November 2008

Assessing Vapor Intrusion Risk at Tank Sites

MO PST Insurance Fund

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Training Overview

Part 1 - Overview of Vapor Intrusion

Part 2 - Review of Some Basic Principles

Part 3 - Review of VI Guidances

Part 4 - Methods to Assess Vapor Intrusion

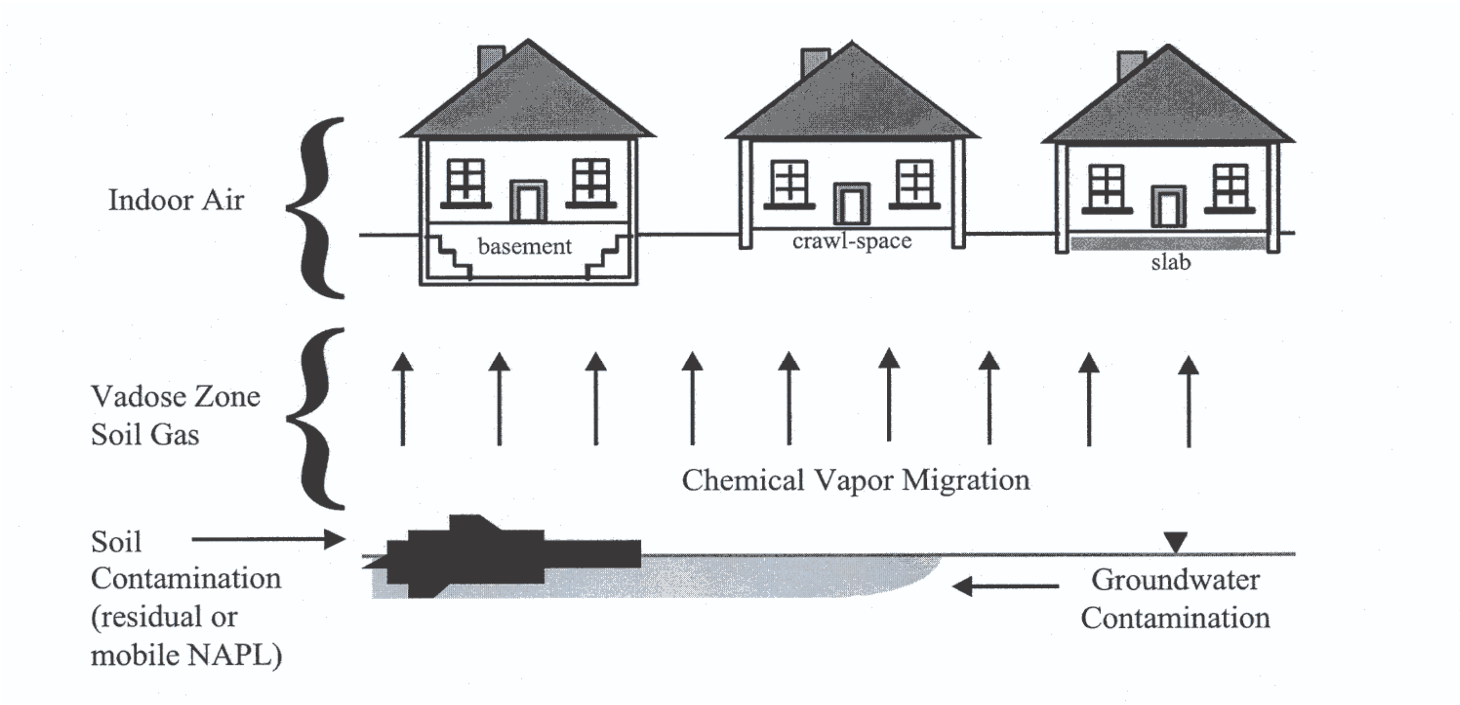
Part 5 - Soil Gas Sampling & Strategies

Part 6 – Field Exercise

Part 1: Overview of Vapor Intrusion

- What Is It?
- Why Do You Care about It?
- When Should You Worry About It?
- What Sites to Worry?

What Is Vapor Intrusion?



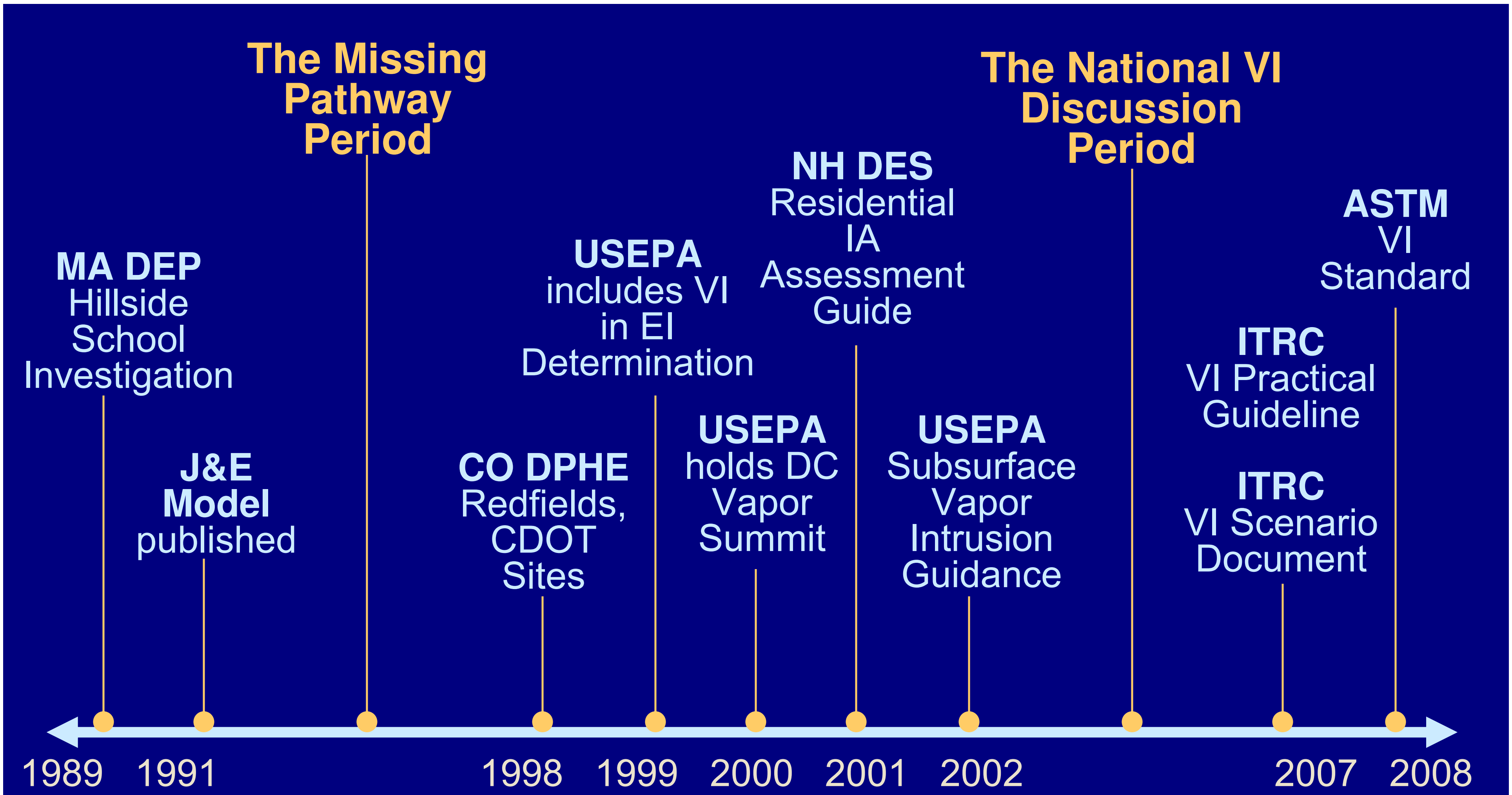
Key Assumptions:

- Risk level (1 in 10,000? 100,000? 1,000,000?)
- Toxicity of Compounds
- Exposure Factors (time, rates, ventilation)

Why Do You Care About VI?
(Risk Often More Perceived Than Real)

- Health & Safety of Occupants
- EPA - Draft VI Guidance Exists
- Individual State Guidances
- ASTM New Phase 1 Standard
- Attorneys & Citizen Groups

Historical Perspective



ITRC Survey Results

- 39 of 43 states say vapor intrusion is a current concern being actively addressed
- VI concerns in every program (RCRA, FUDs CERCLA, brownfields, UST, dry-cleaning
- Most preferred methods for evaluating vapor intrusion: shallow soil gas/subslab sampling followed by indoor air measurements
- 9 states allow for biodegradation of petroleum hydrocarbons

When to Worry About VI?

- If VOC Contamination & Structures Exist:
  - Laterally within: EPA: 100' MO: 25' for HC
  - Vertically Within: EPA 100' MO: not specified
- Complaining Occupants
- Structures With Odors, Wet Basements
- Sites With Contamination & Future Use
- Attorneys & Communities

What Compounds?

- VOCs:
  - Hydrocarbons (benzene, aliphatics)
  - Methane
  - MTBE, other oxys
  - EDB & EDC
- Semi-VOCs:
  - Naphthalene

What Types of Sites?

- Petroleum Hydrocarbons
  - Service Stations, USTs, Pipelines
  - Oil Furnaces (naphthalene)

Low Target Levels Mean More Sites to Assess

- Typical Groundwater Levels:
  - benzene: 5 ug/L – domestic use

- Benzene Levels Exceeding 1E-5 Risk:
  - Indoor Air: 0.003 ug/L

Part 2 – Some Basics

- Units
- Fick's Law
- Contaminant Partitioning
- Attenuation (alpha) Factors
- Conceptual Site Model (CSM/SCM)
- Risk Based Target Levels (RBTL)

The Most Common Goof

1 ug/L Benzene equals:

a) 1 ppbv
b) 1 ppmv
c) 330 ppbv
d) None of the Above

How do Contaminants Move?

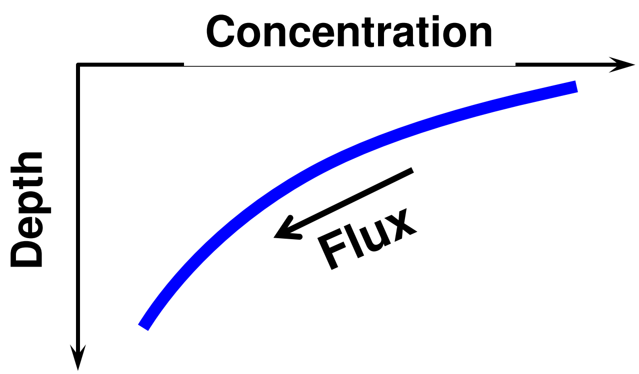
<u>Movement (Flux) = K d?/dx</u>

where: K is a proportionality constant
d?/dx is a gradient

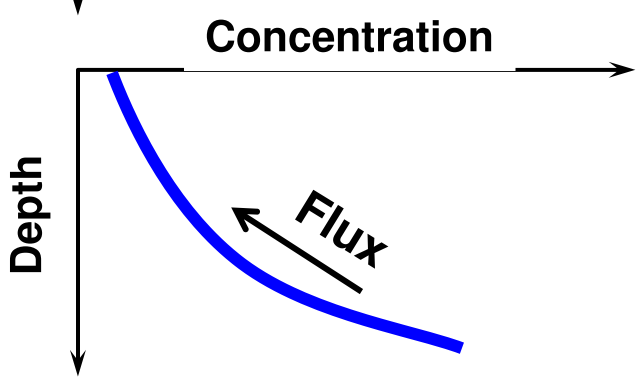
Property	Equation	Constant
Momentum:	Flux = K dH/dx	hydraulic cond
Heat (Poisson's):	Flux = Φ dT/dx	thermal cond
Mass (Fick's):	Flux = D dC/dx	diffusivity

Momentum, Heat, Mass ALL Move from High to Low

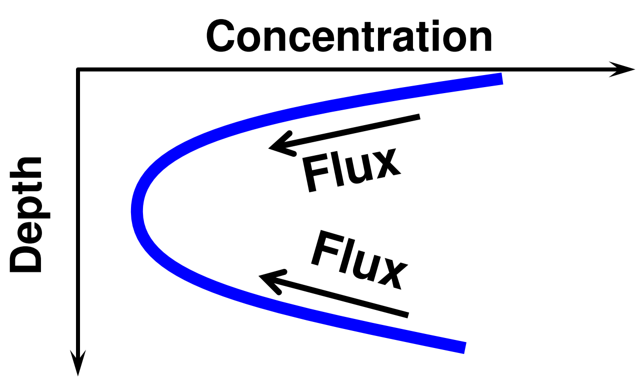
Common Vapor Profiles



Surface Source



Deep Source



Surface and Deep Sources

Contaminant Partitioning

Groundwater to Soil Gas (Henry's Constant):

H = Csg/Cw, so, Csg = Cw * H

Example: $H_{benzene}$ = 0.25 (dimensionless)
For GW Conc = 10 ug/L
Csg = 10 * 0.25 = 2.5 ug/L

Assumes Equilibrium. Very Rarely Achieved
(no mixers or blenders in the subsurface)

