The Significance of Hydrocarbon Biodegradation: Interpreting Observations of Hydrocarbon and Oxygen Behavior Above Shallow LNAPL Sources

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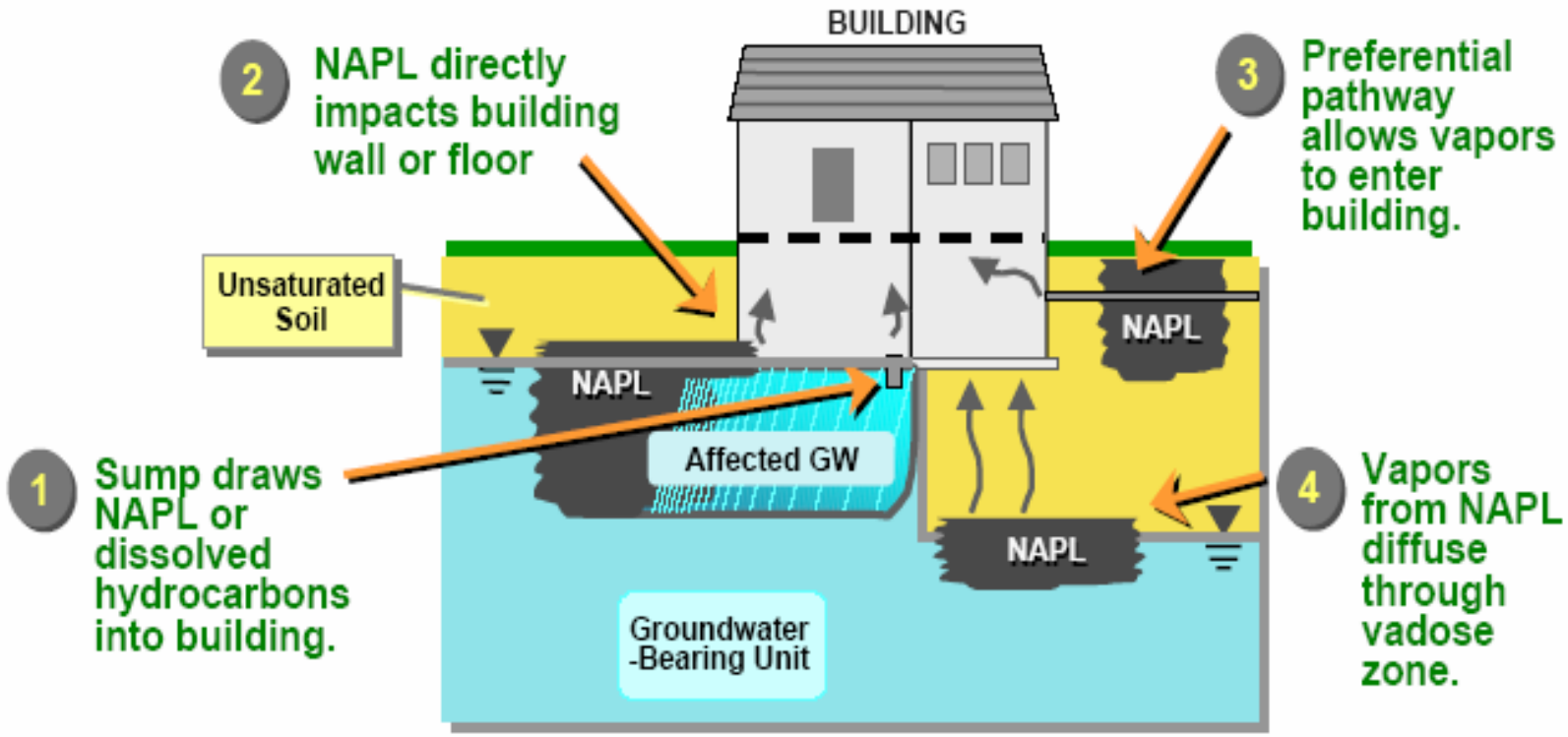
 DOC ID

Vapor Intrusion is Restricted to a Narrow Set of Site Conditions for Biodegradable Compounds



KEY POINT: For petroleum sites, vapor intrusion is generally associated with i) direct impacts or ii) NAPL sources, but not diffusion of vapors from dissolved plumes.

Key Publications

Empirical Data

- Hers, I., Atwater, J., Li, L., Zapf-Gilje, R. Evaluation of Vadose Zone Biodegradation of BTX Vapors; *Journal of Contaminant Hydrology*, **2000**, 46, 233-264
- Roggemans, S.; Bruce, C.L.; Johnson, P.C.; Johnson, R.L. Vadose Zone Natural Attenuation of Hydrocarbon Vapor *American Petroleum Institute Bulletin: No. 15*; **Dec. 2001**
- Davis, R. Vapor Attenuation in the Subsurface from Petroleum Hydrocarbon Sources: An Update and Discussion on the Ramifications of the Vapor-Intrusion Pathway; *LUSTline Bulletin* 52, **May 2006**

Modeling

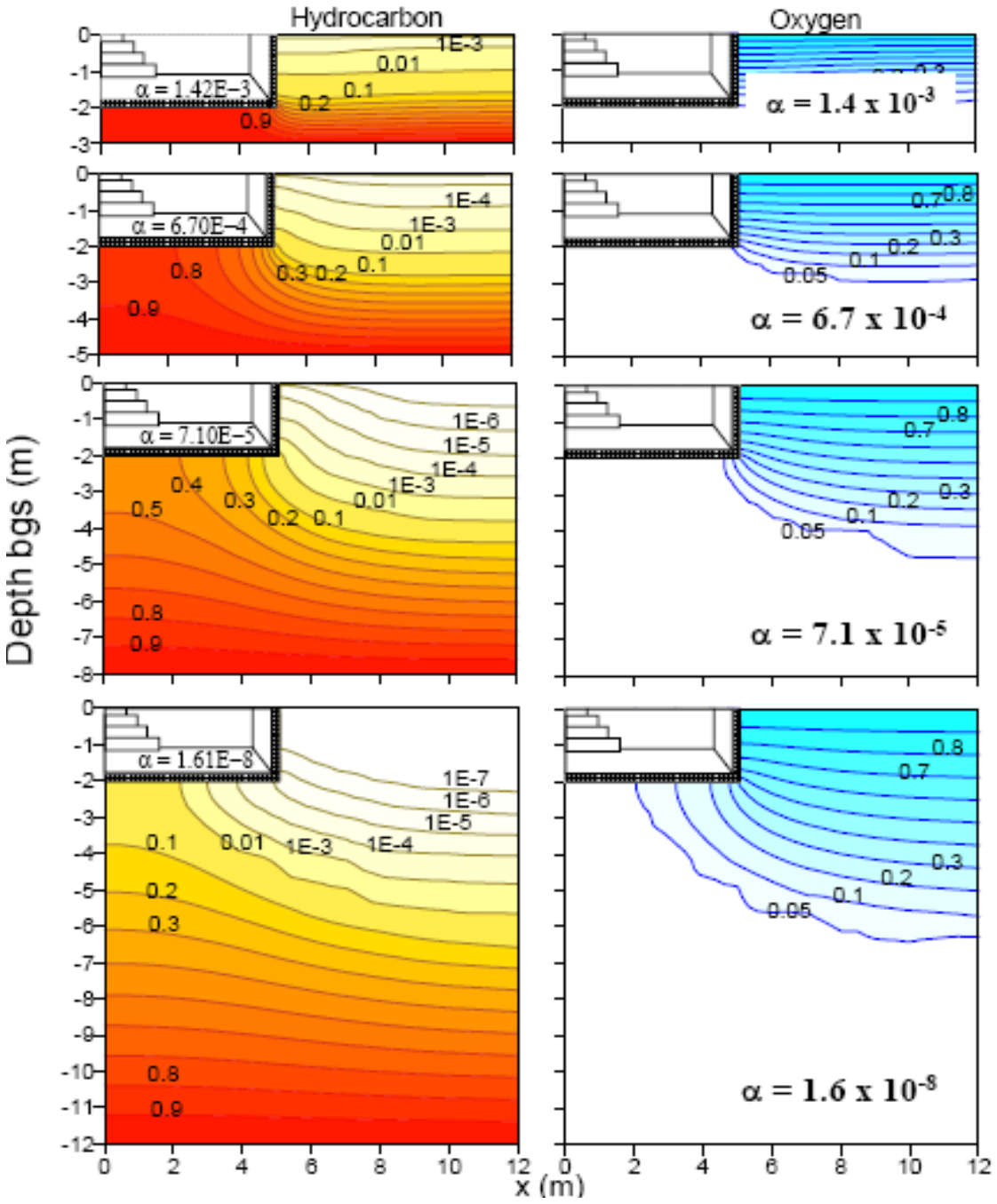
- Abreu, L.D.V., Johnson, P.C. Simulating the Effect of Aerobic Biodegradation on Soil Vapor Intrusion into Buildings: Influence of Degradation Rate, Source Concentration, and Depth; *Environmental Science and Technology*, **2006**, 40, 2304-2315

Source Depth Sensitivity

Constant **200 mg/L** source at differing depths

•First order $\lambda = 0.18\ h^{-1}$

Where a high concentration source is located at a shallow depth, O_2 is consumed before it can migrate beneath the foundation



