Status of Generic Screening Levels – Update on Empirical Vapor Attenuation Factor Analysis

AEHS Work Shop
Vapor Intrusion
San Diego, March 16, 2006

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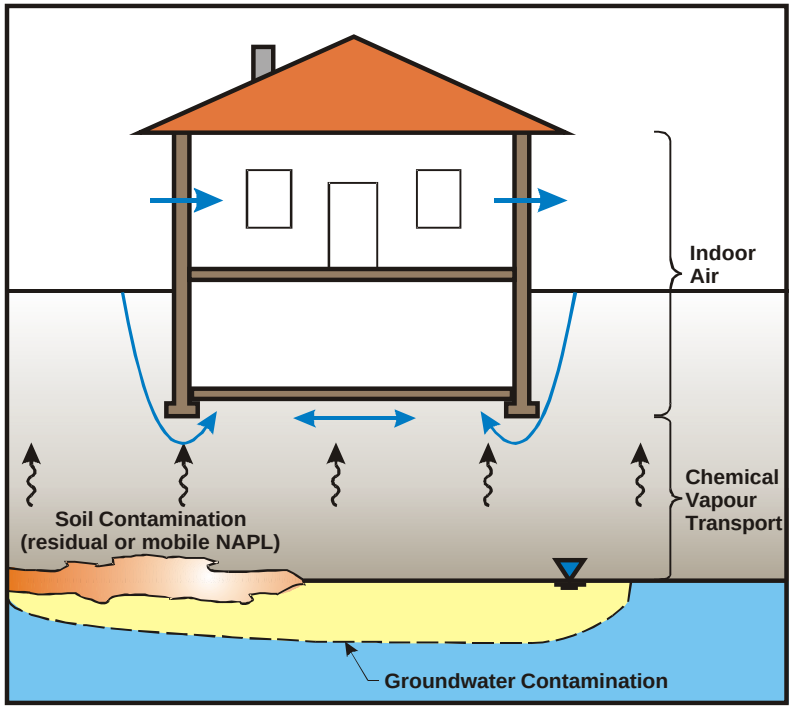
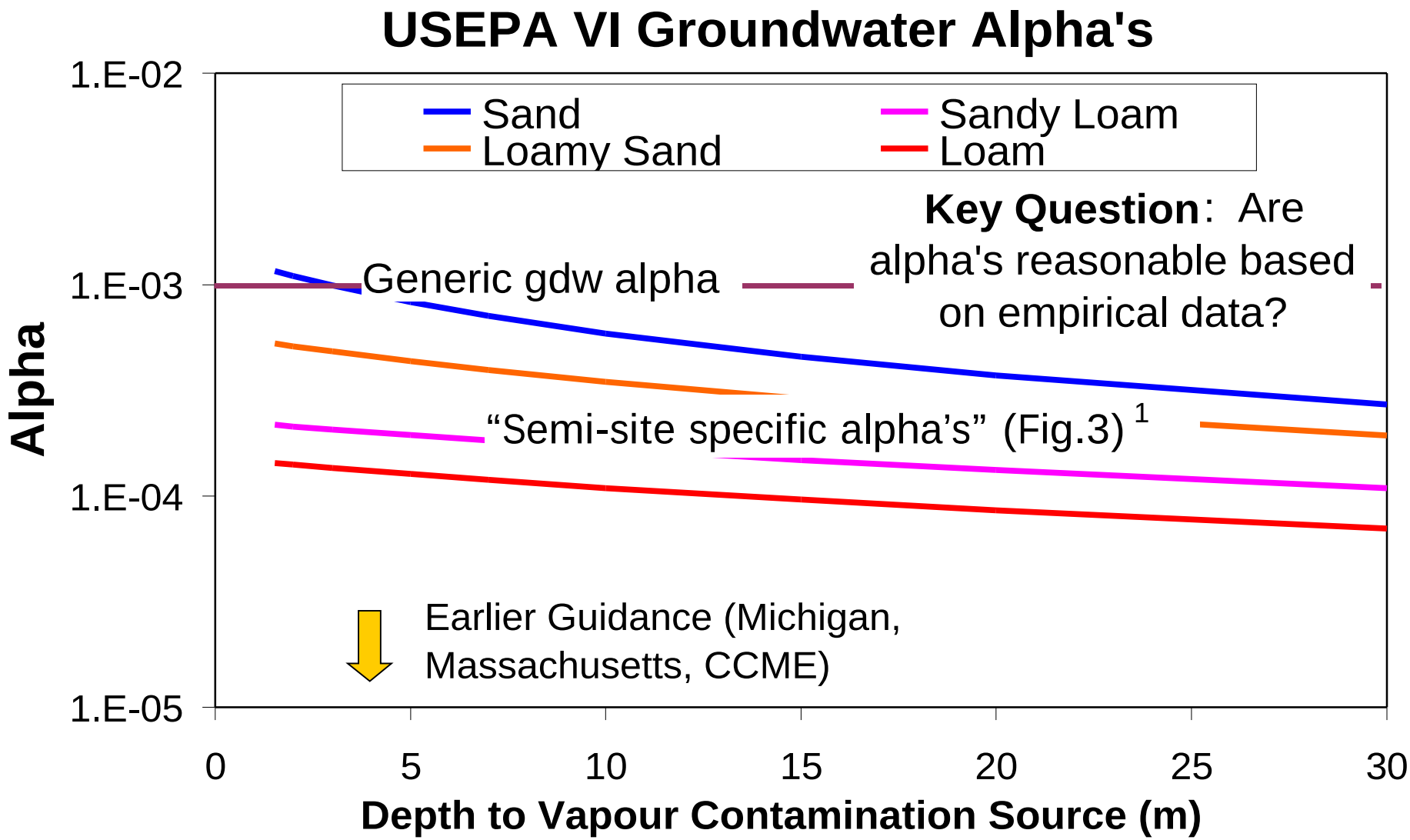