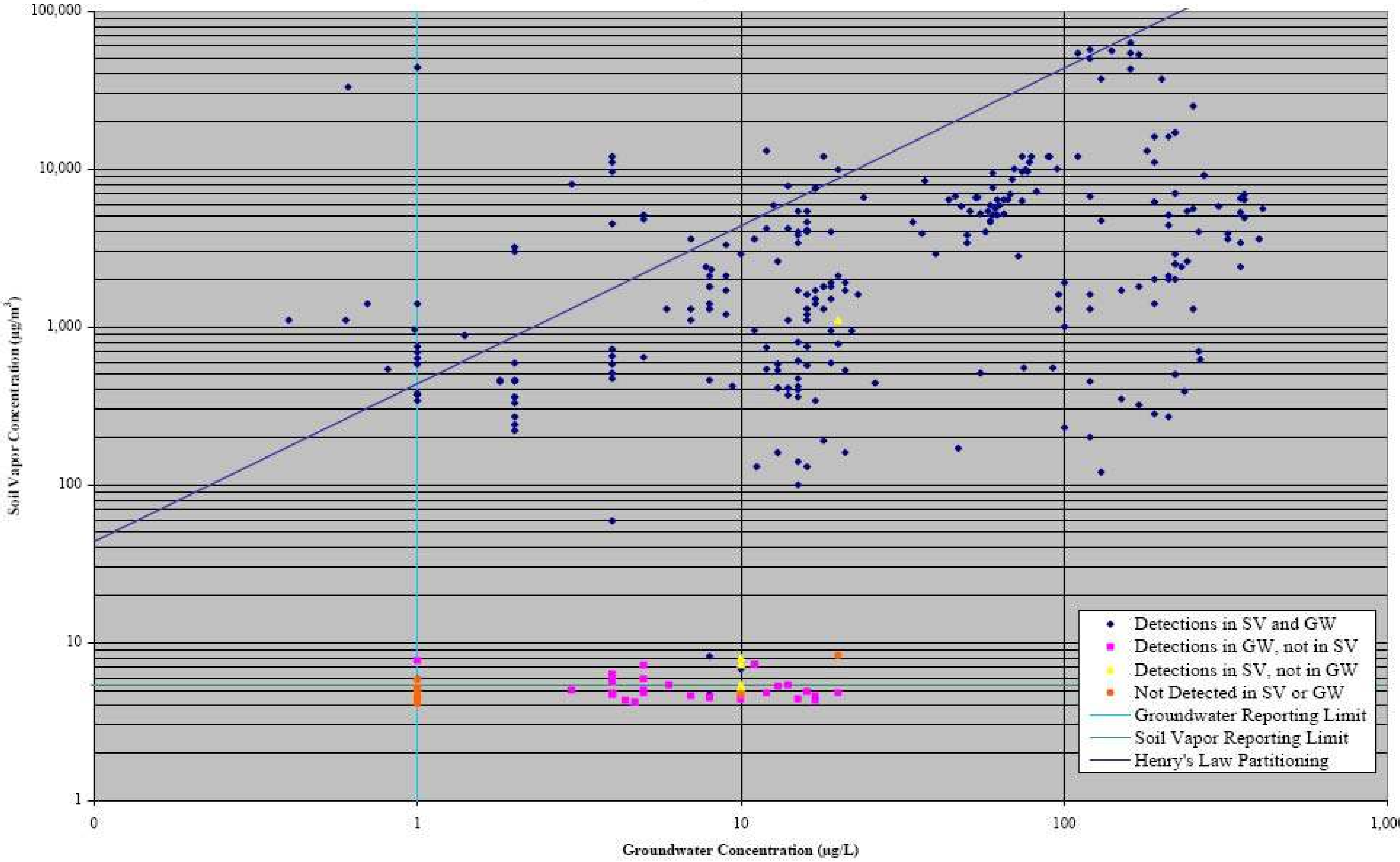
Figure 2

TCE in Water Table Depth Soil Vapor and Groundwater

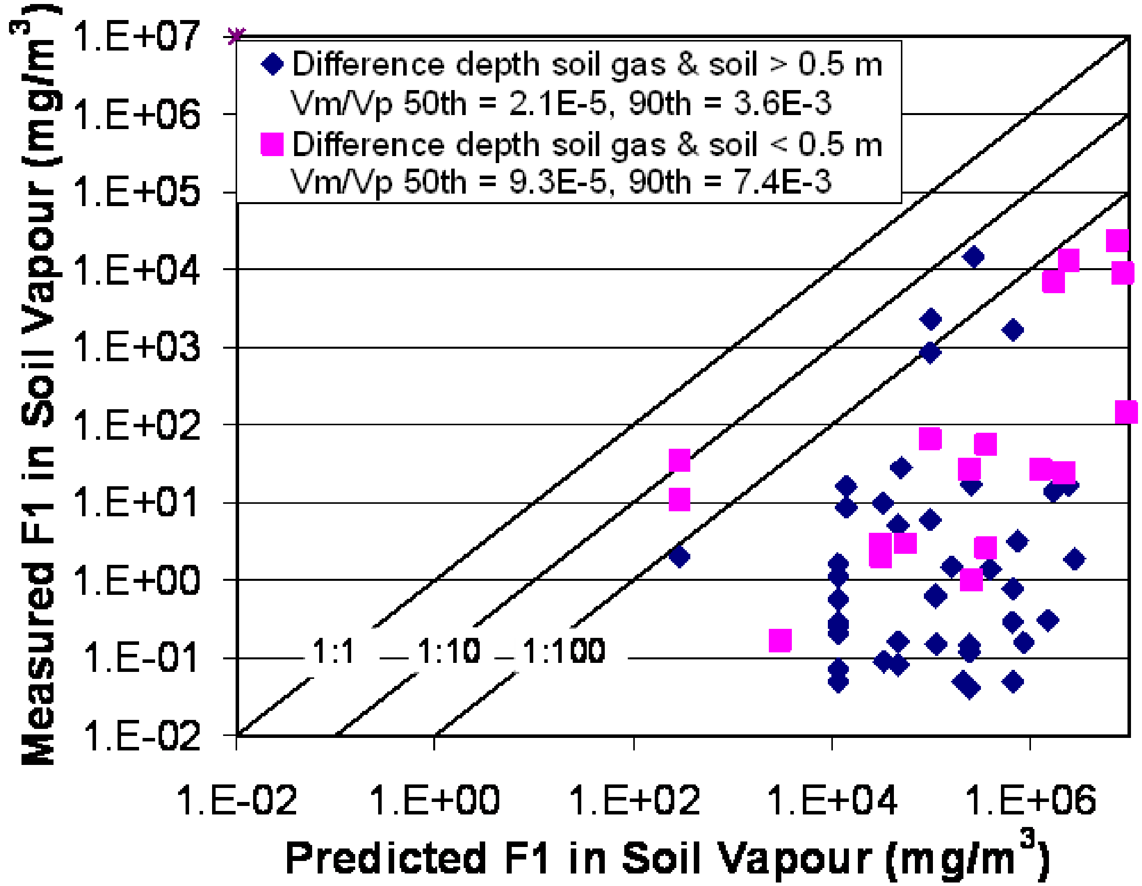
Quarterly Report - Soil Vapor Monitoring

Comprehensive Operations, Maintenance, & Monitoring Program

Endicott, New York



Measured Soil Gas Data vs. Predicted from Soil Phase Data



CPPI Database

.005

Key point:	Measured vapor concentrations 10 to 1000x less than predicted

Attenuation (alpha) Factors

$$\alpha_{sg} = C_{indoor}/C_{sg}$$

$$\alpha_{gw} = C_{indoor}/(C_{gw}*H)$$

- Lower alpha means higher attenuation
- Current VI guidances:
  - EPA αsg = 0.002 for 5’, 0.1 for sub-slab
  - Hydrocarbon αsg likely <0.00001

Figure 3a- DRAFT
Vapor Attenuation Factors - Soil Vapor to Indoor Air Pathway
Basement Foundations

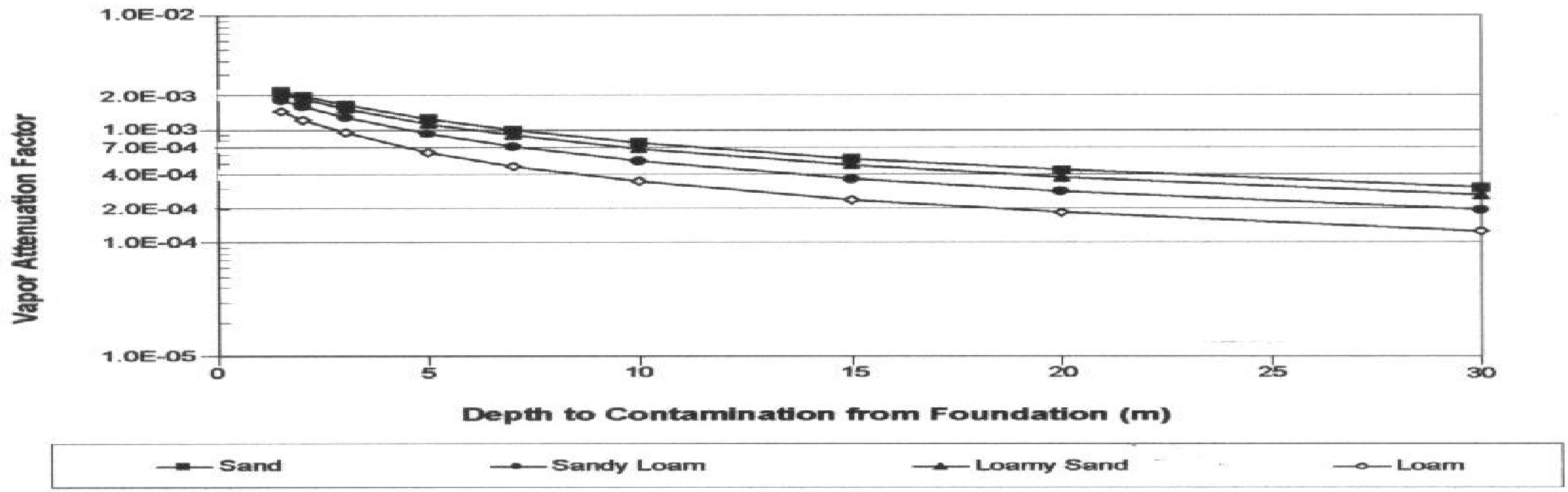
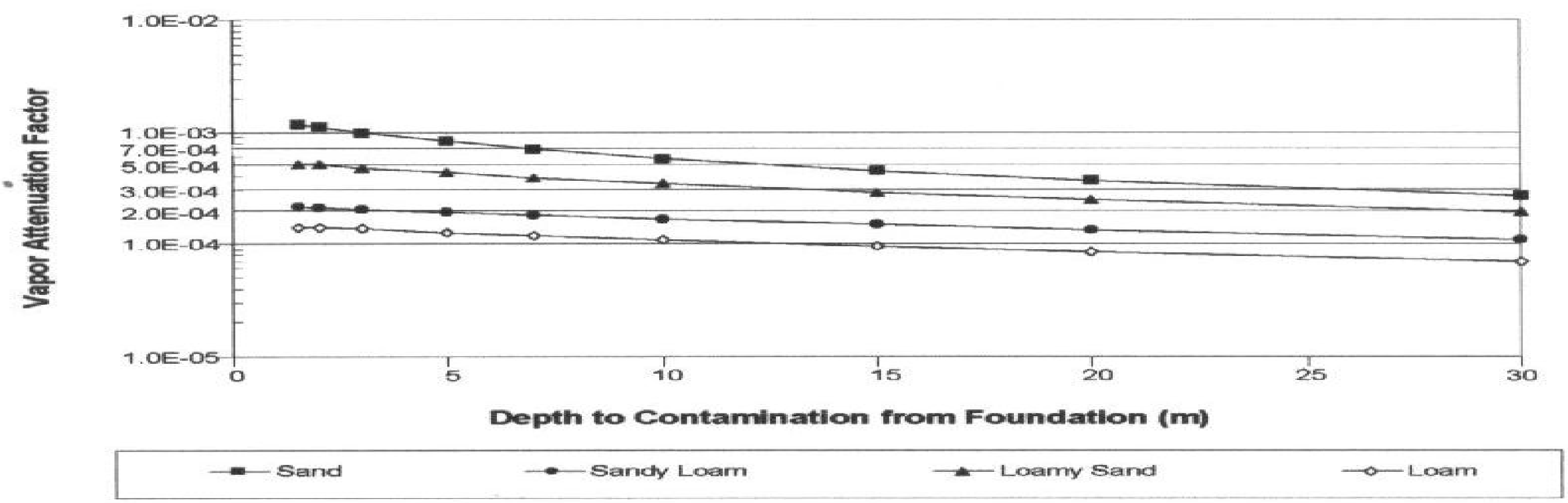


Figure 3b- DRAFT
Vapor Attenuation Factors - Ground Water to Indoor Air Pathway
Basement Foundations



Using Alpha Factors to Calculate Screening Levels

For Soil Gas:

$$C_{sg} = C_{indoor}/\alpha_{sg}$$

For Groundwater:

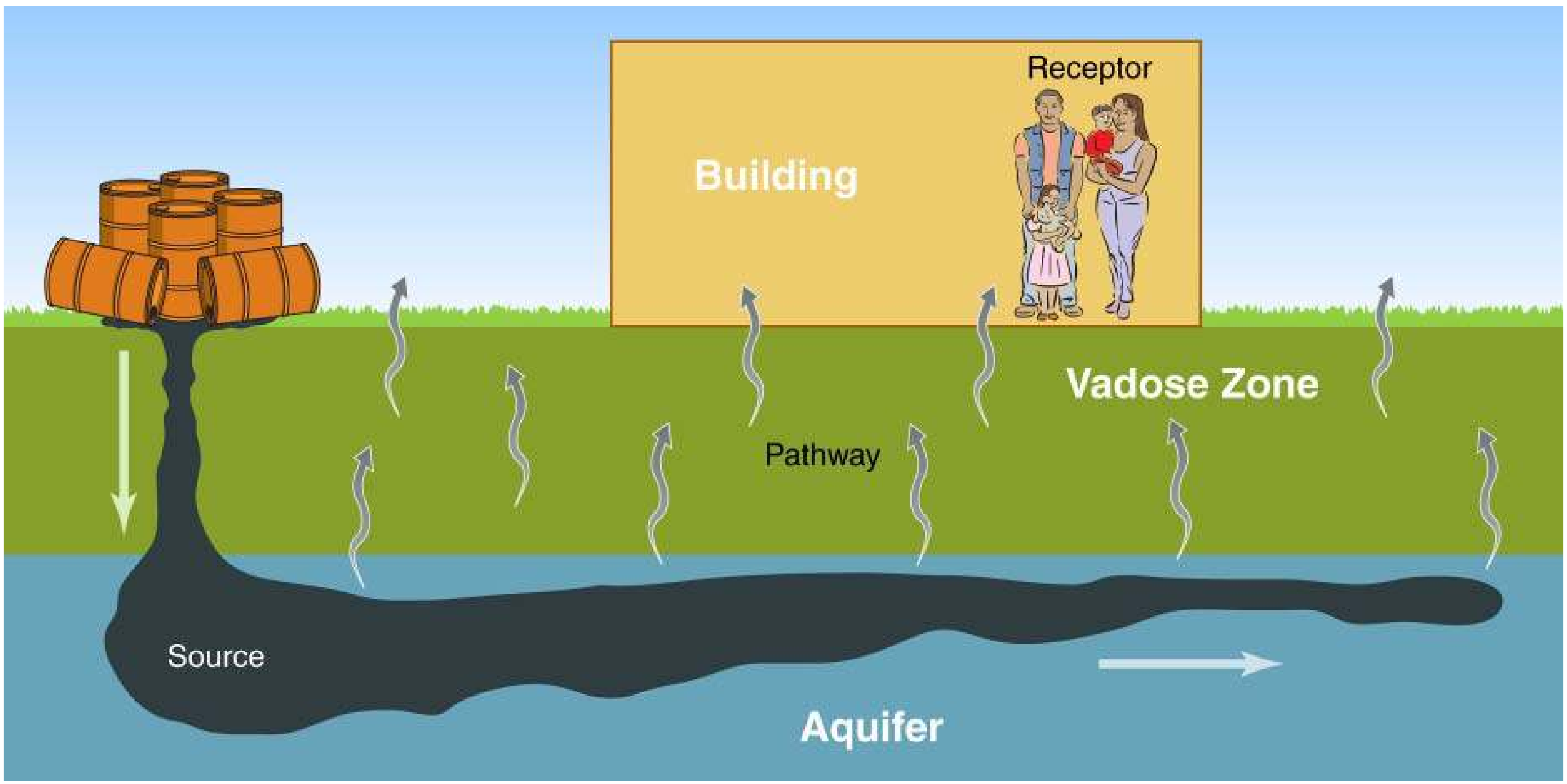
$$C_{gw} = C_{indoor}/(H^*\alpha_{gw})$$