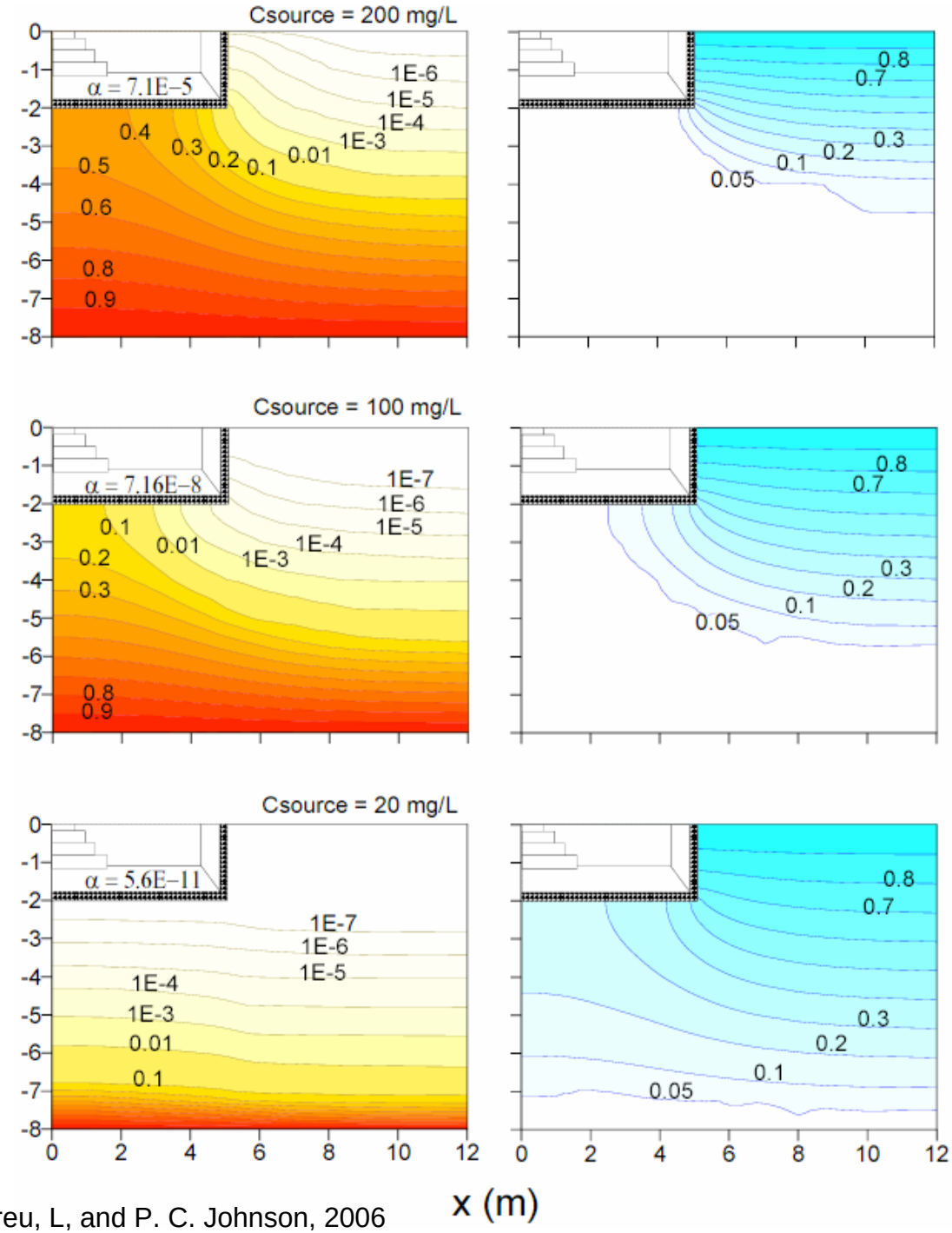
Abreu, L, and P. C. Johnson, 2006

Source Strength Sensitivity

Effects of biodegradation with differing source strengths at constant depth of 8 m.

- Assumes first order rate of $\lambda = 0.18\ h^{-1}$

One order of magnitude reduction in source concentration results in over 6 orders of magnitude difference in sub-foundation hydrocarbon concentrations



Abreu, L, and P. C. Johnson, 2006

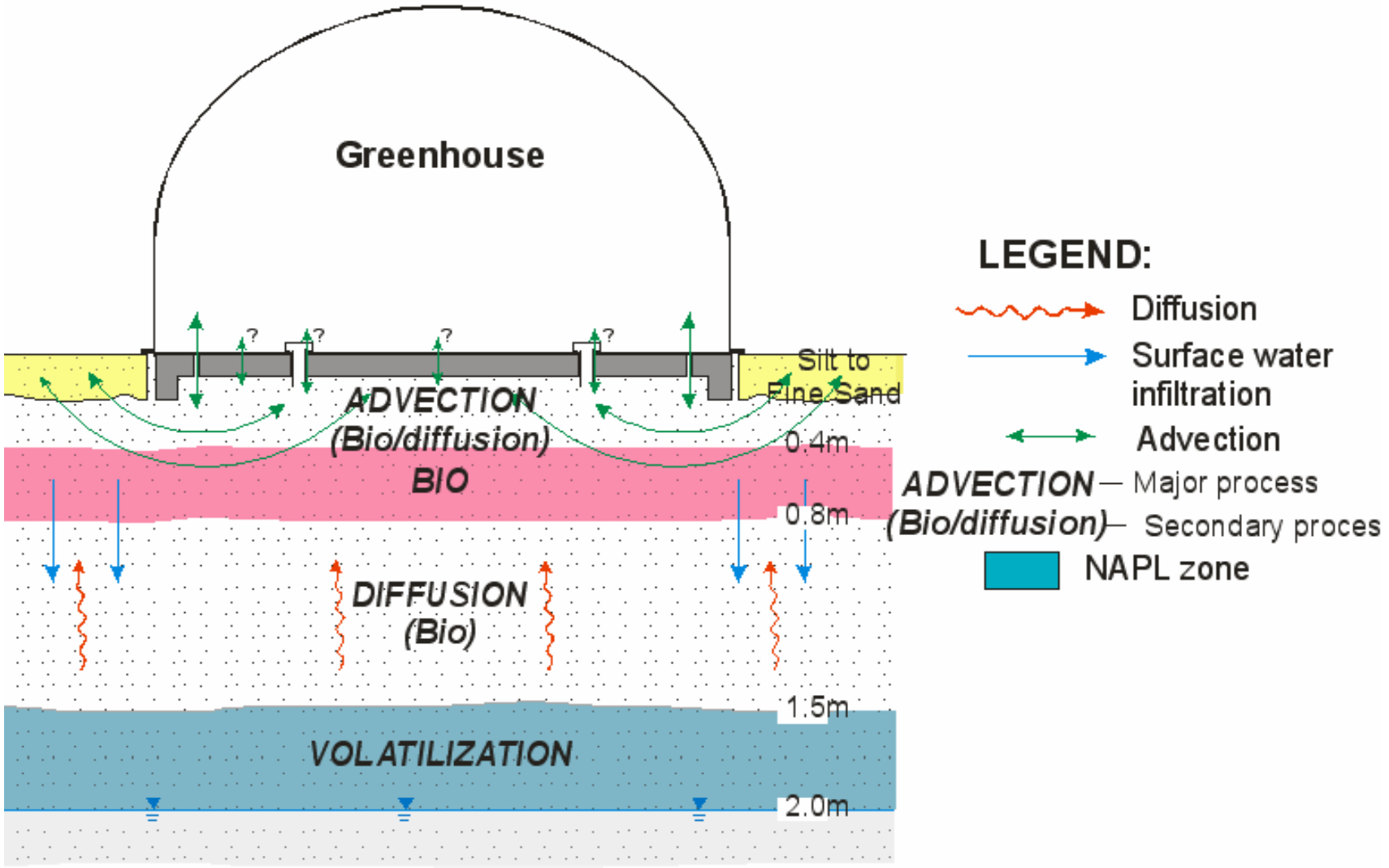
Screening Criteria Derived from Modeling and Supported by Empirical Data

1. Source strength vs. depth for given stratigraphic setting, building type, and footprint should provide a Tier I screening criteria defining where further investigation is unnecessary:
    - Applied when source strength and distribution are reasonably known (e.g., no vadose zone sources, no near-surface stratigraphic caps)
2. Examining real-world slabs and basements where subsurface vapors have accumulated and an anoxic zone developed can validate model boundary conditions

Chatterton Research Site
Delta, B.C.

Courtesy Dr. Ian Hers, Golder Assoc., 2001

Conceptual Model
Vadose Zone Processes Below Greenhouse



Courtesy Dr. Ian Hers, Golder Assoc., 2001

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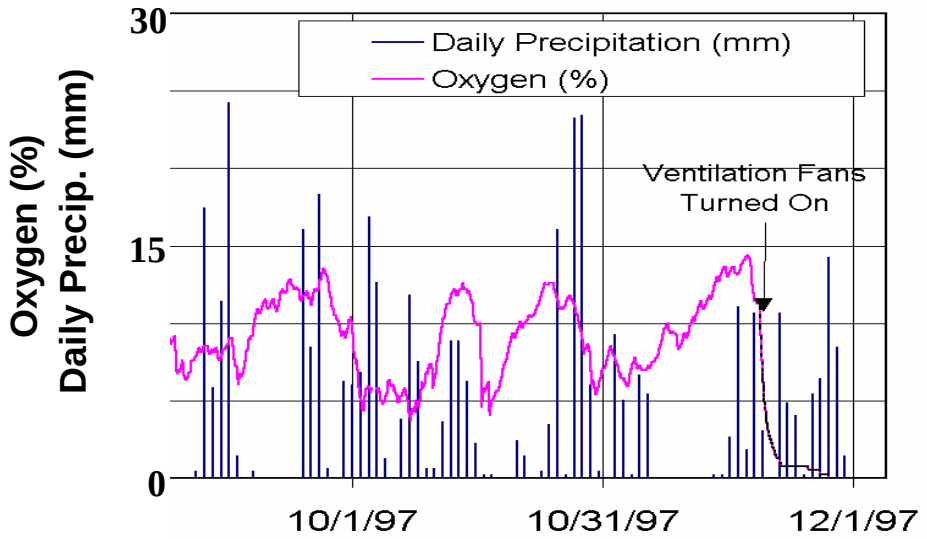
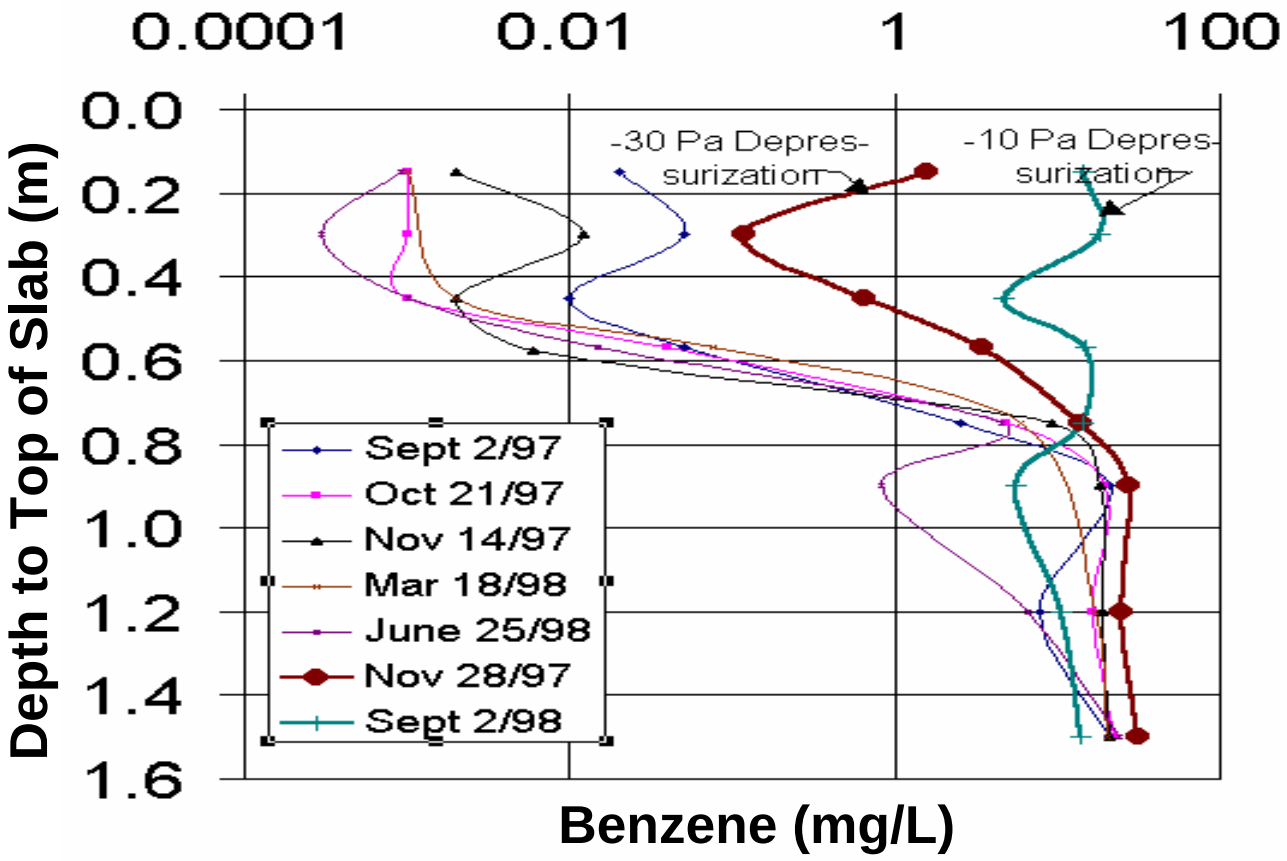


