# Alternate Model-Based Approach for Assessing Vapor Intrusion at Petroleum Hydrocarbon Sites

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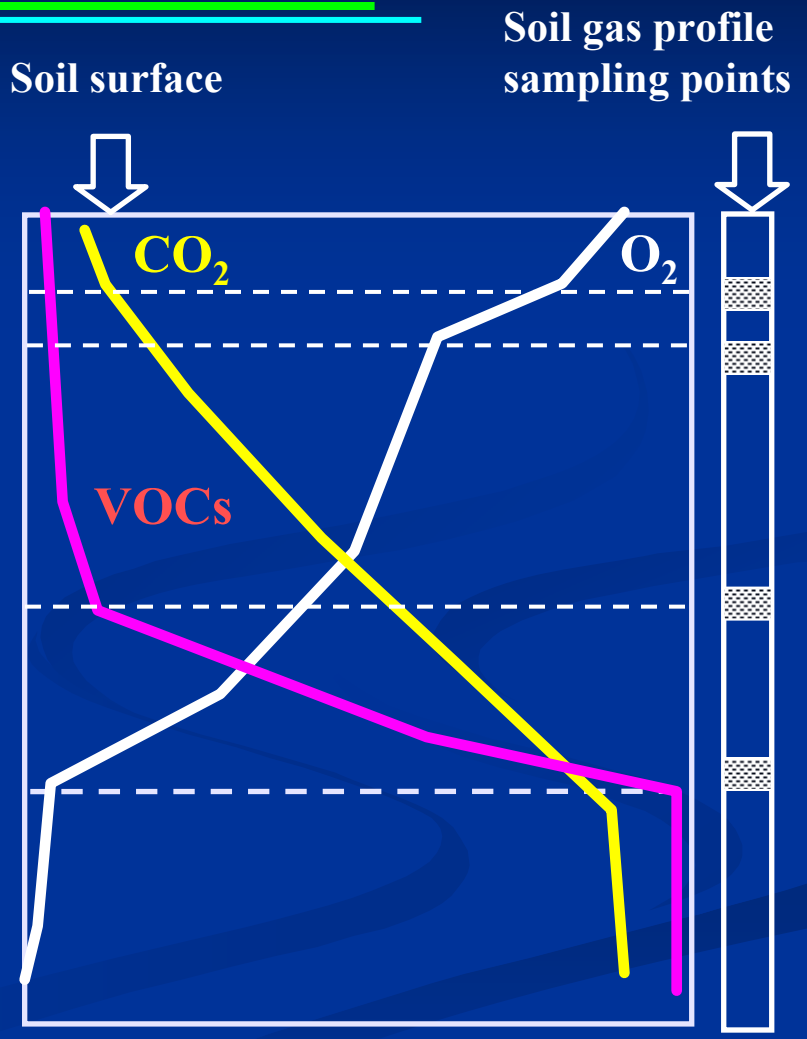
# Problem Description

- Biodegradation significantly affects petroleum compound vapor migration
- Soil gas profile data recommended to assess biodegradation
- No common approach to use soil gas profile data to quantitatively evaluate vapor intrusion pathway



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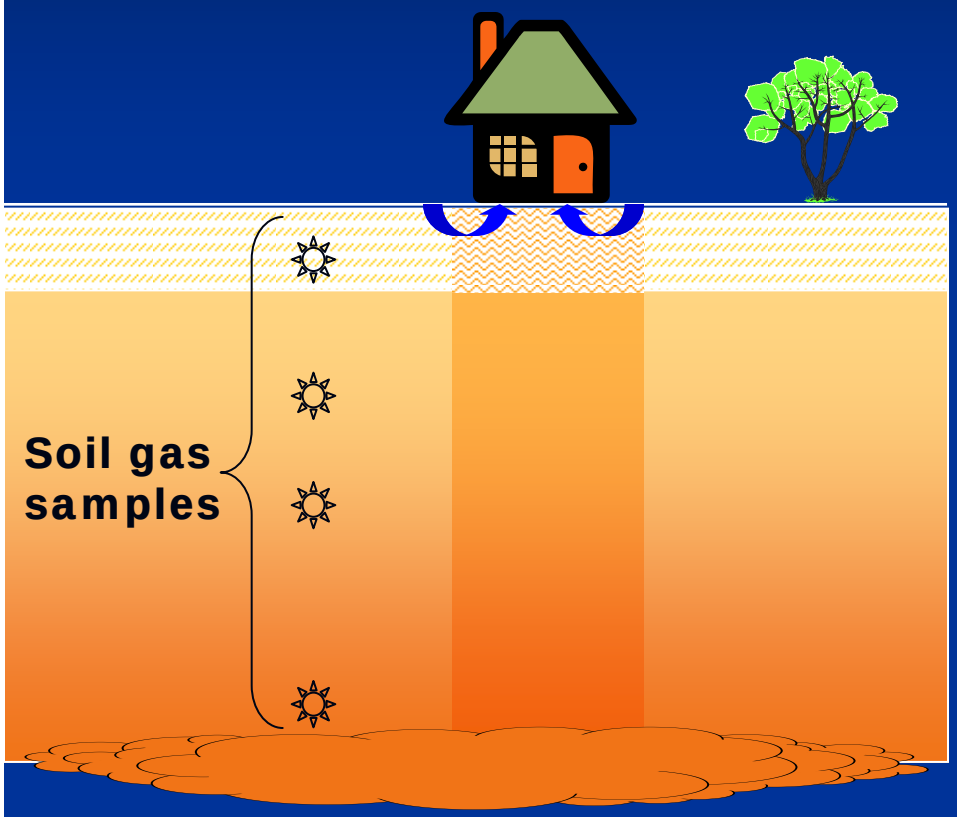
# Objectives

- Illustrate approach to incorporate soil gas profile data in pathway analysis.
- Demonstrate calibration and application of biodegradation model for vapor intrusion
- Evaluate the significance of biodegradation on the vapor intrusion pathway.





