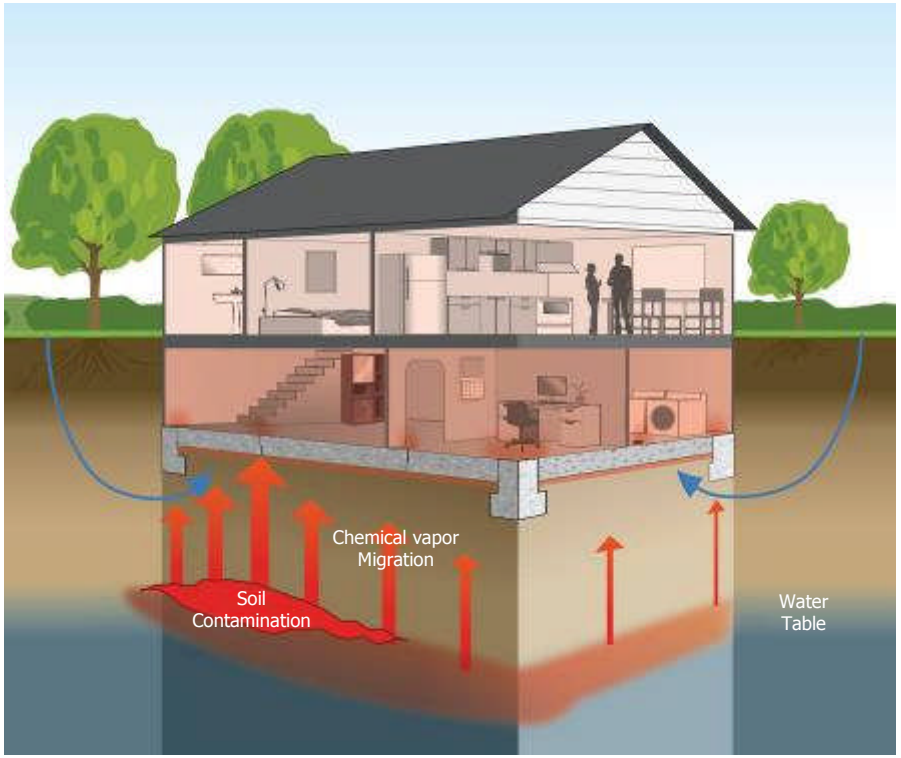
Recent Trends and Critical Issues for Assessment of Vapour Intrusion Pathway

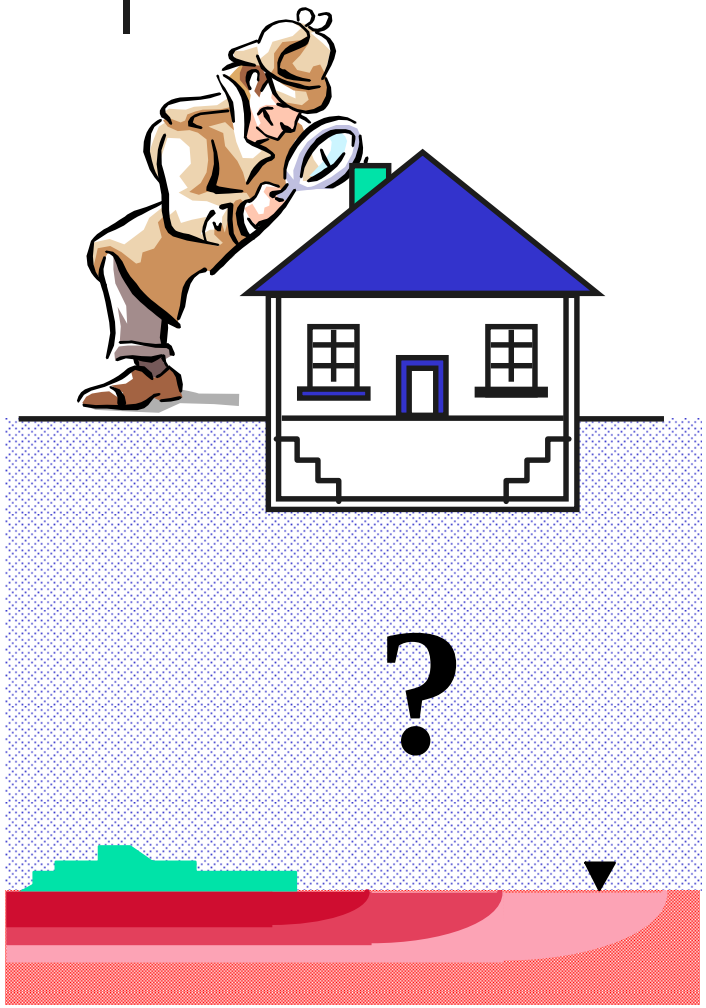


SABCS Soil Vapour Forum
July 8, 2008,
Vancouver, BC

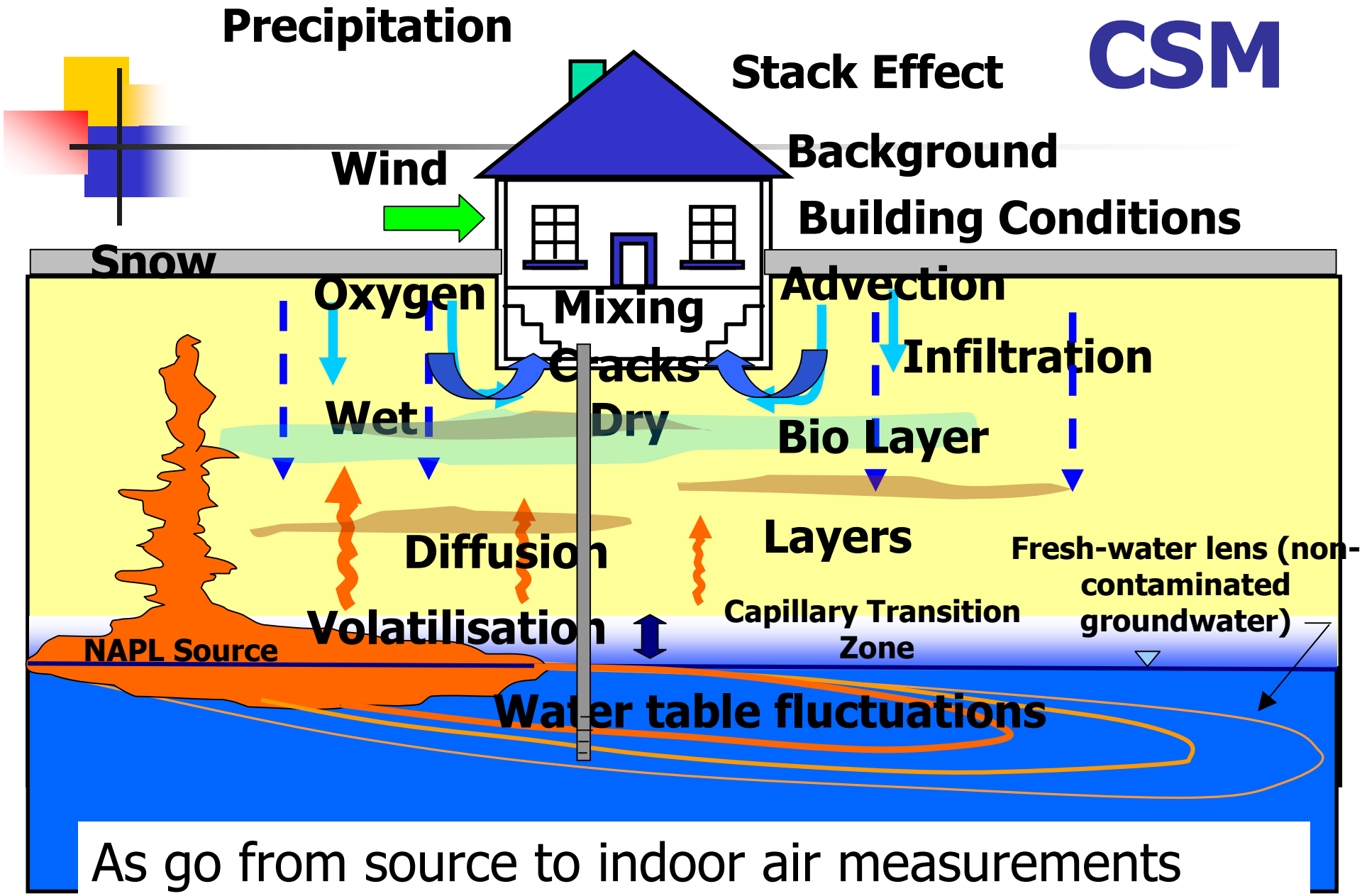
Dr. Ian Hers
Golder Associates Ltd.

Golder Associates

Assessment Challenge



- Identify buildings/sites with potentially complete pathway for vapour intrusion (VI)
- Determine whether indoor vapour presents adverse impacts/risks to those in buildings
- Use the right tool kit of methods and approaches
- Do this is way that is sufficiently certain, efficient and cost effective



As go from source to indoor air measurements there is compounding effect of variability

The Recent Context

- Vapor intrusion (VI) is a ***potential*** exposure pathway at sites with volatile chemicals (many sites!)
- Perception and potential for breathing "toxic" vapours makes this a challenging pathway
- Increasing number of sites with demonstrated VI including several high profile sites with large chlorinated solvent plumes below residential areas
- VI has caught the attention of regulators, lawyers and public (several large lawsuits, Cambridge Ontario 100M, Quebec site 250 M, Redfields 400 M) http://www.tceblog.com/posts/1147841386.shtml

Historical Overview

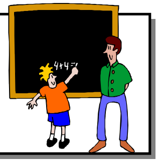
Early IAQ Concerns (1970's & early 1980's) (VOCs as Carcinogens**)**

↓

Early Experience (1980's)
(Love Canal, 1985; Hillside MA School 1989)

↓

Johnson & Ettinger Model (1991) **[The beginning of the end…]**



↓

Early Guidance (1990's)
(MA 1992, ASTM E-1739 1995, CCM… 2000 **[Limited knowledge of pathway…]**

↓

Experience (~ 2000 on)
("Colorado" Sites, Endicott, NY)
[We need to take this pathway seriously …]

↓

Recent Guidance (2005 on)
(USEPA 2002, Health Canada 200… 2005, NJ 2005, ITRC 2007, ASTM …)
[Hmmm…Lot of different approaches]

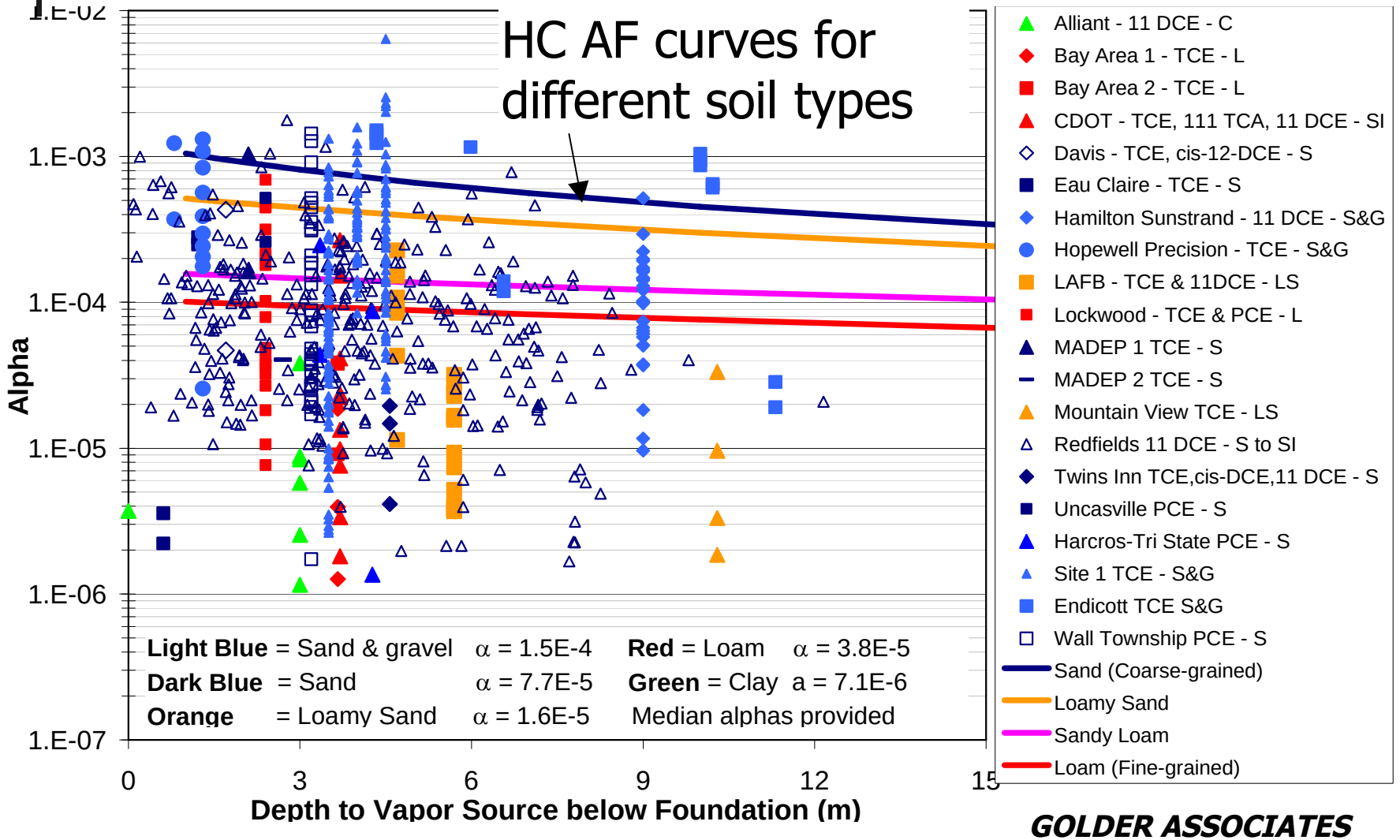
- It has been a 20 year process for:
  - ► **Recognition**
    - ► **Science**
      - ► **Experience**
        - ► **Guidance**
- Knowledge improving but questions (and misconceptions!) remain

IAQ = indoor air quality

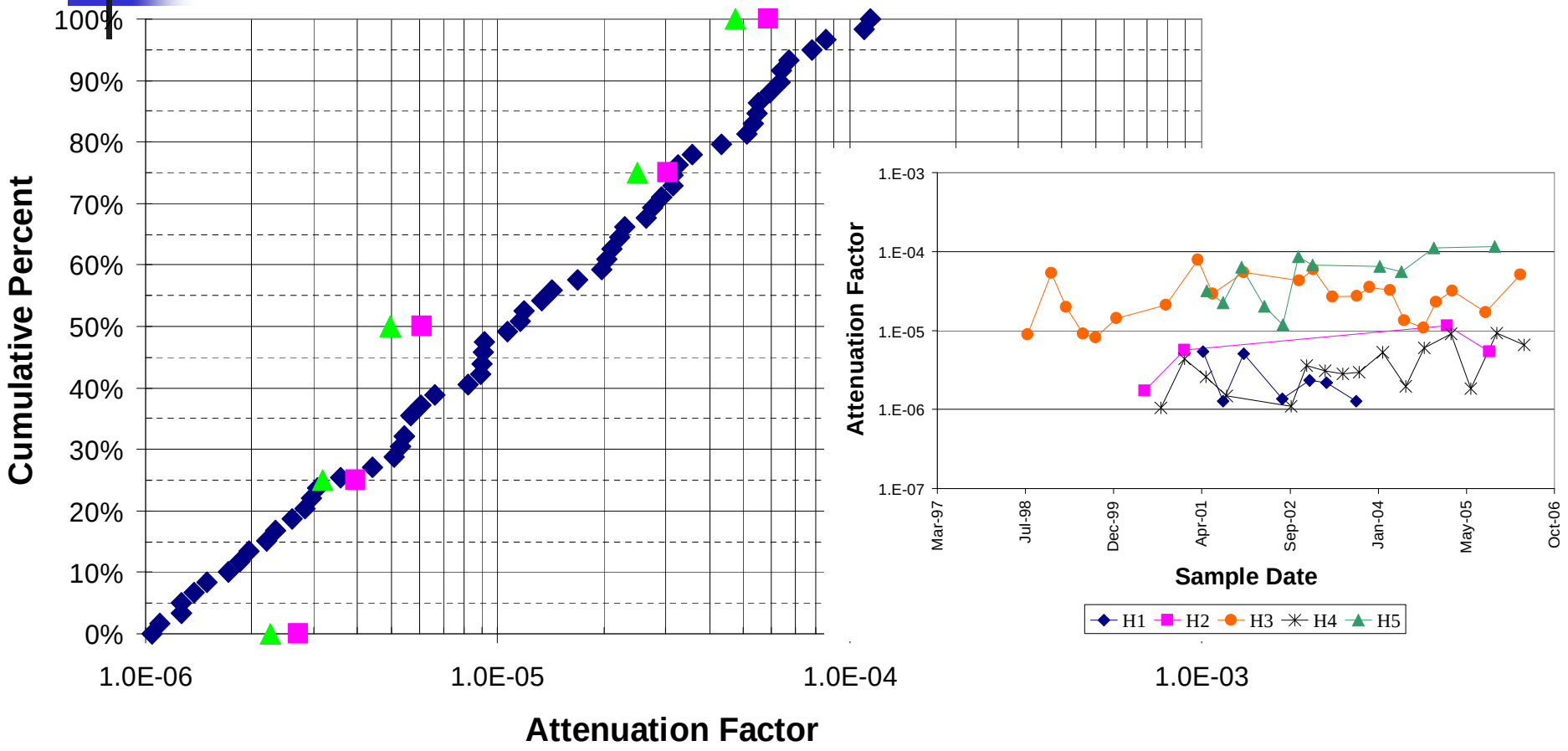
What do we know
(from observations)