No measurable BTX flux to building and only moderate oxygen depletion beneath building under ambient conditions

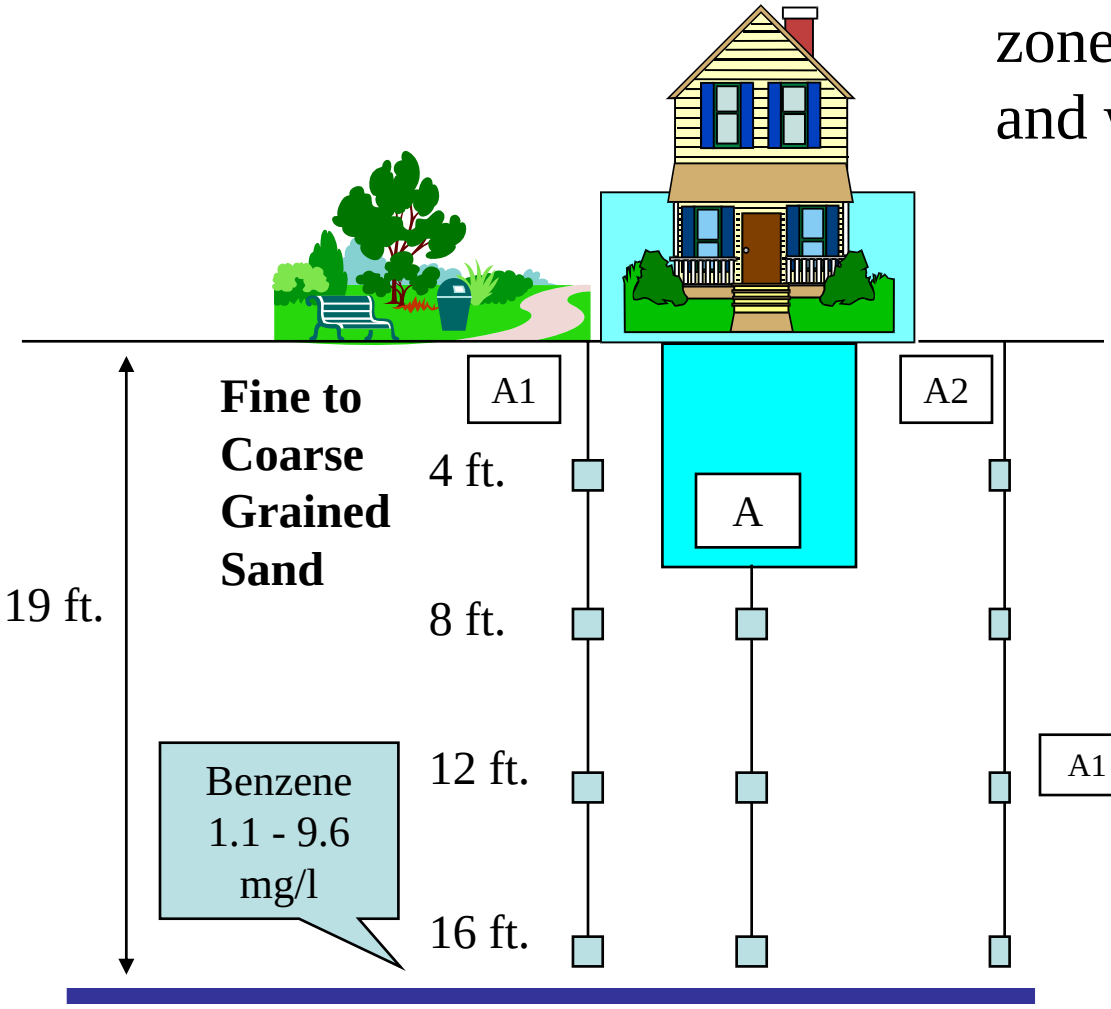


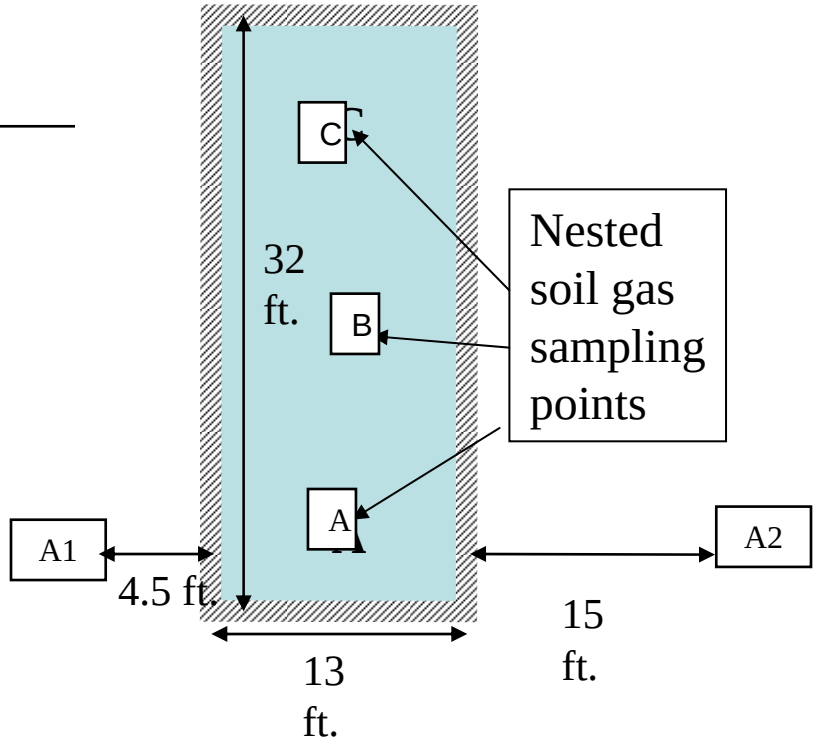
anoxic zone fully developed and significant BTX flux to building during depressurization

Courtesy Dr. Ian Hers, Golder Assoc., 2001

Residence Underlain by Gasoline LNAPL Plume, Paulsboro NJ

Gasoline LNAPL smear zone underlies 2-story home with basement floor ~7 ft. Depth to water ~19 ft., sandy vadose zone, nested probes alongside and within building footprint