# Soil Gas Profile Data




- Soil gas profile underneath building may be different than that outside building footprint.
- May need to assess potential exposure scenarios
- Evaluate soil gas data to address uncertainty in sub-surface transport (diffusion and biodegradation)
- Reassess vapor intrusion evaluation from subsurface source (include convection and ventilation effects)



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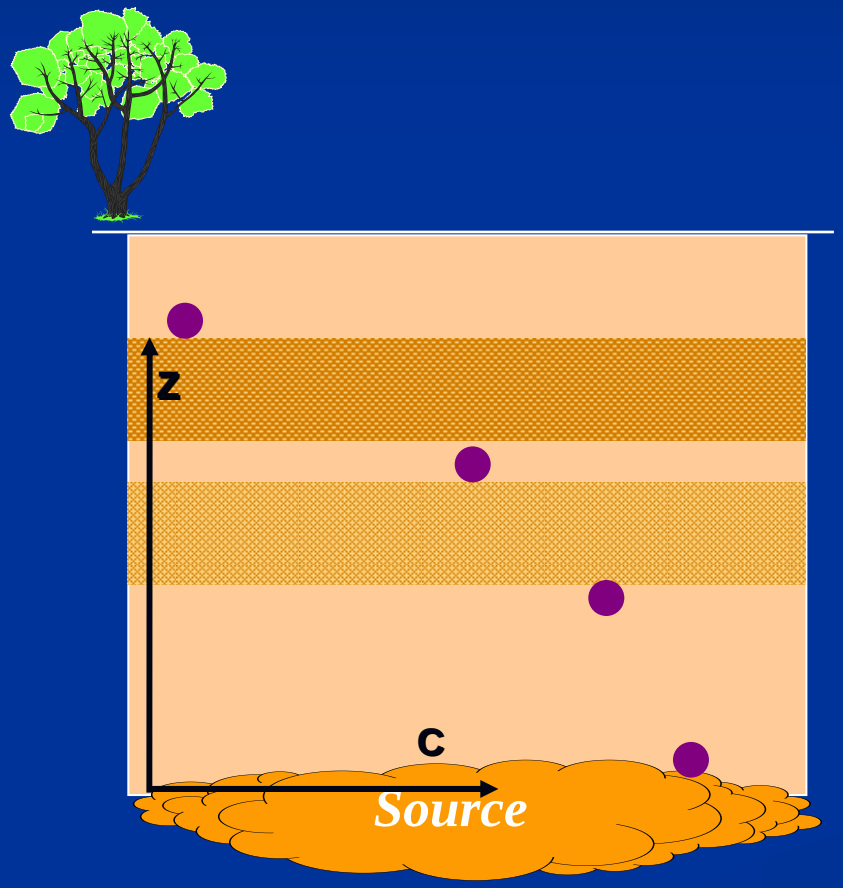
# Modeling Process
## No Biodegradation Scenario

**Soil Gas Profile Data**




- Soil gas concentration as function of depth from measured data
- Soil characterization and physical property data



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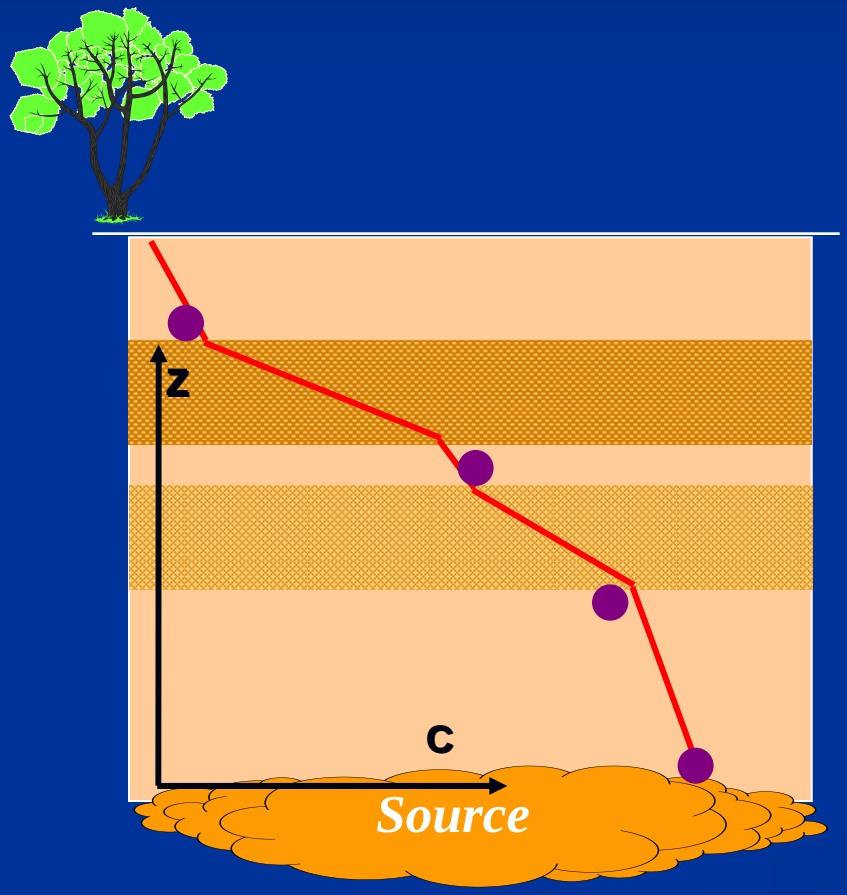
# Modeling Process
## No Biodegradation Scenario

**Vapor Diffusion Model**




- Compare data to vapor diffusion model predictions.
- Verify diffusion model inputs (e.g., soil properties) to predict measurements