- Many chlorinated solvent sites with significant VI impacts, much smaller number of petroleum sites (aerobic biodegradation)
- Large degree spatial variability in groundwater and soil vapour; and temporal variability in soil vapour and indoor air
- Significant VI impacts for range of building types and foundations (buildings generally depressurized, flux controlled by soil)
- USEPA VI database has contributed significant to understanding of pathway – 4 yrs, 44 sites, over 2000 data points

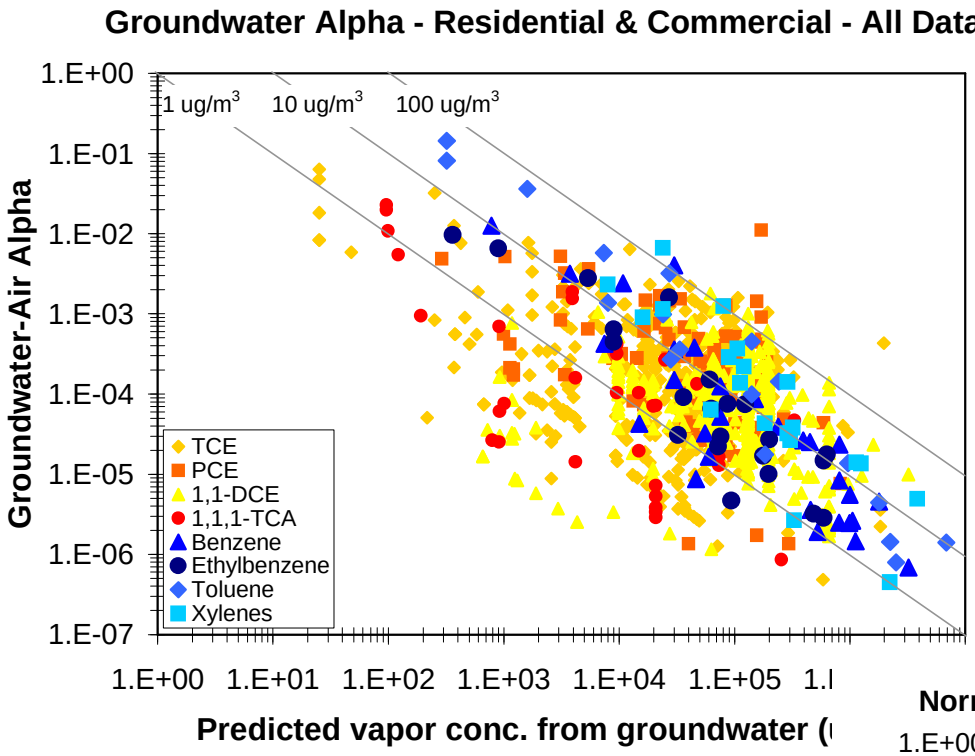
Comparison J&E –AFs to Empirical Data (Groundwater AF, Chlorinated hydrocarbons)



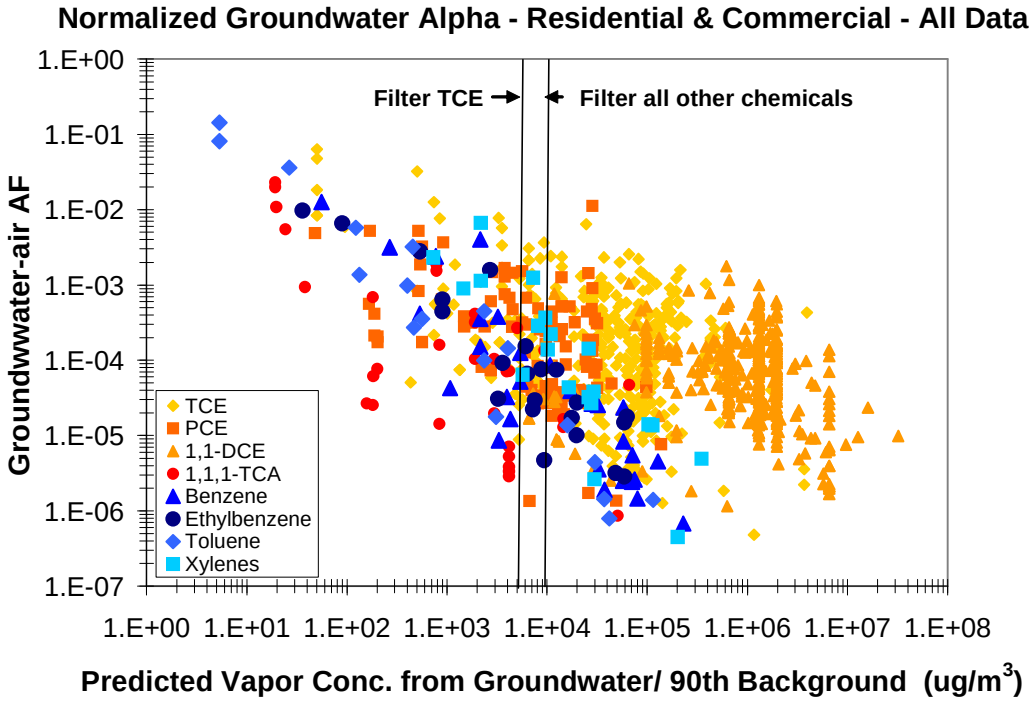
Redfield, Single Point vs Average Alpha (Redfield Site)



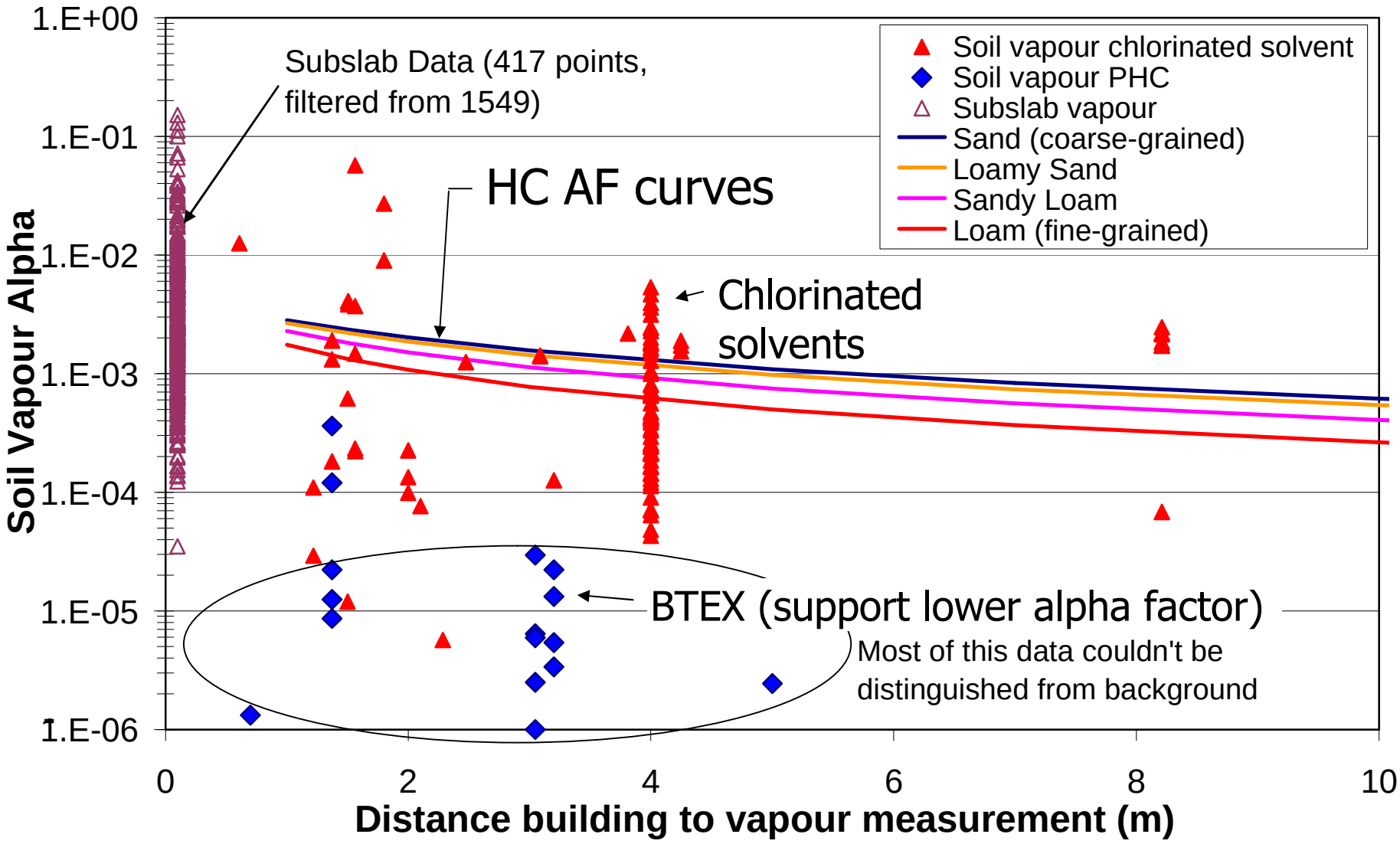
Courtesy David Folkes, Envirogroup

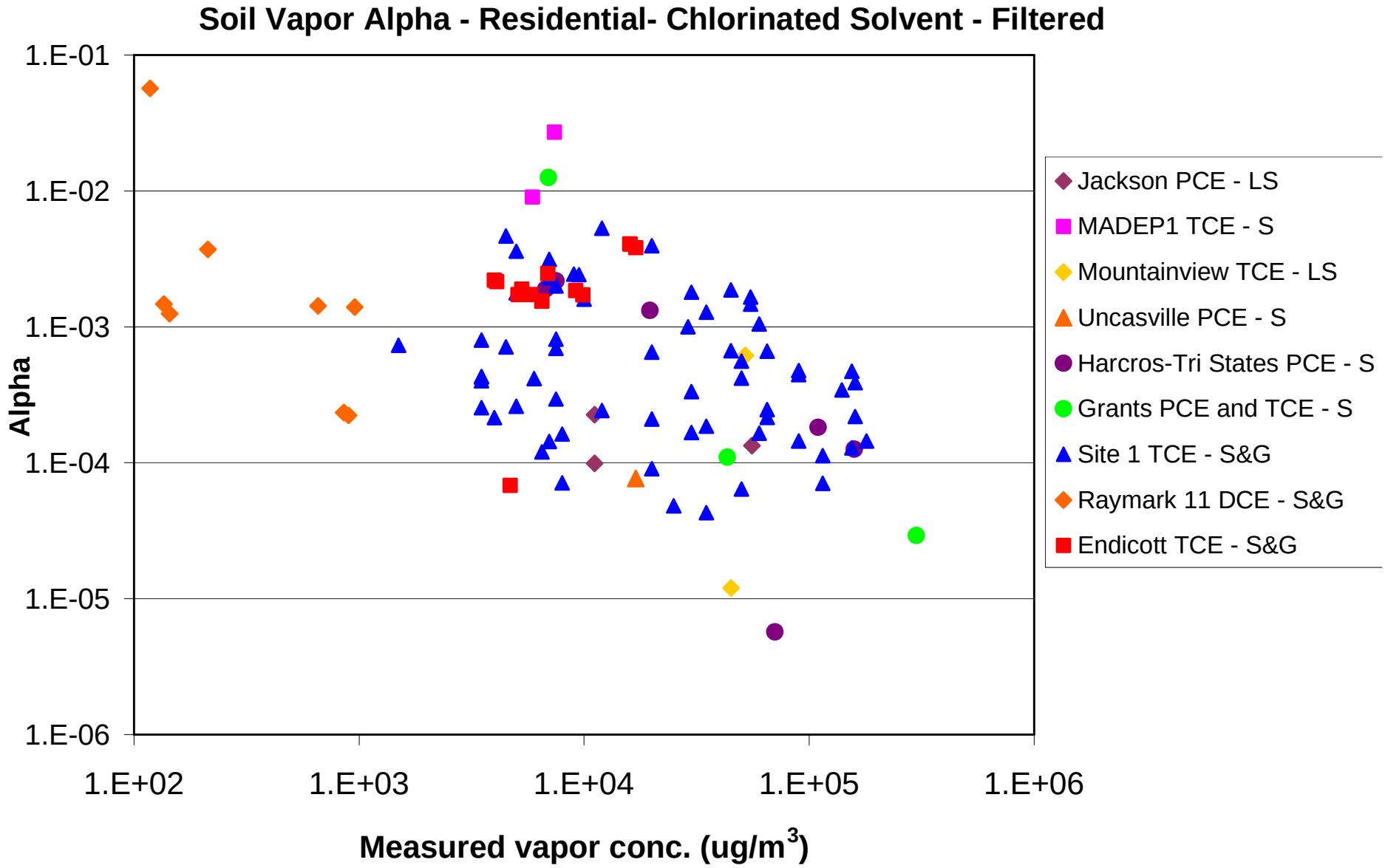


Normalized to background

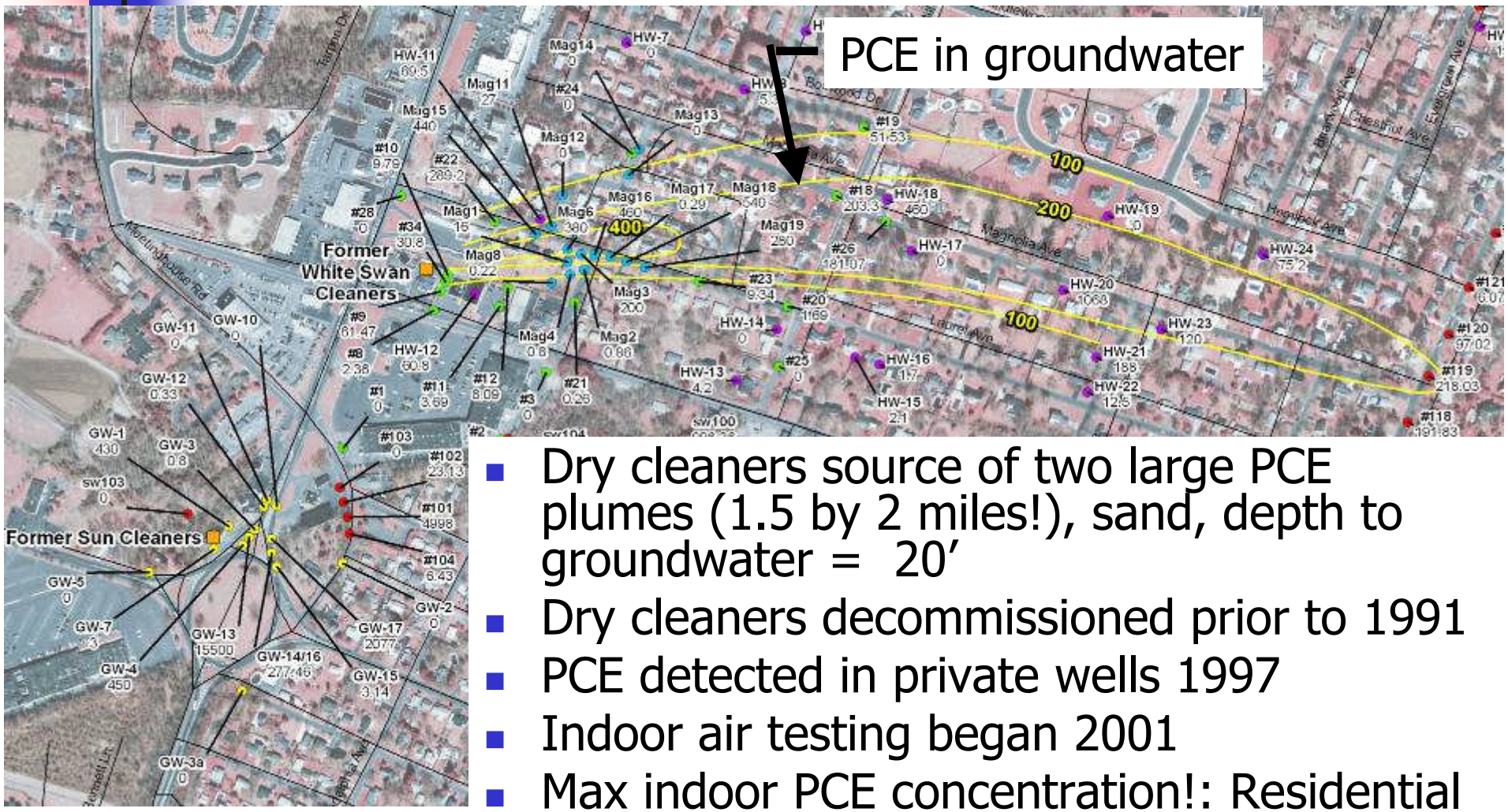


Comparison J&E - AFs to Chlorinated and Petroleum Hydrocarbon Empirical Data (soil vapour aresidential, filtered)