Why is Empirical Data Important?

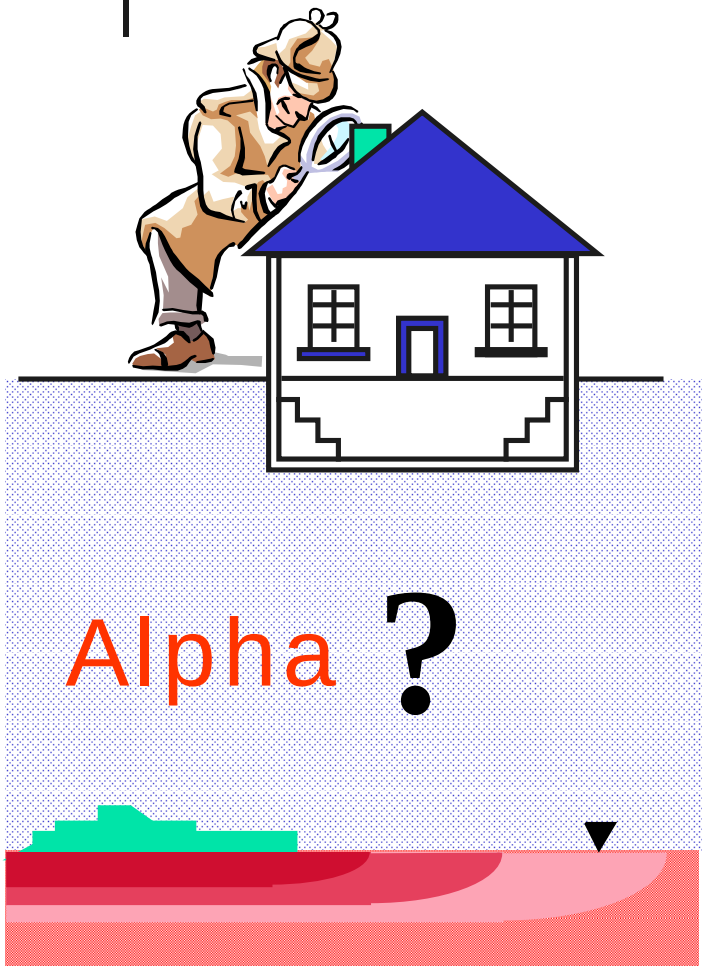
- Context of USEPA guidance
  - Establish generic alpha's (Tier 2)
  - Evaluate modeled alpha's using J&E model (Tier 3)
  - Evaluate precluding factors
- More generally
  - Instrumental for evaluation of predictive models
  - Provide insight on important factors influencing VI
    - Soil properties, depth to contamination, seasonal factors, building type, biodegradation