Example: C_{in} benzene = 3.1 ug/m3

C_{sg} (5') = 3.1/0.002 = 1500 ug/m3

Conceptual Site Model

DEFINITION:
A conceptual site model (CSM) is a simplified version of a complex real-world system that approximates its relationships



Components of a CSM

- Underground utilities & pipes
- Existing & potential future buildings
- Construction of buildings
- Type of HVAC system
- Soil stratigraphy
- Hydrogeology & depth to water table
- Receptors present (sensitive?)
- Nature of vapor source
- Vadose Zone characteristics
- Limits of source area & contaminants of concern
- Surface cover description in source and surrounding area

RISK 101: Screening Levels

- RBTL: Risk Based Target Level (MO)
- RBC (from ASTM): Risk Based Concentration
- RBSL: Risk Based Screening Level

Need to Know When & How to Use

RISK 101:
Why Are Indoor Air RBTLs So Low?

- MO Benzene: 3.1 ug/m3 (1e-5 risk)
- Values Assume Exposure Times of:
  - 18 hr, 350 days/yr, 30 years

Ultra Conservative Assumptions Lower Allowed Levels and Bring in More Sites

Inhalation Exposure Parameters

20 m^3/day for Res. *vs* Comm.-Ind. Exposure				
Parameter	Symbol	Res.	Comm-Ind.	Units
Exposure Duration	ED	30	25	years
Exposure Frequency	EF	350	250	days/year
Exposure Time	ET	24	8	hours/day

$$\left(\frac{Residential}{Comm-Ind}\right)=\left(\frac{30\ years}{25\ years}\right)x\left(\frac{350\ days/\ year}{250\ days/\ year}\right)x\left(\frac{24\ hours/\ day}{8\ hours/\ day}\right)=5.1\cong\mathbf{5}$$

Methods for Target Level Determination

- Soil & GW: MO Table 7.1 through 7.3
- Soil Gas: Tier 2 Target Levels
- From Spreadsheet/Model (RAM Group)
- Use Custom Software (Tier 3)

Other Models

- Johnson-Ettinger Most Common
  - GW, soil, soil gas spreadsheets
  - Screen & advanced versions
  - Hard to compare defaults vs actual values used

- Variables You Can Change (Tier 3)
  - GW or soil gas concentration
  - Soil type (diffusivity)
  - Ventilation rate
  - Exposure time
  - Building Size

Part 3 – Review of VI Guidance

- EPA OSWER VI Guidance
- ITRC Guidance
- ASTM VI Standard

OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils
(Subsurface Vapor Intrusion Guidance)

Federal Register Notice - November 29, 2002

- Fact Sheet: Evaluating the Vapor Intrusion into Indoor Air
  - Adobe PDF File [17 KB]

Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)
(Complete Document): Adobe PDF File [3019 KB]

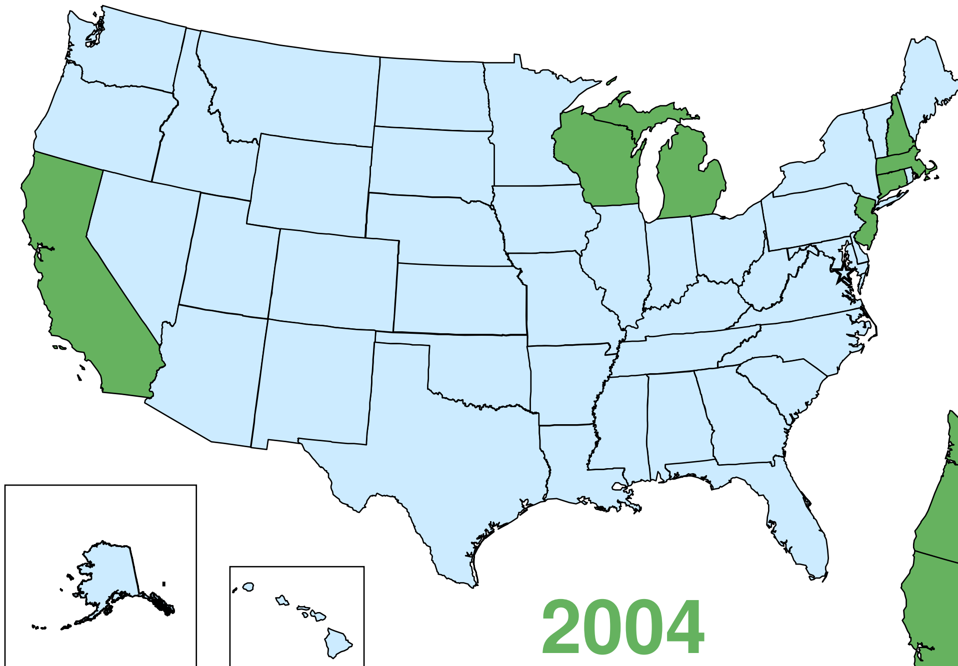
- Draft Guidance
  - Adobe PDF File [516 KB]
- Tables
  - Adobe PDF File [353 KB]
- Appendices A-C
  - Adobe PDF File [972 KB]
- Appendices D-F
  - Adobe PDF File [722 KB]
- Appendices G-I
  - Adobe PDF File [475 KB]

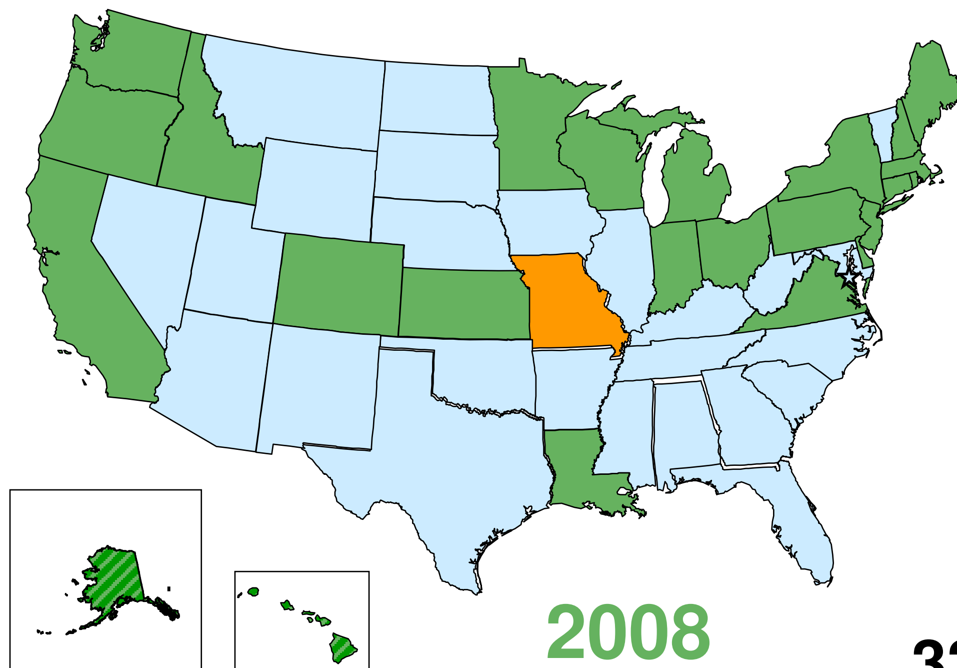
E-Docket is an on-line system that allows viewers to search the Agency's major public dockets on-line, view the index listing of the contents for the dockets included in the system, and access those materials that are available on-line. You may also submit comments on-line while this docket is open for public comment.

EPA-OSWER Draft Guidance

- Tier 1: **<u>Primary</u>** Screening
  - Q1: VOCs present?
  - Q2: Near buildings?
  - Q3: Immediate concern?
- Tier 2: Secondary Screening
  - Q4: Generic screening
  - Q5: Semi-site specific screening (alphas from charts & tables)
- Tier 3: Site-Specific Pathway Assessment
  - Q6: Indoor air (and/or subslab)

VI Regulatory State Guidance



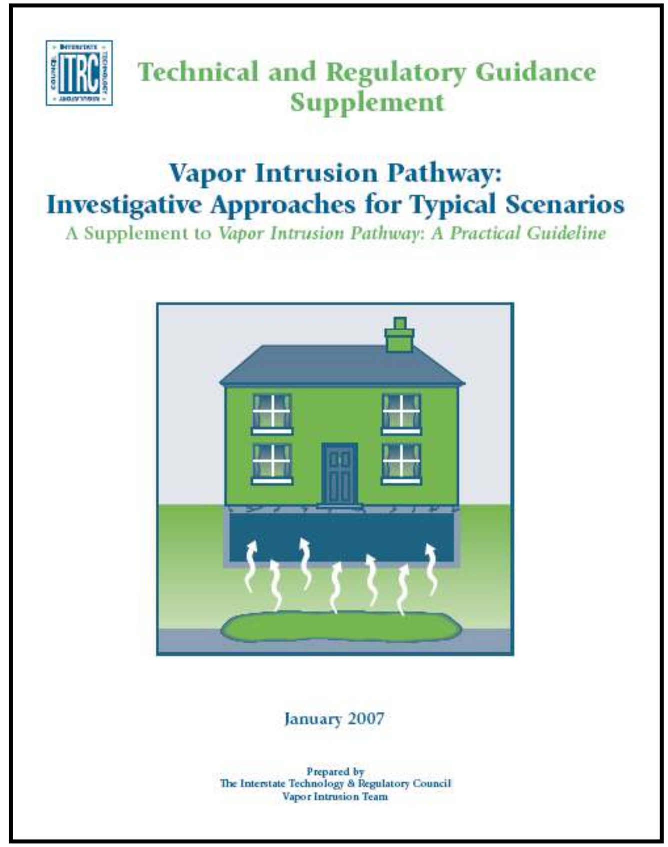


ITRC VI Guidance

- Practical How-to Guide
- Stepwise Approach
- Discussion of Investigatory Tools
- Thorough Discussion of Mitigation
- Scenarios Document
- Classroom Training in 2008

ITRC VI Scenario Document

- Gas station in residential neighborhood
- Dry-cleaner in strip mall located adjacent to neighborhood
- Large industrial facility with long plume under several hundred buildings
- Vacant lot with proposed Brownfields development over groundwater plume
- Vacant large commercial building with warehouse space and office space
- Apartment building with parking garage over groundwater plume


Technical and Regulatory Guidance Supplement

Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios

A Supplement to *Vapor Intrusion Pathway: A Practical Guideline*

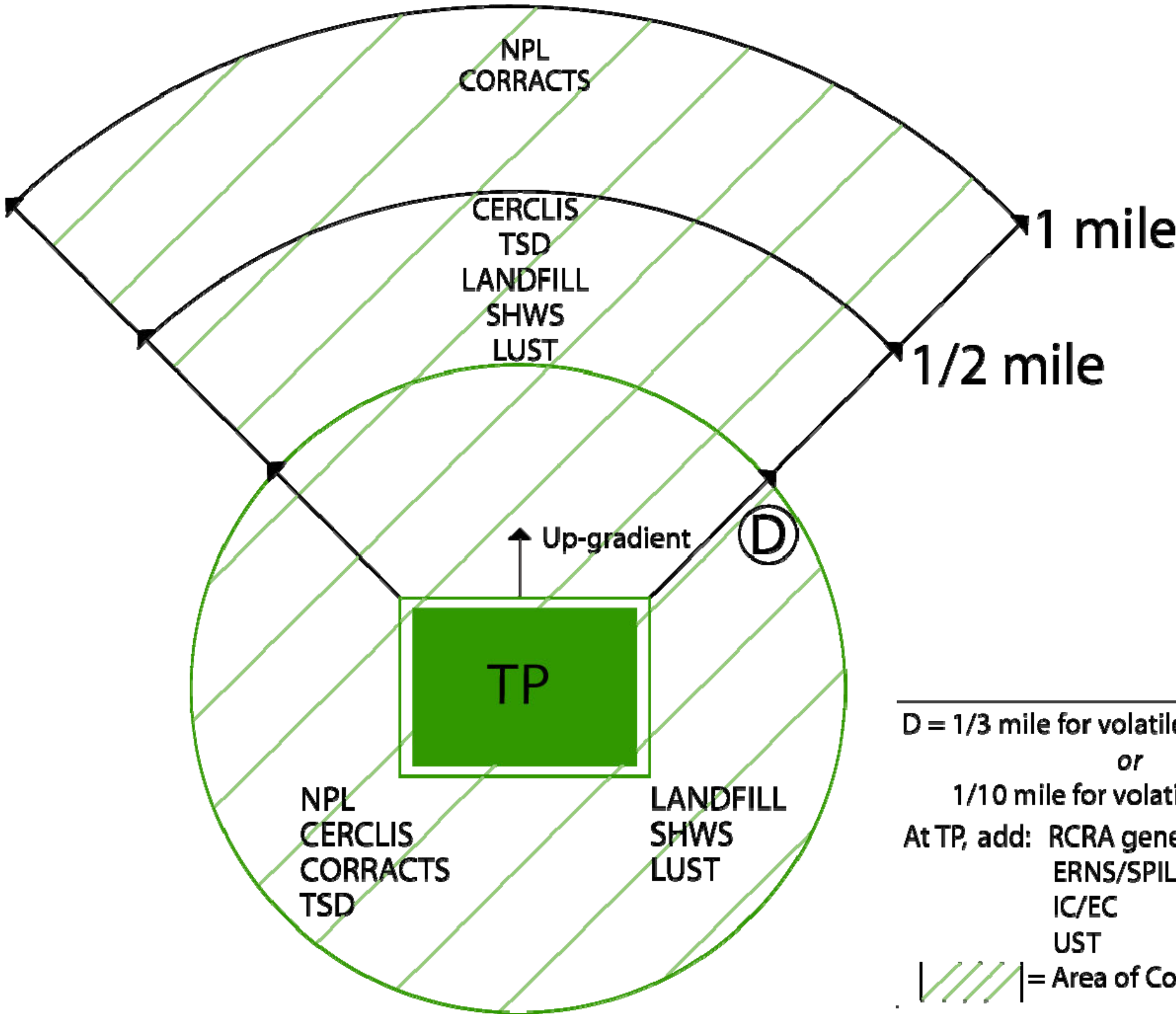
January 2007

Prepared by
The Interstate Technology & Regulatory Council
Vapor Intrusion Team

ASTM VI Standard

- Focus on Property Transactions
- Prescriptive Screening Distances
- No RBSLs (RBC)
- No Assessment Recommendations
- Legal Standards
- Mitigation
- Released March 3, 2008