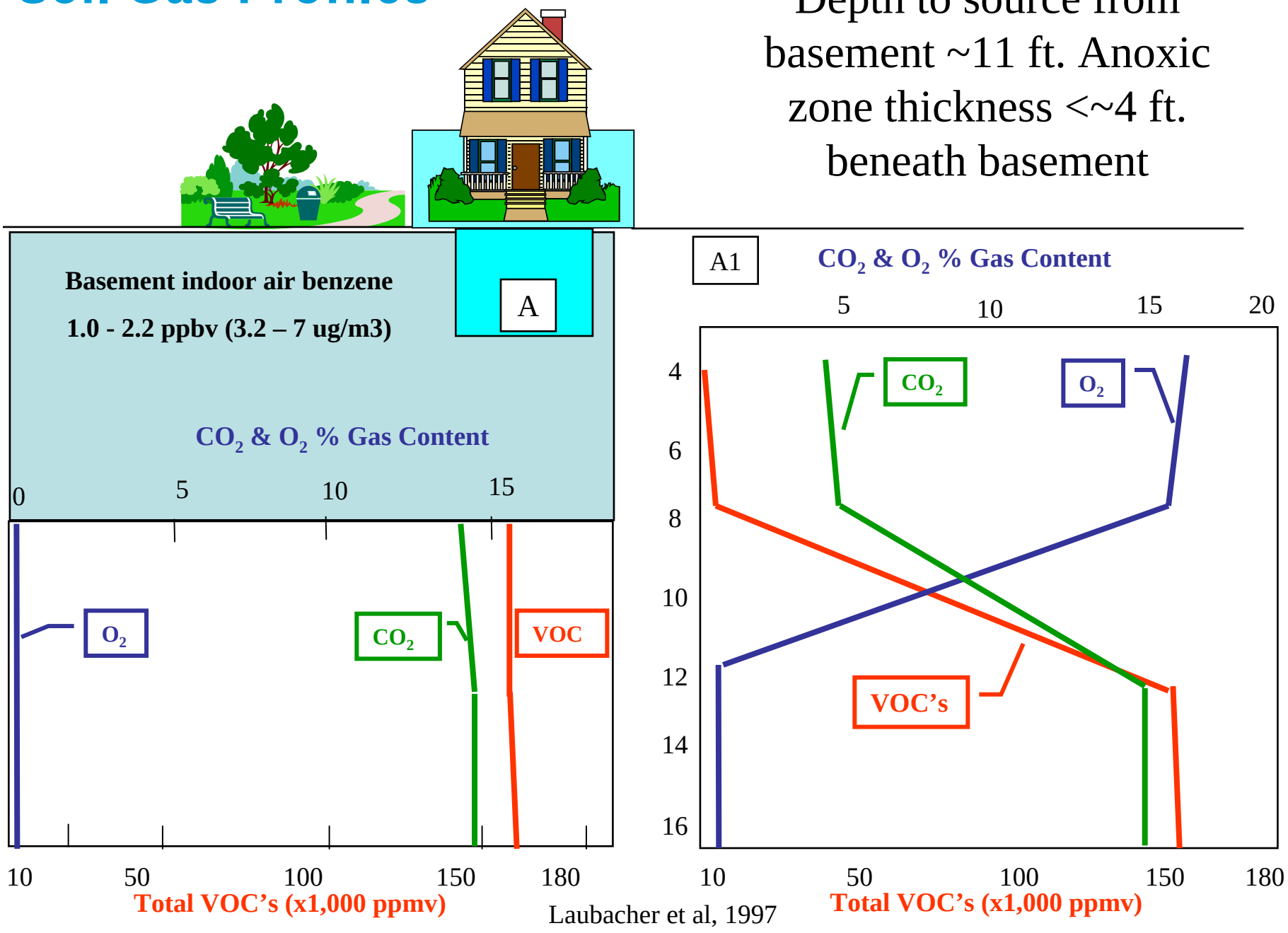




Laubacher et al, 1997

Soil Gas Profiles

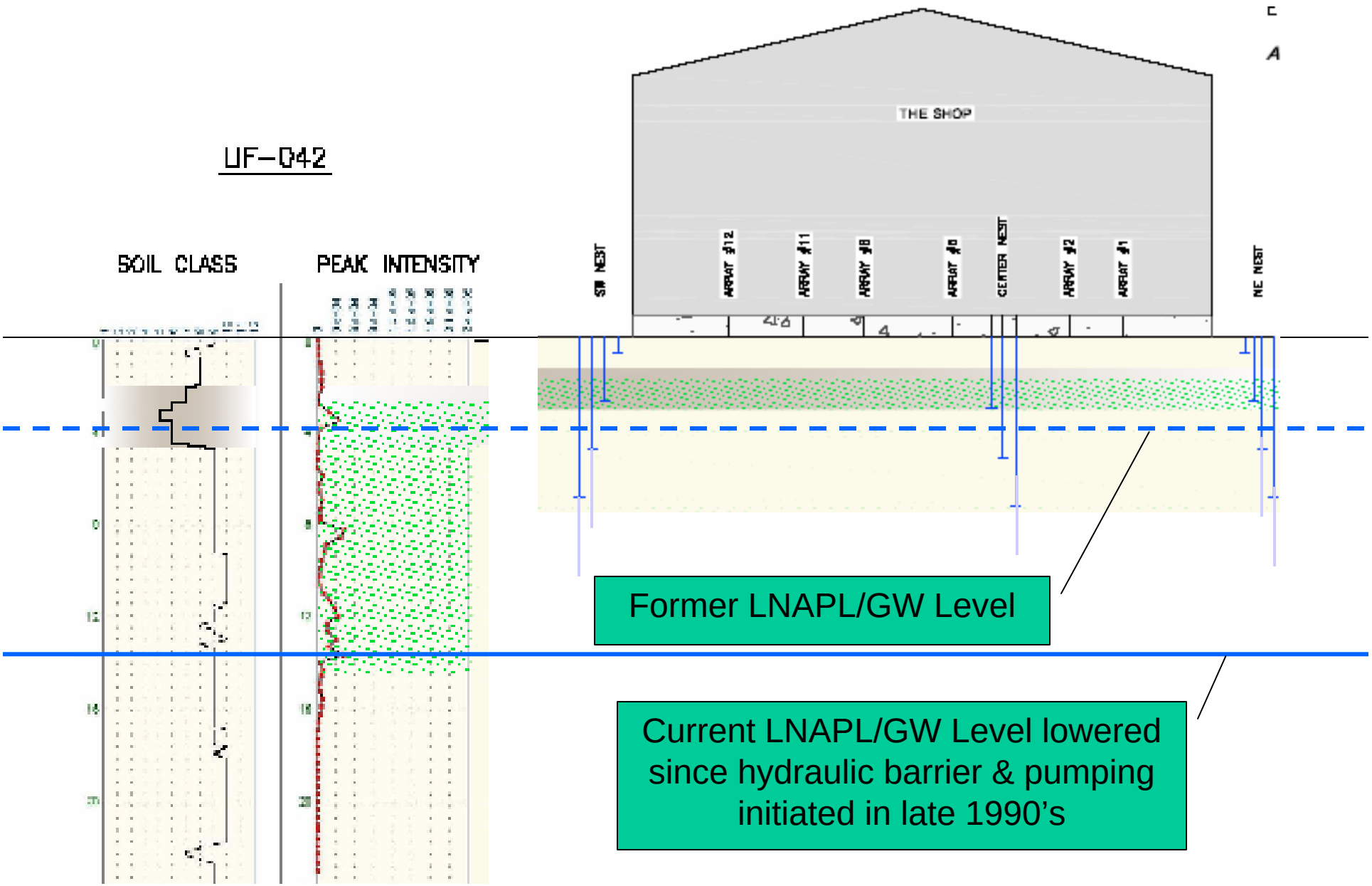
Depth to source from basement ~11 ft. Anoxic zone thickness <~4 ft. beneath basement



Laubacher et al, 1997

Casper Shop Site

Casper WY Refinery VI Field Experiment



Data Collection

31 soil gas sampling locations; sampling ports at 0 (sub-slab), 2 ft, and 4 ft BGS

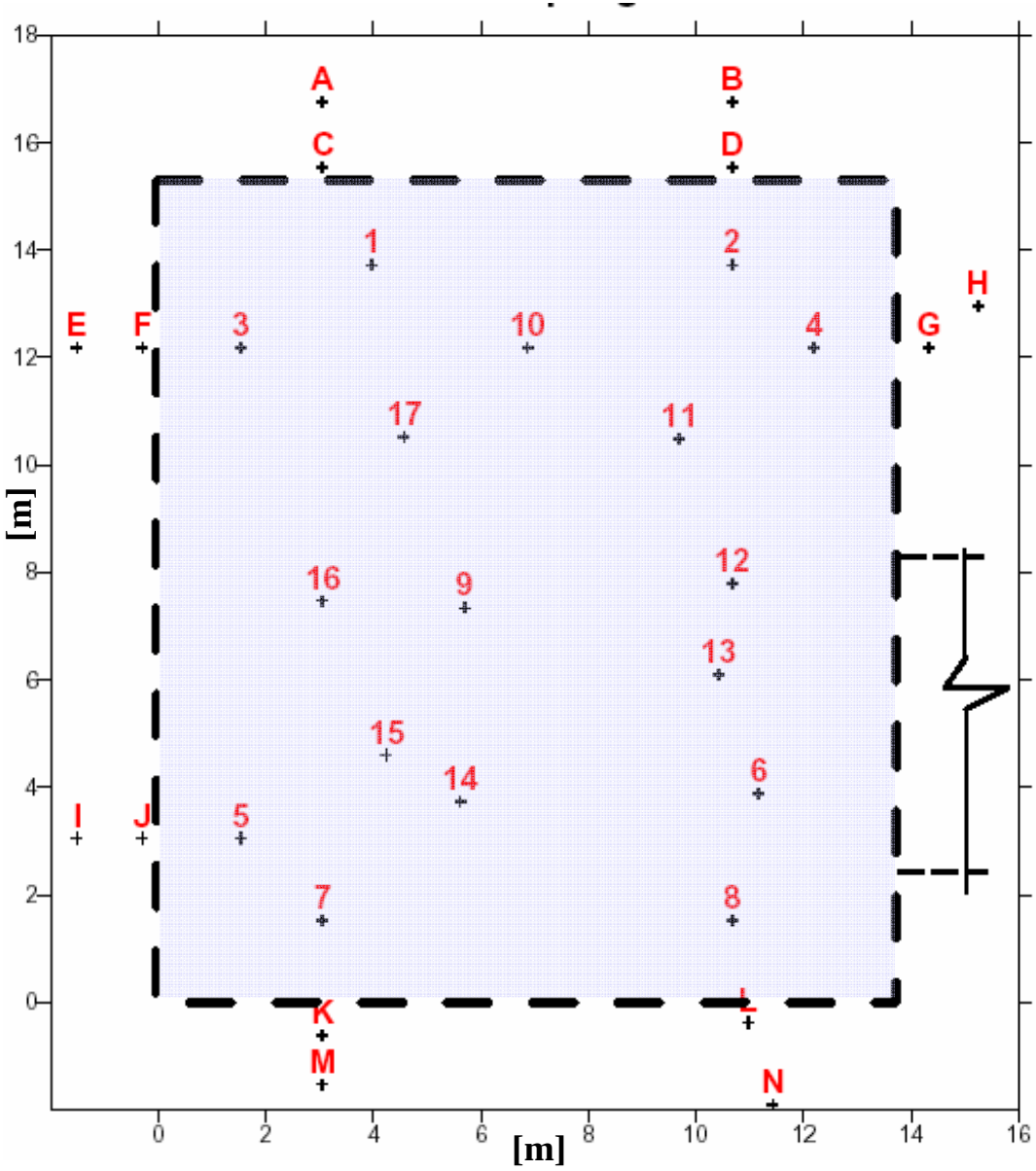
62 real-time in situ oxygen sensors sampled every 10 minutes (2 ft and 4 ft BGS)

21 real-time differential pressure sensors sampled every 10 minutes (16 sub-slab/indoor; 4 cross-slab; 1 barometric)

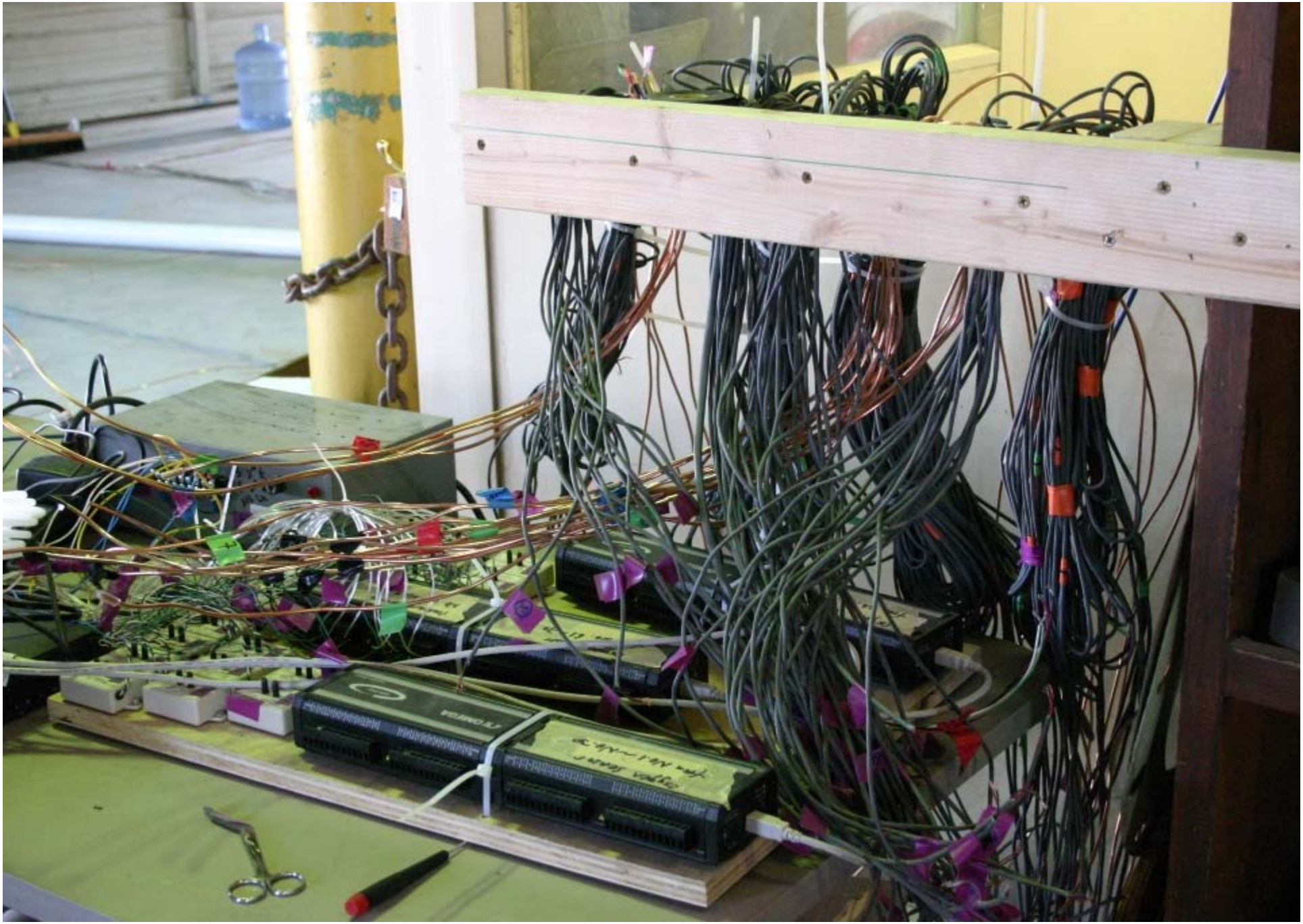
Weather data sampled every 10 minutes (wind direction, wind speed, wind gusts, temperature, rainfall, RH and dew point, water content)

