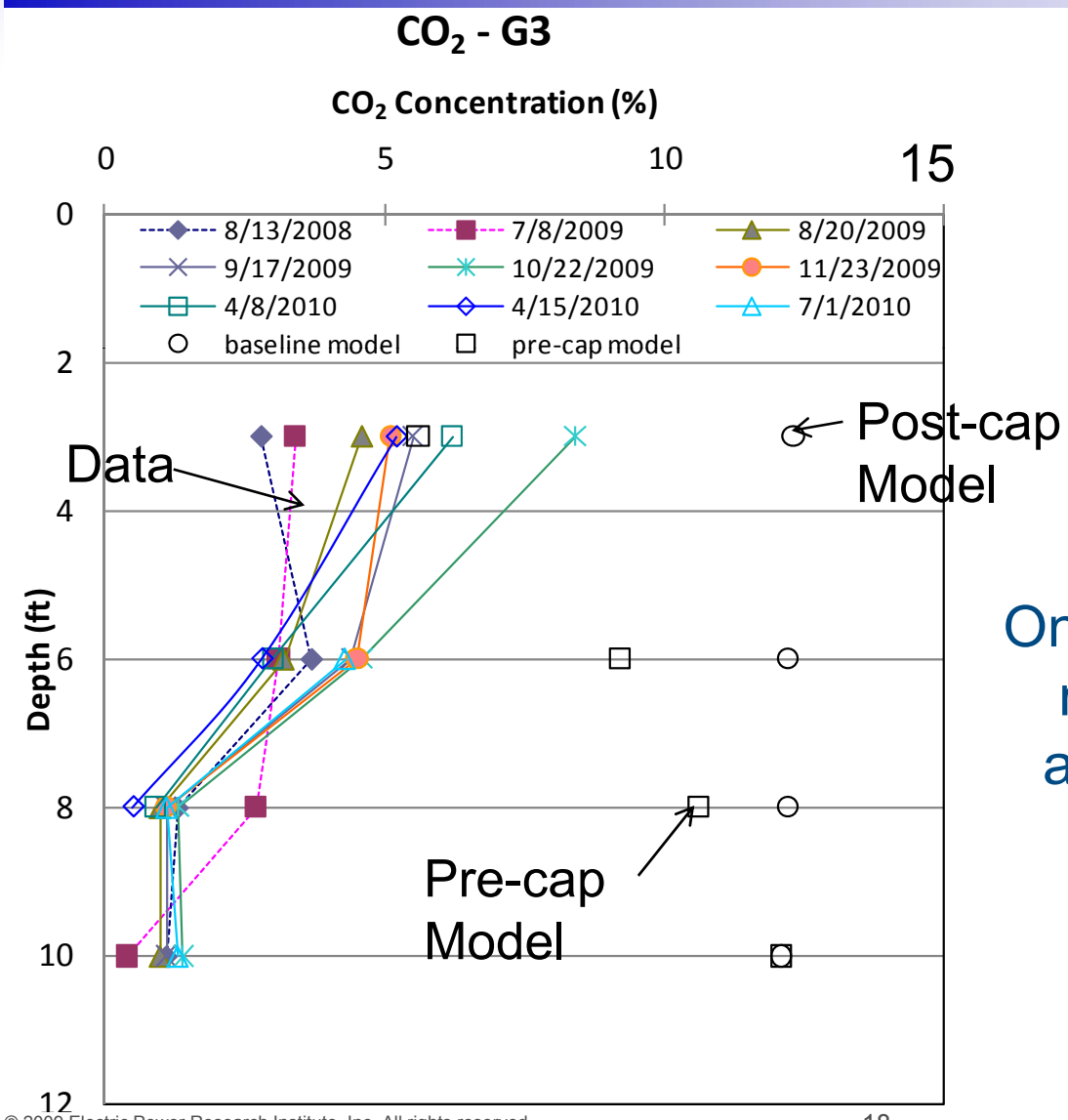
Modeling Study – Carbon Dioxide



Measured carbon dioxide profile was unusual – More often profiles indicate higher CO_2 at depth

One way we have been able to match measured data is to assume high calcite content minerals