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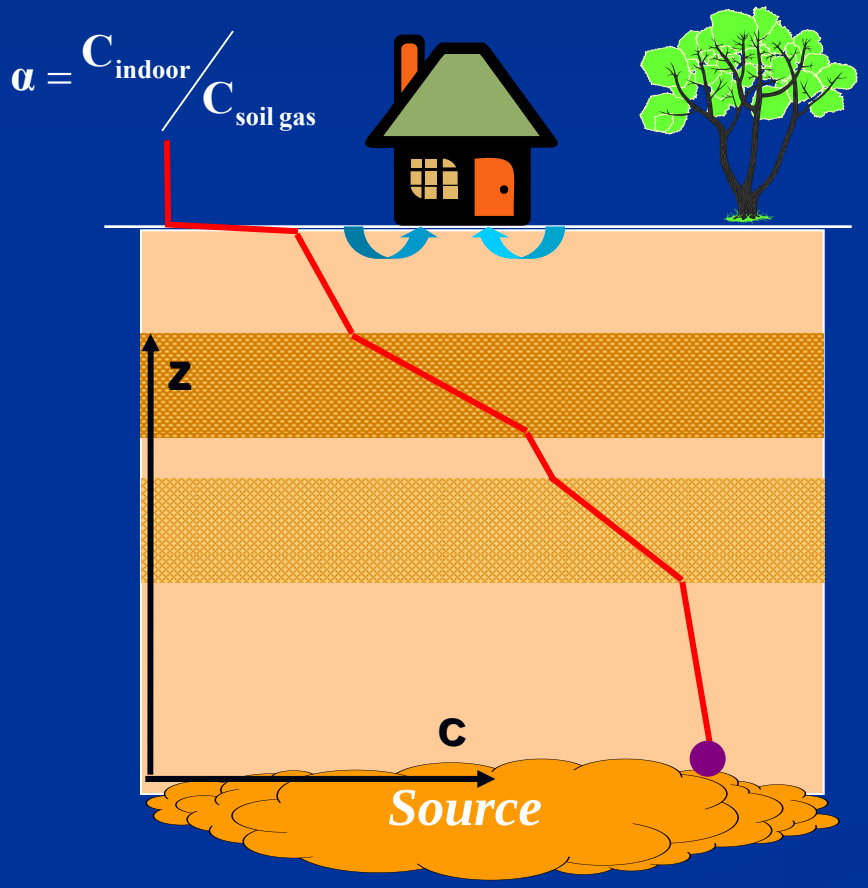
# Modeling Process
## No Biodegradation Scenario

### Vapor Intrusion Model




- Calculate vapor intrusion attenuation factor using:
  - Site source concentration
  - Soil physical properties confirmed by diffusion modeling
  - Default building properties (air exchange rate and soil gas entry rate)



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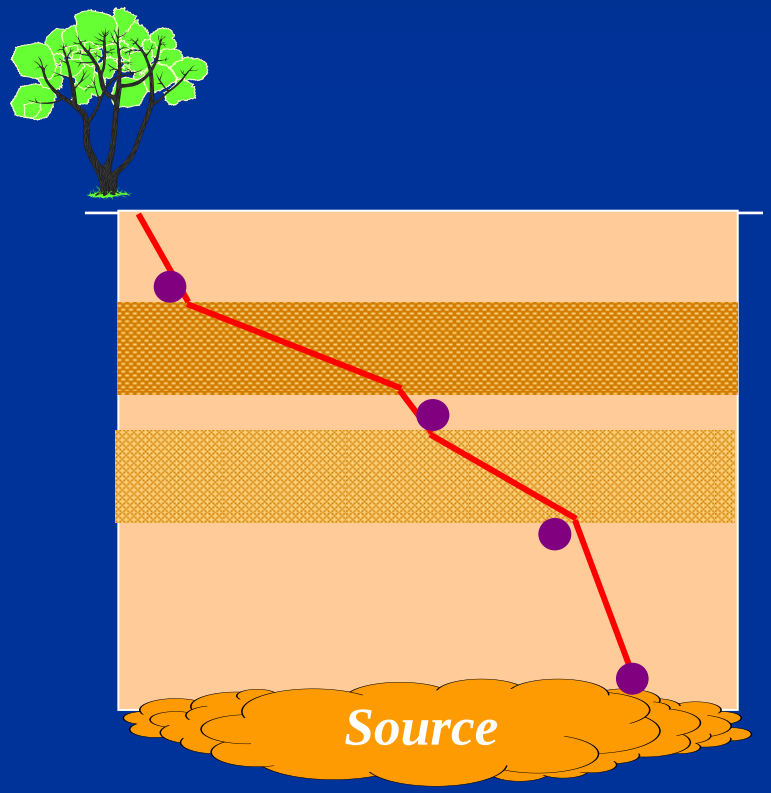
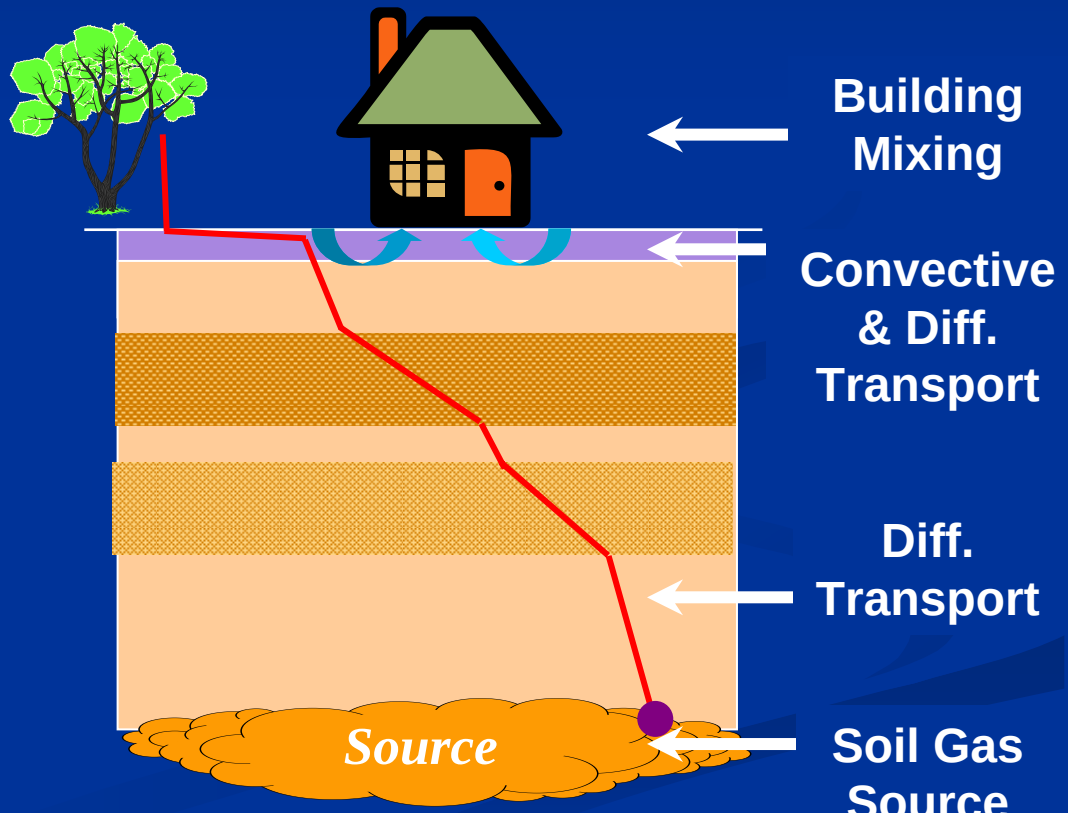
# Modeling Process
## No Biodegradation Scenario