SEARCH DISTANCE TEST



D = 1/3 mile for volatile chemicals

or

1/10 mile for volatile petroleum HCs

At TP, add: RCRA generators
ERNS/SPILLS
IC/EC
UST

= Area of Concern

Part 4 – Methods to Assess VI

- Indoor Air Sampling
- Groundwater Sampling
- Soil Phase Sampling
- Use of Predictive Models
- Measure Flux Directly
- Soil Gas Sampling
- Supplemental Tools/Data

Some Key VI Issues

- Experience of the Collector/Consultant
  - Have they done this before?
  - Do they understand RBTLs?
  - Quality/experience of field staff? Sr or Jr?
- Spatial & Temporal Variability
  - GW, Indoor Air, Soil Gas
- Ultra Low Screening Levels
  - Increases chances for false positives

Ingredients for Effective VI Assessments

- Investigatory Approach
- Determine Correct Screening Levels
- Sample & Analyze Properly
- Know & Use Supplemental Tools
- Demonstrating Bioattenuation

Approach Generalizations

- Indoor Air
  - Always find something
  - Multiple sampling rounds: extra time & $
- Groundwater Data
  - Typically over-predicts risk
- Soil Phase Data
  - Typically not allowed; over-predicts risk
- Soil Gas Data
  - Transfer rate unknown
  - Sub-slab intrusive

Groundwater Data

- Preexisting Data Often Exist
  - Over proper well screen interval?
  - Coverage typically limited; interpolation
- Gather New Data
  - Well location, construction, sampling
  - Might miss actual contamination zone
- Perched/Clean Water Layer?
- Tier 1 Risk-Based Target Levels Exist

Soil Phase Data

- Soil Data OK to Use in MO
- Tier 1 Target Levels Exist

Soil Gas Measurement

- Pros:
  - Representative of Subsurface Processes
  - Higher Target Levels Than Indoor Air
  - Relatively Inexpensive
  - Can Give Real-time Results
- Cons:
  - Transfer Rate Unknown
  - Sampling Protocols Vary

Currently Most Preferred Approach

Part 4 – Soil Gas Sampling

- Soil Gas Methods
- Sampling & Analysis Issues
- Sampling Strategies
- Bioattenuation of Hydrocarbons
- Other Tools/Approaches

Which Soil Gas Method?

- Active?
- Passive? (qualitative)
- Flux Chambers? (limited use)

Active method most often employed for VI

Passive Soil Gas

- Pros:
  - Easy to Deploy
  - Can Find Contamination Zones
  - Low Permeability soils
- Cons:
  - Does not Give Concentration
  - No Less Expensive

Considered as Screening Tool by MO-DNR

Passive Soil Gas Samplers

Adsorbent inside tube open on one end

Adsorbent inside badge

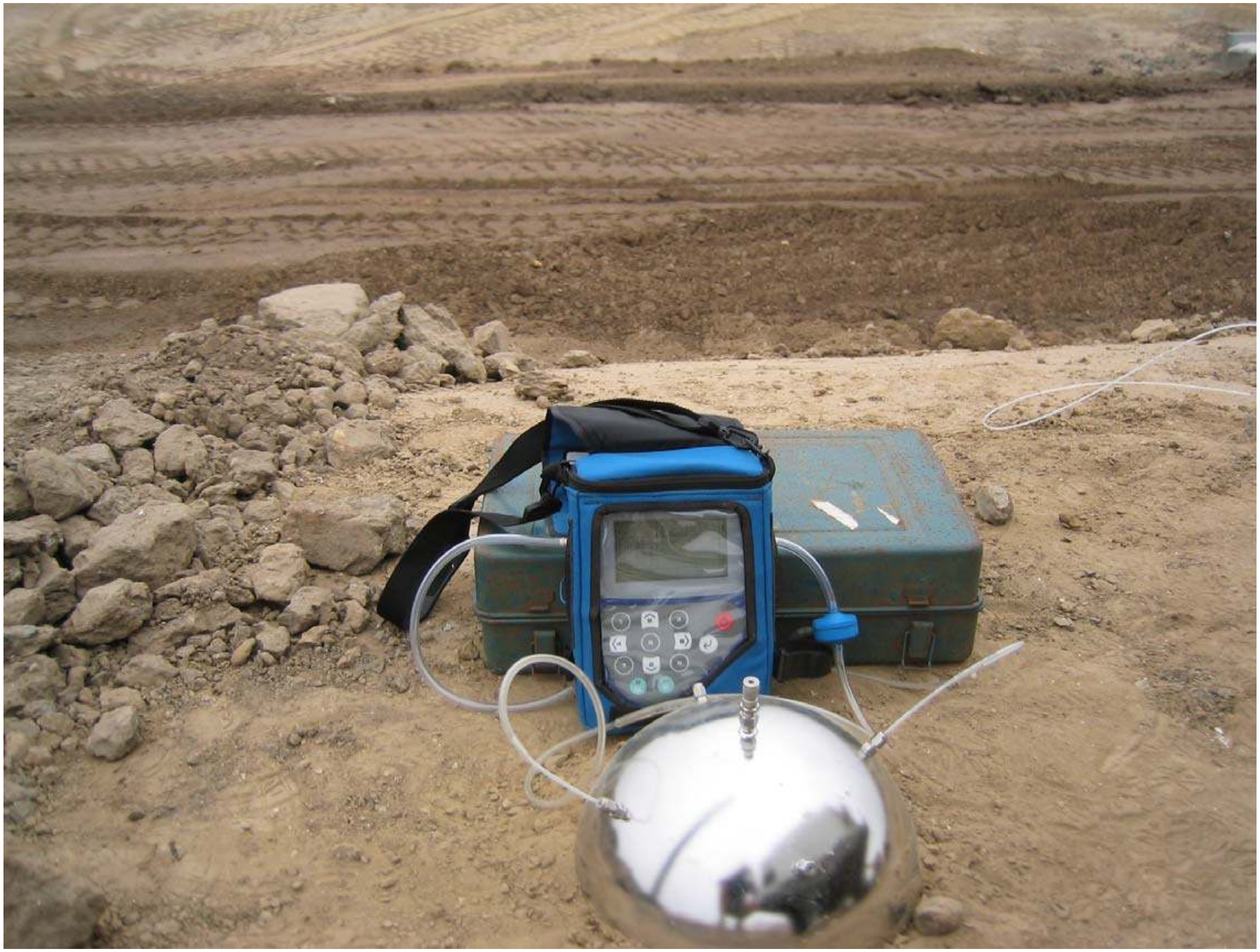
Adsorbent inside vapor permeable, waterproof membrane

Direct Flux Measurement
(Flux Chambers)

- Pros:
  - Direct Measurement of Intrusion
- Cons:
  - Proper Location?
  - Protocols Debated
  - How to Use Data?

MO-DNR: Will Consider Use

Static Flux Chamber



Get Enough Data

- Soil Gas Not Homogeneous
- Spatial & Vertical Variations Exist
-
- Don’t Chase 1 pt Anomalies
- Get Enough Data Near/Around/Under
- On-site Analysis Enables Real-Time Decisions

Probe Installation Methods

- Driven Rod Methods (Temporary)
  - Hand equipment, direct-push
  - Collect sample while probe in ground
  - MO-DNR wants accurate location

- Vapor Mini-Wells/Implants - MO Preferred
  - Inexpensive & easy to install/remove
  - Allow repeated sampling
  - Can “nest” in same bore hole
  - Must construct to remain for at least 6 months

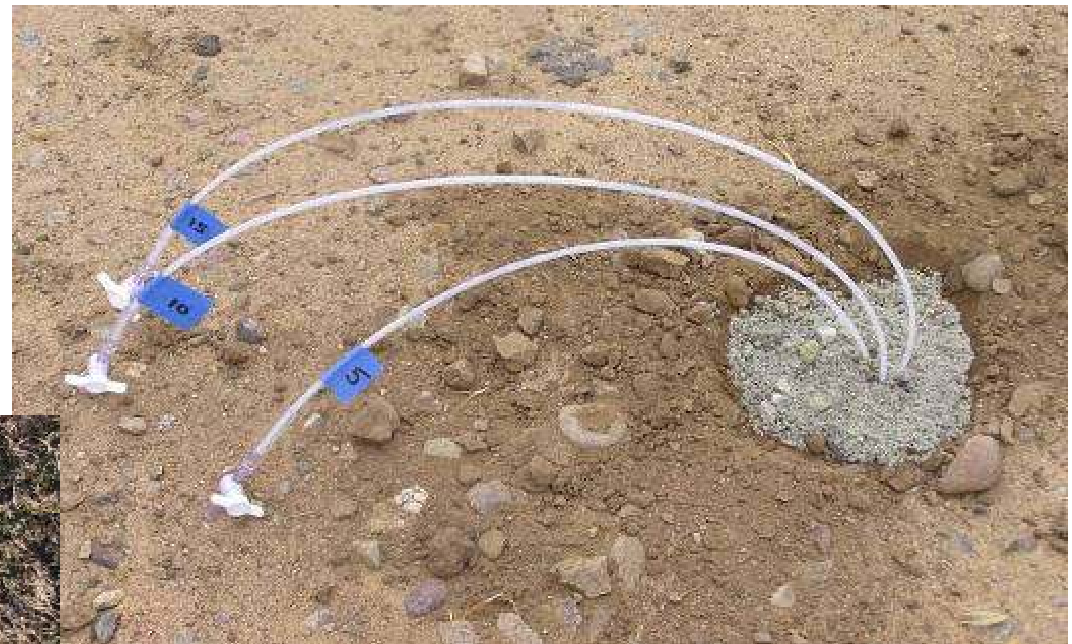
Probe Installation/Abandonment

- Must follow MO Well Construction Rules

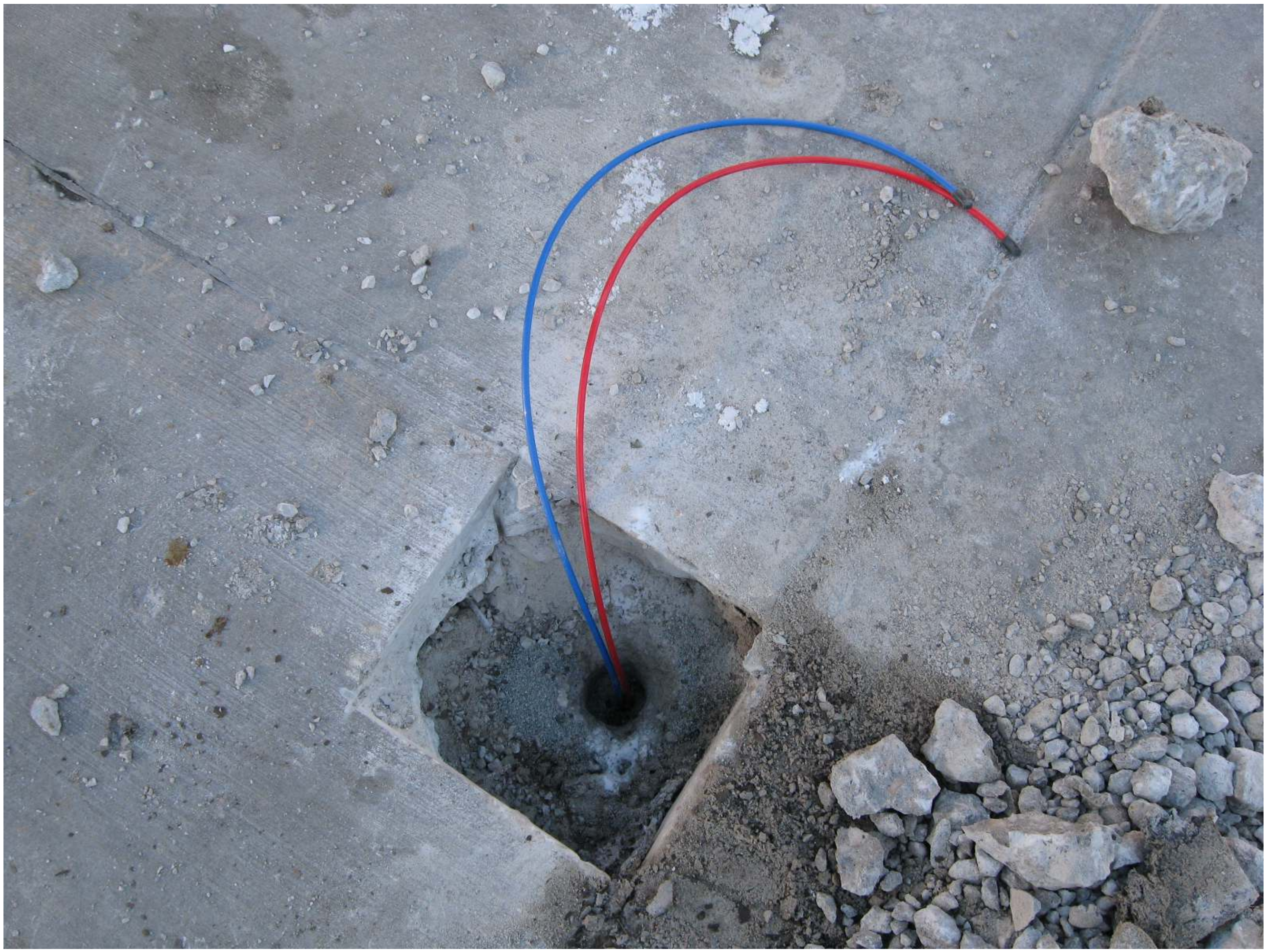
- Wells > 10’ with riser < 2” or in a Borehole <6” OD Require Variance from GSRAD