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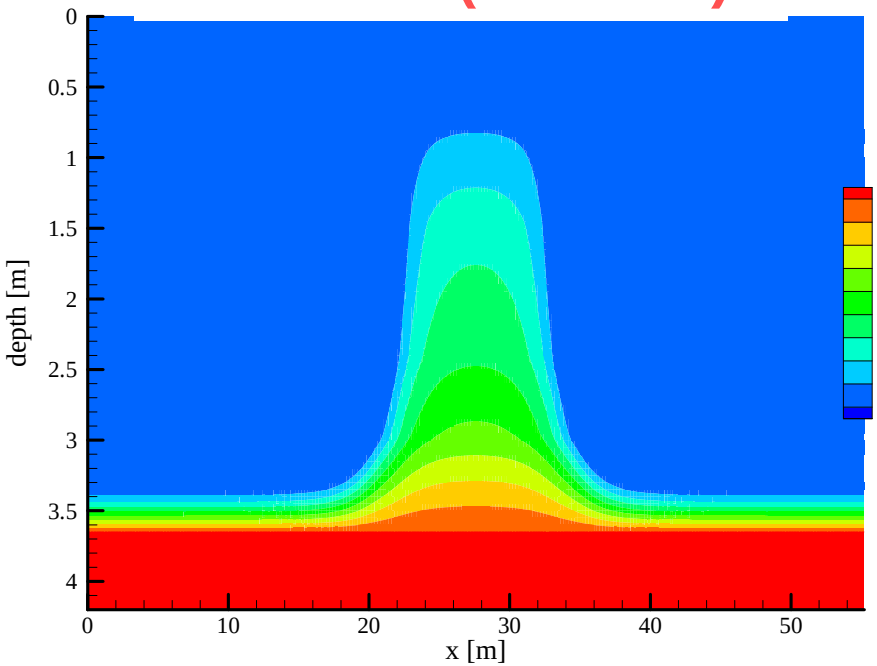
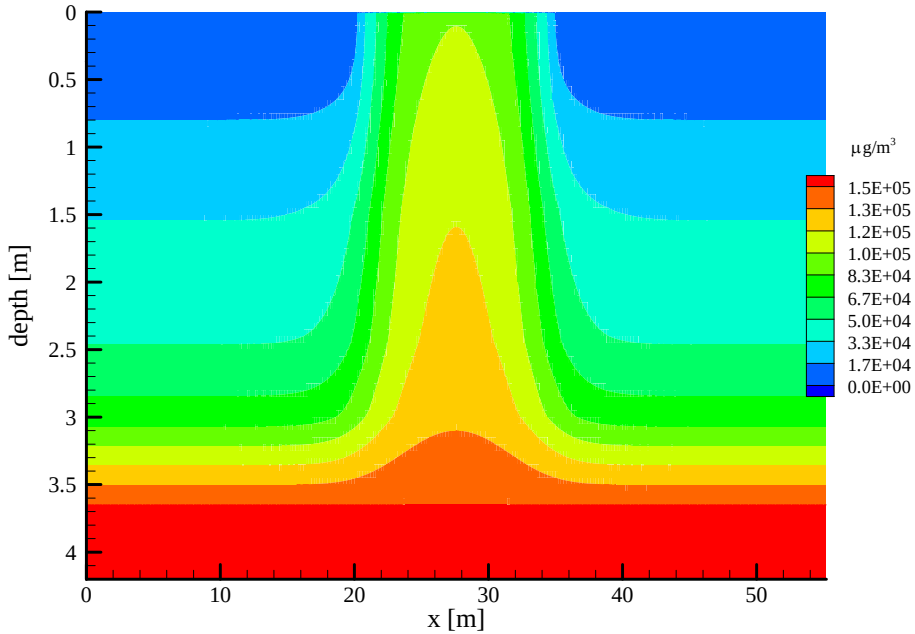
Modeling Study – Comparison Aromatics and Aliphatics

For these model runs divided non-CH_4 hydrocarbons into aromatics and aliphatics

Aromatics (benzene)



Aliphatics (methylcyclohexane)