### Vapor Diffusion Model




### Vapor Intrusion Model



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# Biodegradation Modeling

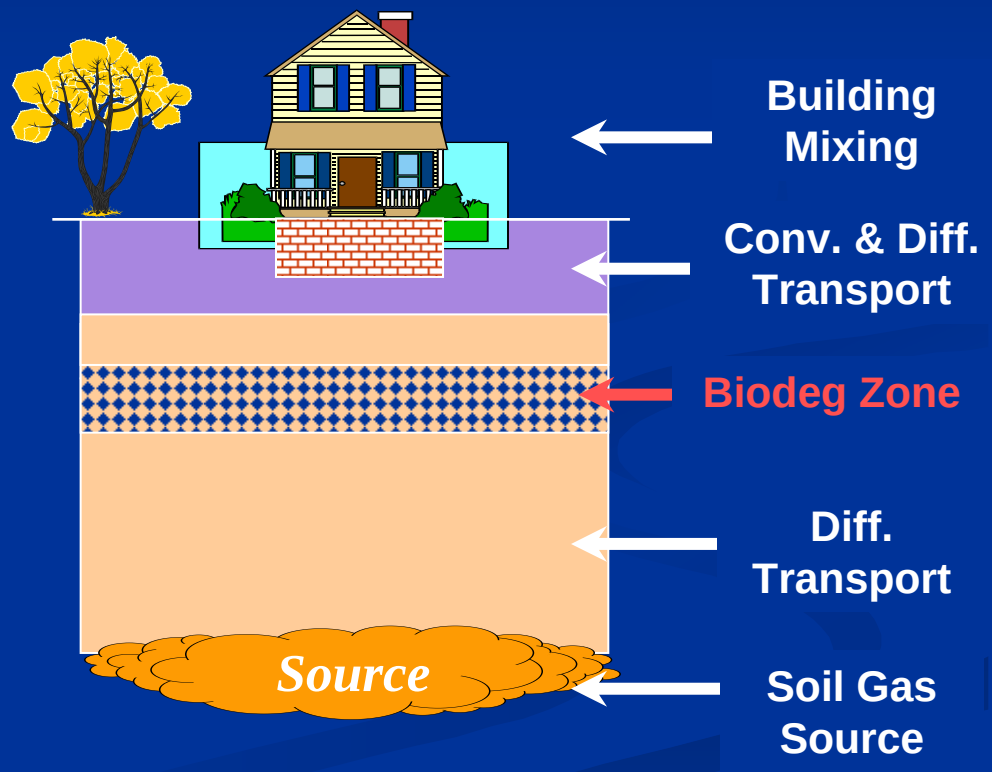
- Different models available with varying levels of sophistication
  - **Screening Bio-Model (Lahvis, 2006)**
    Biodegradation throughout vadose zone
  - **Dominant Layer Model (Johnson et al., 1999)**
    Biodegradation in user-defined degradation zone
  - **Oxygen Limited Model (DeVaull, 2006)**
    Biodegradation in zone of sufficient oxygen
  - **Three Dimensional Model (Abreu & Johnson, 2005)**
    Numerical code calculating VOC and oxygen fate and transport





# Dominant Layer Model

- Dominant Layer Model (Johnson et al., 1999)
  - 1D Analytical Model
  - Considers diffusion, convection, biodegradation, and mixing in building
  - First order biodegradation over specified interval



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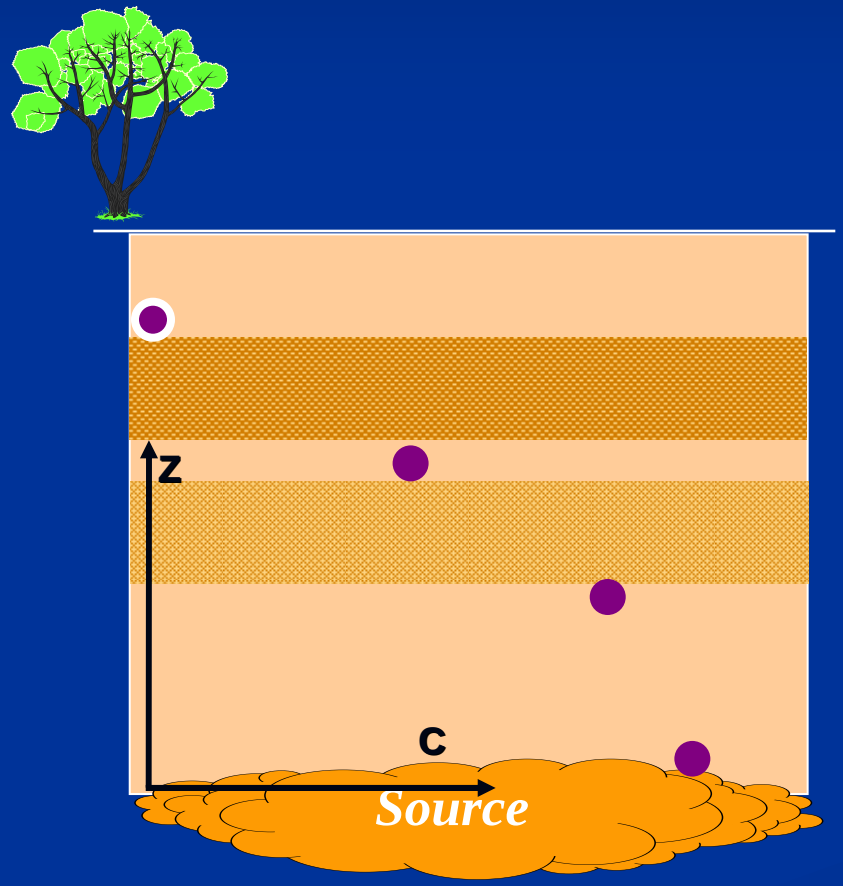
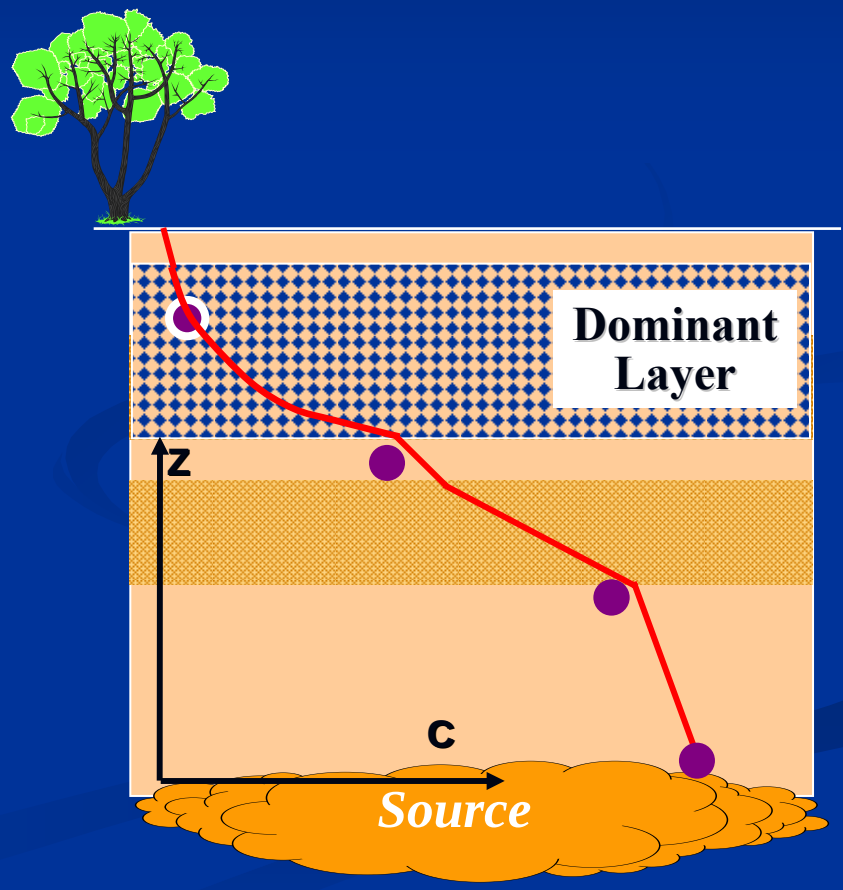
# Modeling Process
## Biodegradation Scenario