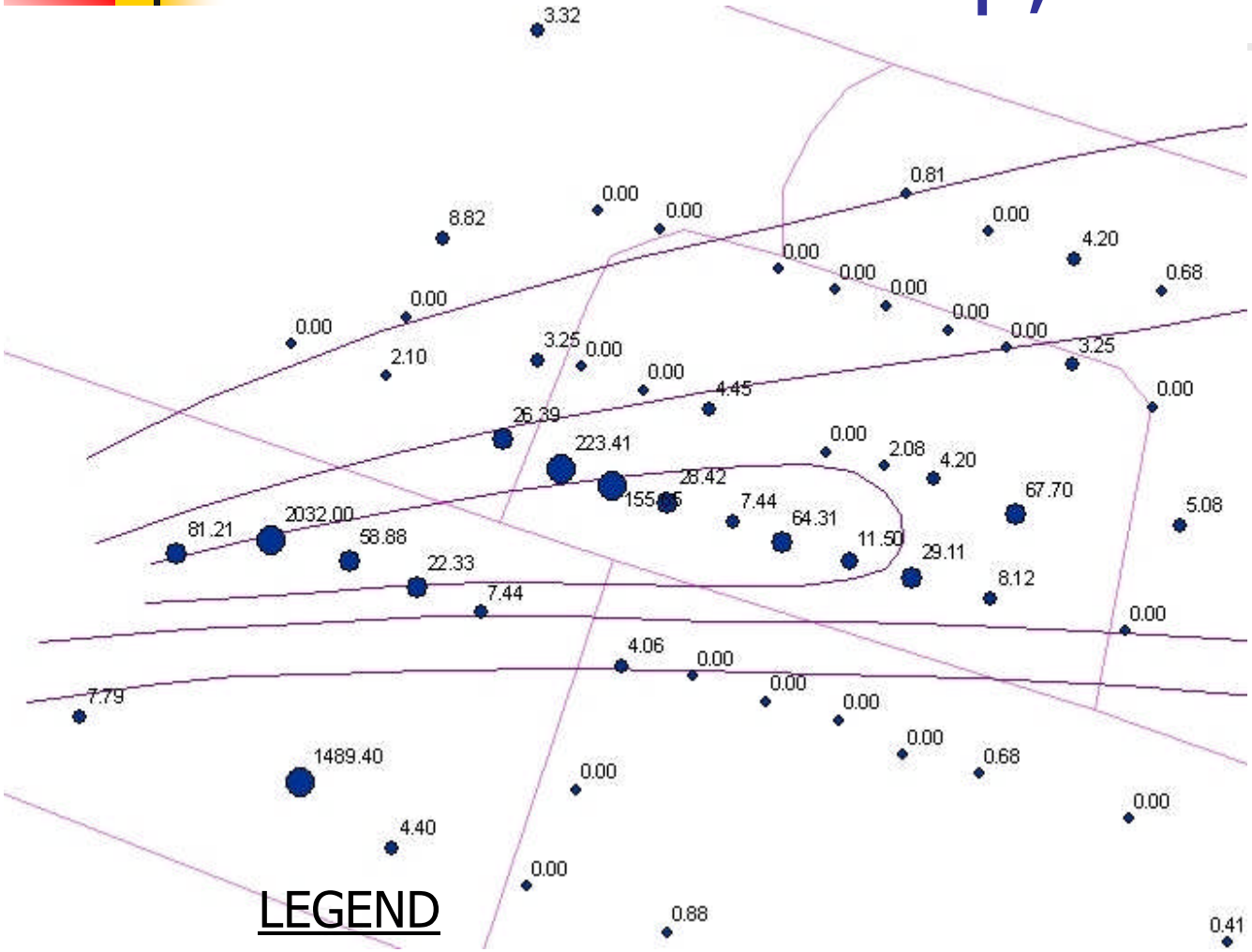

Soil Vapor Alpha - Residential- Chlorinated Solvent - Filtered
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
Alpha
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
Measured vapor conc. (ug/m3)
Jackson PCE - LS
MADEP1 TCE - S
Mountainview TCE - LS
Uncasville PCE - S
Harcros-Tri States PCE - S
Grants PCE and TCE - S
Site 1 TCE - S&G
Raymark 11 DCE - S&G
Endicott TCE - S&G

Wall Township, NJ



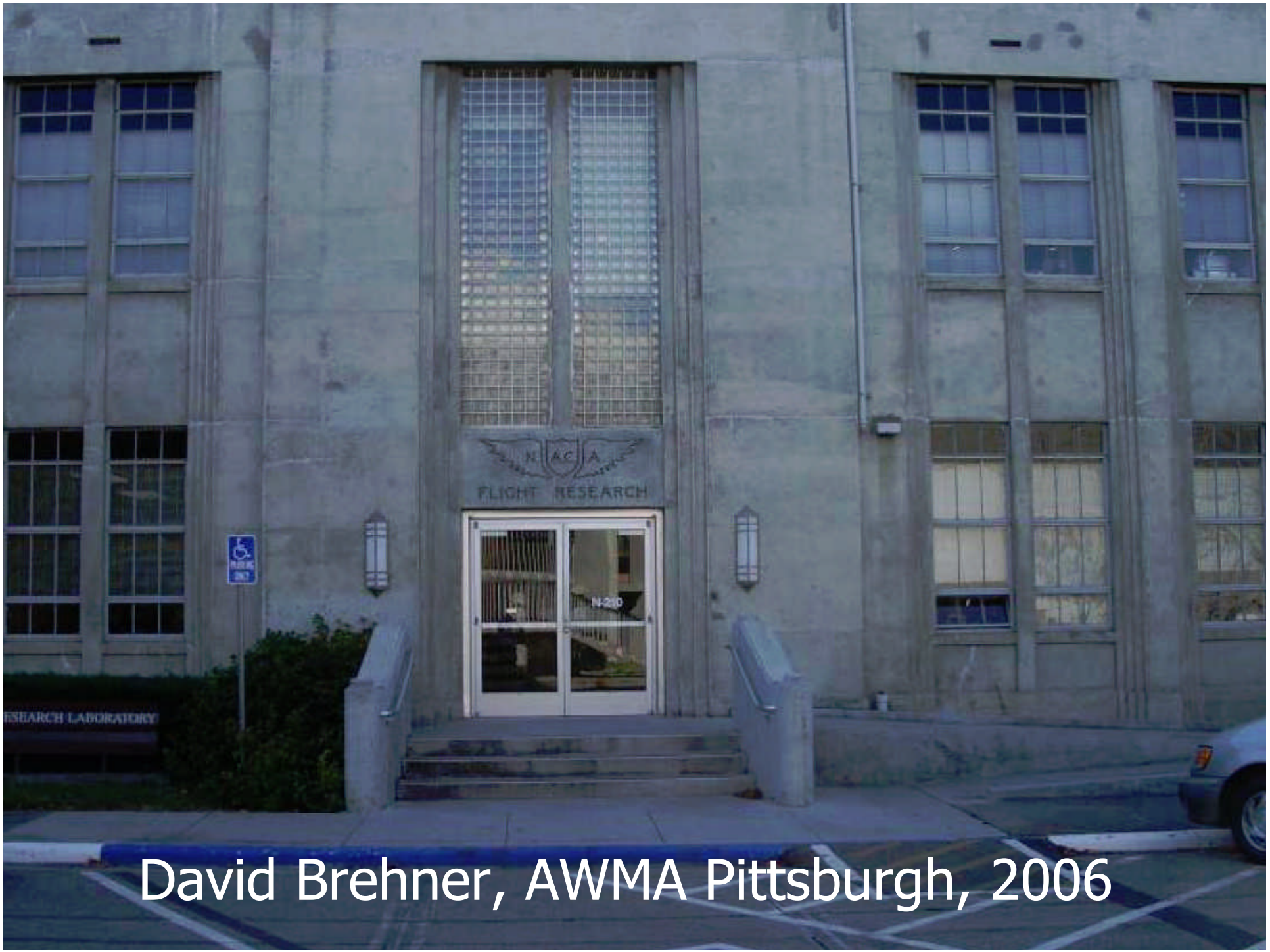
- Dry cleaners source of two large PCE plumes (1.5 by 2 miles!), sand, depth to groundwater = 20’
- Dry cleaners decommissioned prior to 1991
- PCE detected in private wells 1997
- Indoor air testing began 2001
- Max indoor PCE concentration!: Residential ~ 2000 ug/m^3, Commercial ~ 1500 ug/m^3

Wall Township, Indoor Air



- PCE concentration indoor air (ug/m^3)

- Max indoor PCE concentration!: Residential houses ~ 2000 ug/m^3, Commercial (1 building) ~ 1500 ug/m^3



David Brehner, AWMA Pittsburgh, 2006

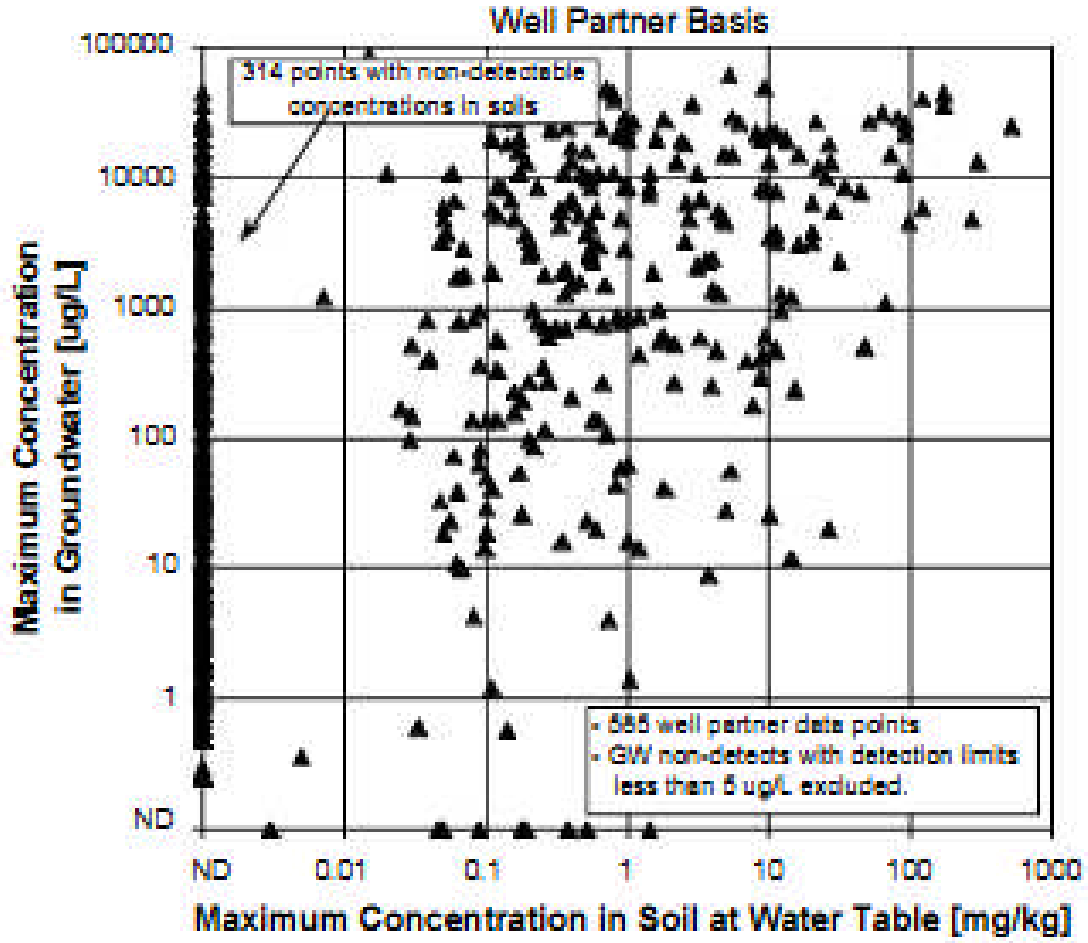
TCE Results


1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
Concentration (ug/m3)
1st Floor Breathing Zone
2nd/3rd Floor Breathing Zone
Pathway
Outdoor Ambient
Background
Pre-Fix
Post-Fix
07-Jun-04
08-Jun-04
09-Jun-04
10-Jun-04
11-Jun-04
21-Jun-04
22-Jun-04
23-Jun-04
24-Jun-04
25-Jun-04
07-Sep-04
09-Sep-04
14-Sep-04
16-Sep-04
12-Jul-05
14-Jul-05
19-Jul-05
21-Jul-05
27-Sep-05
29-Sep-05
03-Jan-06
05-Jan-06
06-Feb-06
07-Feb-06
08-Feb-06
09-Feb-06
10-Feb-06
13-Feb-06
14-Feb-06
15-Feb-06
16-Feb-06
Maximum Detected
95th Percentile
75th Percentile
Median
25th Percentile
5th Percentile
1st Floor Pre-Fix
2nd Floor Pre-Fix
1st Floor Post-Fix
2nd/3rd Floor Post-Fix
Ambient Pre-Fix
Background Pre-Fix
Ambient Post-Fix
Baclground Post-Fix