Why is Empirical Data Important?



"Alpha Charts" to be replaced with "Constrained" Use of J&E Model, however concept similar

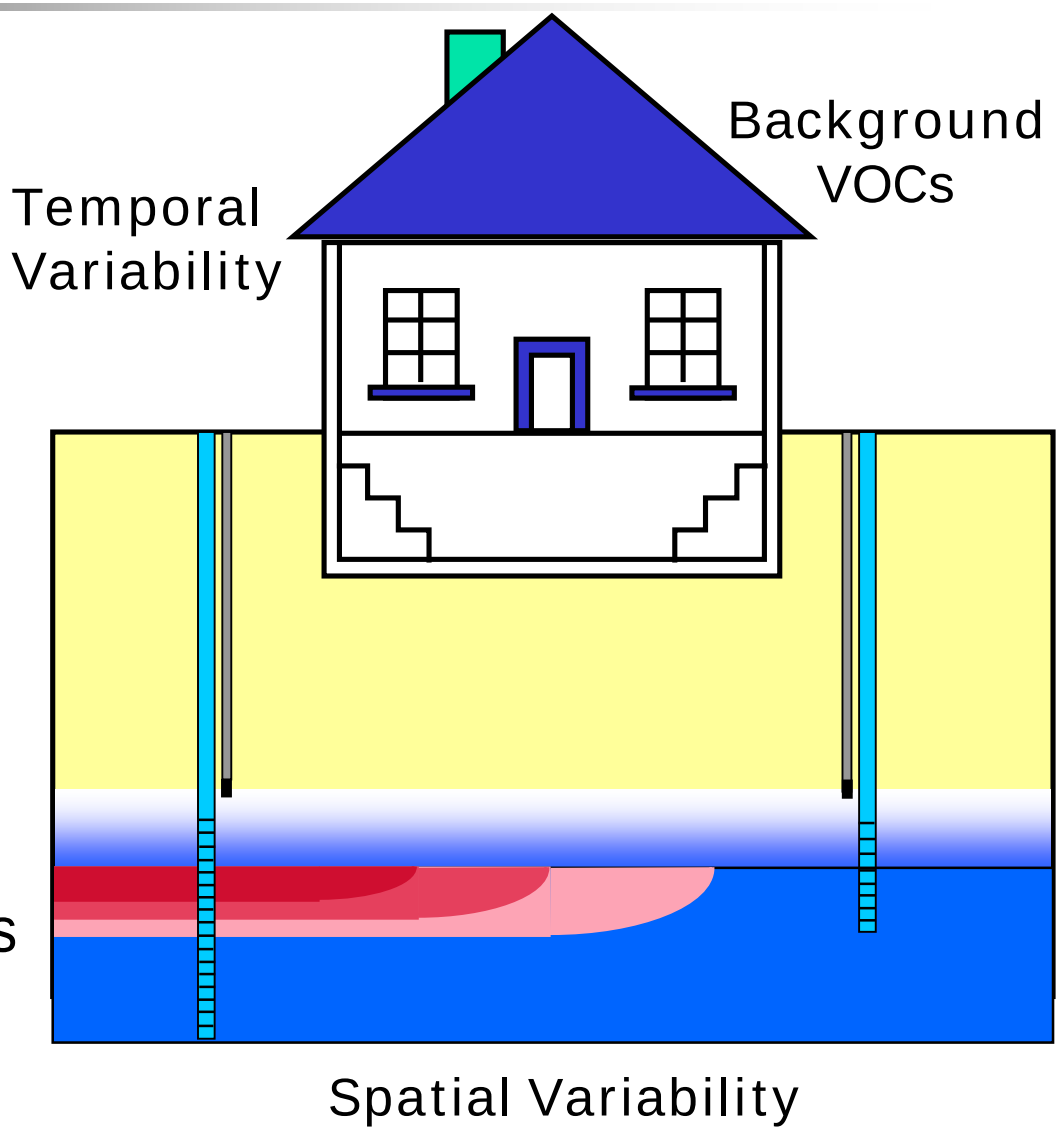
Data Evaluation Scope



- Database 38 sites, several thousand data points
- Mostly residential sites
- More data points chlorinated sites than petroleum hydrocarbons
- IAVI database created for USEPA by RTI – significant effort has gone into data collection over past two years
- Ph.D. research, Golder Associates projects over past decade

What are Challenges for Empirical Analysis

- Hugh variation data quality and quantity
- Groundwater and soil vapor below building are interpolated values
- Methodology (e.g., long screens groundwater)
- Significant spatial & temporal variability
- Background sources VOCs
- Data reliability?



Empirical Alpha Evaluation
(to get "real" alphas)

- Data Quality Screening
  - Appropriate methods, acceptable QC
  - Near concurrent data (or consistent trends)
  - No obvious background sources
- Data Filters
  - Reduce potential influence of background
  - Remove less precise low concentration data
- Data Consistency/Reliability Assessment
  - Lines of evidence evaluation to answer whether data suggests vapor intrusion?