### Soil Gas Profile Data




### Vapor Diffusion Model



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# Modeling Process
## Biodegradation Scenario

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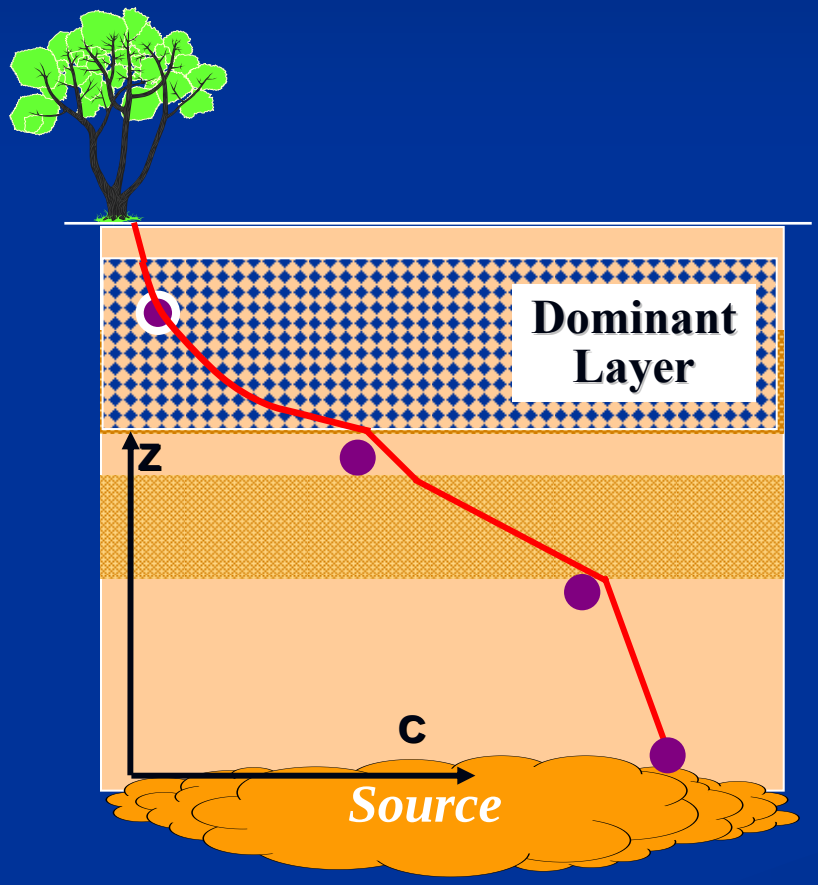
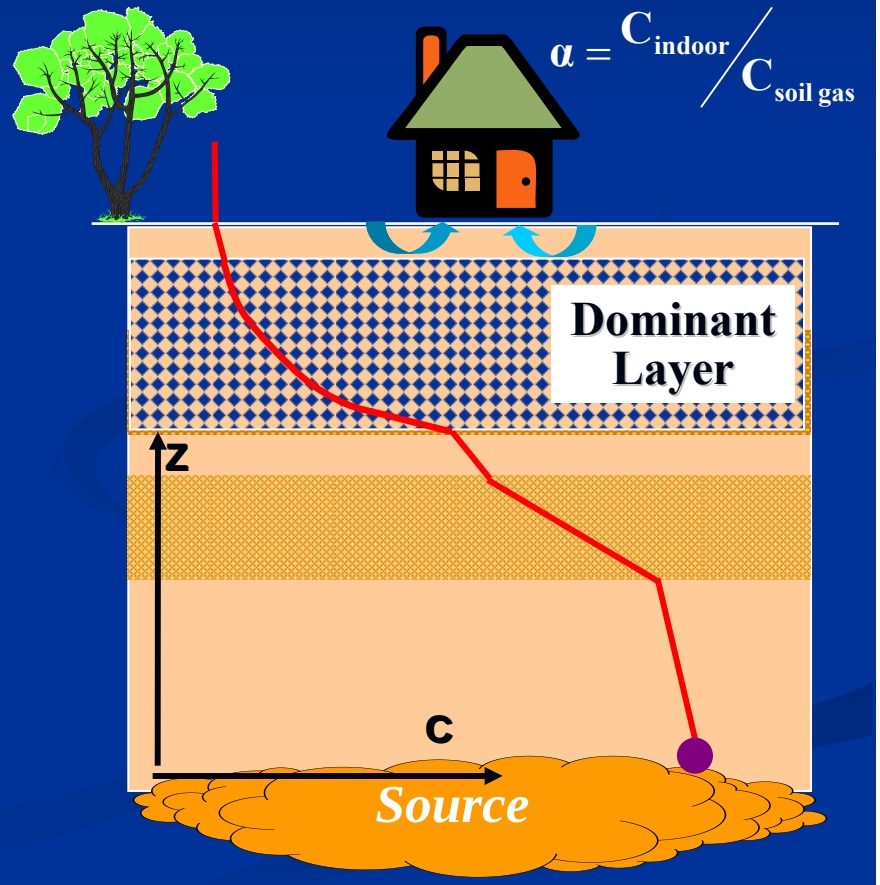