Different behavior observed;
measured data consistent with model

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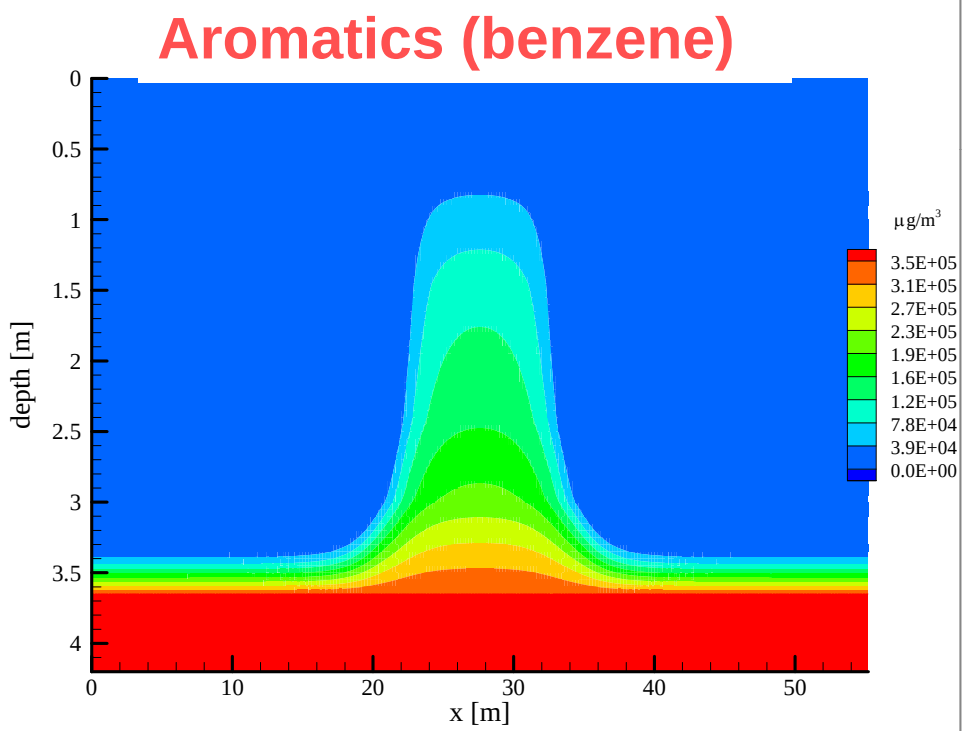
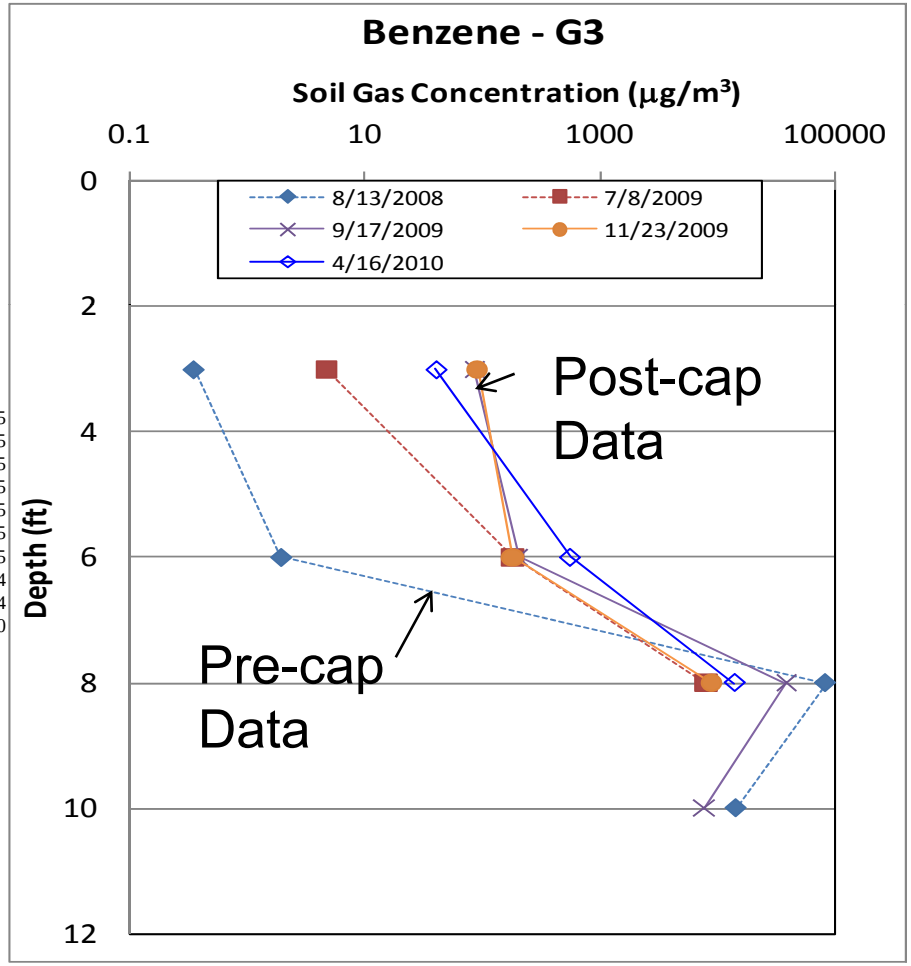
Modeling Study – Aromatics