Sampling Through Rod

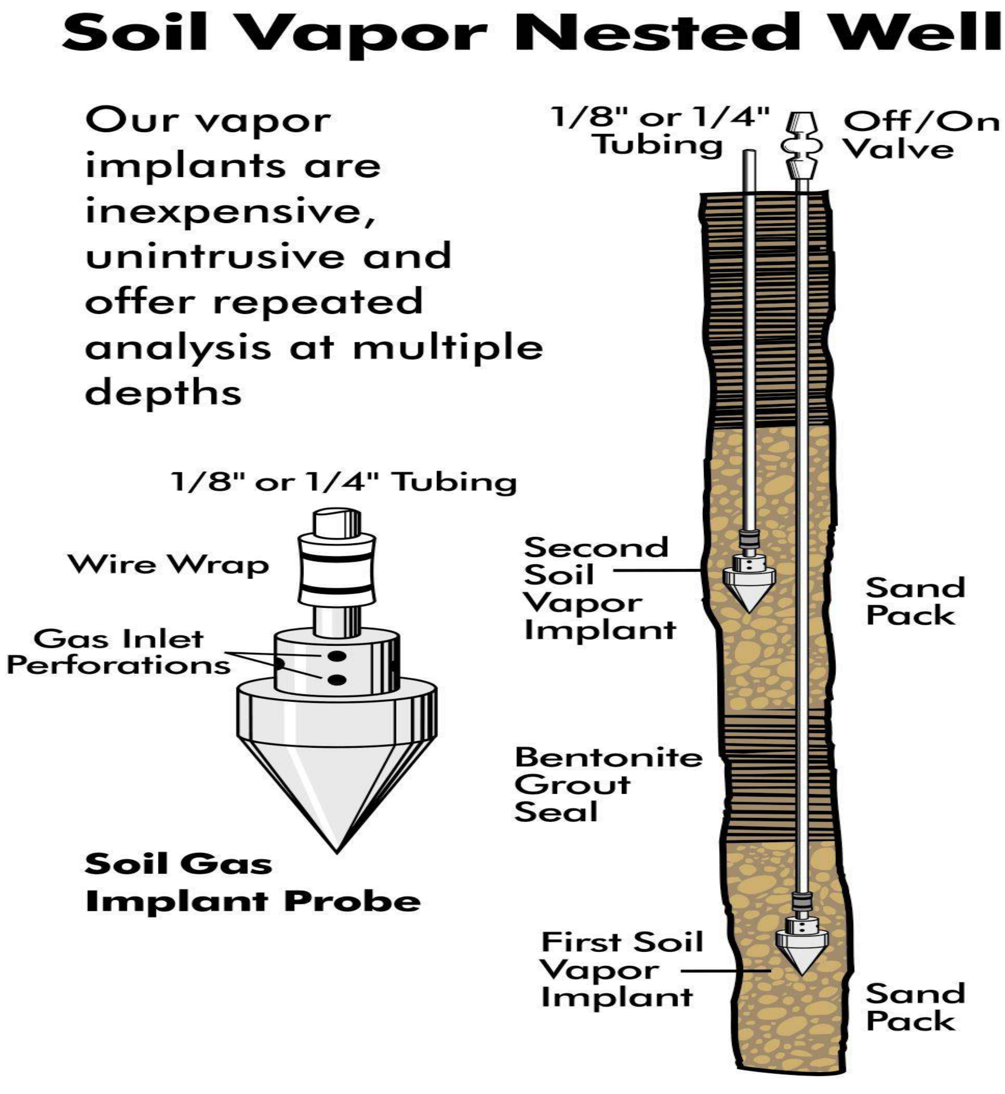
Soil Gas Implants



Nylon Tubing



Multi-Depth Nested Well



Probe Considerations

- Tubing Type
  - Rigid wall tubing ok (nylon, teflon, SS)
  - Flexible tubing not (tygon, hardware store)
  - Small diameter best (1/8” or ¼”)
- Probe Tip
  - Beware metal tips (may have cutting oils)
- Equilibration Time
  - 30 minutes for direct push, 48 hrs rotary
  - Effects of air knife?
- Equipment Blanks
  - Need to collect blank through collection system

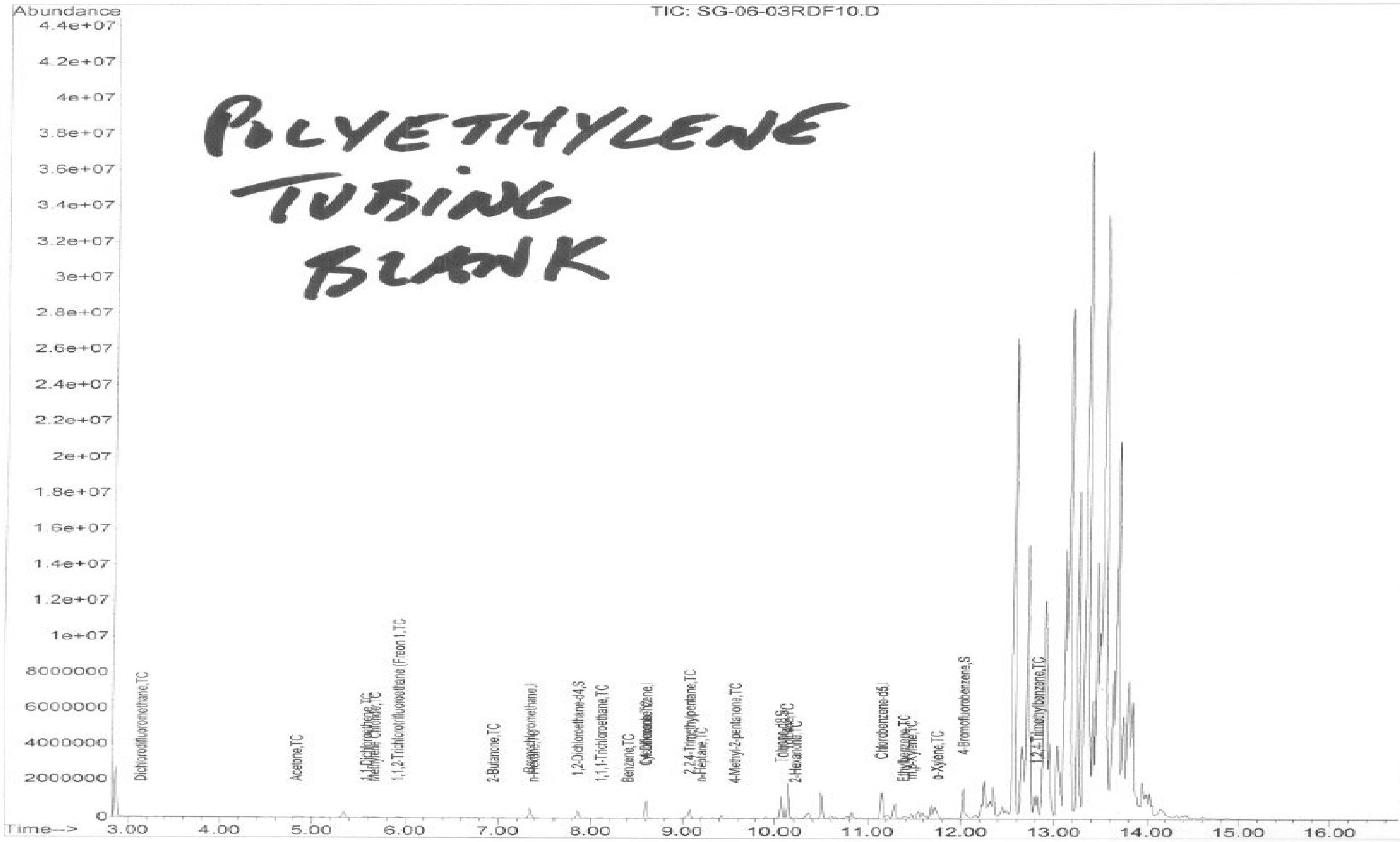
Tubing Test

Tubing	TCE #1 (ug/m3)	TCE #2 (ug/m3)	Average
SS	470	350	410
PEEK	460	340	400
Nylaflow	400	390	395
Teflon	380	410	395
Polyethylene	310	310	310
Cu	nd	170	?

MO-DNR currently allows PolyEthy & Cu

Data Path : D:\111406.12p\
Data File : SG-06-03RDF10.D
Acq On : 14 Nov 2006 6:05 pm
Operator : cb
Sample : [redacted]
Misc : 10
ALS Vial : 11 Sample Multiplier: 1

Quant Time: Nov 15 08:59:47 2006
Quant Method : C:\MSDCHEM\1\METHODS\102406TOUGM3.M
Quant Title : TO-15 Full Scan Mode
QLast Update : Fri Oct 27 07:30:49 2006
Response via : Initial Calibration



Soil Gas Sampling Issues

- Sample Size
  - Smaller volumes faster & easier to collect
  - MO prefers 1 liter or less
- Containers
  - Canisters: More blank potential. Higher cost
  - Tedlars: Easier to collect
- Flow Rate
  - MO prefers < 200 ml/min
- Applied Vacuum
  - MO requires < 100 inches of water
  - Must flag data if > 100 inches of water

Soil Gas Sampling Issues

- Rain
  - Generally wait 48 hours after rain event
  - Depends upon depth & surface cover

- Tracer Compound/Leak Test
  - Test sample train with vacuum test
  - Liquids (IPA, pentane, freon)
  - Gases (He, CO2)

Sample Volumes

Use of Tedlar Bags

Advantages offered by Tedlars:

- Many Consultants More Familiar With than Swageloks
- Easy to Fill: Perhaustalic Pump, Syringe, Lung Box
- Disposable - No Chance of Carry-over/False Positives
- Allows Repeat Analysis of a Sample if in Field
- Allows Measurement of Gaseous Tracer
- Allows On-site & Off-site Analysis of Same Sample!

Liquid Tracer Method

- Pros
  - Fast & easy
  - Can cover multiple spots easy
  - Very conservative (100 ug/L = 0.1% leak)

- Cons
  - Typically qualitative
  - Don’t know results in real-time without lab
  - Small leak can raise DLs of VOC analysis

Gas Tracer Method

- Pros
  - Quantitative
  - Real-time results with portable meters

- Cons
  - More complicated and slower. Increases costs
  - Harder to cover multiple locations, esp with DP

Best Method if No Lab On-site

Liquid Method

Post-Run Tubing (PRT) Fitting

Gas Method

Tent Shroud

Sampling in Shroud

Purging with Syringe

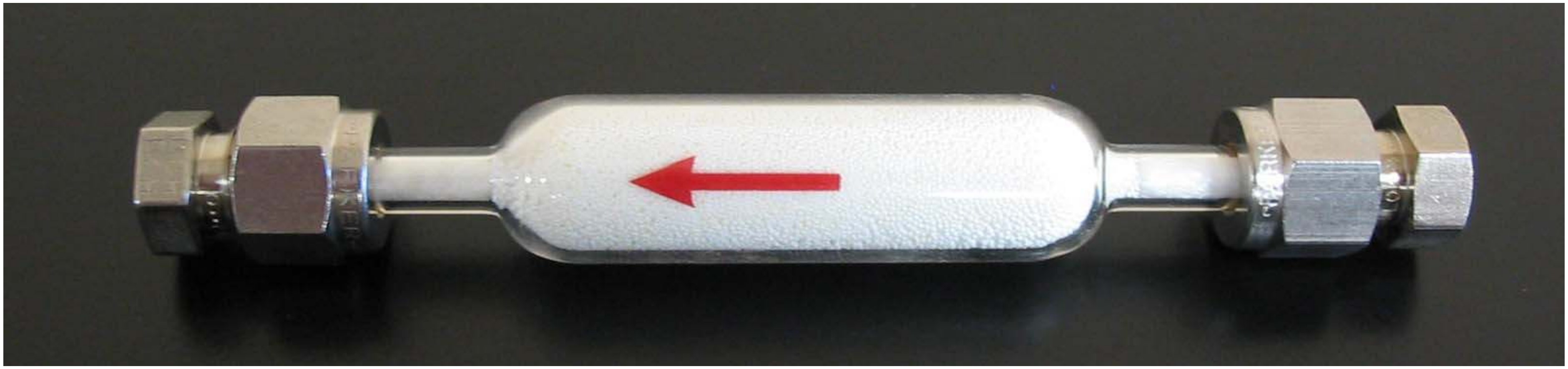
Sample Collection

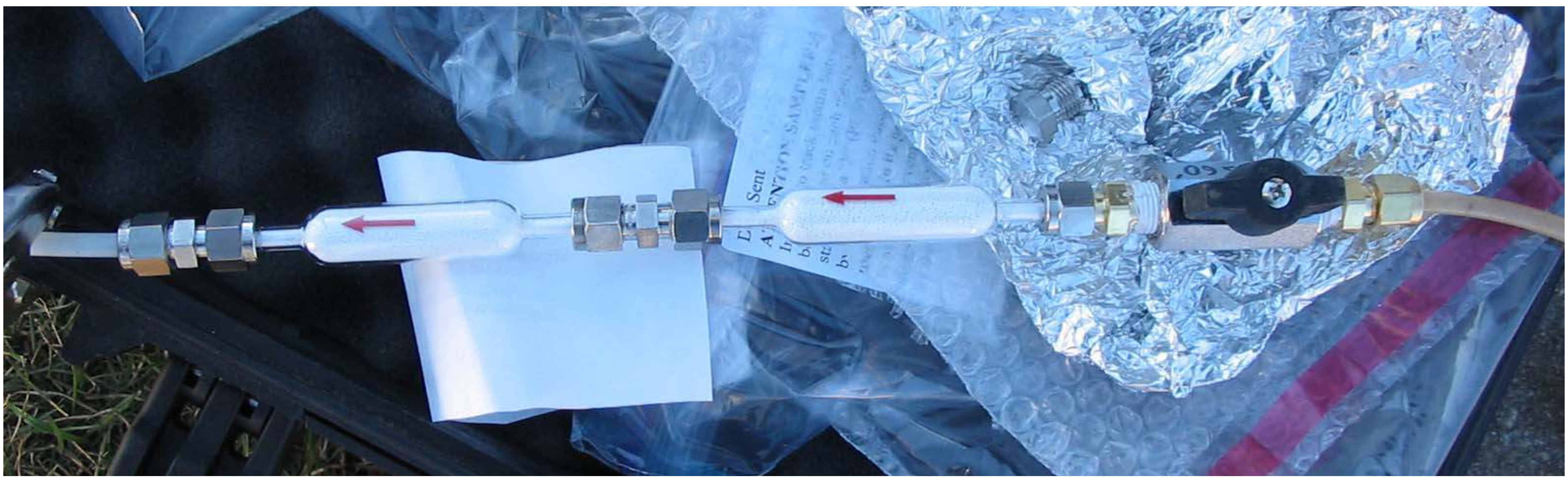
Sample Transfer

Beware of the Hardware

Sample Collection

SVOC Sampling





Some Final Sampling Issues

- Certified Clean Canisters
  - Not needed if DL > 5 ug/m3
- Residual Vacuum in Canisters
  - Not critical for soil gas samples
- Dedicated Flow Restrictors
  - Not necessary if cleaned between samples