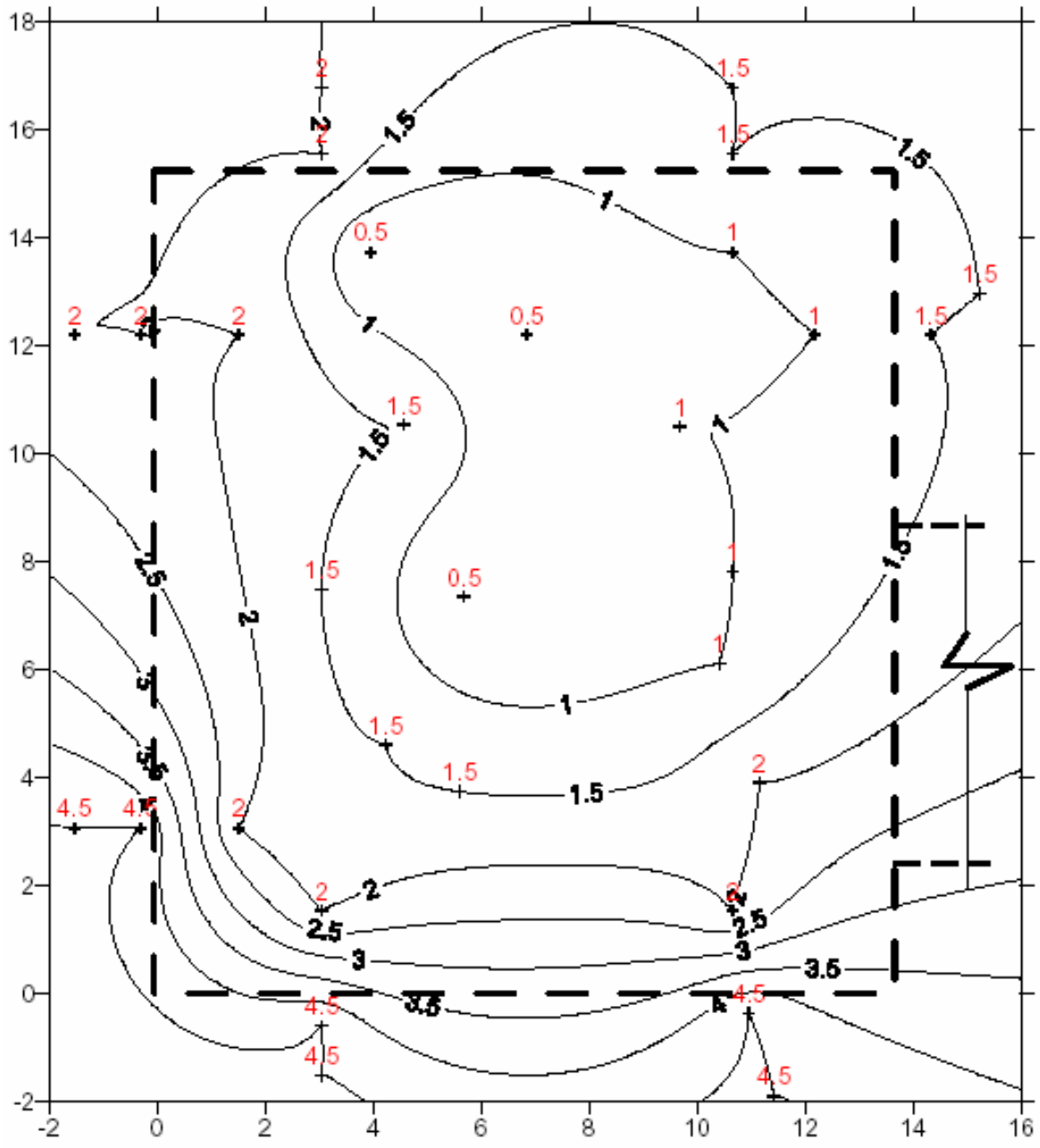
Real-time GC/FID/PID sampling at 4 locations

Data logging start: 9/14/05




SAFETY FIRST
THINK SAFE-WORK SAFE
BE SAFE





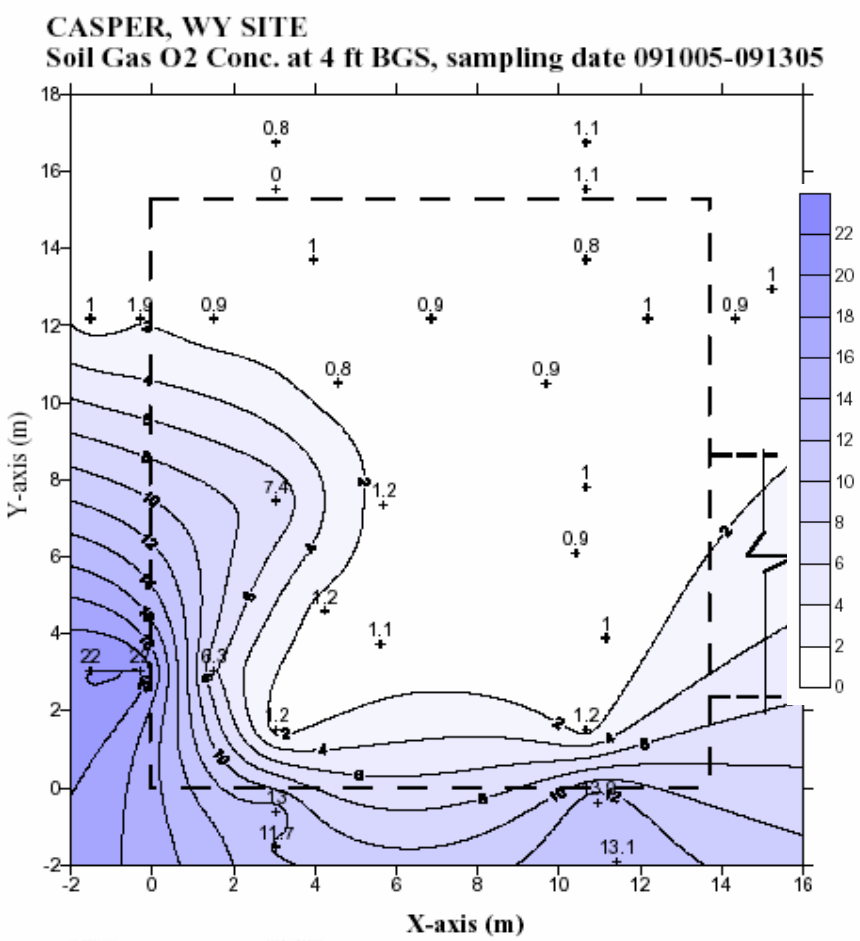
Luo et al, 2006

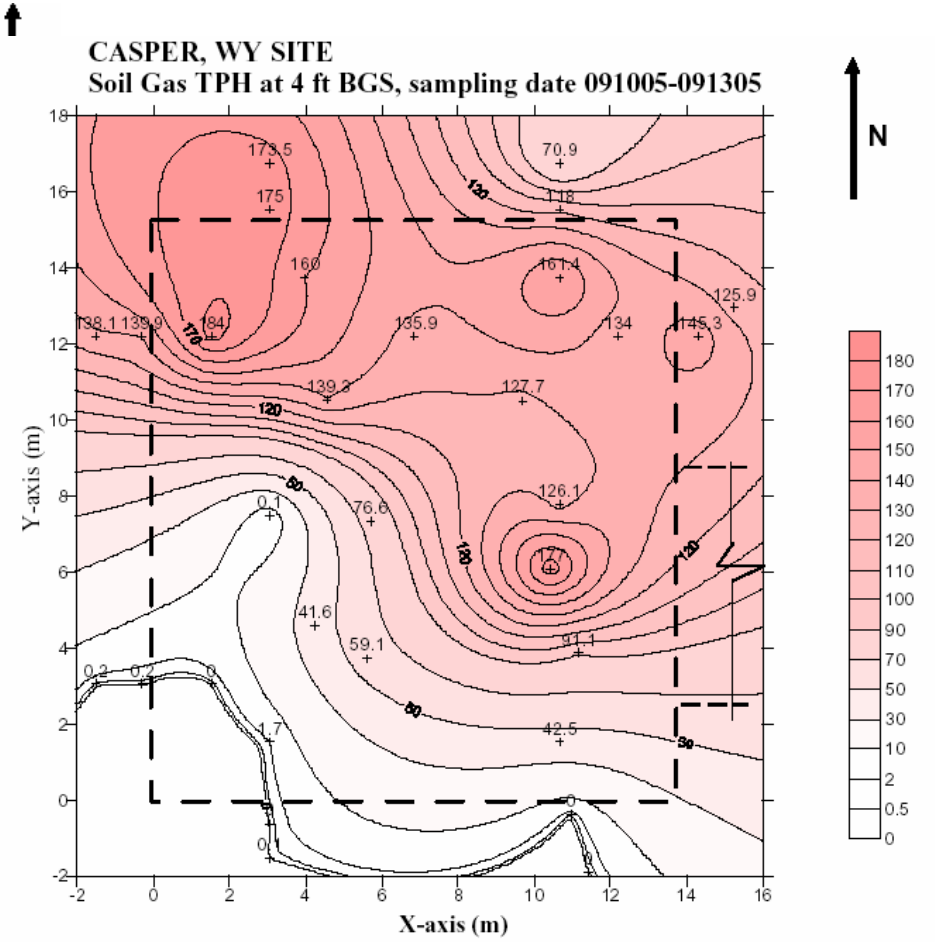
Depth to Top of Source Material

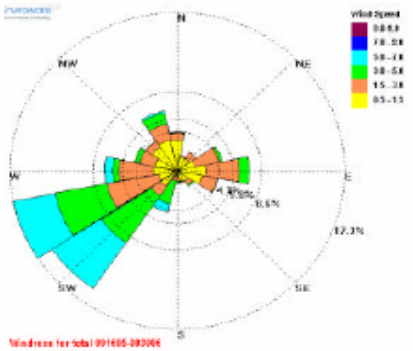
Depth to top-of-source varies; based on visual evidence, it can be found from 0.5 - 1.0 ft in some areas and 4.5 - 5.0 ft in others. Soil is primarily a mixture of sands and gravels