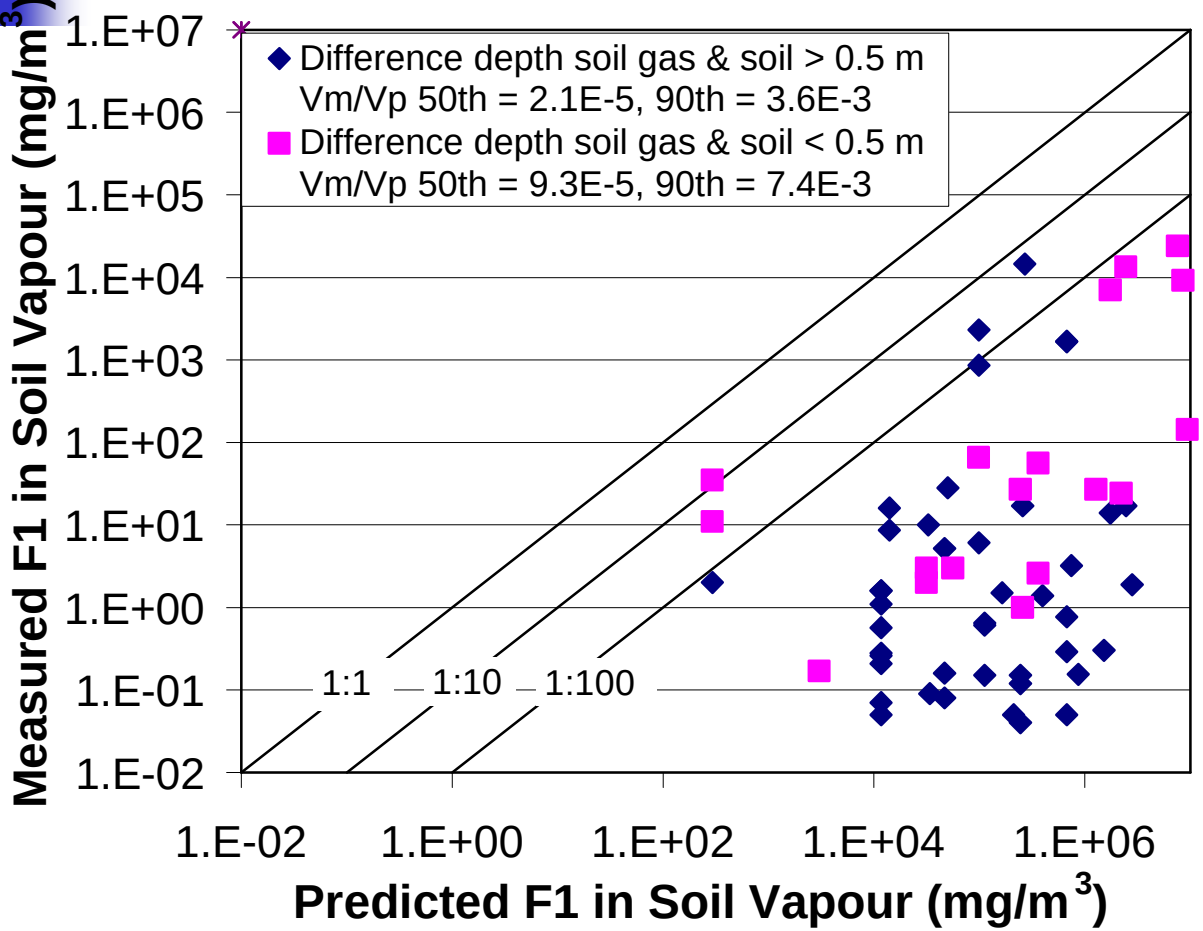
Pro's & Con's Different Media

Media	Pro's	Con's
Soil	Data may be available, low cost, low temporal variability	Partitioning highly uncertain, high spatial variability
Ground water	Data may be available, low cost, moderate temporal variability	Partitioning uncertain, not representative if unsaturated zone source
External soil vapour	Avoids partitioning, more direct indication exposure, may integrate sources	Spatial variability moderate to high, temporal variability moderate, method issues
Subslab vapour	Closer to receptor, avoids lateral variability	Intrusive, cost, small scale spatial variability can be high
Air	Most direct indication (only for existing building)	Intrusive, cost, temporal variability moderate to high, background issues

Relationship Groundwater and Soil (or lack thereof) (Paul Johnson)



Meta-data Analysis – Co-located soil-soil vapor



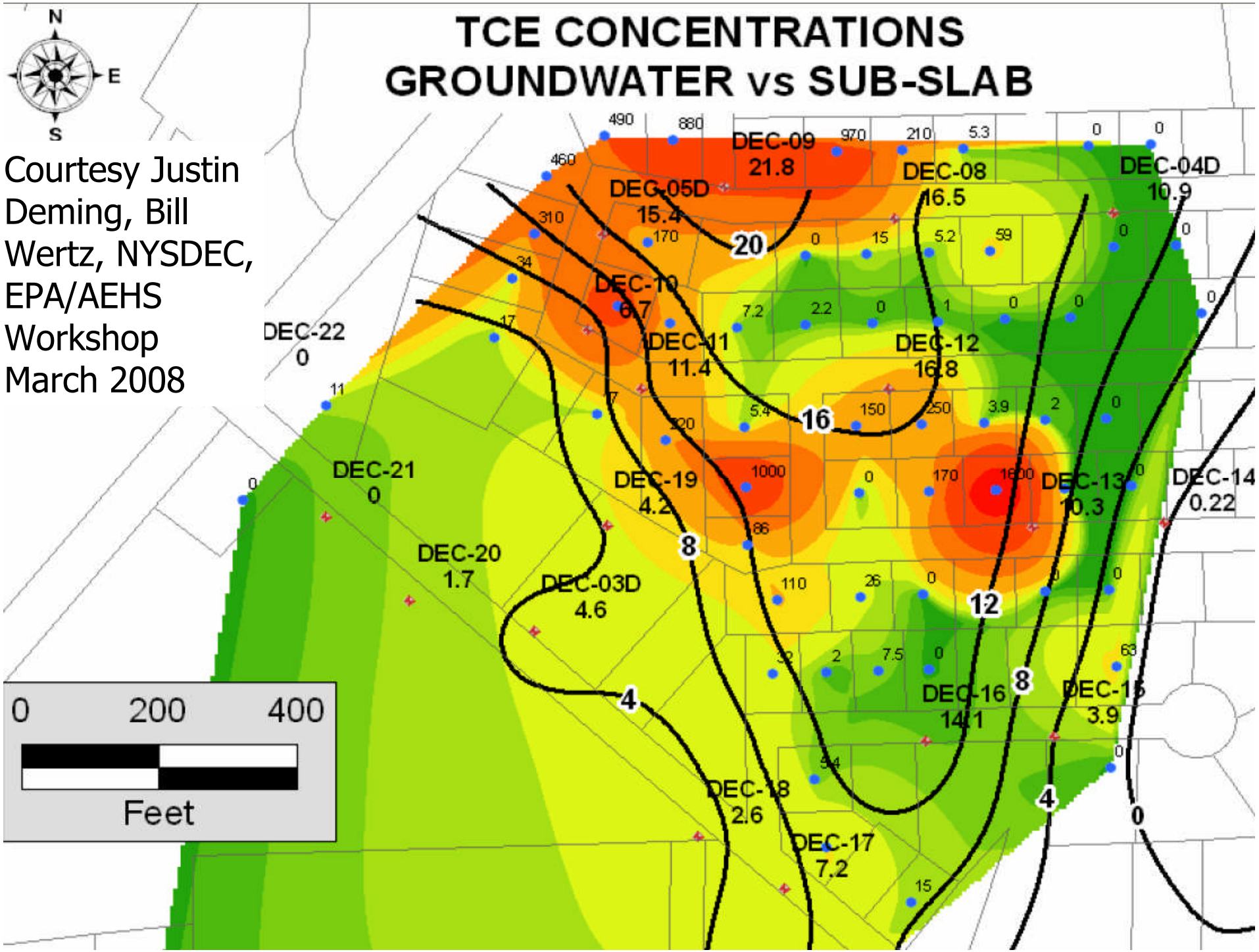
CPPI Database

F1 (TPH_g) vapor concentrations predicted using 3-phase model, f_{oc} = 0.005

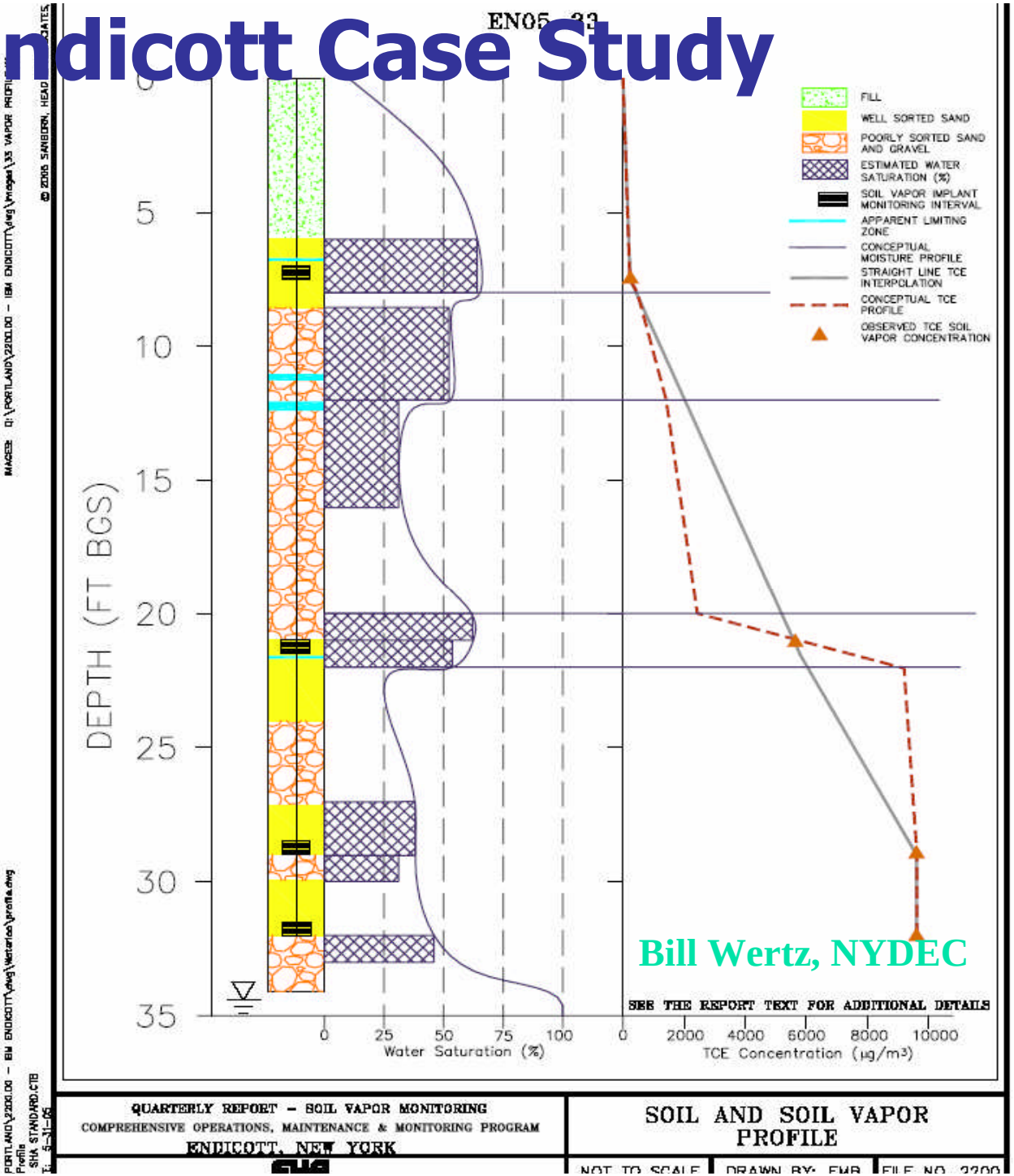
Key points:	Approximate relationship between measured & predicted vapor concentrations. Measured vapor > 10X less than predicted.

Soil Vapour Data

- More direct indication of potential exposure, can integrate sources (if in right location!), potentially less conservative, but …
- Significant challenge is observed spatial and temporal variability in soil vapour concentrations:
  - Capping effect of building
    - **"Rain shadow"** and drier soils below building
    - **"Oxygen limitations"** leading to reduced biodegradation
  - Barometric pumping
  - Influence of building (subslab fill, utilities, advection)
- Deeper near source data least affected by variability (shallow external data may not be representative)
- Poor sampling methods also a problem


TCE CONCENTRATIONS
GROUNDWATER vs SUB-SLAB
N
E
S
Courtesy Justin Deming, Bill Wertz, NYSDEC, EPA/AEHS Workshop March 2008
DEC-09 21.8
DEC-08 16.5
DEC-04D 10.9
DEC-05D 15.4
DEC-10 6.7
DEC-11 11.4
DEC-12 16.8
DEC-22 0
DEC-21 0
DEC-19 4.2
DEC-13 10.3
DEC-14 0.22
DEC-20 1.7
DEC-03D 4.6
DEC-16 14.1
DEC-15 3.9
DEC-18 2.6
DEC-17 7.2
20
16
12
8
4
0
0 200 400
Feet