Common Soil Gas Analyses

- VOCs
  - Soil & Water Methods: 8021, 8260
  - Air Methods: TO-14, TO-15, TO-17
- Hydrocarbons
  - 8015 m, TO-3
- Oxygen, Carbon Dioxide
  - ASTM 1945-96
- SVOCs: TO-4, TO-10, TO-13

Soil Gas Analysis Issues
(TO-14/15 or 8260 or 8021)

- All Methods Give Reliable Results
- Detection Level Discriminator:
  - TO Methods: <1 to 1 ug/m^3
  - 8021: 2-5 ug/m^3
  - 8260: 10-100 ug/m^3
- On-Site Analysis:
  - Extremely Helpful for VI
  - Minimizes False Positives

High SG Concentrations Create Headaches

- Typical Soil Gas Concentrations
  - Benzene near gasoline soil: >100,000 ug/m3
  - TPH vapor: >1,000,000 ug/m3
  - PCE under dry cleaner: >100,000 ug/m3
- TO-15 Maximum Conc: 2,000 ug/m3
  - Must do large dilutions, DL goes up
  - False positives from hot samples
- Canister & Hardware & Instrument Blanks

New Advance:
On-Site TO-15 Scan/SIM

- Simultaneous Scan/SIM mode enables
  <10 ug/m3 for All VOCs &
  ~2 ug/m3 for subset of compounds.

- Only 2cc of Sample. Eliminates Hardware

- Real-time Analysis in Structures: Control!

Part 5: Soil Gas Sampling Strategies

- Where to Collect Samples
- Exterior vs. Interior (sub-slab)
- How Often to Sample
- Documenting Bioattenuation

Where to Sample - Vertically

- Generally Two Depths per Location
  - One of the two <3’ below foundation
  - Basements: Within 5’ of wall at mid-depth
  - Slabs: Within 3’ of bottom of slab
  - Source below: collect below foundation

- Future Buildings
  - Two depths, nominally 3’ & 10’ bgs
  - Just below future foundation if contamination shallow

- Shallow GW
  - Above cap fringe
  - Just below future foundation if contamination shallow

Where to Sample - Laterally

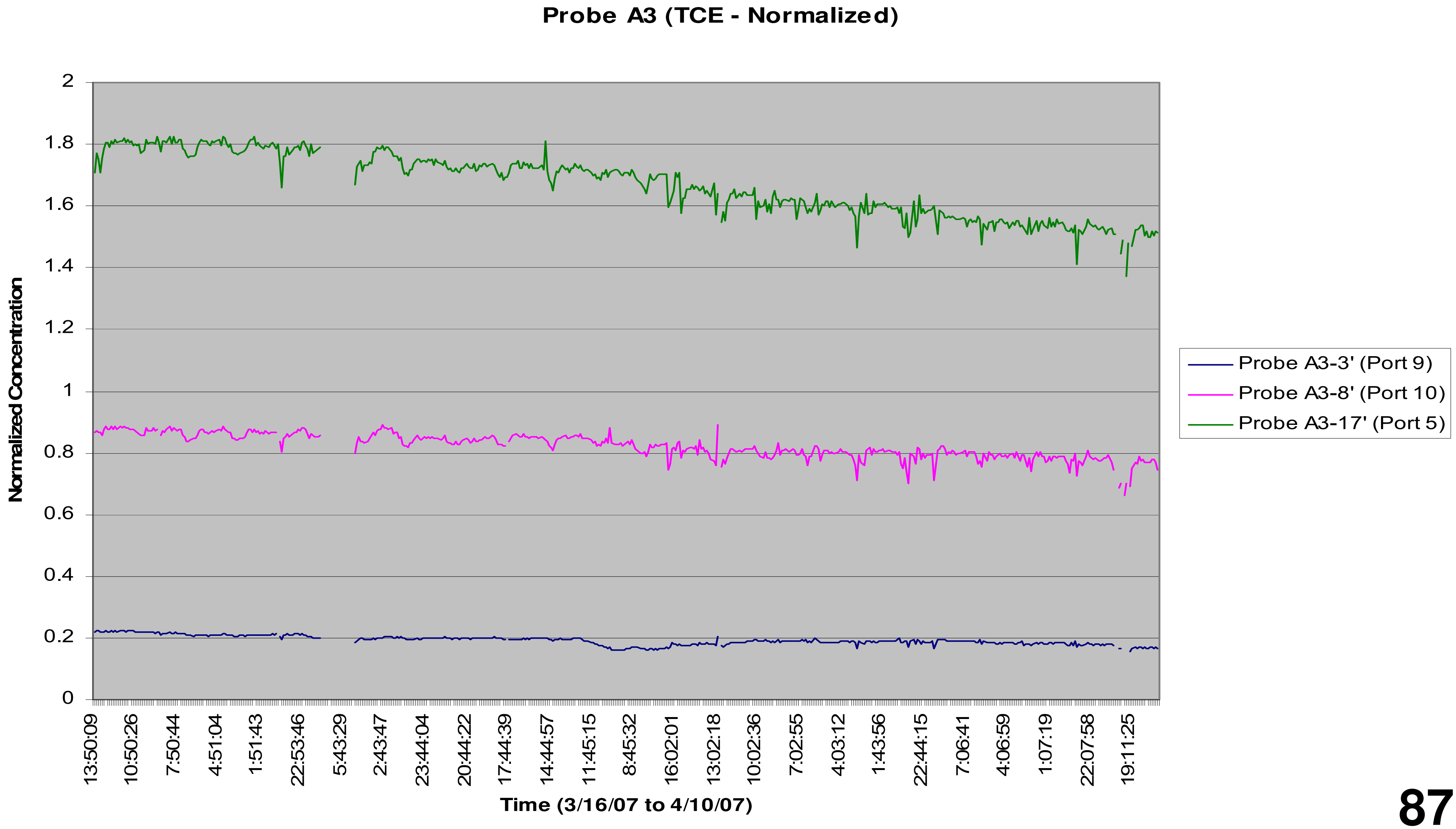
- Source Not Immediately Below
  - Collect on side towards source
  - Approx 25’ spacing

- Future Structures
  - In areas with highest contamination
  - Minimum of 4 samples; ~50’ max spacing
  - Preferably within footprint of future bldg.

How Deep to Sample?

- Depth Below Surface
  - 3’ to 5’ bgs generally considered stable
  - MO allows as shallow as 18”
  - Temporal Studies Ongoing

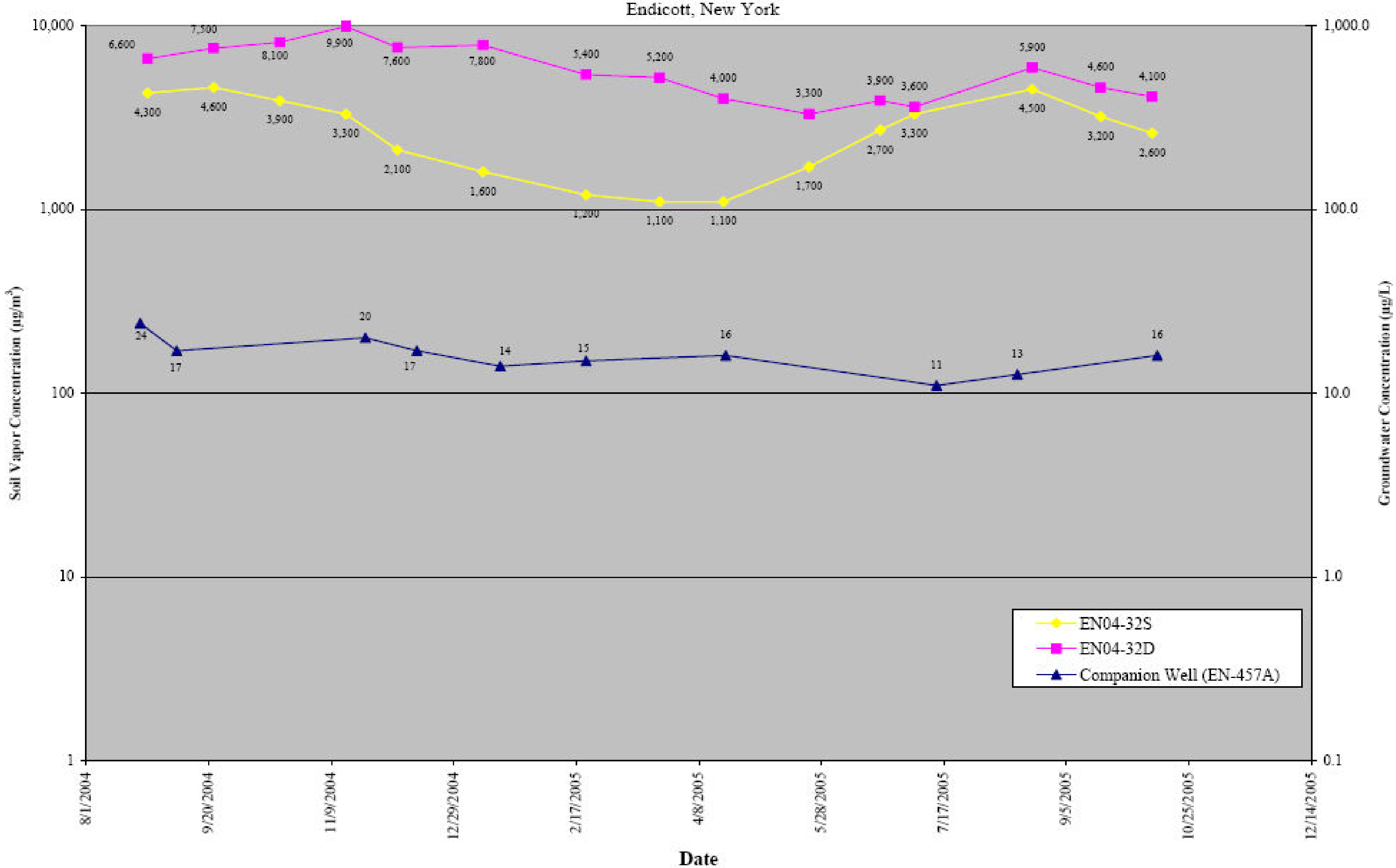
Soil Gas Temporal Study



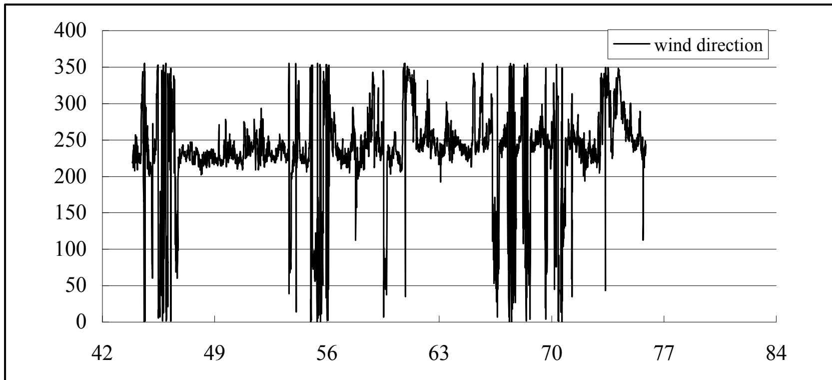
How Often to Sample?