### Vapor Intrusion Model



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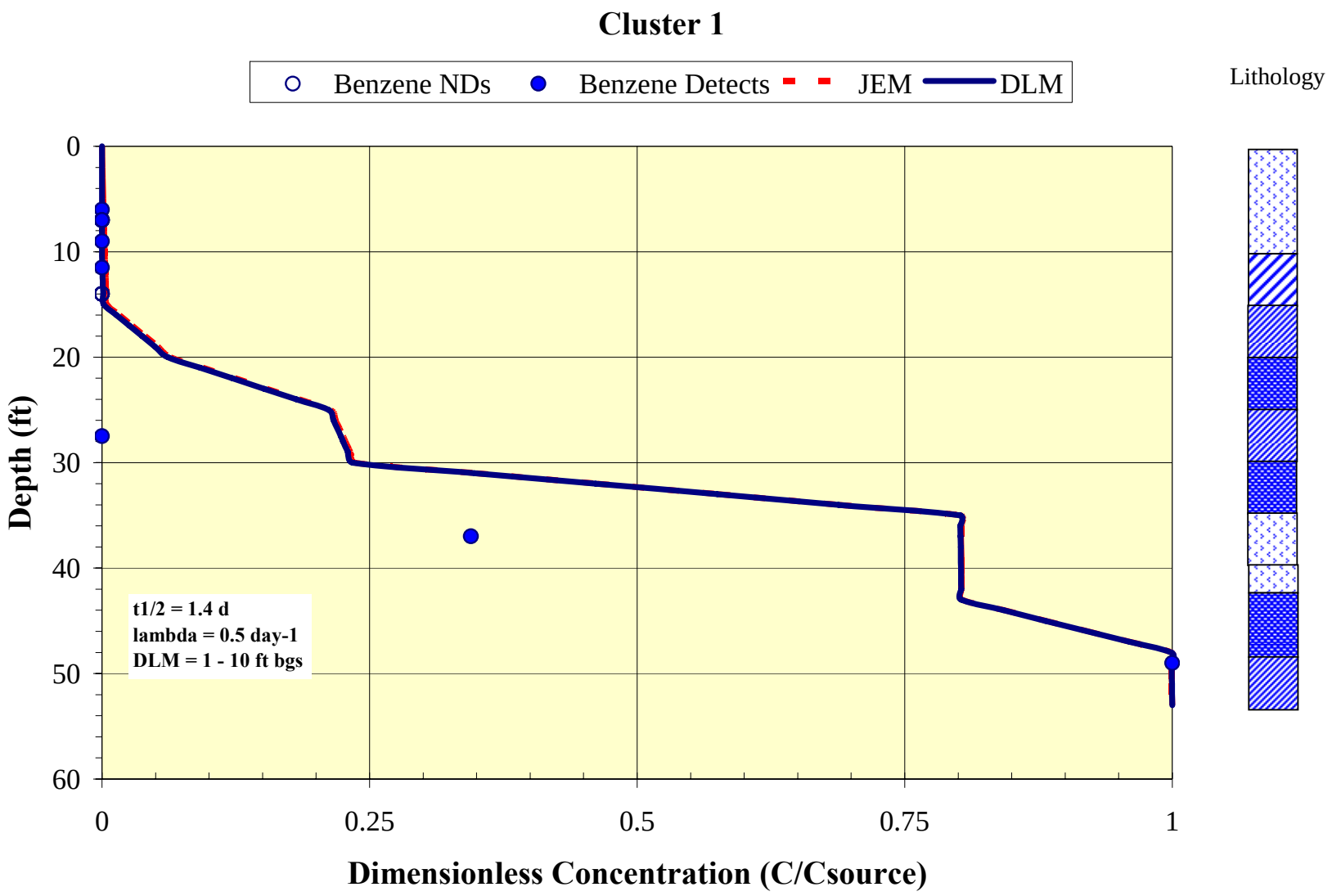
# Example Evaluation

- Evaluate site soil gas profile data from a chemical release site
  - Soil gas VOC concentration profile data and soil property data available (benzene primary chemical of concern)
- Follow previously described methodology to determine vapor intrusion attenuation factor
  - Develop conservative site-specific estimates for biodegradation rate and biodegradation interval