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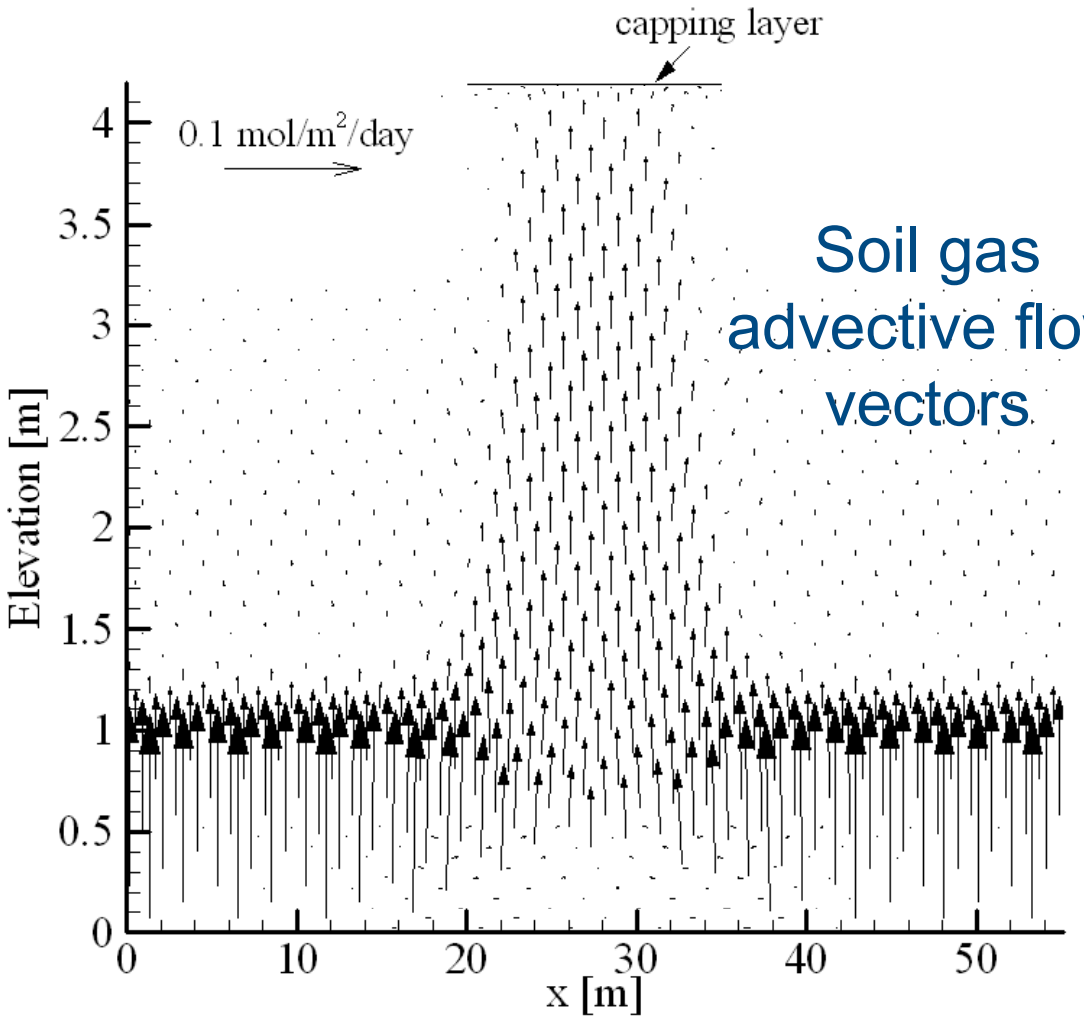
Modeling Study – Results of Advection



Soil gas advective flow vectors

For one model run, turned off advection – resulted in a 5% decrease in the methane flux

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Conclusions – Measured Data for Capping Condition

- A zone of oxygen depletion formed below cap and methane concentrations increased after several months
- Benzene concentrations increased slightly but there was still significant degradation observed (but was steady state reached?)

Conclusions – Some Things Modeling Showed

- Generally good comparison obtained between model predicted and measured concentrations (except CO_2)
- May take several years for steady state conditions to be reached for benzene
- Oxygen below cap is highly dependent on diffusion rate through the cap (a 10X change resulted in completely different profile!)