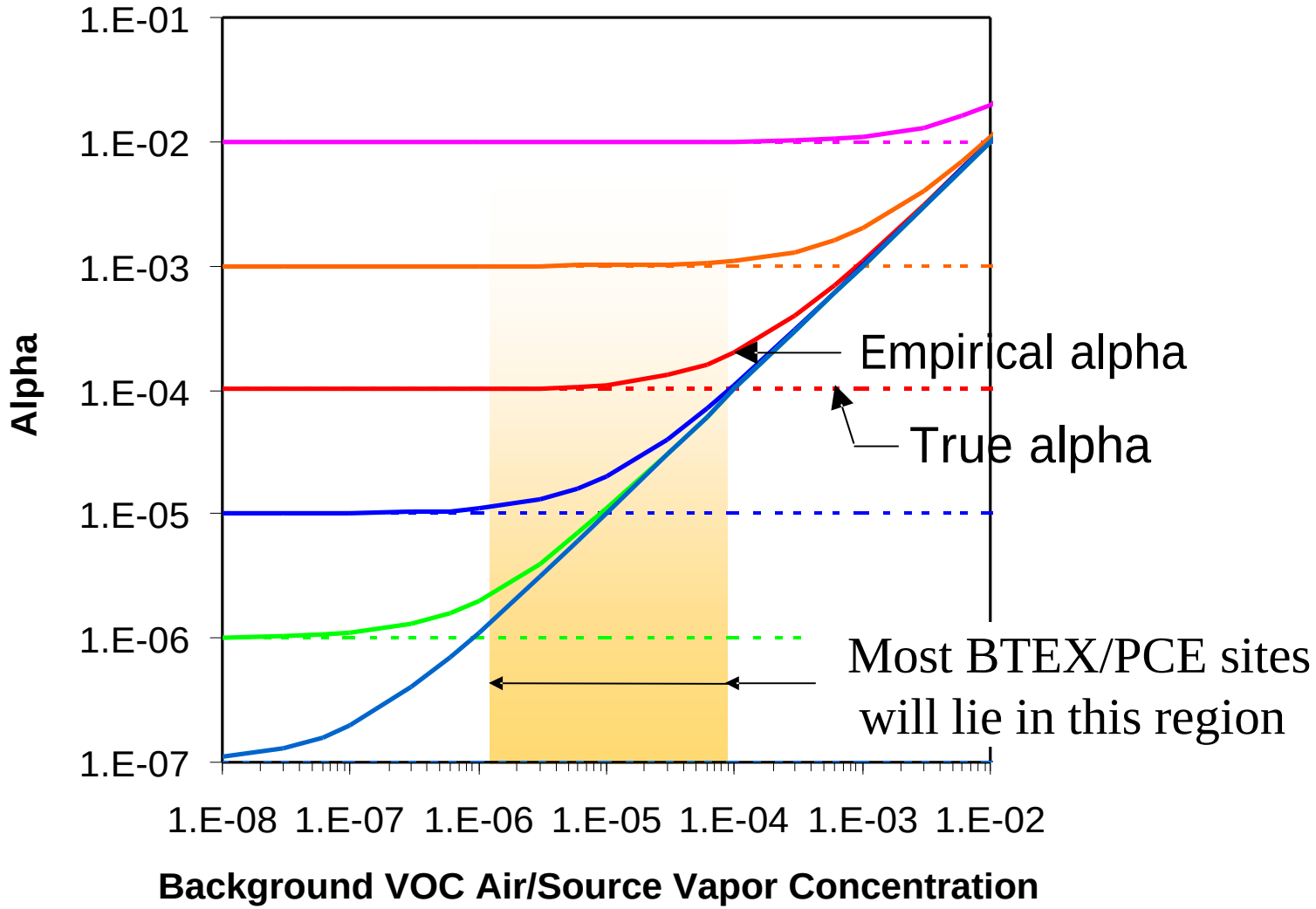
Data Quality Screening

- Data of reasonable quality, representative of site conditions
- Concurrent analyses
  (or consistent time trend for groundwater)
- No obvious indoor sources
  - Documented in indoor survey
  - Indoor air concentration > subslab concentration
  - For multiple chemicals, widely disparate alphas for any one sampling event in a building

Data Filters (main ones)

- Remove low source strength data as indoor vapor concentrations unlikely to be > background levels:
  - Subslab: $C_{vapor} > 100 \times C_{background}$
  - Soil vapor: $C_{vapor} > 1{,}000 \times C_{background}$
  - Groundwater: $C_{vapor} > 10{,}000 \times C_{background}$
  - $C_{background} = 90^{th}$ percentile literature
- Remove data with significantly different concentration ratios for chemicals with similar fate & transport characteristics:
  - Discard data where $\alpha_{i,\ chemical} > 10X\ \alpha_{min,\ chemical}$
  - Where available, compare to 11DCE ratio (tracer)