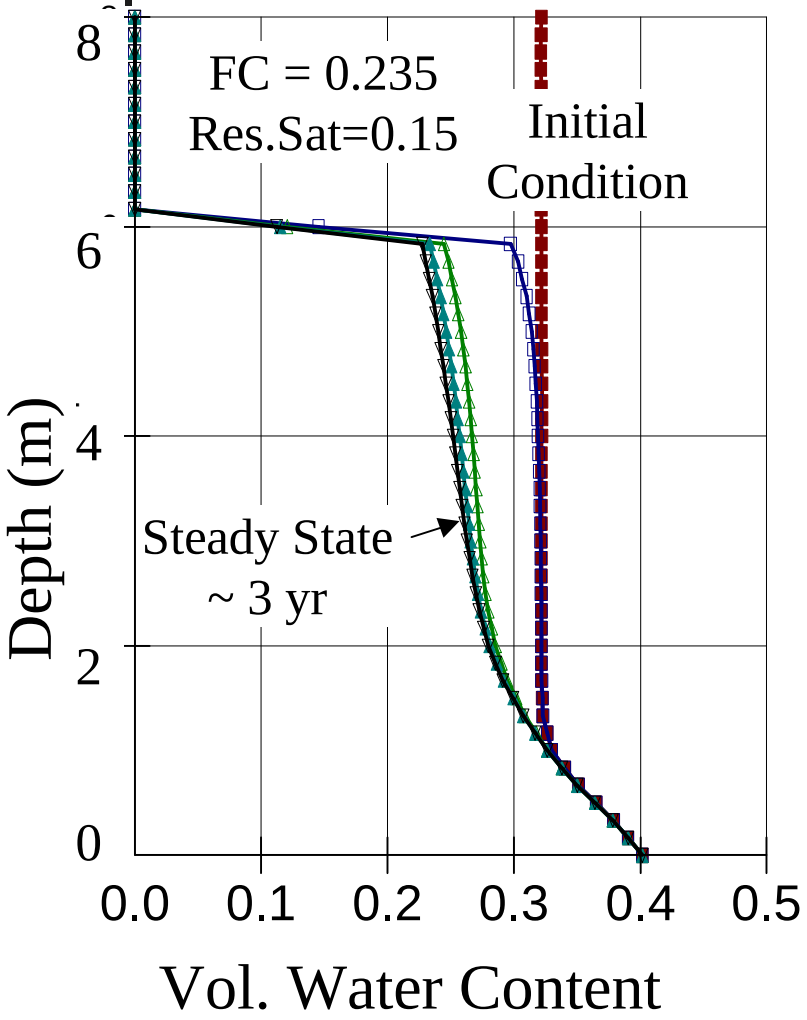
Endicott Case Study

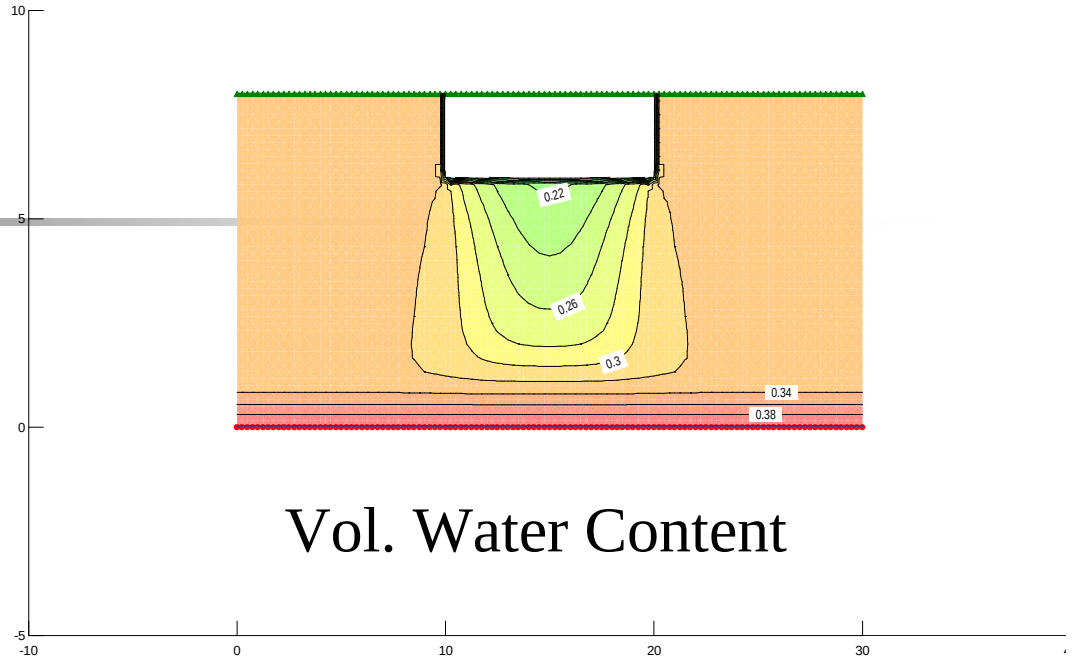


Bill Wertz, NYDEC

SEEP-W Modeling

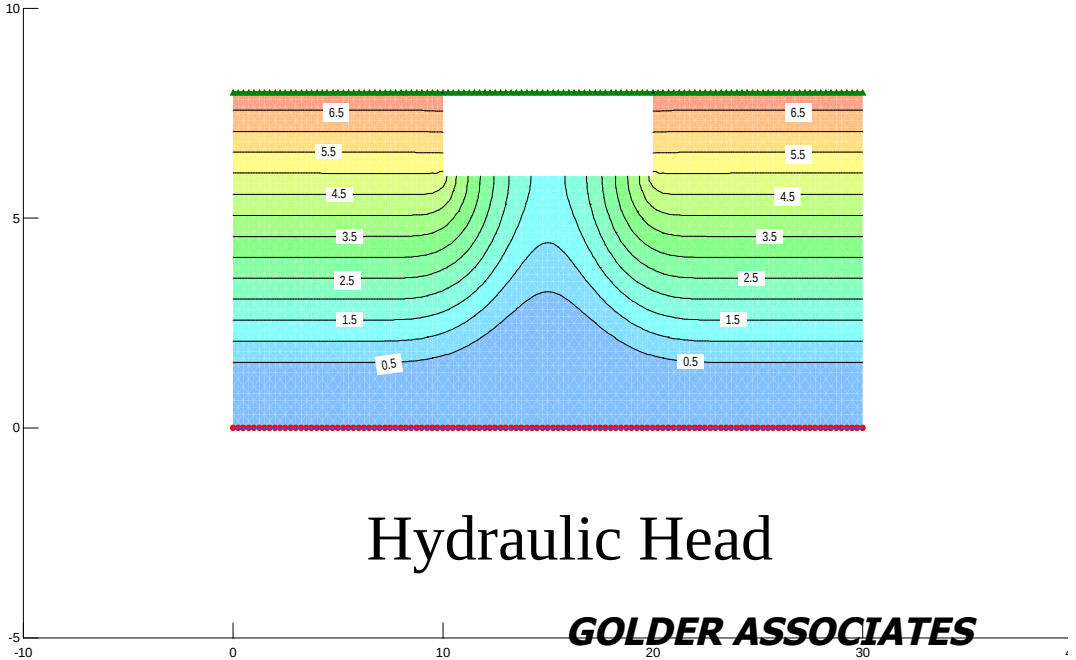
SCS Loam





Vol. Water Content

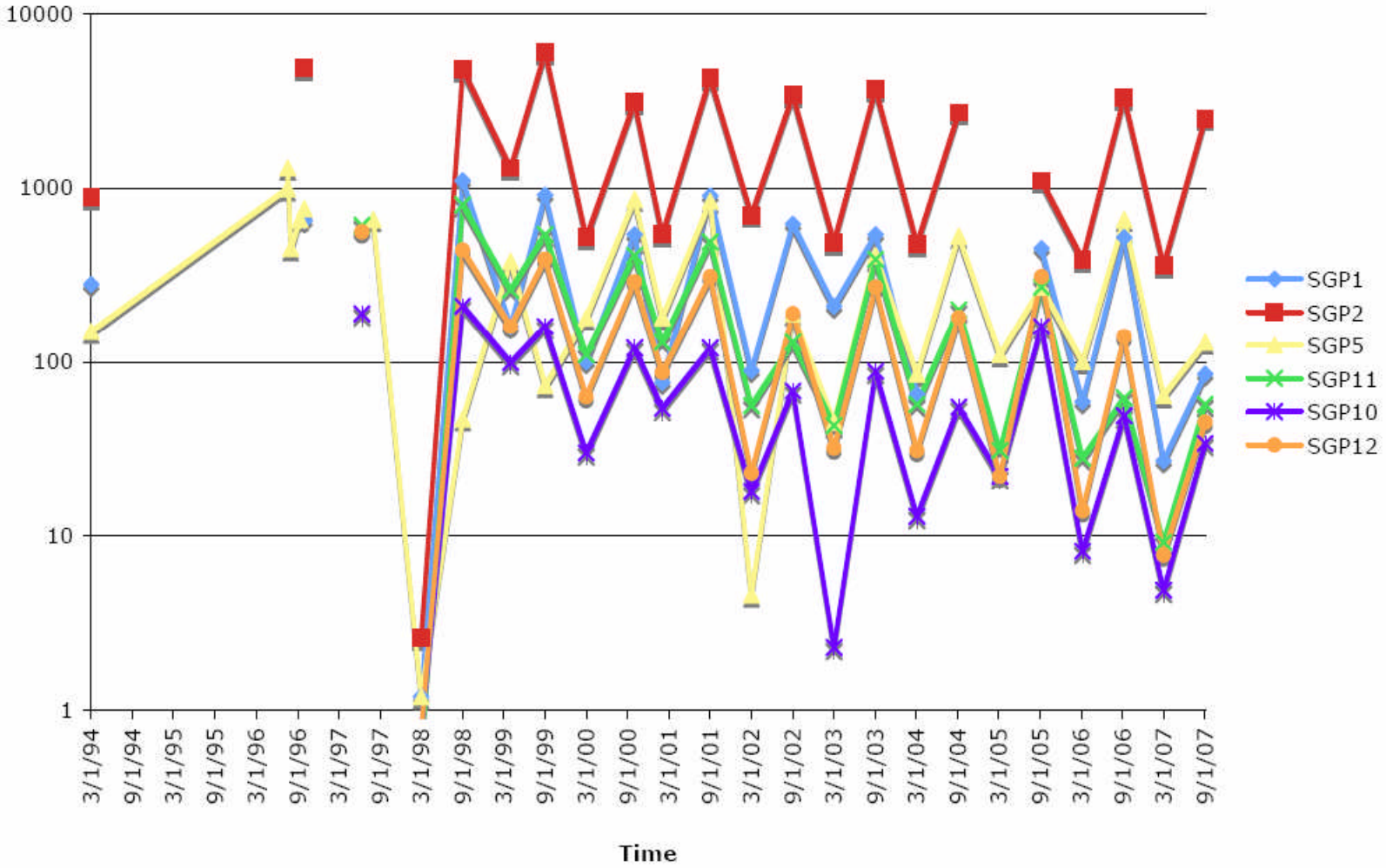
Ksat = 1.39E-04cm/sec



Hydraulic Head

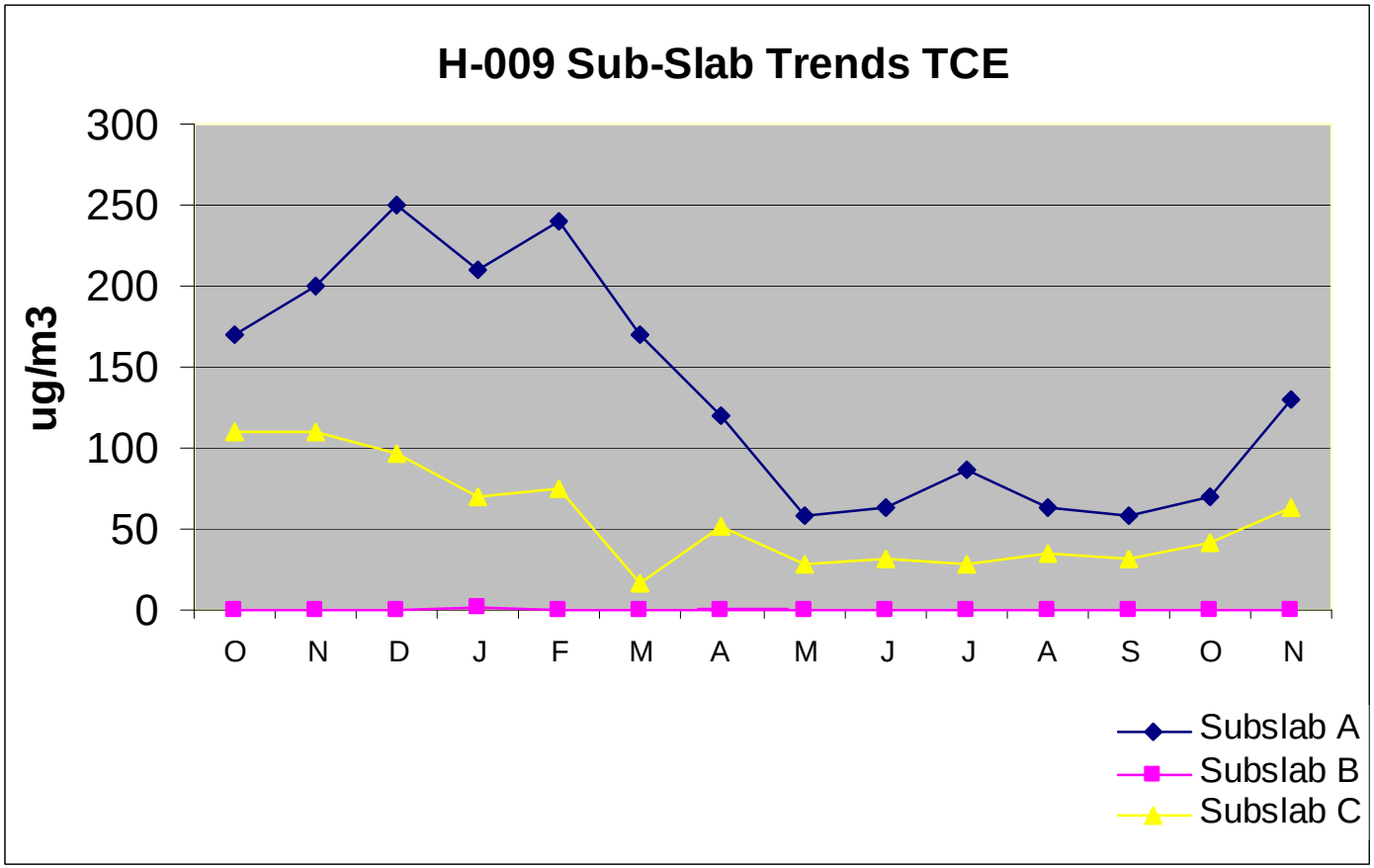
Spring&Fall TCE in Soil Gas

Courtesy Todd McAlary, AEHS/EPA Mar 08 Workshop



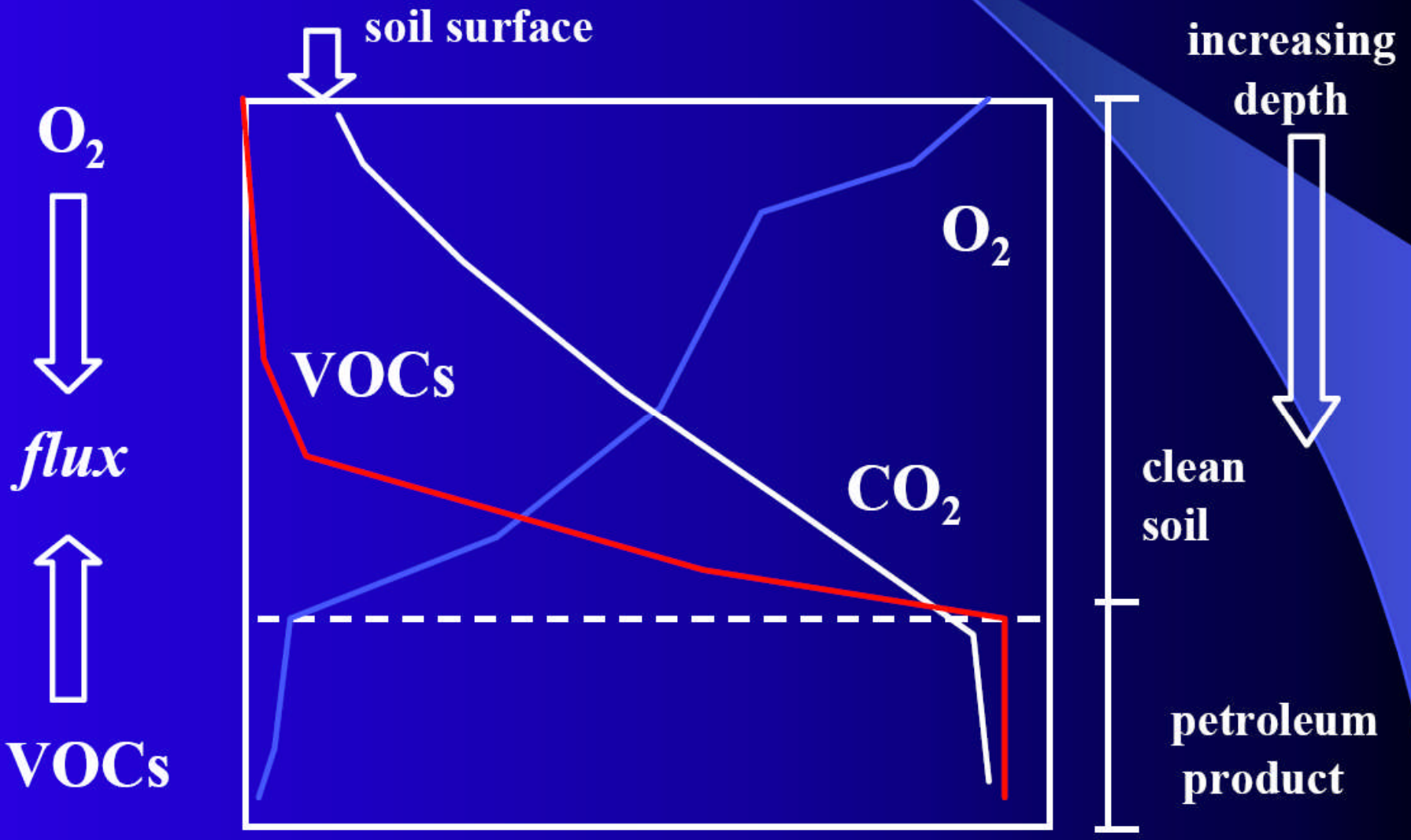
Geosyntec

Temporal Trends



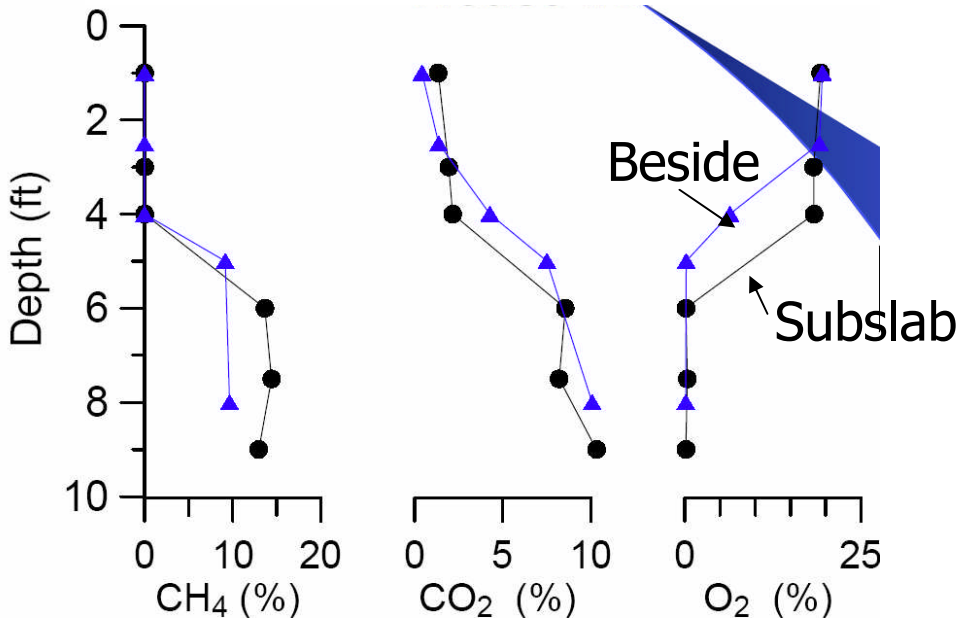
Courtesy Bill Wertz, NYDEC

Conceptual Hydrocarbon Vapour Profile

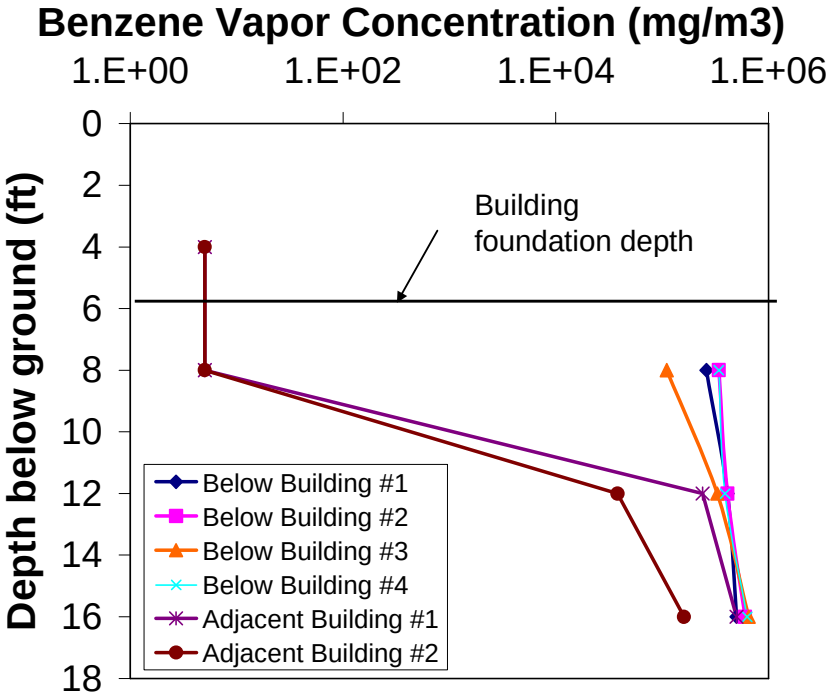


Aerobic Biodegradation

Santa Maria House, CA (Paul Lundegard, Unocal Oil Seeps)

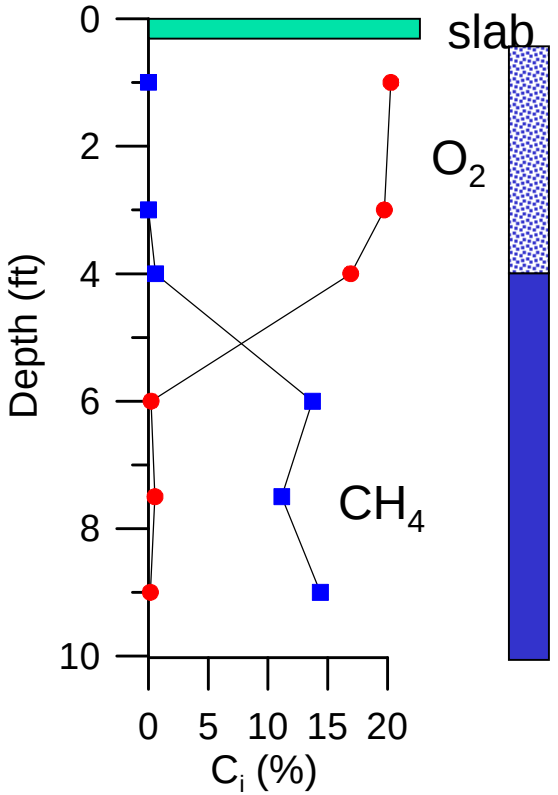