Gasoline-range residual LNAPL source. 31 soil gas sampling locations; sampling ports at 0 (sub-slab), 2 ft, and 4 ft BGS. 62 real-time in situ oxygen sensors sampled every 10 minutes (2 ft and 4 ft BGS). 21 real-time differential pressure sensors sampled every 10 minutes (16 sub-slab/indoor; 4 cross-slab; 1 barometric)

O_2 and VOC's at 4 ft depth



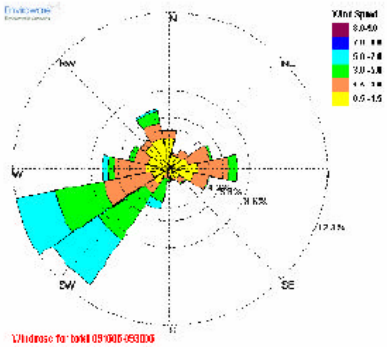




Legend:

Building boundary

0.2 Location and its oxygen concentrati



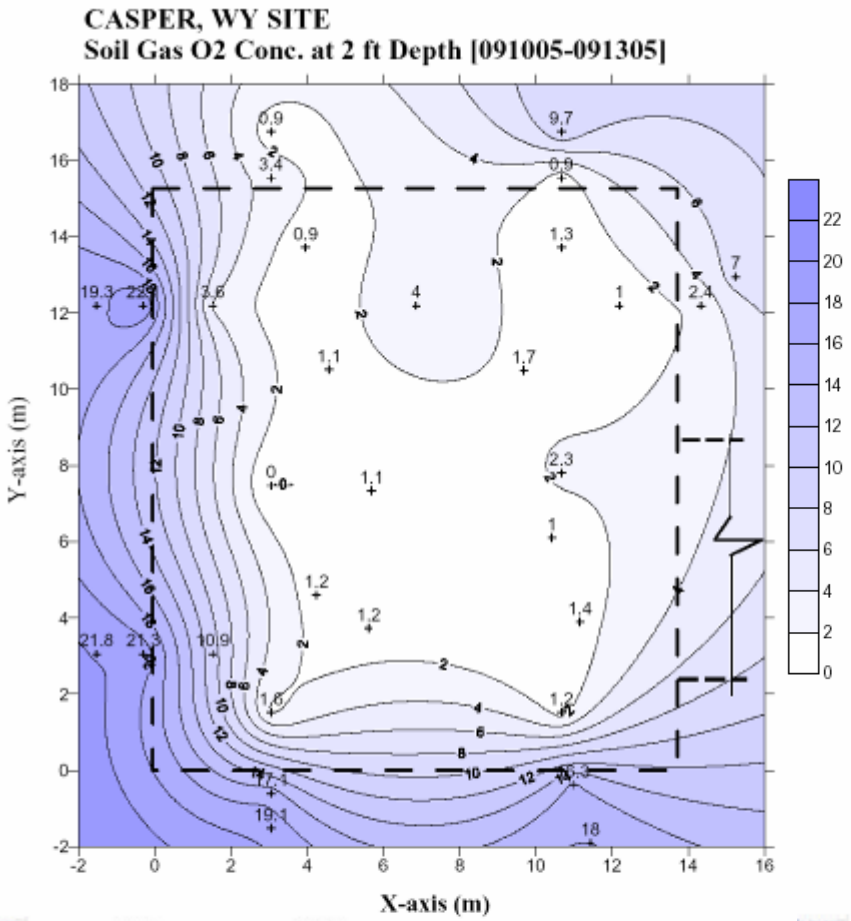
Legend:

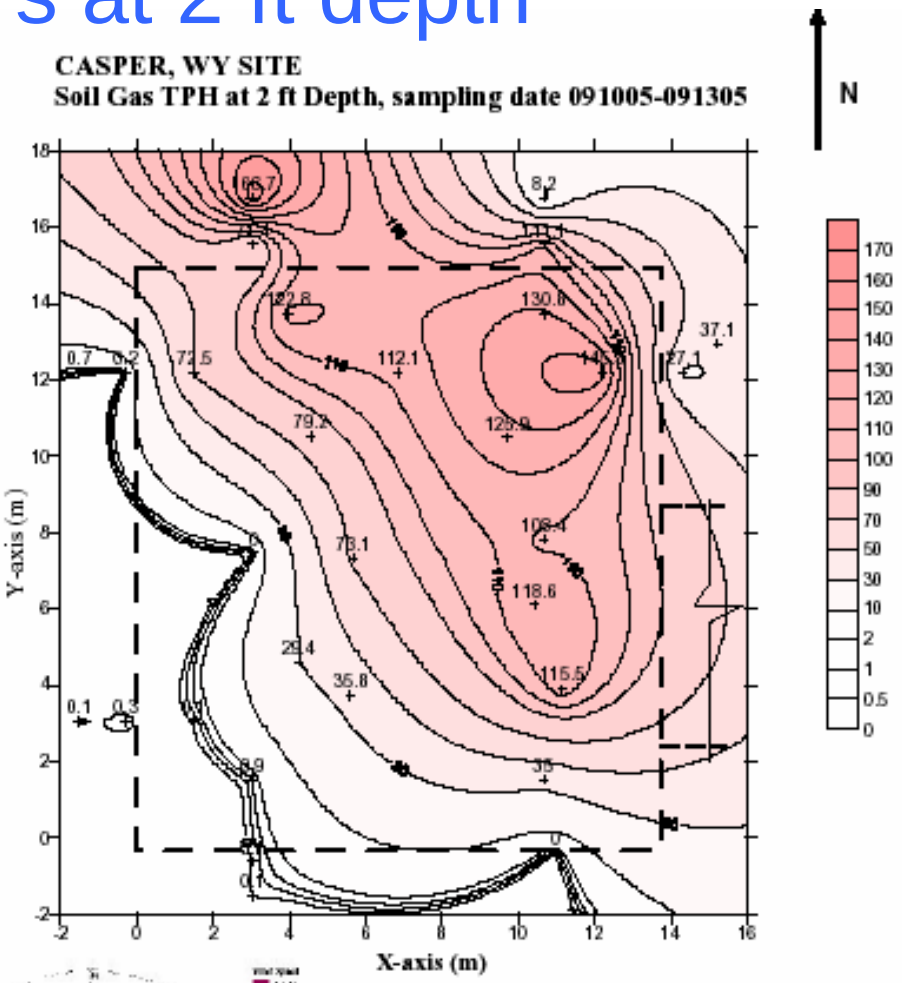
Building boundary

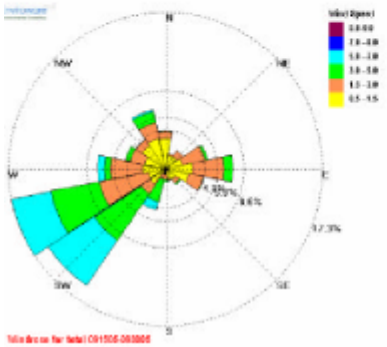
0.2 Location and its TPH concentration in mg/L

Luo et al, 2006

O2 and VOC's at 2 ft depth



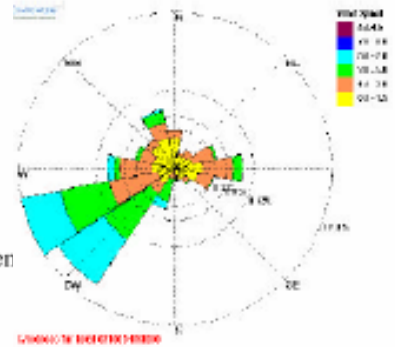




Legend:

Building boundary

0.2 Location and oxygen concen

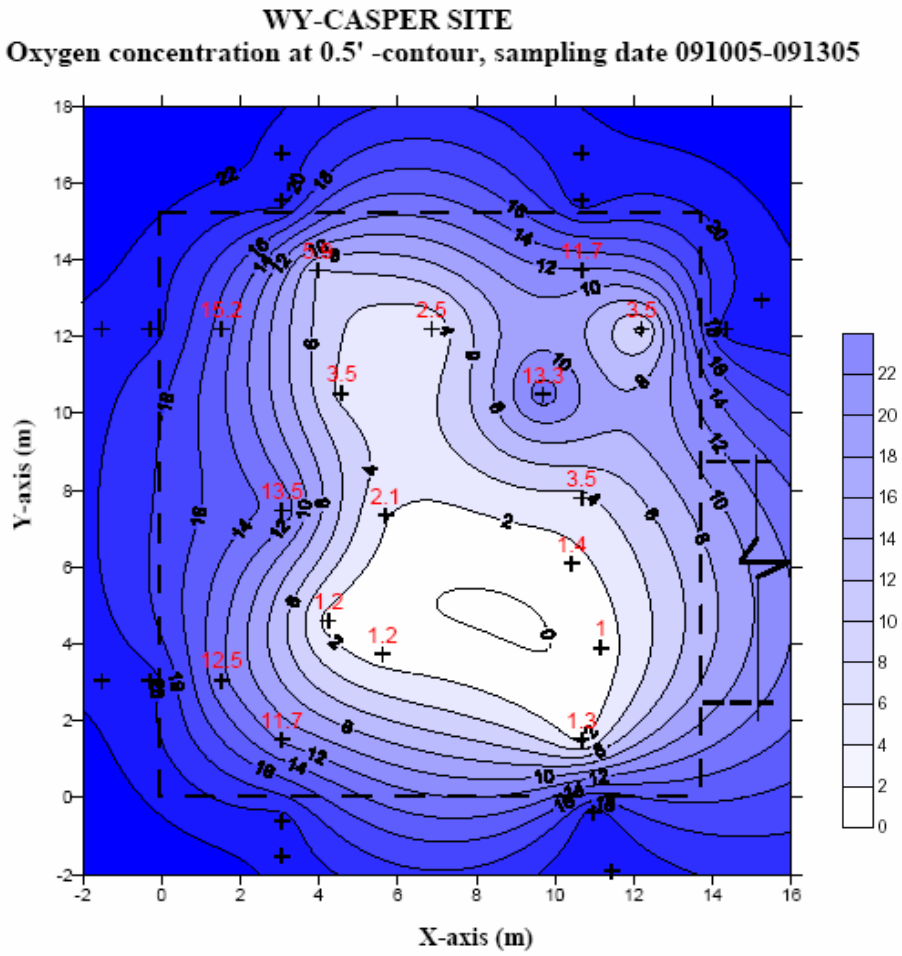


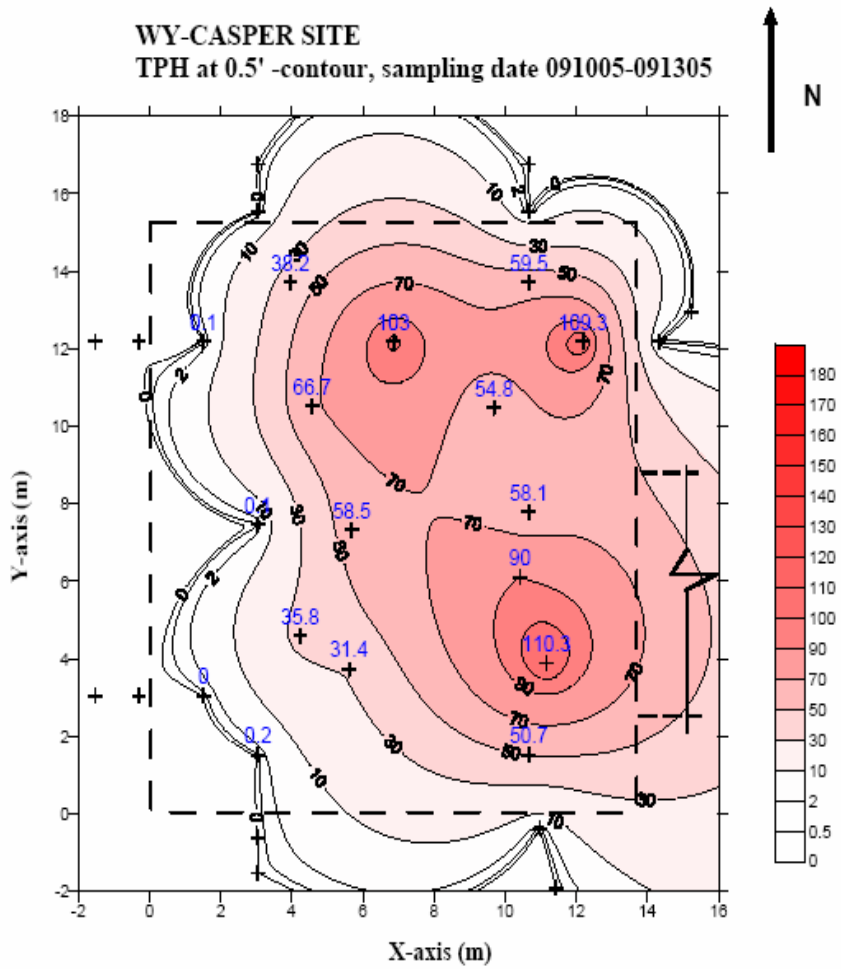
Legend:

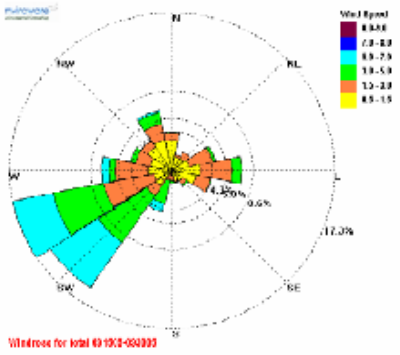
Building boundary

0.2 Location and its TPH concentration in mg/L

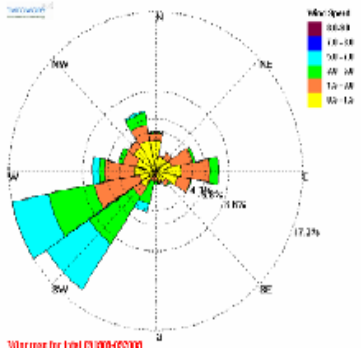
O_2 and VOC's Sub-Slab







Legend:
Building boundary
0.2 Location and its oxygen concentrat



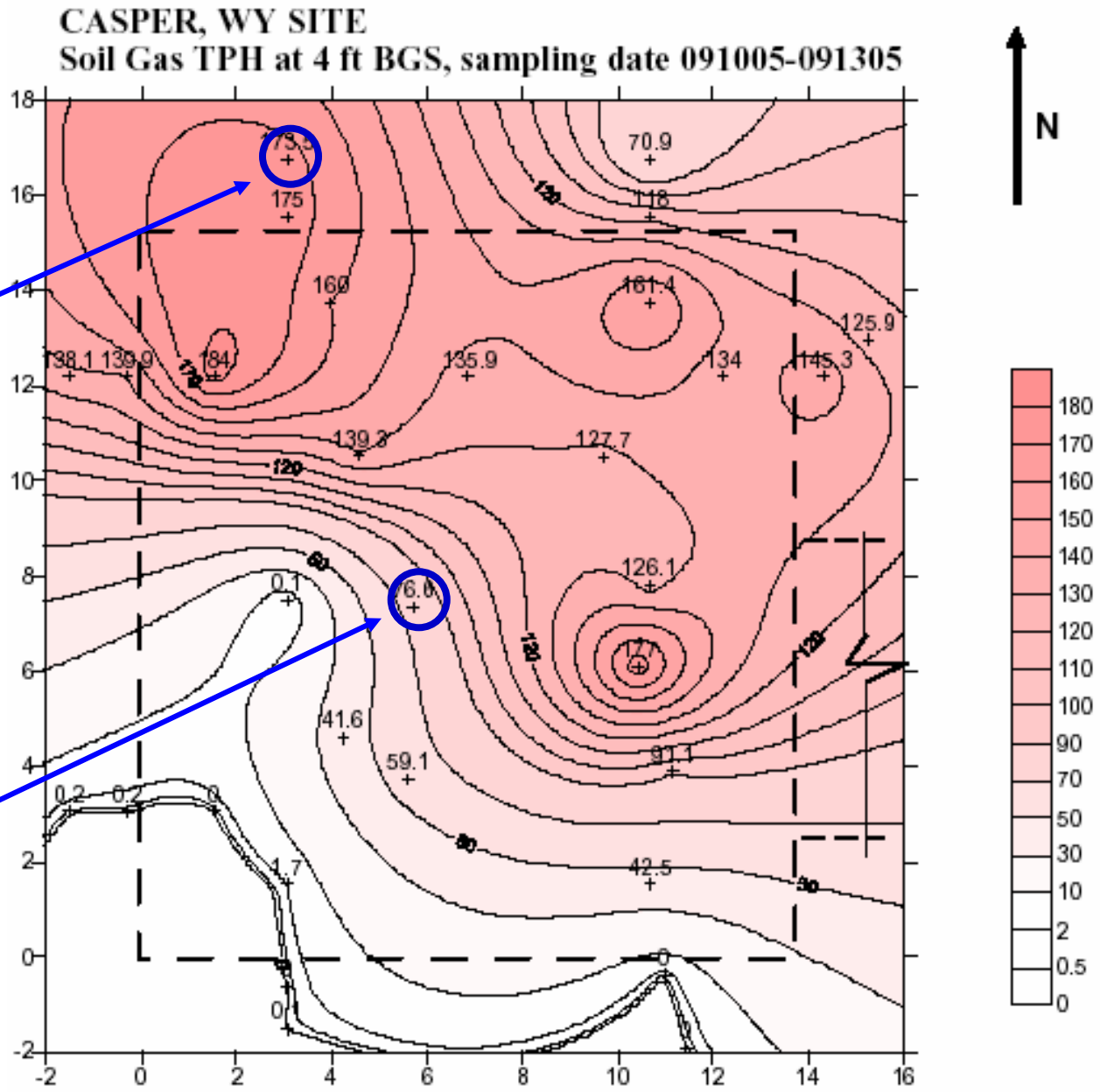
Legend:
Building boundary
0.2 Location and its TPH concentration in mg/L