Influence Background VOCs on Alpha



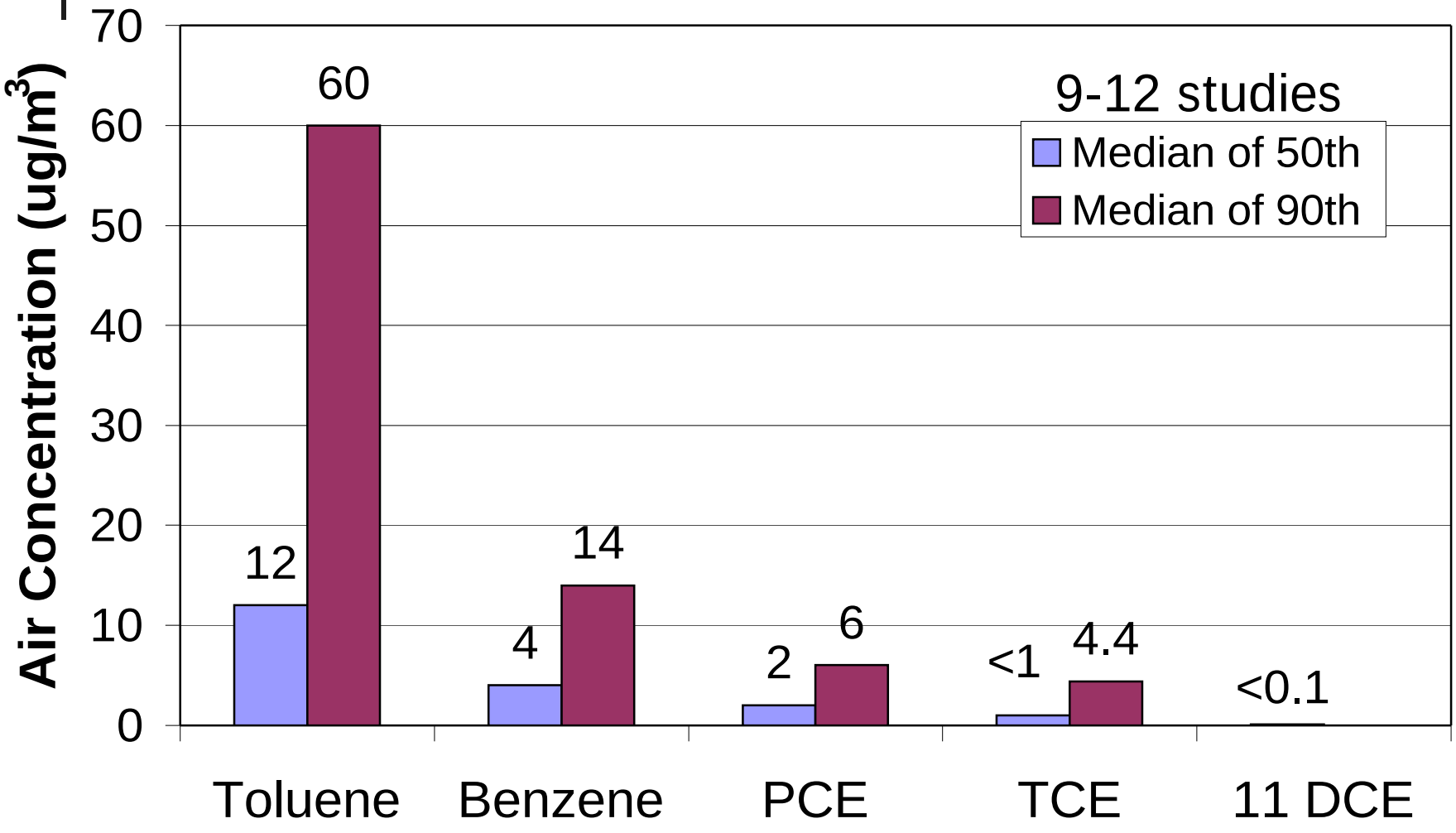
Data Filters (cont.)

- Remove additional lower less precise low concentration data when large number data points (CDOT, Redfields)
- Remove data when other tests indicate background source
  - In house survey using highly sensitive field GC/MS
  - Air testing under negatively and positively pressurized building conditions