Paulsboro House, NJ (BP) (Gasoline NAPL, sand, sm. silt)

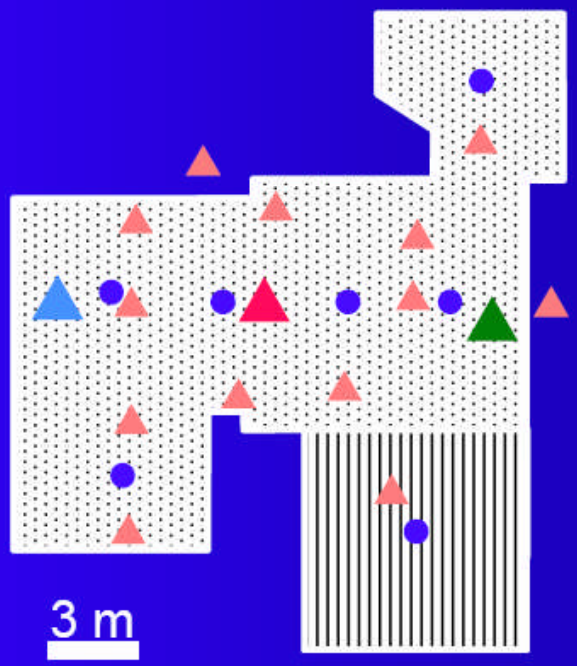


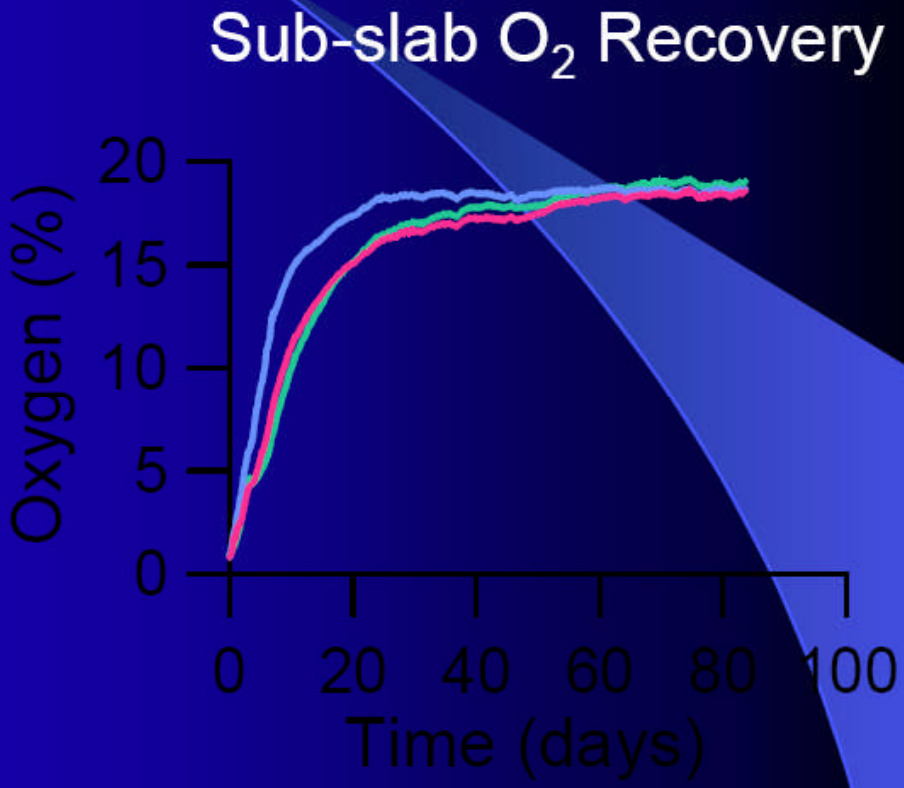
Santa Maria, CA Study
(Is O_2 Transport Below House Slow or Fast)

Paul Johnson, ASU, Paul Lundegard, Unocal and Paul Dahlen, Golder



Sub-Slab O_2 Transport Experiment





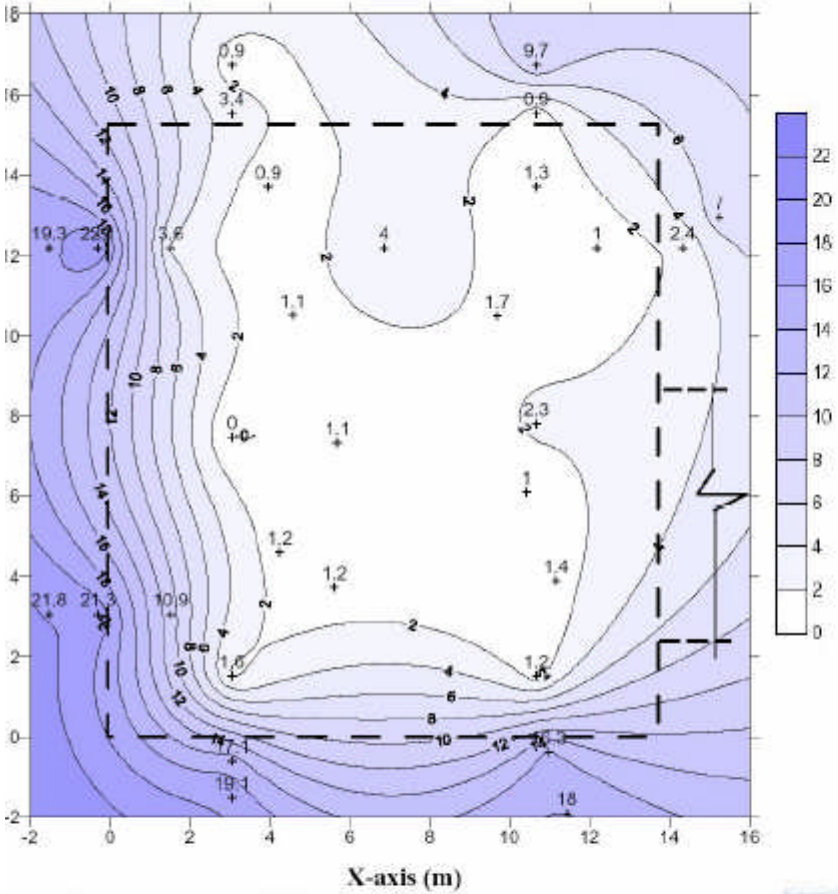
Diffusion most important, wind induced O_2 recharge also important. Rainfall can affect recharge

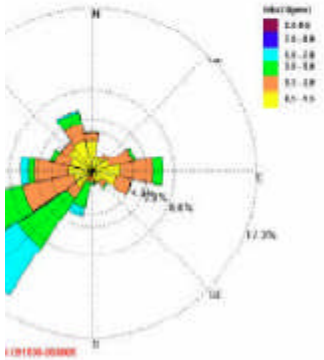
Paul Johnson, ASU, Paul Lundegard, Unocal and Paul Dahlen, Golder

Casper, WY Site

[A classic case of significant people intrusion]

CASPER, WY SITE
Soil Gas O2 Conc. at 2 ft Depth [091005-091305]





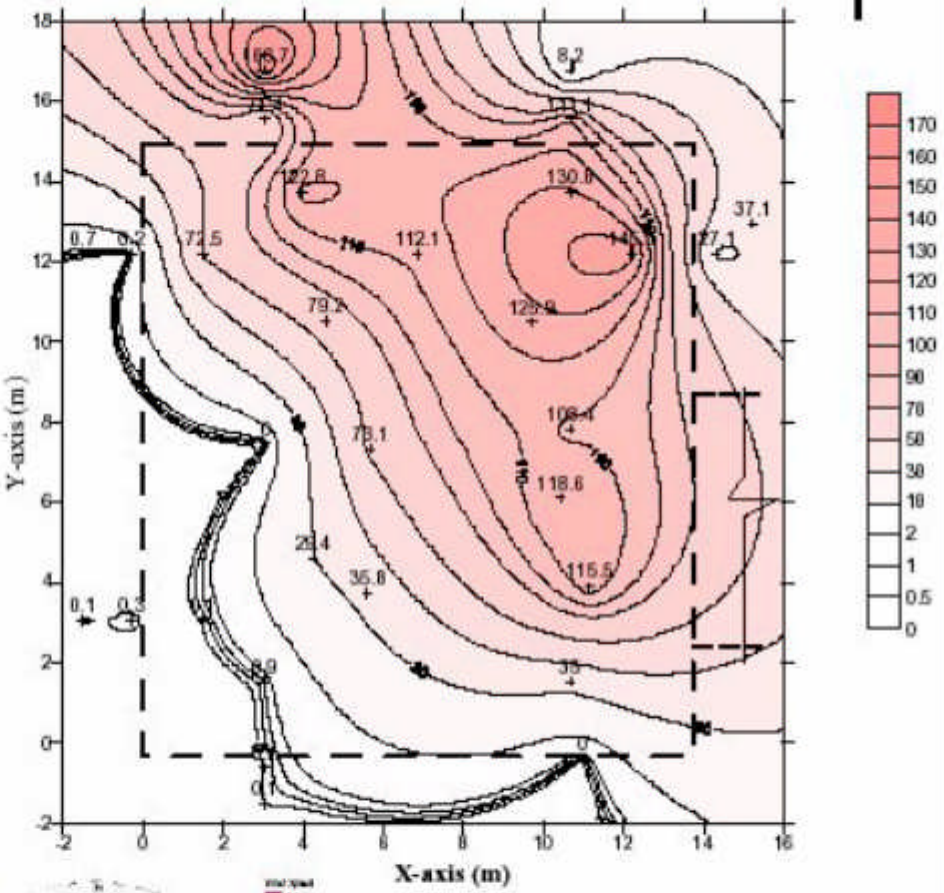
Legend:

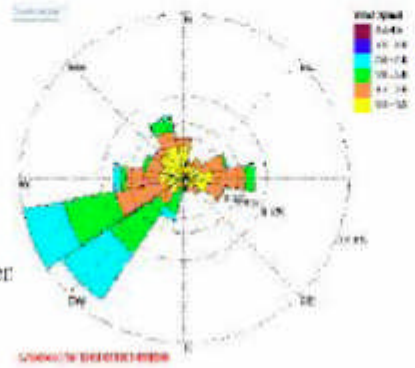
Building boundary

0.2 Location and oxygen concer

CASPER, WY SITE
Soil Gas TPH at 2 ft Depth, sampling date 091005-091305

N



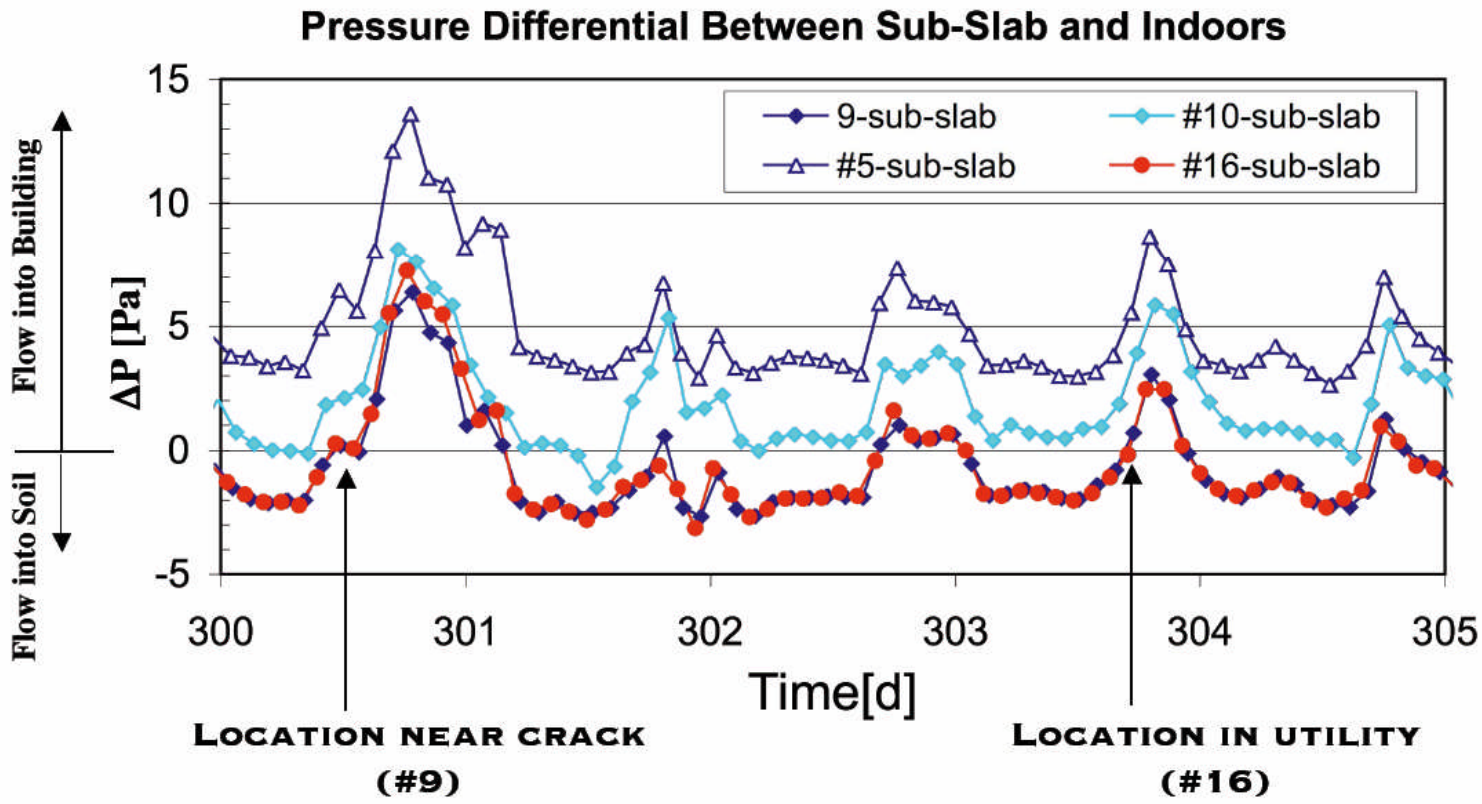


Legend:

Building boundary

0.2 Location and its TPH concentration in mg/L

Variability in Pressure Differentials

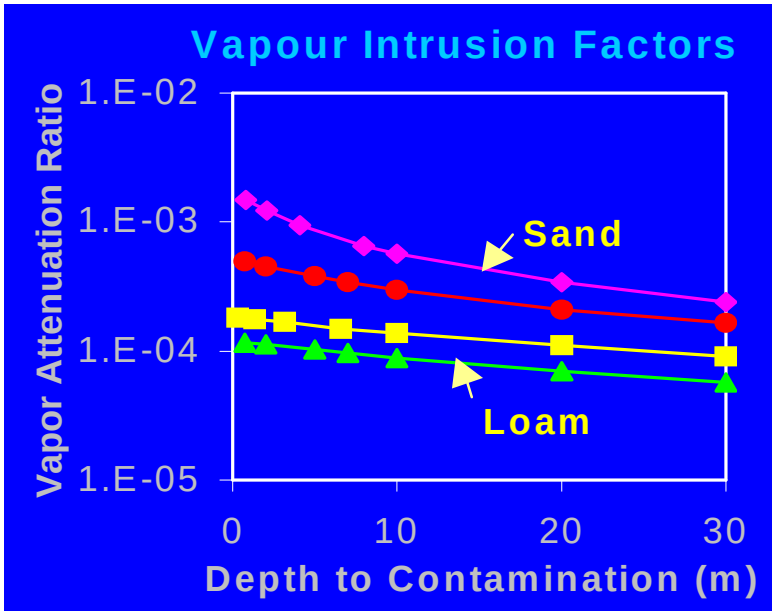


Guidance Overview

- Health Canada – tiered approach based on soil, groundwater and soil vapour; supporting PQRA and SSRA spreadsheets
- Alberta and Ontario – Tier 1 soil and groundwater guidelines, Tier 2 soil vapour
- Draft USEPA 2002 OSWR VI Guidance – current status will not be updated, but several white papers/tools to be produced
- ITRC VI Guidance (2007) – multiple lines of evidence
- ASTM E2600 – Phase 1 screeening approach and pre-emptive mitigation

Health Canada VI Guidance

- Preliminary Screening for pathway completeness
- Secondary Screening using ***Attenuation factor (AF)*** ***"alpha" curve*** approach for soil type and depth
- Adjustments for:
  - Aerobic biodegradation (10X)
  - Mass flux for groundwater
  - Source depletion for soil
  - Building properties
- Tier 3 process? (not defined)



Soil vapour AF = C_{air}/C_{vapour} (measured)

Groundwater AF = C_{air}/C_{vapour} (predicted)

Proposed Bioattenuation Adjustments for Health Canada Guidance
(simpler approach may be adopted)

Media	Contamination	Criteria	Bioattenuation Adjustment Factors (BAF)
Groundwater	Dissolved - Low	Benzene < 0.1 mg/L F1 < 5 mg/L F2 < 1 mg/L	100X for Ds > 1 m
	Dissolved – High	Benzene < 1 mg/L F1 < 15 mg/L F2 < 5 mg/L	10X for Ds > 1 m 100X for Ds > 3 m
	NAPL		10X for Ds > 5 m
Soil Vapour	Dissolved	Cg < 1 mg/L	10X for Ds > 1 m 100X for Ds > 1 m, Dp < 1 m
	Transition dissolved & NAPL	Cg > 1 mg/L Cg < 50 mg/L	10X for Ds > 2 m
	NAPL	Cg > 50 mg/L	10X for Ds > 5 m
Soil	All		20X for Ds > 1 m

Note: BAFs may only be applied when there is no significant capping effect.

C_g = BTEX + F1 + F2 + CH_4

Ds = Separation distance between contamination source and building

Dp = Distance from contamination to soil gas probe

ES

Pathway Assessment – Possible Future Refinements

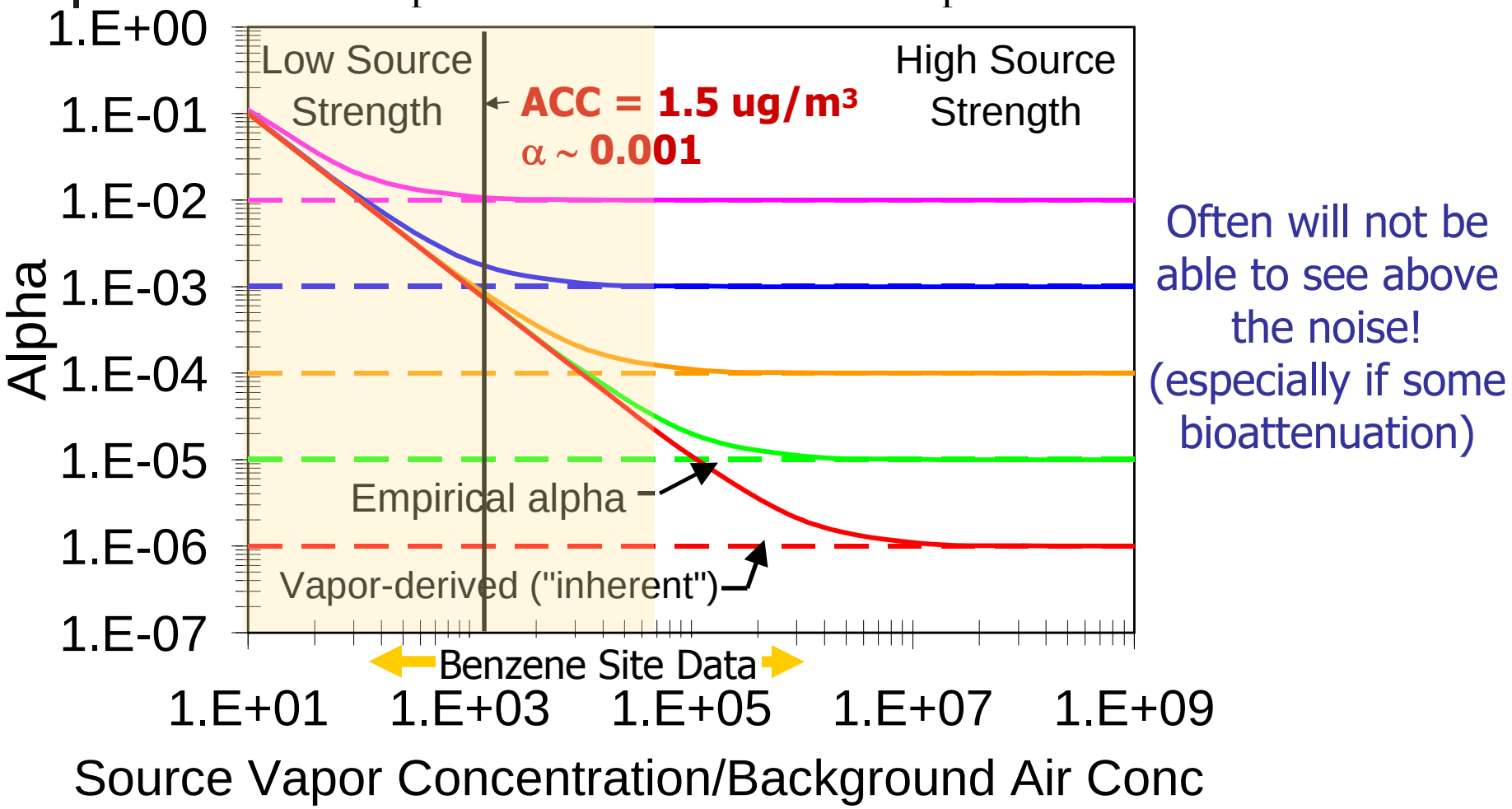
- Need better screening approach to categorize sites
  - No brainer – there is a problem
  - Likely a problem – lets not think to much about it
  - Grey zone – more assessment needed
  - Not a problem – let's move on (biodegradation critical here – source strength, depth, capping effect)
- One size does not fit all, more flexibility needed in media and models that may be used (biodegradation, source depletion, building properties)

Pathway Assessment – Possible Future Refinements

- Need to get a better handle on soil vapour spatial and temporal variability and influence of building – more research is needed in this area
- Sampling and analysis tools and practice needs to be improved – hopefully next session will contribute to this
- Updated surrogate approach for TPH
- Greater standardization for mitigation design
- Use of more sophisticated models

Meta-data Analysis – Influence of Background

$$\alpha_{emp} = C_{air}^{background} / C_{vapour\ source} + \alpha_{inherent}$$

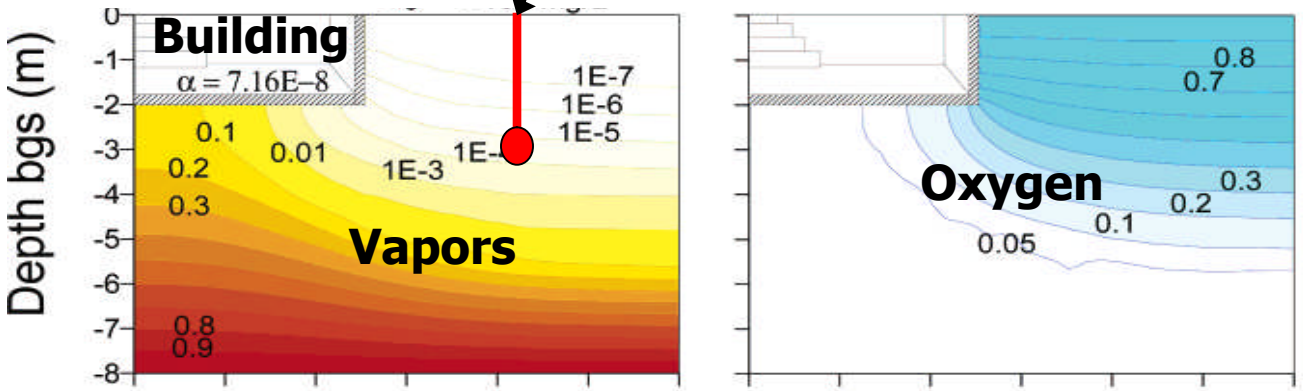


Often will not be able to see above the noise! (especially if some bioattenuation)

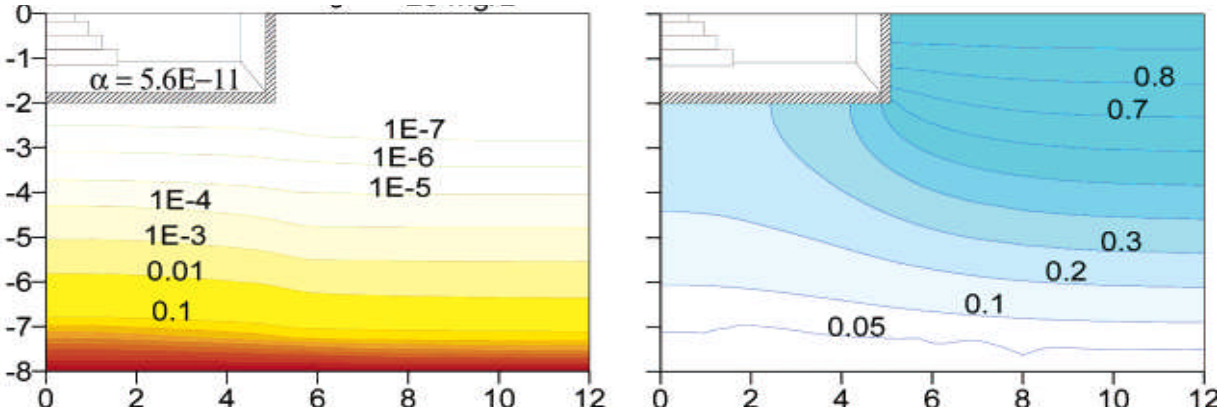
Modeling Study

(Illustrates spatial variability & effect of biodegradation)

What if you sample out here?



V. High gasoline concentrations

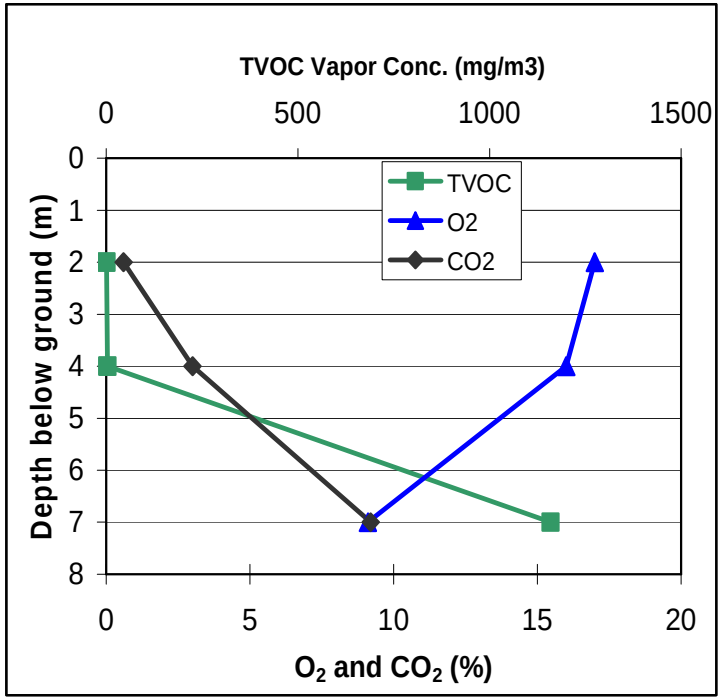


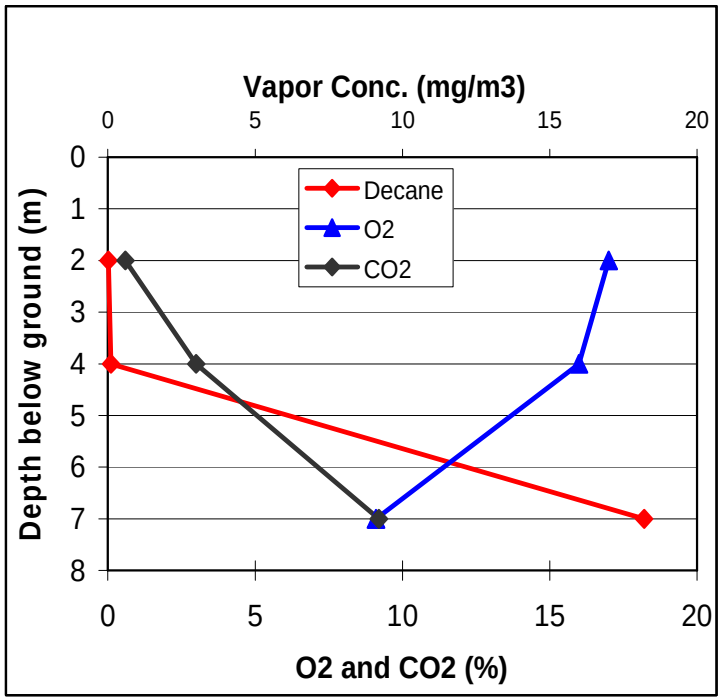
Slightly lower gasoline concentrations

3-D Numerical Model (this is a slice through the house)
Abreu & Johnson, ES&T, 2005

First Nations Site Strategic Soil Vapour Sampling

PHC, O_2, CO_2, CH_4 profiles helpful to evaluate biodegradation!