Luo et al, 2006

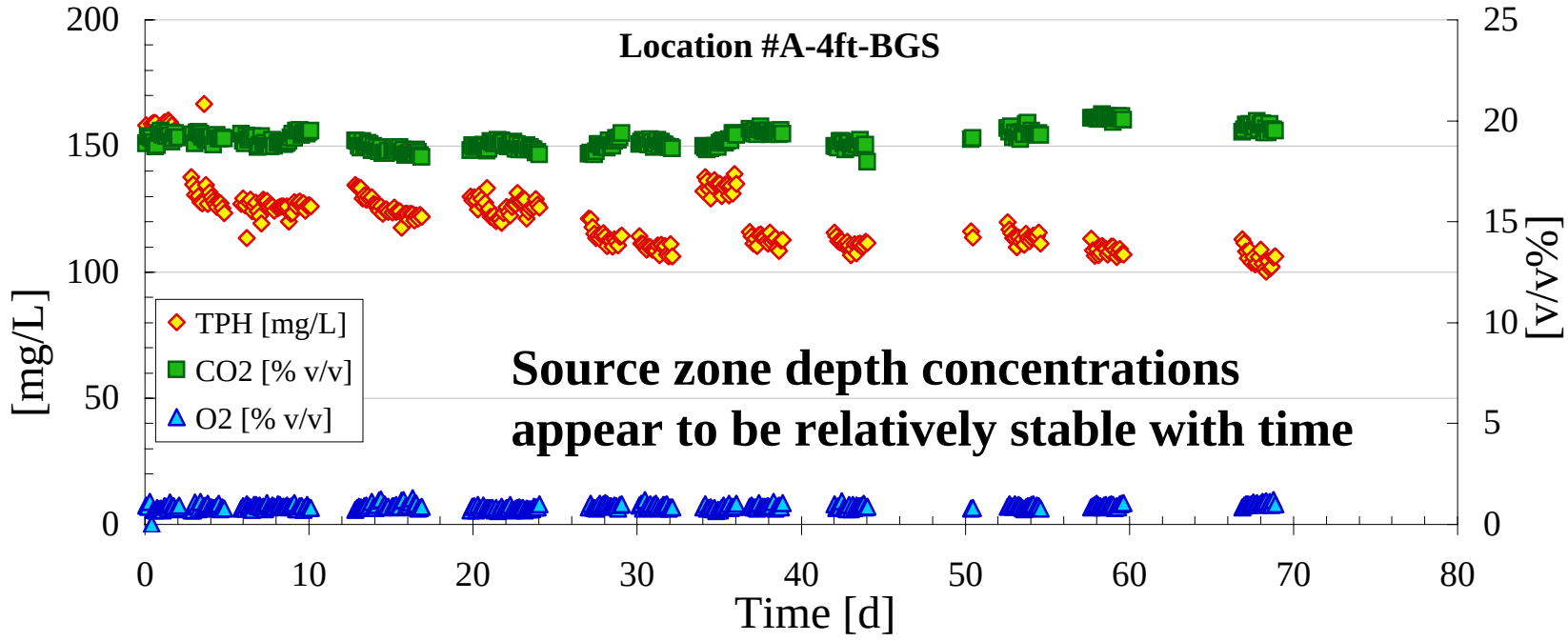
GC Real-Time Sampling

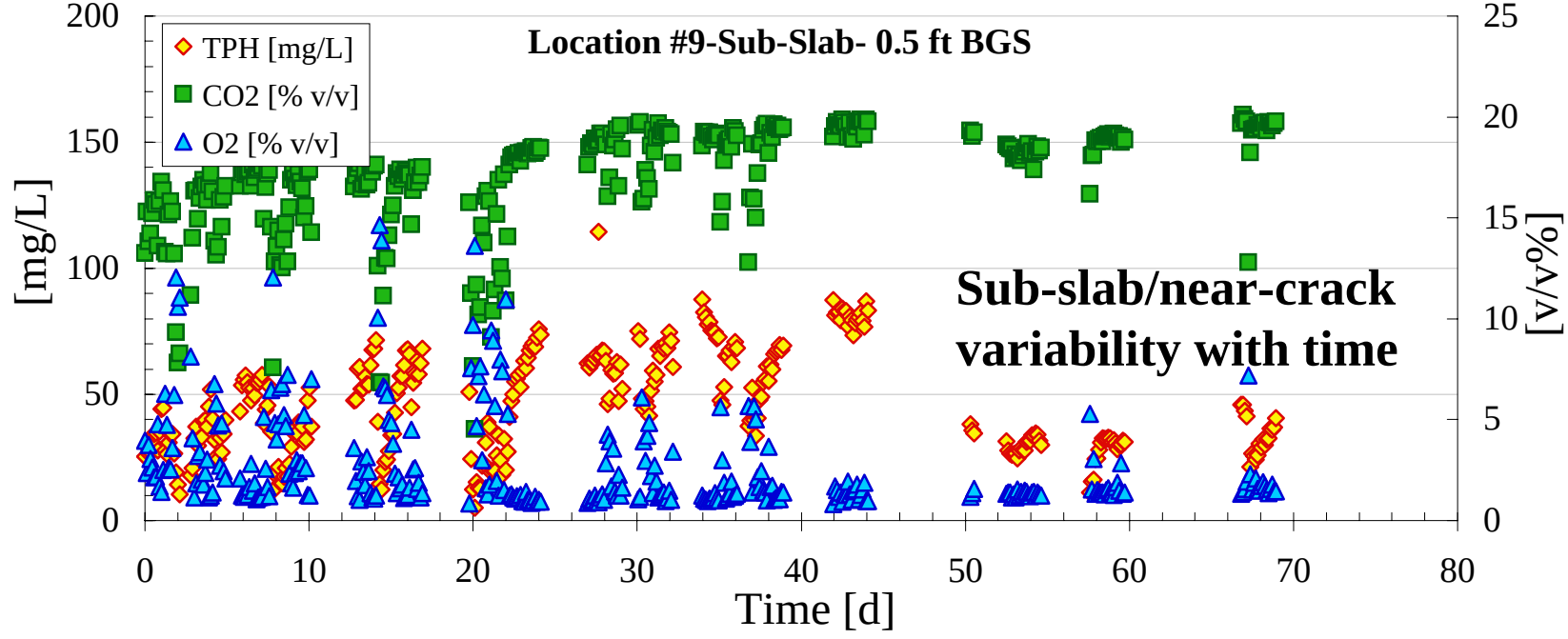
Away from Foundation: Source Zone (4 ft BGS) and Shallow Vapor-Only Area (2 ft BGS)

Under-Foundation and Near-Crack: Sub-Slab (0.5 ft BGS) and Source Area (4 ft BGS)

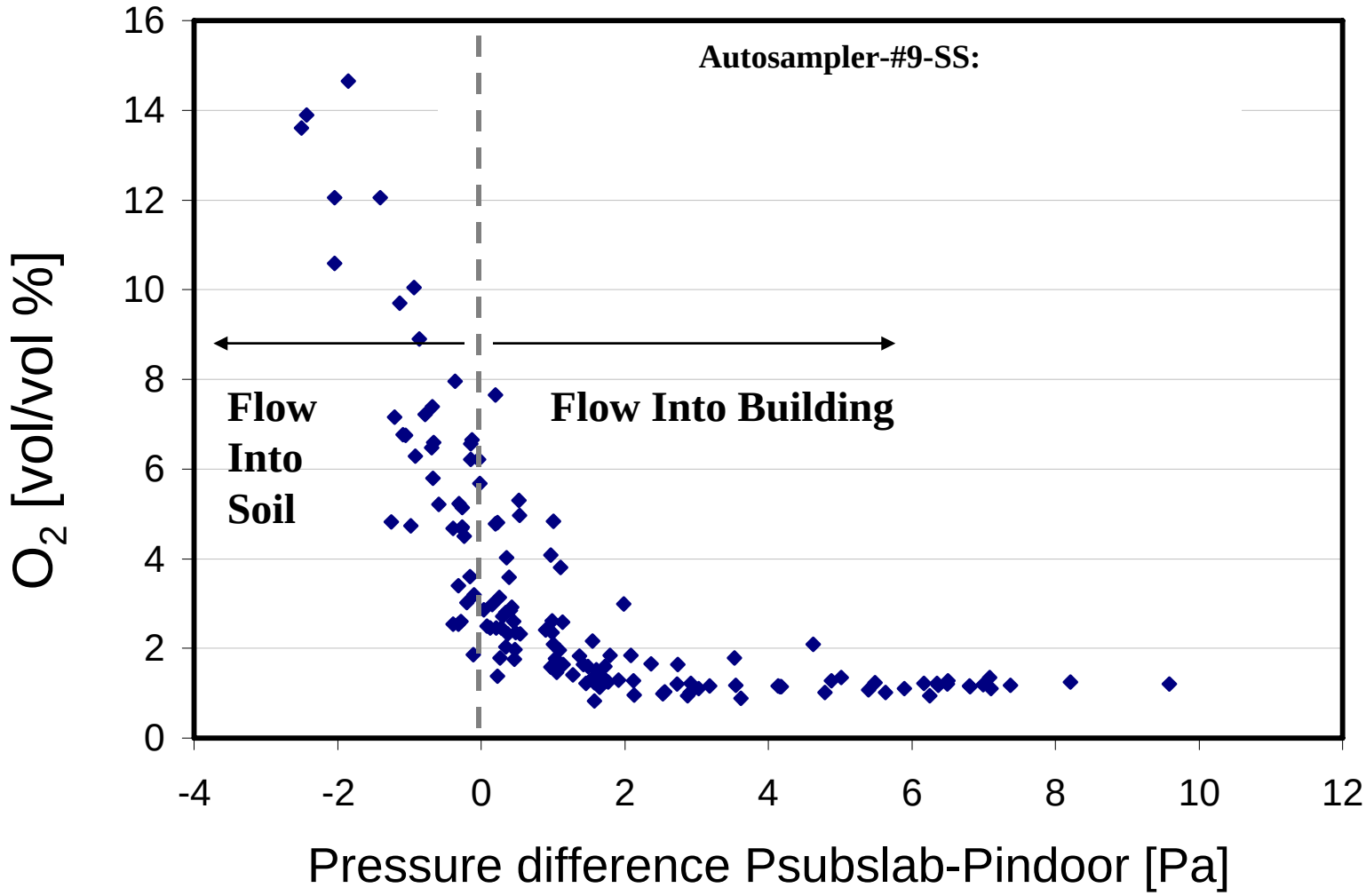


Real-Time GC Sampling

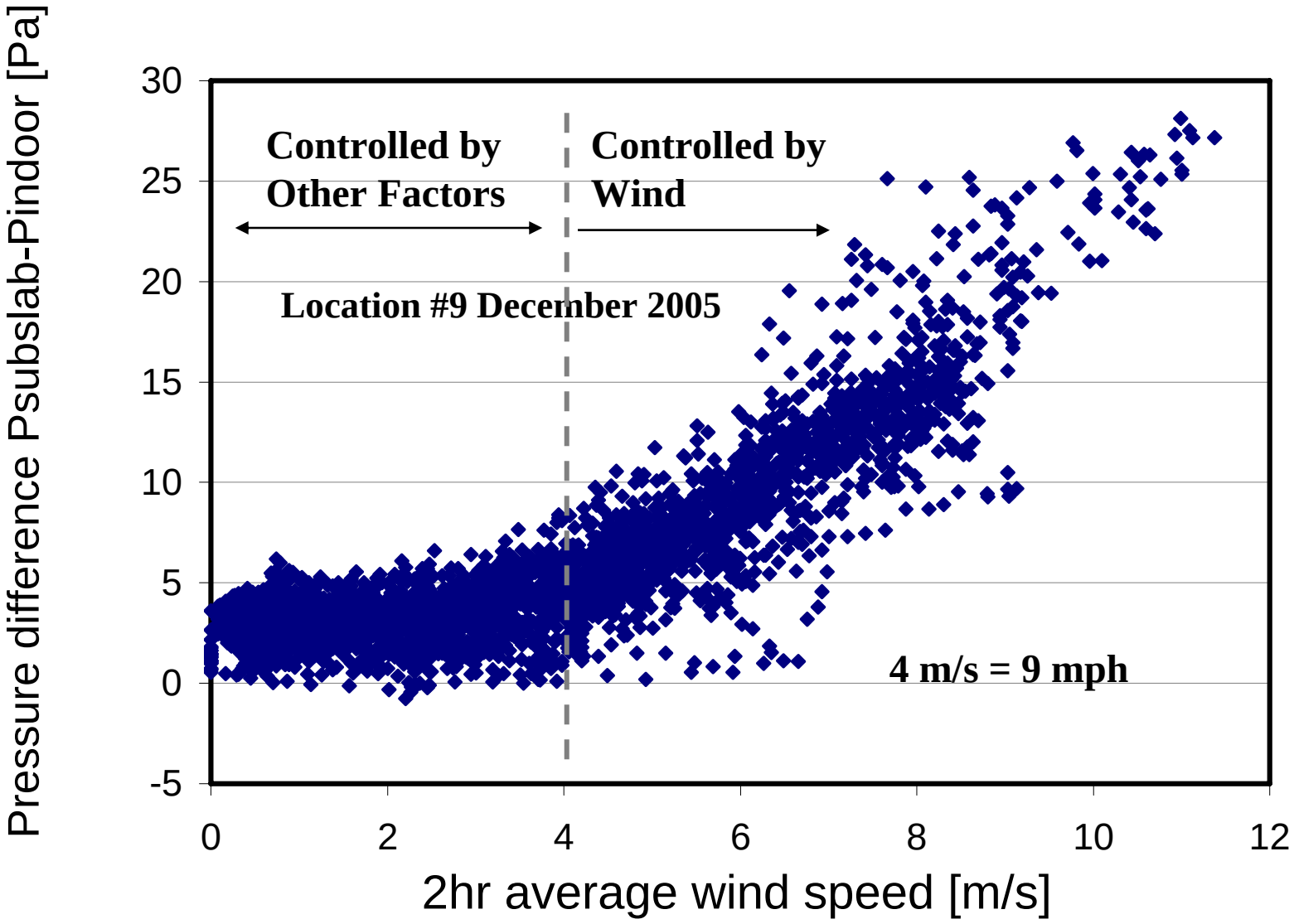




Sub-slab O_2 vs ΔP Near a Crack



Wind Speed vs ΔP



Summary

- Case studies validate building characteristics simulated by Abreu & Johnson (2006) modeling:
  - Shallow, high strength source and uniform sandy vadose zone
  - Hydrocarbon accumulations and associated anoxic zones beneath building foundation
- Empirical databases (Roggemans et al 2001; Davis 2006) verify that these conditions are only rarely encountered, and are easily recognized
- Expanded empirical datasets, supported by modeling, should allow derivation of screening criteria based on source strength, depth, stratigraphic setting, building type, and footprint