# Soil Gas Profiles



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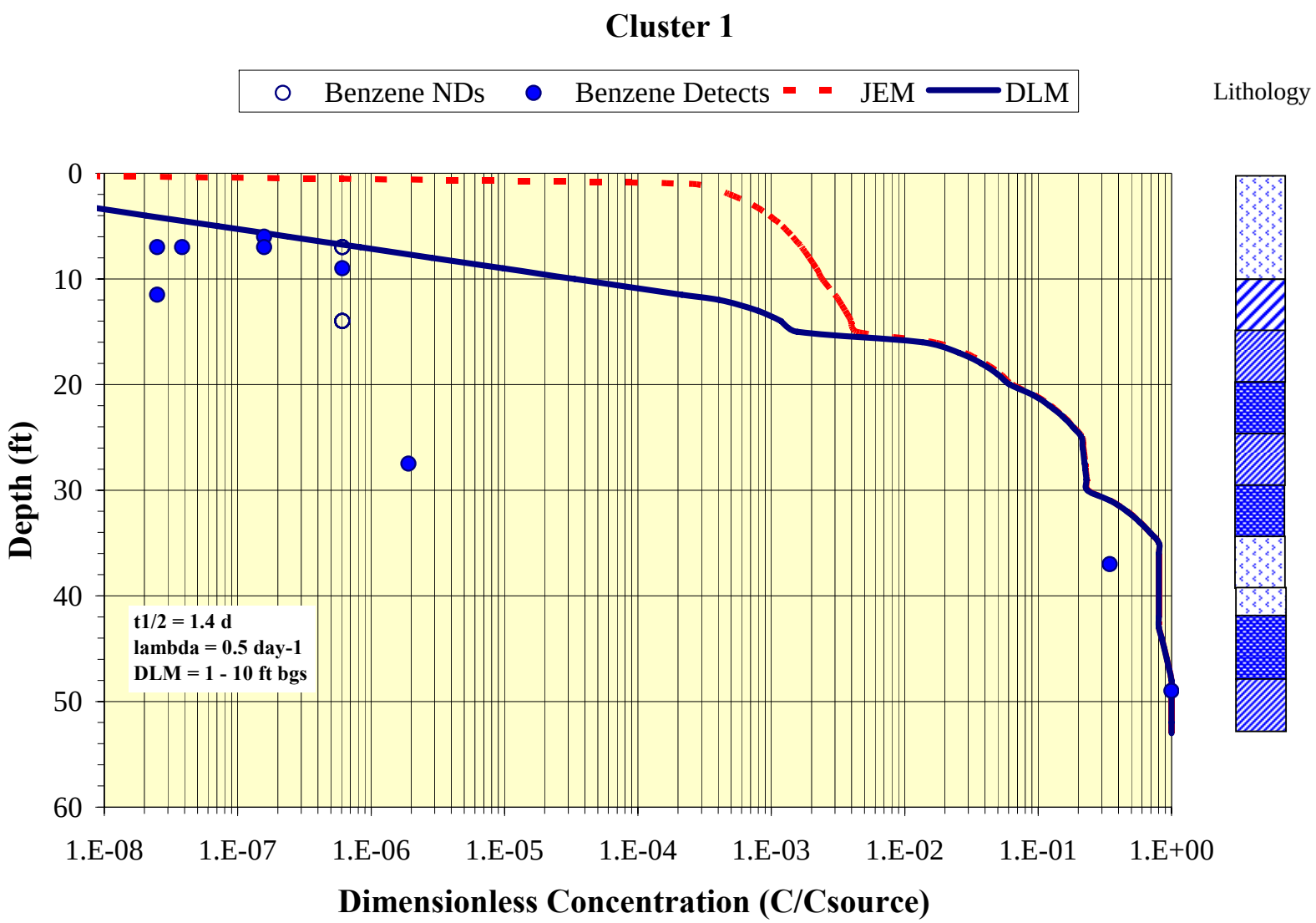
# Soil Gas Profiles



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# Calibration Results

- Evaluation made for several locations across the site
- Benzene soil gas profiles do not match the "No-Bio" model
- Dominant Layer Model can be used to simulate soil gas profiles
  - Range in 1st order degradation rate constants:
    - 0.05 – 0.6 per day
  - Range in Dominant Layer intervals
    - 1 – 4 ft to 1 – 10 ft bgs





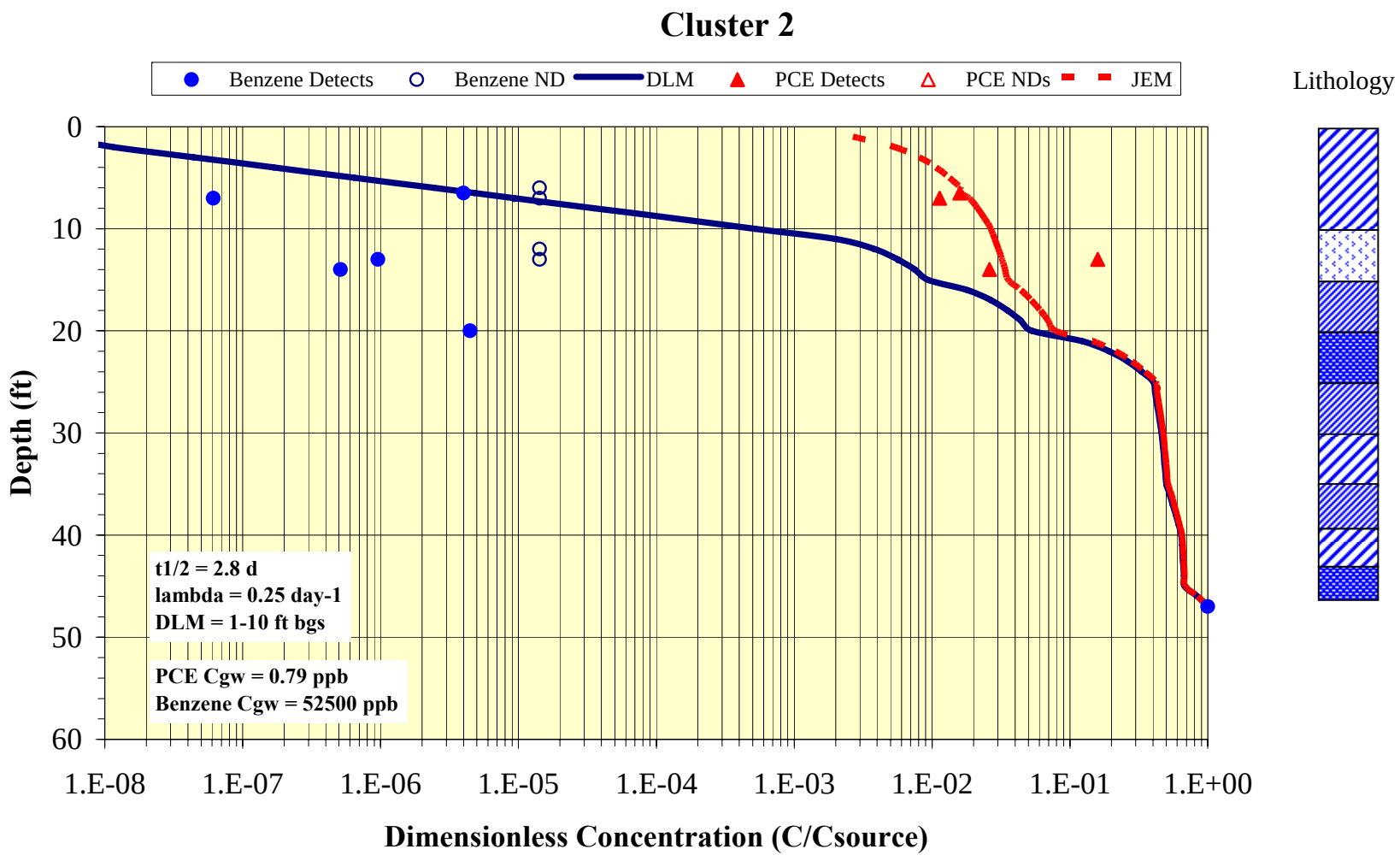
# Additional Modeling Evaluation

- Compare model results to soil gas profiles for recalcitrant compounds
  - Limited data for chlorinated compounds available
- Compare PCE soil gas profile with benzene data and model results