- MO Requires Minimum of Two Events
  - No less than 3 months between events
  - More events if data variable
  - 4 events nominal, but more if necessary

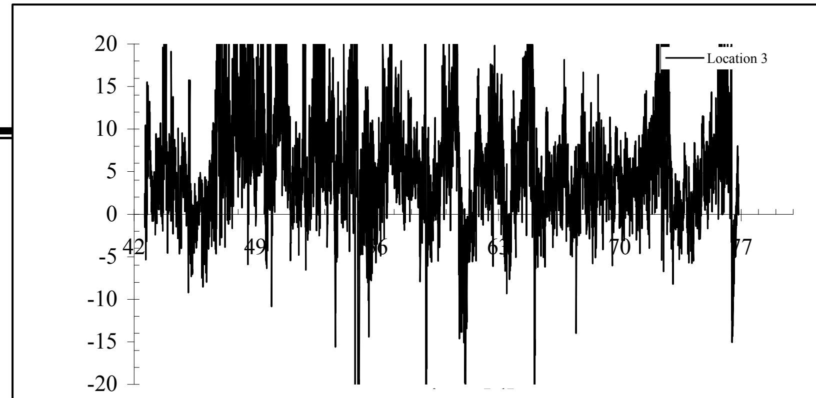
Figure B.32
TCE in Soil Vapor and Groundwater
Quarterly Report - Soil Vapor Monitoring
Comprehensive Operations, Maintenance, & Monitoring Program
Endicott, New York



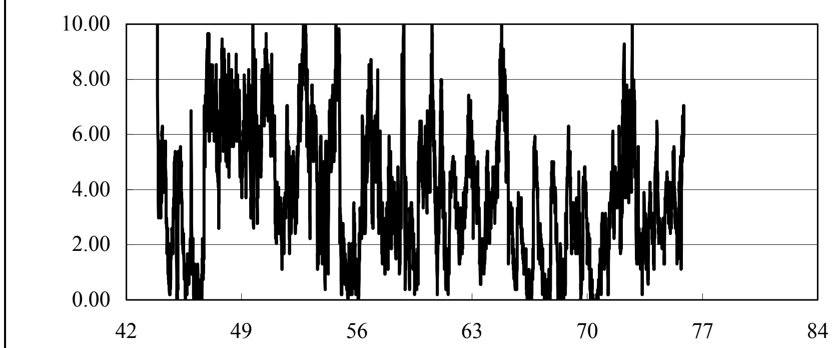
Meteorological Effects on Soil Gas



Wind Direction

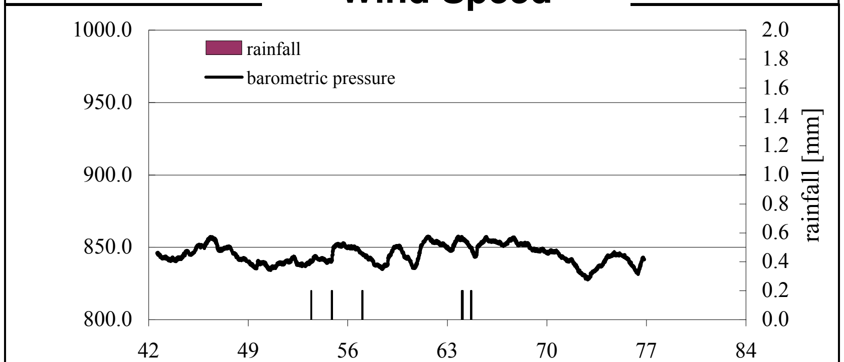


Pressure Differential

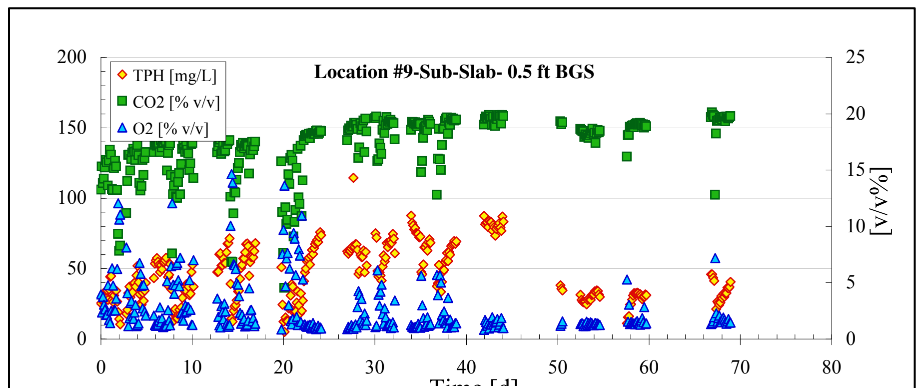


Wind Speed

?

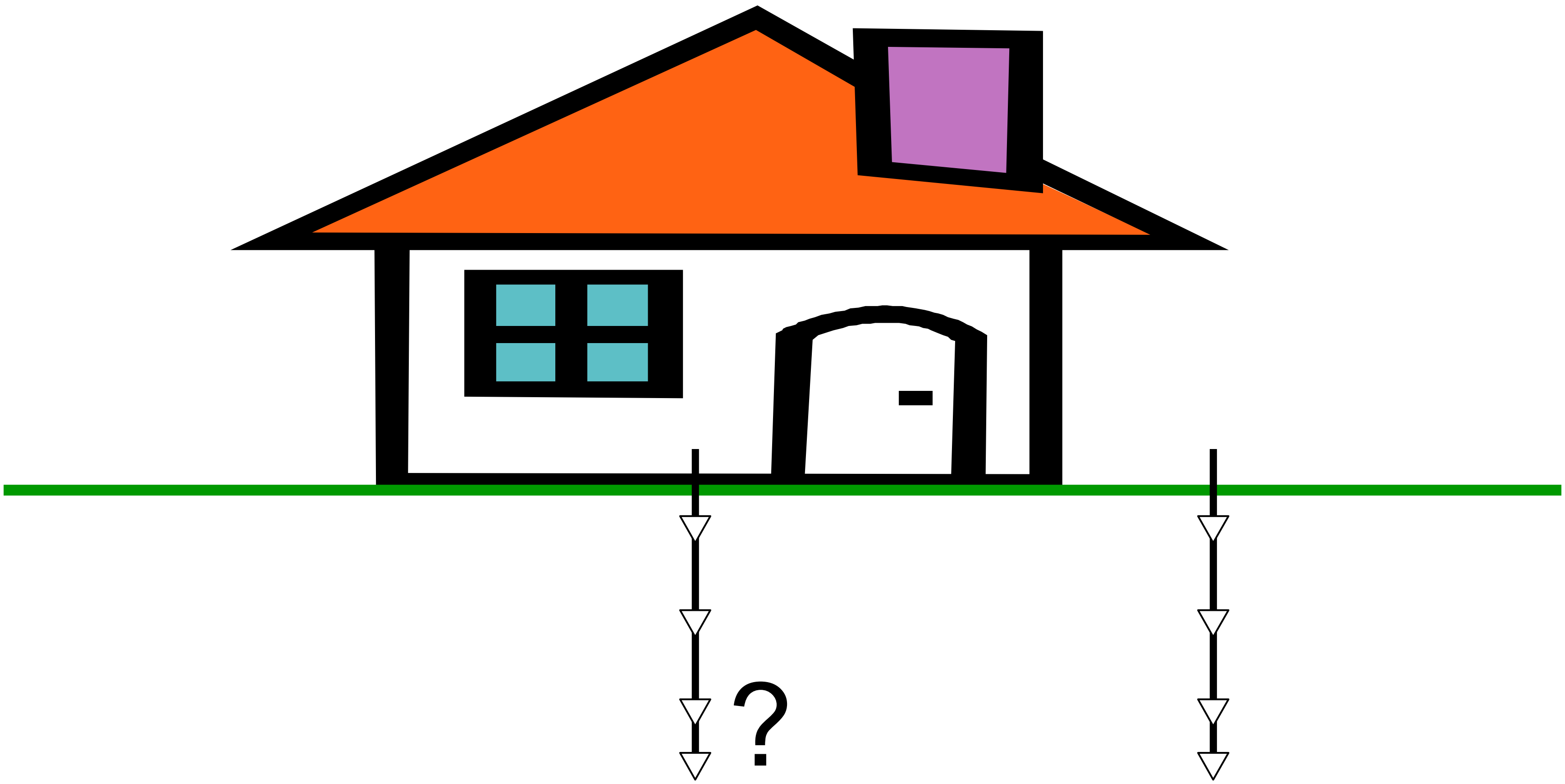


Barometric Pressure



O_2 and HC Concentrations

Sub-Slab vs. Near-Slab Samples



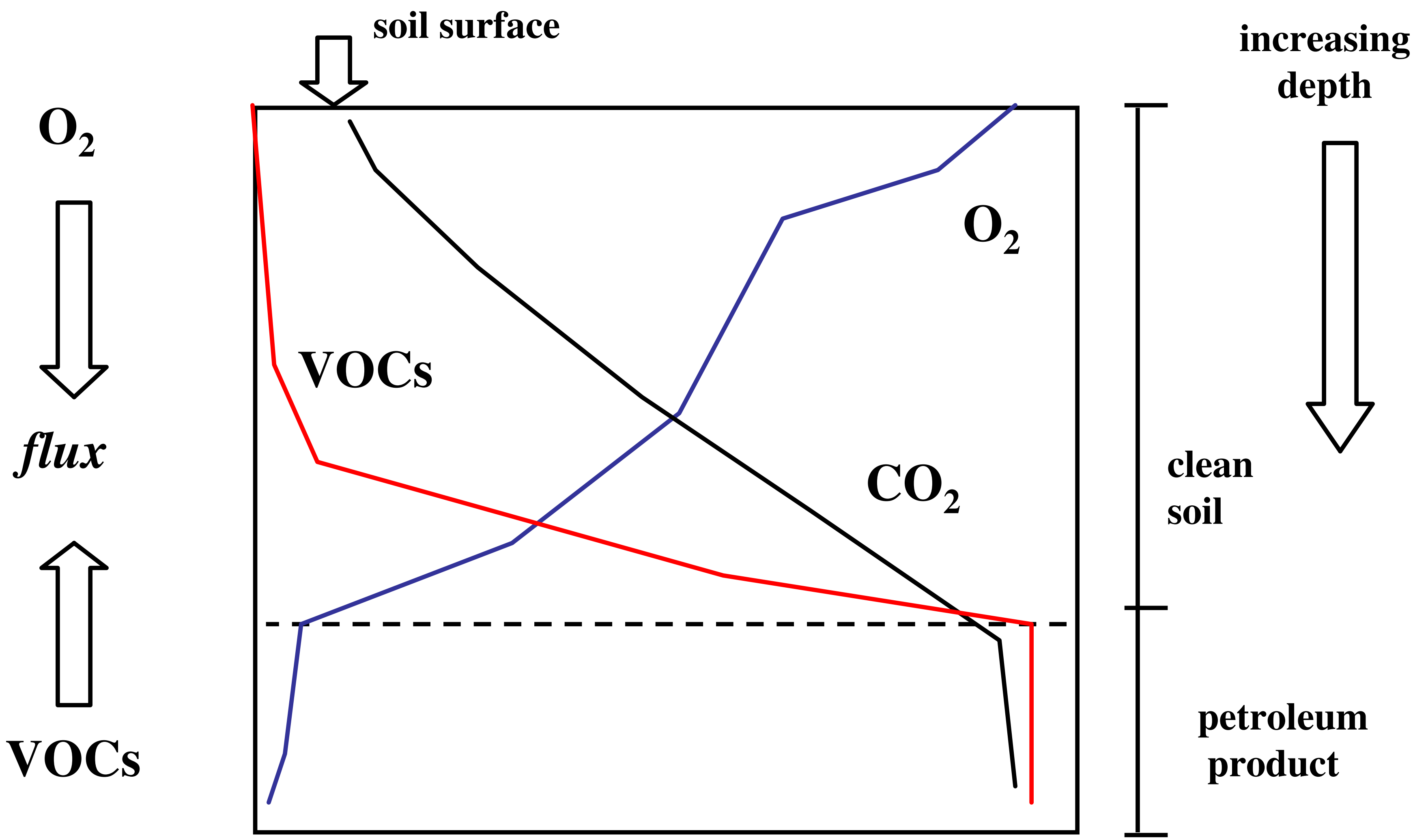
Sub-Slab vs. Near-Slab

- MO-DNR Does Not Require
- Very Intrusive; Legal Complications
- HCs: If O_2 High, Near-slab OK
- May Have More Bioattenuation

Bioattenuation of HCs

- Existing Data Suggest O_2 Effective Barrier
- Attenuation > 10,000 Times Over Default
- Document By Vertical Profiles of COC & O_2
- Recent 3-D Modeling Substantiates
- MO-DNR Will Consider Bioattenuation