- Diesel NAPL above water table, sand and gravel, teacherage with basement
- Health Canada protocol requires minimum depth ½ way between building and contamination

RISC Model

Advection & Diffusion
Building

Boundary layer model
for O2 flux (Ko)

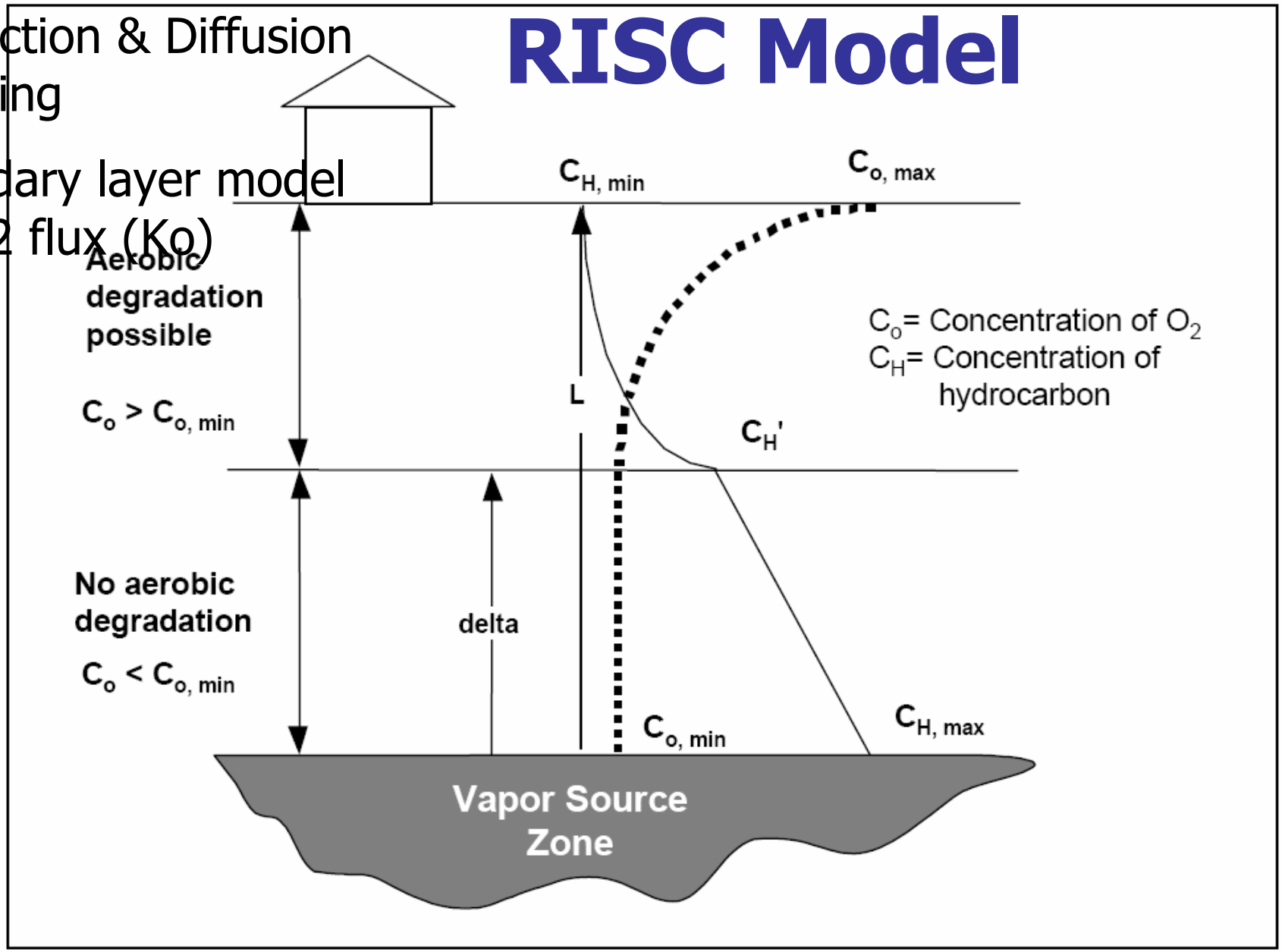
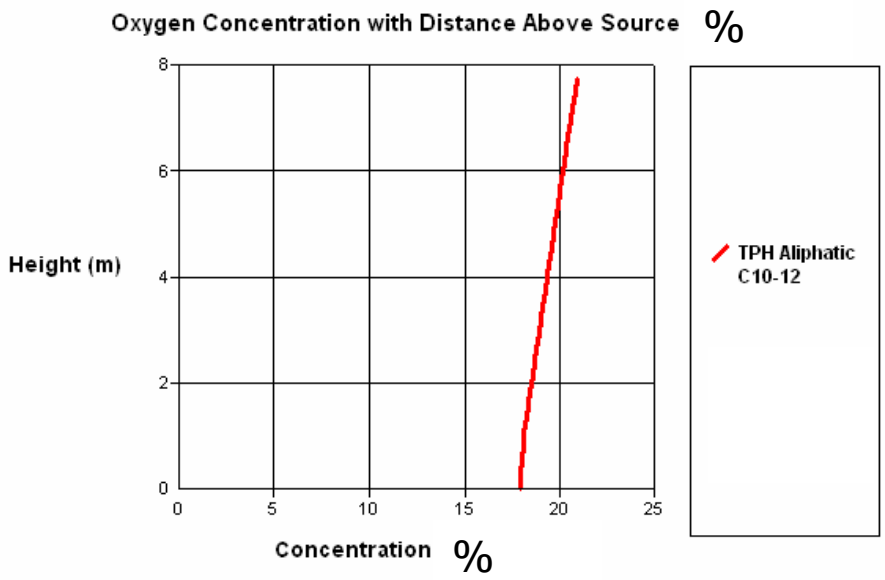
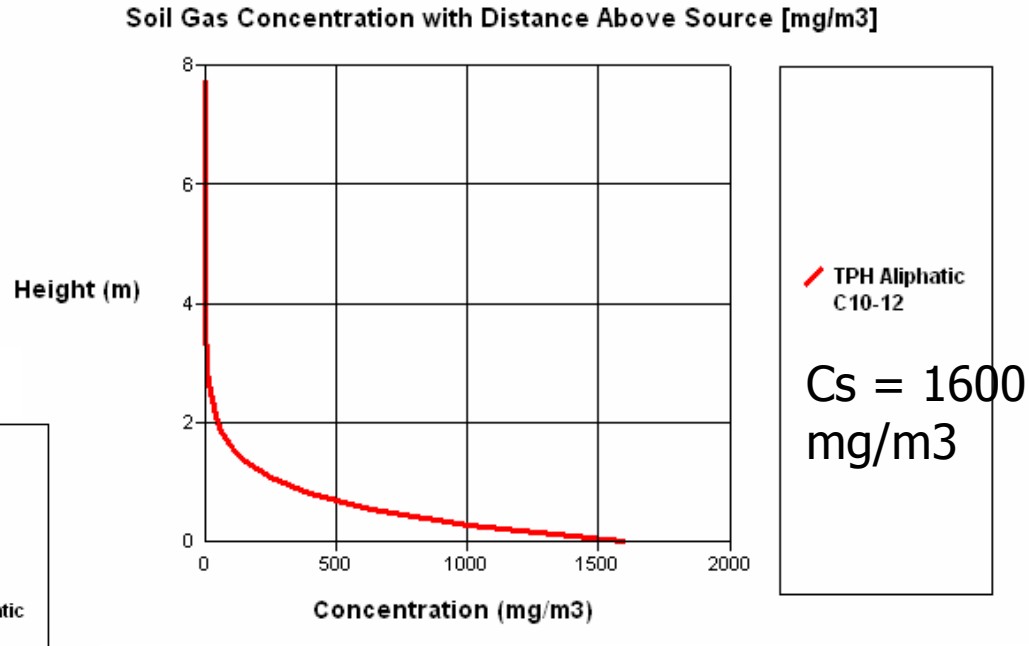
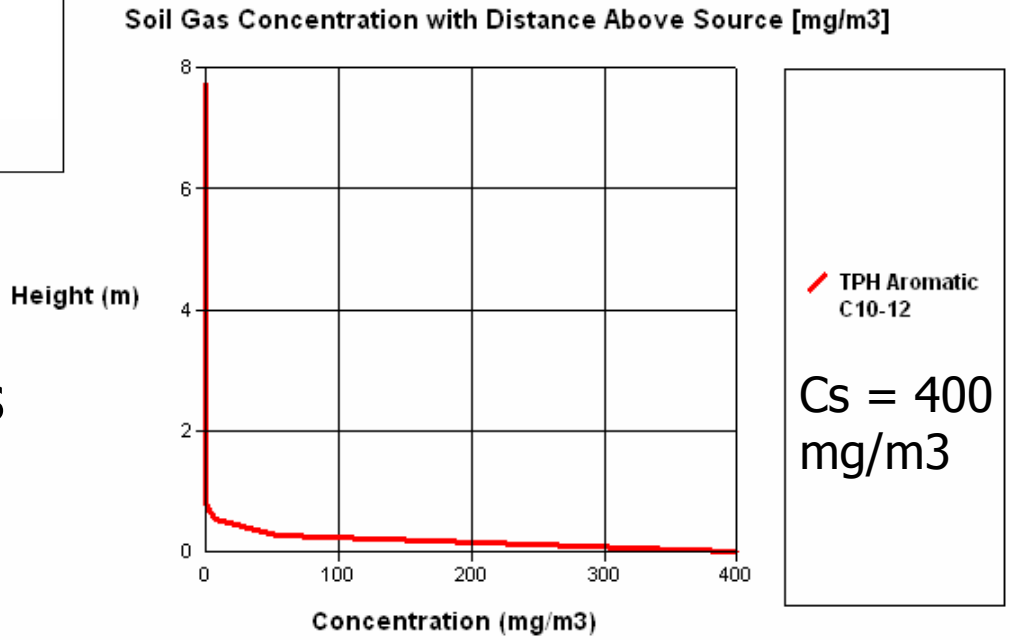


Figure K-1. Schematic of the Oxygen-Limited Vapor Transport Model.

RISC Output







First order decay aromatics = 20 day-1

Aliphatics = 1000 day-1

Soil Vapor Methods

- Similar or higher level of care than groundwater
- Preference small diameter probes
- Carefully seal boreholes
- Leak tracer tests to test seals and sampling trains

"Geoprobe"

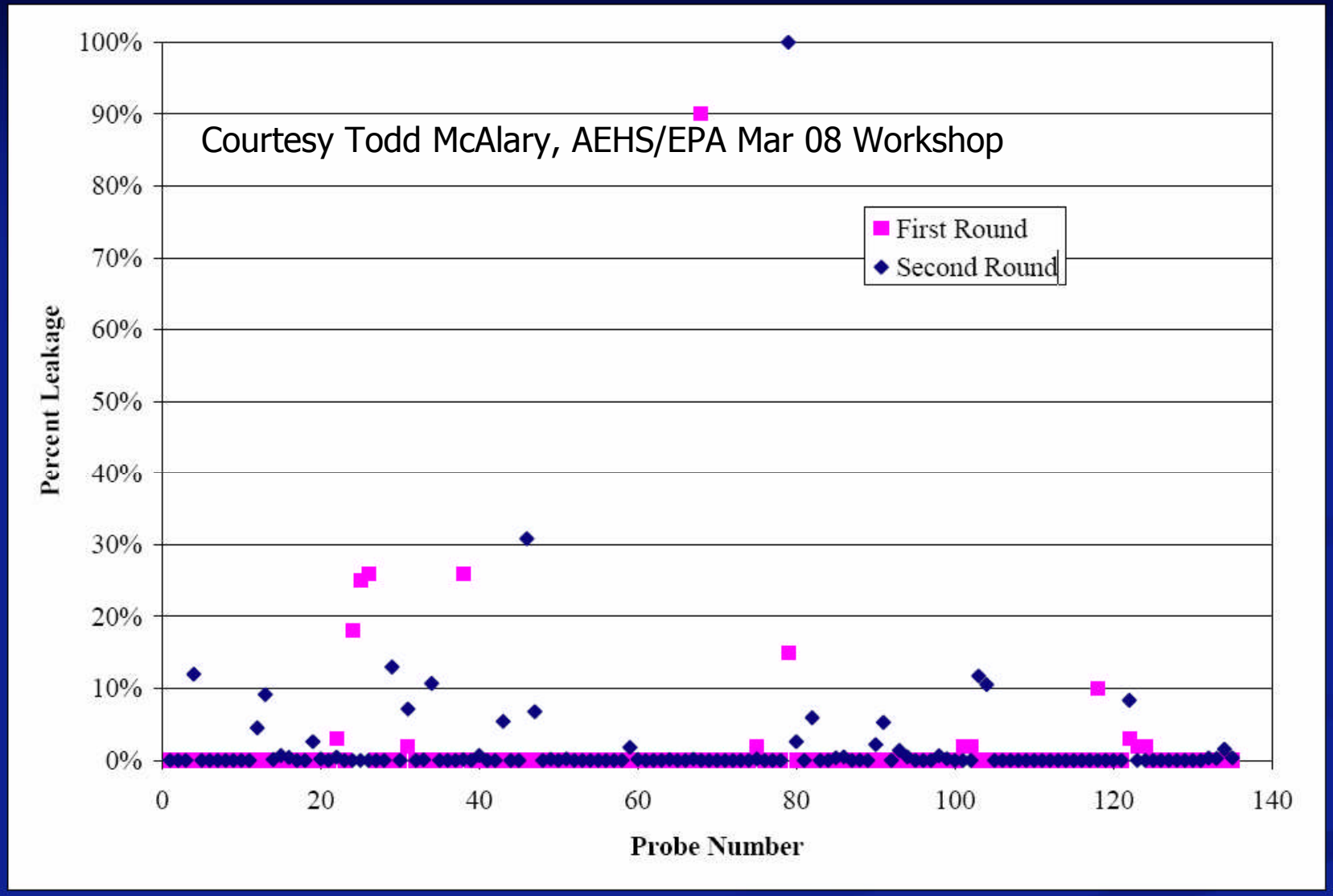
Helium tracer test

Soil Vapour Tool Box

- Low flow (100-200 ml/min) and low vacuum (< 5 in H_20) purging and sampling
- Vacuum chamber (lung box) sampling warranted in some cases
- Analytical methods carefully chosen (sorbent tubes, Summa canisters – hardware key issu
- QC samples (equip-ment blanks, duplicates)


GeoEnvirologic Course June 5, 2008

Helium Tracer Data



21 of 270 samples had leaks >5% (100% passed shut-in test)

All but two were corrected using Helium and Mass Balance

Geosyntec consultants