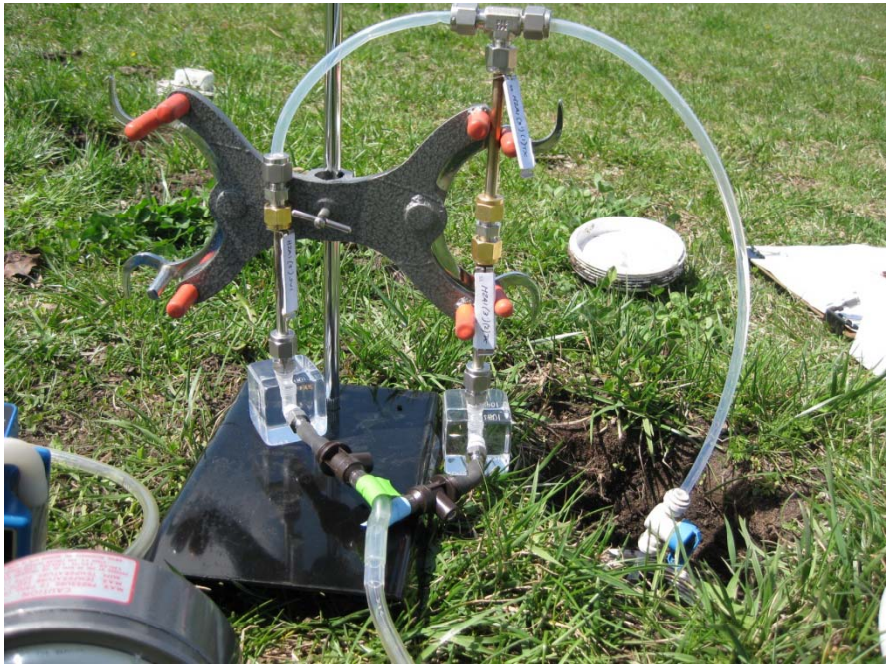
Conclusions – Some Things Modeling Showed (cont.)

- Critical to include methane oxidation demand (otherwise will over predict biodegradation)
- When methane concentrations are high (e.g., 6% in our case) a model that includes advection is more accurate (but difference is fairly small (5%))
- Less attenuation for aliphatic compared to aromatic hydrocarbons (consistent with data)

Conclusions – Big Picture and Future Directions

- Effect of cap not un-expected given elevated methane concentrations, however …
- Aerobic biodegradation is highly sensitive to oxygen diffusion through top boundary – how would this change if concrete slab was simulated? Or if there was a mechanism for oxygen recharge to below slab (e.g., wind, barometric pumping)
- Knowledge gained from modeling studies and empirical data provide basis for framework for identifying when biodegradation can be included in site screening and models

TO-17 Sorbent Media Comparative Study



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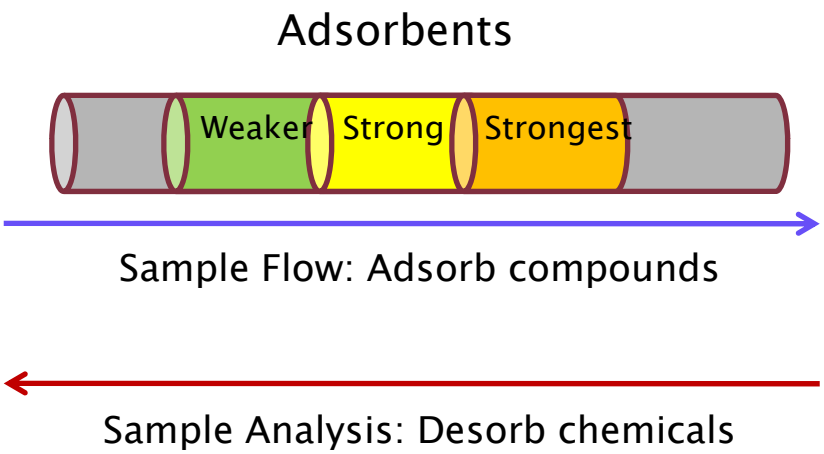
New TO17 Sorbent Technology

Multi-bed 'hydrophobic' sorbent tube designed andtested by Perkin Elmer



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TO17 Sorbent Comparison

✓Little retention of water, ideal for high humidity soil vapor

✓Good performance and sensitivity for naphthalene and PAHs through Pyrene

xElevated RL for benzene due to background from Tenax

xBreakthrough observed for Benzene under high concentration conditions

✓Largely hydrophobic, designed and validated for soil vapor applications

✓Good performance and sensitivity for benzene, naphthalene through Pyrene

✓Low Benzene background translating into a lower reporting limit

✓Retains benzene even when sampling high concentration soil vapor

- Tenax TA TO-17 Tubes

- SVI™ TO-17 Tubes

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TO-17 Naphthalene + PAHs

- Naphthalene + PAH Detections using TO-17
  - April 2010 round: One site had detectable naphthalene levels by TO-17, no sites had detectable levels by TO-15

Compound	Tenax TA µg/m³	VI µg/m³	TO-15 µg/m³
Naphthalene	12	7.4	<24
2-Methylnaphthalene	12	<5.0	NA

  - Air Toxics Ltd. has optimized PAHs on VI tube for next round, lowering RL by a factor of 10.