# Biodegradable vs Recalcitrant Compounds



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# Attenuation Factors

- DLM used to calculate vapor intrusion attenuation factors
- Assumptions:
  - Commercial use
  - Shallow Soil/Soil Gas, Deep Soil/Soil Gas, Groundwater Sources
  - Most conservative estimates for DLM parameters
- Compare with JEM calculations





# Attenuation Factors

| Source | α DLM | α JEM | Ratio |
|---|---|---|---|
| Shallow Soil / Soil Gas | 4.8E-7 | 3.8E-5 | 78 |
| Deep Soil / Soil Gas | 4.0E-8 | 1.5E-5 | 380 |
| Groundwater | 1.8E-8 | 1.0E-5 | 570 |





# Uncertainties

- Limited coverage of “calibration clusters” across site
- Oxygen profile data not available for evaluation
- Building effects on degradation zone assumed to be limited
- No data available to correlate with measured indoor air data
- Most conservative estimated biodegradation parameters used for attenuation factor estimate





# Conclusions

- Methodology to quantitatively evaluate soil gas profile data is available (for both degradable and non-degradable compounds)
- Dominant Layer Model may be effectively used to evaluate vapor intrusion pathway
- Conservative estimates result in 2 to 3 orders of magnitude reduction in predicted contaminant vapor intrusion





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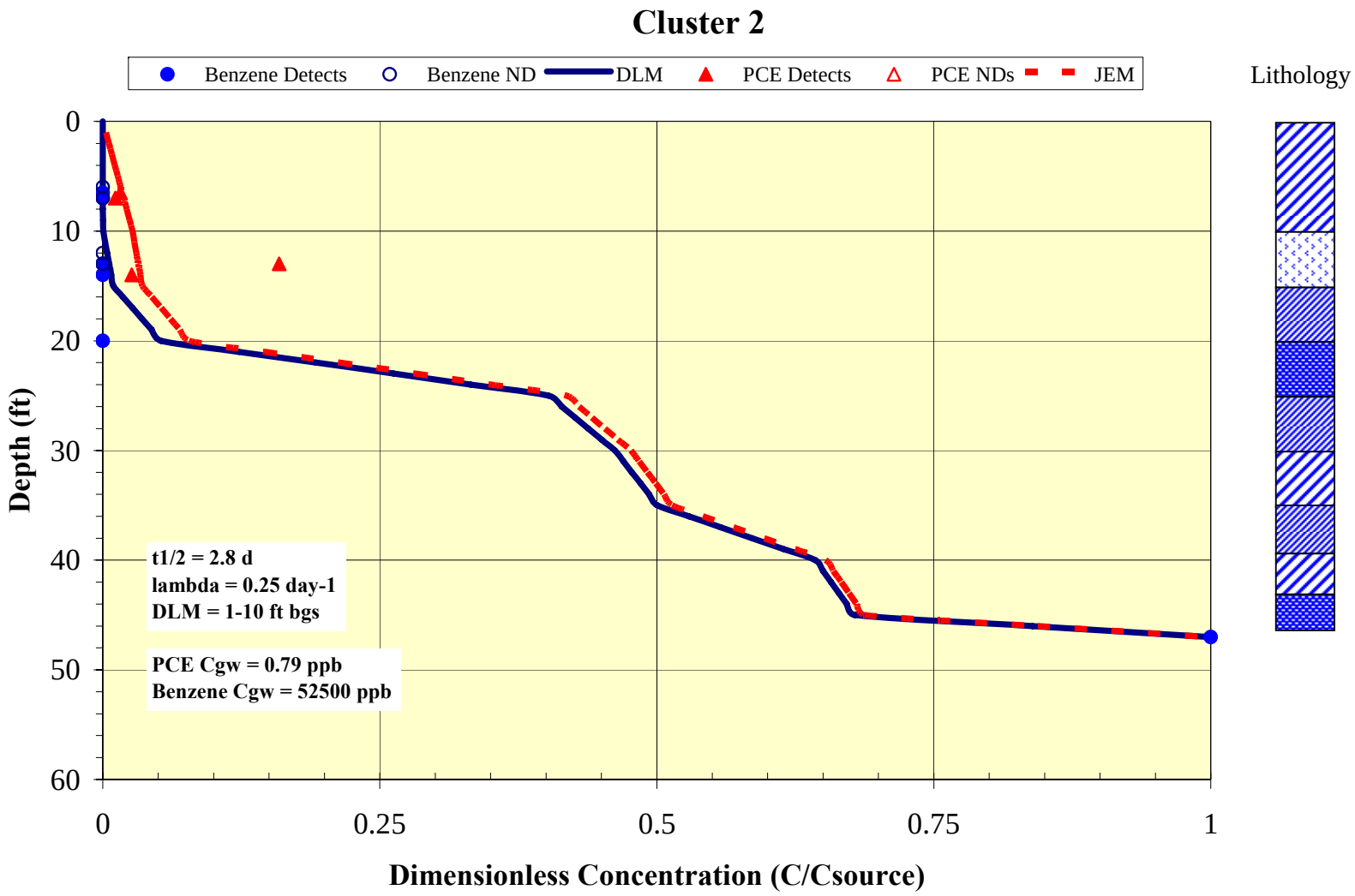
# Biodegradable vs Recalcitrant Compounds



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# Model Calibration Summary

- Comparison of data with vapor transport models demonstrates:
  - Significance of biodegradation
  - Capability of Dominant Layer Model to simulate results
  - Range of degradation rate constants conservative and consistent with literature values