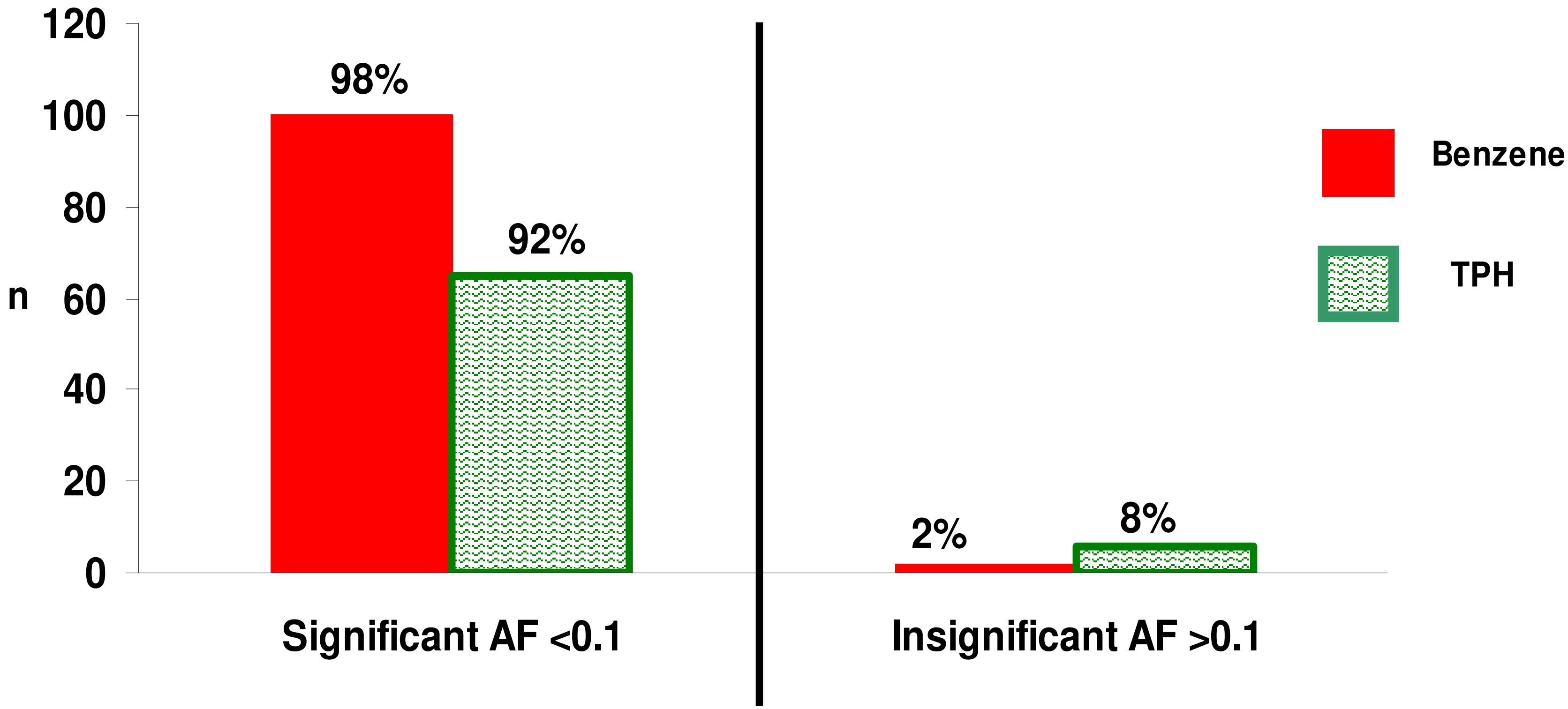
Theoretical Bio Profile



Sample Events and % Attenuation of Benzene and TPH

Study Data Set Events: 102 Benzene, 71 TPH

n=# vapor sample events



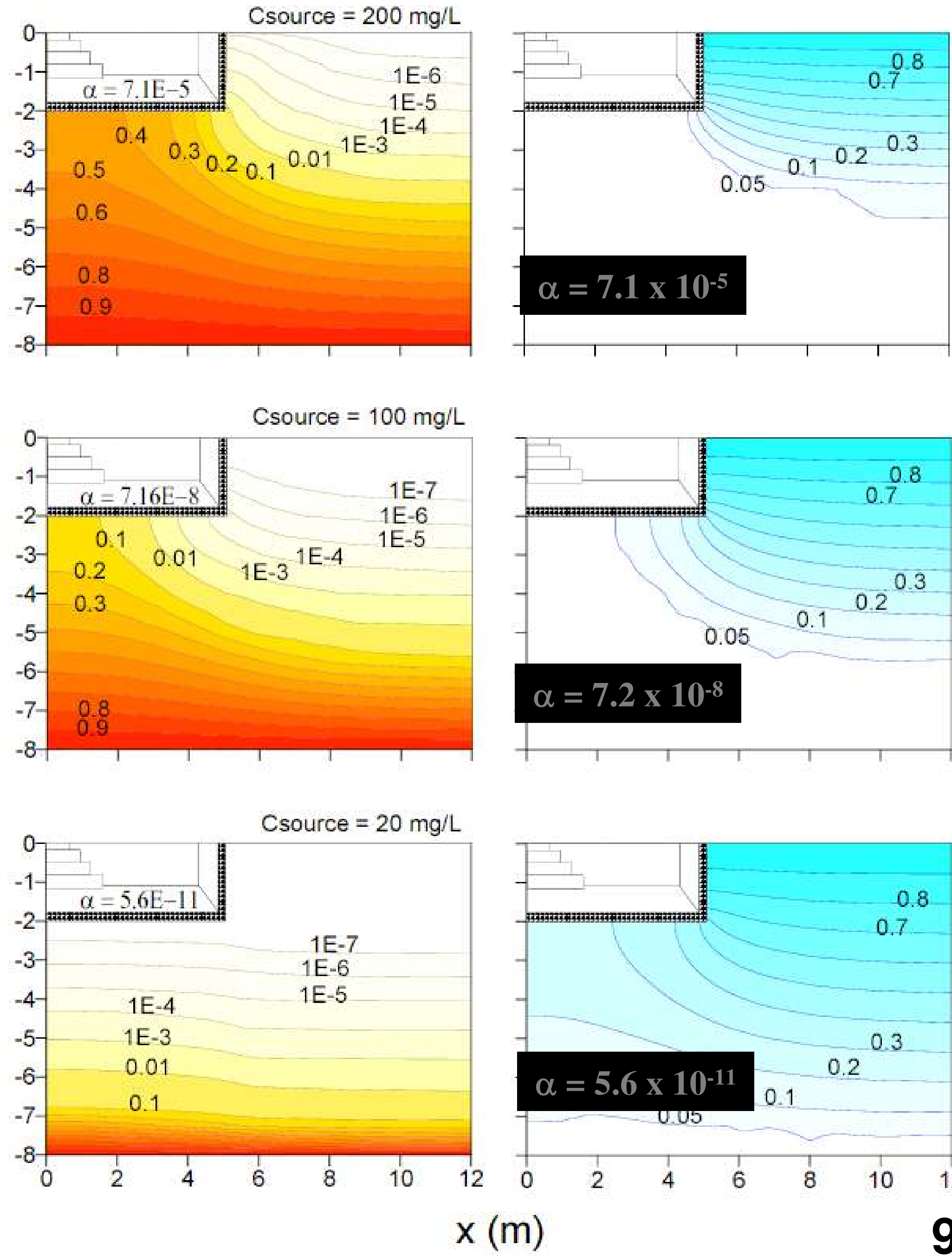
<u>SIGNATURE CHARACTERISTICS OF BIO-ATTENUATION</u>

- 5 feet clean coarse-grained or 2 feet of fine-grained soil overlies contaminant source
- Vapor concentrations decrease significantly vertically away from source
- O_2 depleted and CO_2 enriched near the source, O_2 enriched and CO_2 depleted with increasing distance from the source
- O_2 minimum range 3% to 5%

Effect of Source Concentration

[$\lambda = 0.18\ h^{-1}$]

Results suggest that there may be source vapor concentrations that are of little concern if soil gas beneath the foundation is well-oxygenated (e.g., groundwater plume sources)



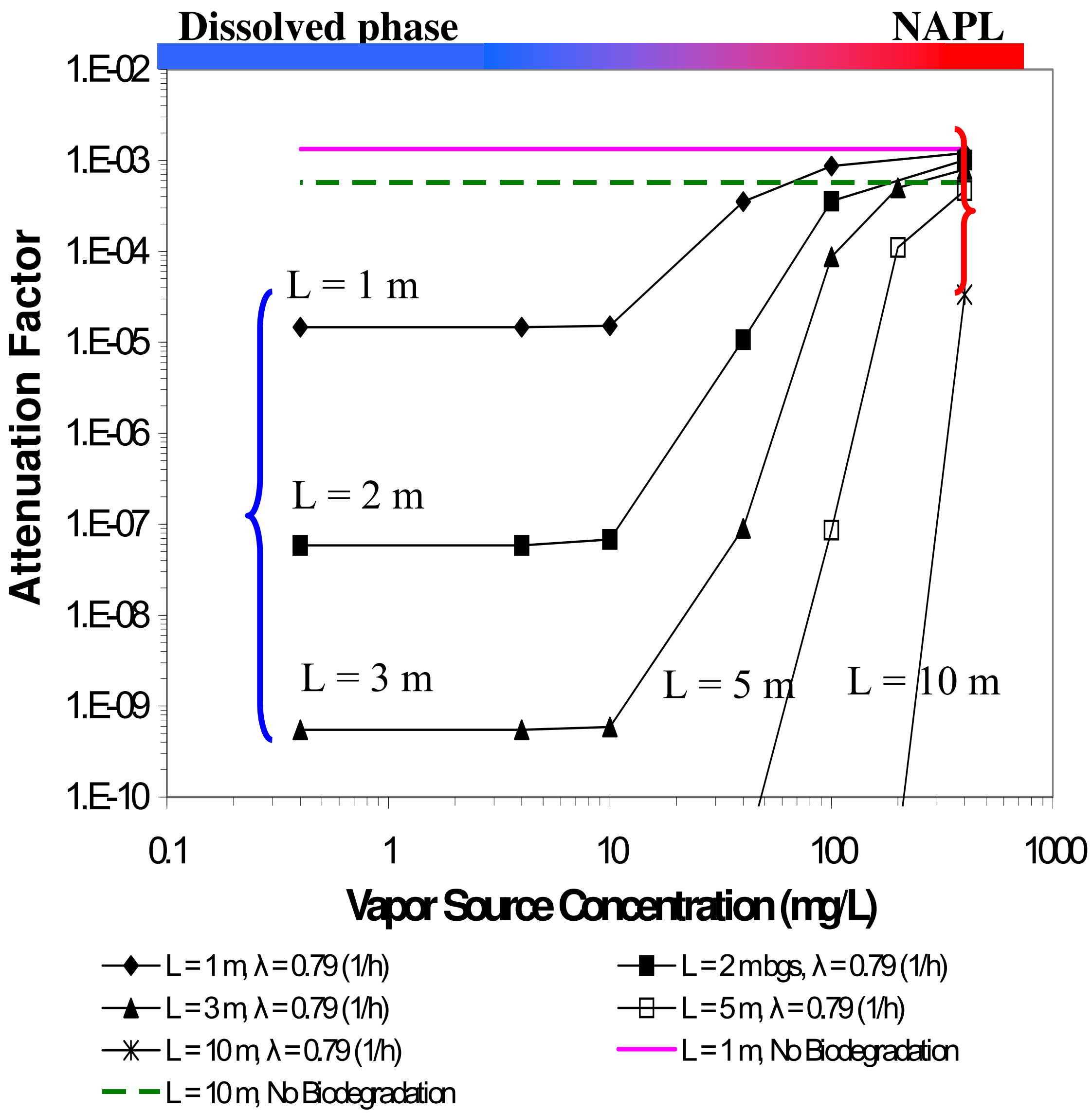
Modeling Assumptions:

- Benzene source
- Sand soil
- Basement scenario
  $\lambda = 0.79\ h^{-1}$

Biodegradation is likely to have a significant effect on α for non-NAPL sources

For NAPL sources, effect of biodegradation on α may be minimal due to oxygen depletion

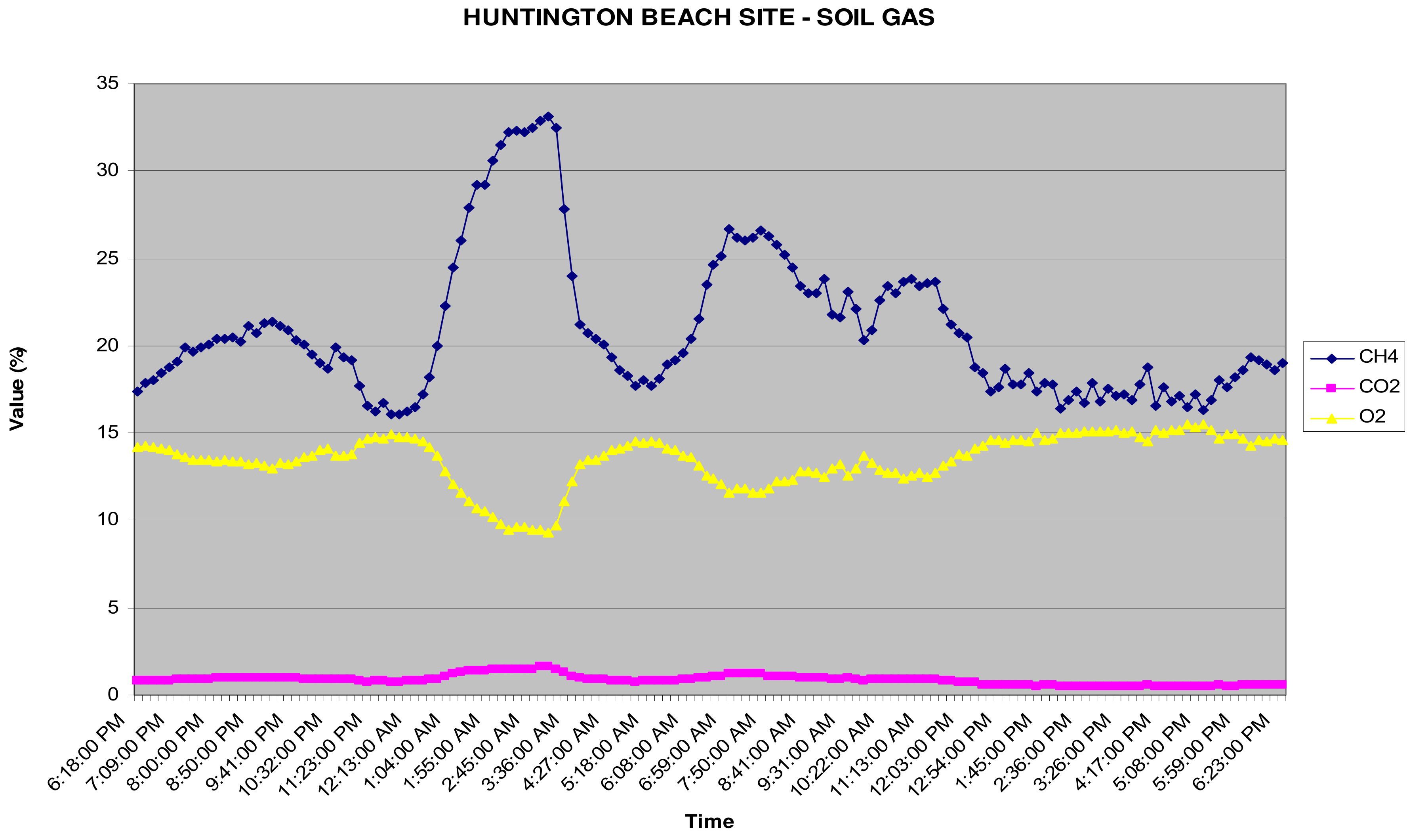
L: source-foundation distance



Supplemental Tools/Data

- Site Specific Alpha Using Radon
  - Factor of 10 to 100. $100/sample
- Indoor Air Ventilation Rate
  - Factor of 2 to 10. <$1,000 per determination.
- Soil Physical Properties
  - Moisture content the key parameter
- Real-Time, Continuous Analyzers
  - Can sort out noise/scatter

Continuous Monitoring Data



VI Documents

- MO-DNR Soil Gas & MRBCA Guidance
  - http://www.dnr.mo.gov/env/hwp/tanks/mrbca-pet/mrbca-pet-tanks.htm
- Overview of SV Methods (www.handpmg.com)
  - LustLine Part 1 - Active Soil Gas Method, 2002
  - LustLine Part 2 - Flux Chamber Method, 2003
  - LustLine Part 3 - FAQs October, 2004
  - LustLine Part 4 – Soil Gas Updates, Sept 2006

Existing Documents & Training

- Soil Gas Sampling SOPs
  - Soil Gas Sampling, Sub-slab Sampling, Vapor Monitoring Wells/Implants, Flux Chambers (www.handpmg.com)
  - EPA-ORD Sub-slab SOP–Draft, Dr. Dom DiGuilio (www.iavi.rti.org/resources)
- Other
  - API Soil Gas Document (www.api.org/bulletins)
  - Robin Davis Lustline Article on Bioattenuation (Lustline June 2006, www.neiwpcc.org)

VI Websites & Links

- http://www.dnr.mo.gov/env/hwp/tanks/mrbca-pet/mrbca-pet-tanks.htm
- www.handpmg.com
  - Soil gas information
  - Units converter
  - Articles & presentations
- www.itrcweb.org
- www.api.org

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