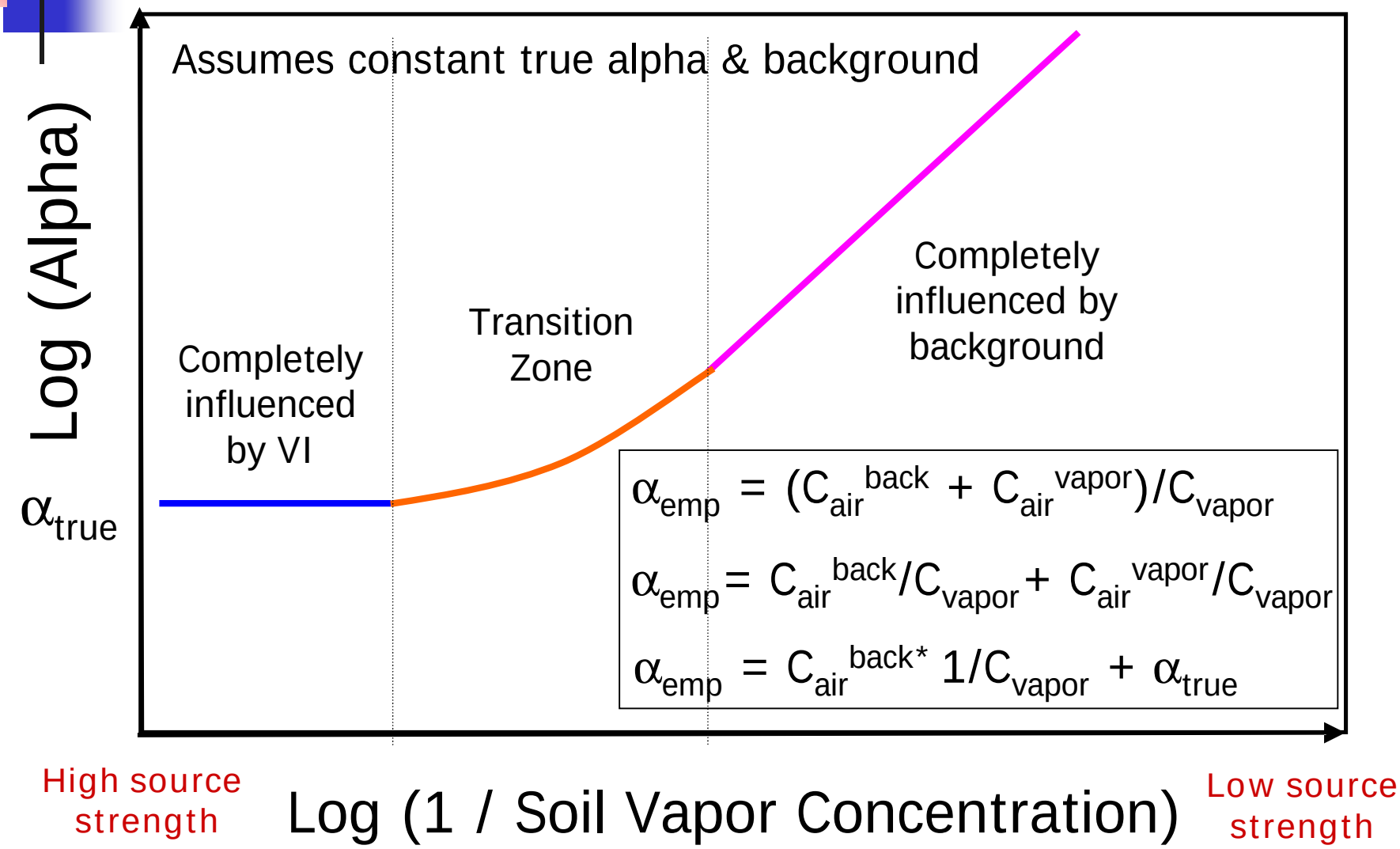
IA Background Concentrations

Chemical	Number of Studies	Median of Median (ug/m^3)	Average of 90th Percentile (ug/m^3)	Median of 90th Percentile (ug/m^3)	Value for Filtering (ug/m^3)
Benzene	12	4	15	14	14
Ethylbenzene	7	4	14	10	10
Toluene	8	12	84	60	60
m,p-Xylene	7	11	36	37	37
o-Xylene	7	4	12	11	11
PCE	12	2	12	6	6
TCE	12	<1	4.4	~1	1
111 TCA	6	3	25	5	5
11 DCA	3	<0.1	INS	INS	0.1
11 DCE	3	<0.1	INS	INS	0.1
cis-12-DCE	3	<5	INS	INS	0.2

Selected Indoor Air Literature Background (Helen Dawson, USEPA)

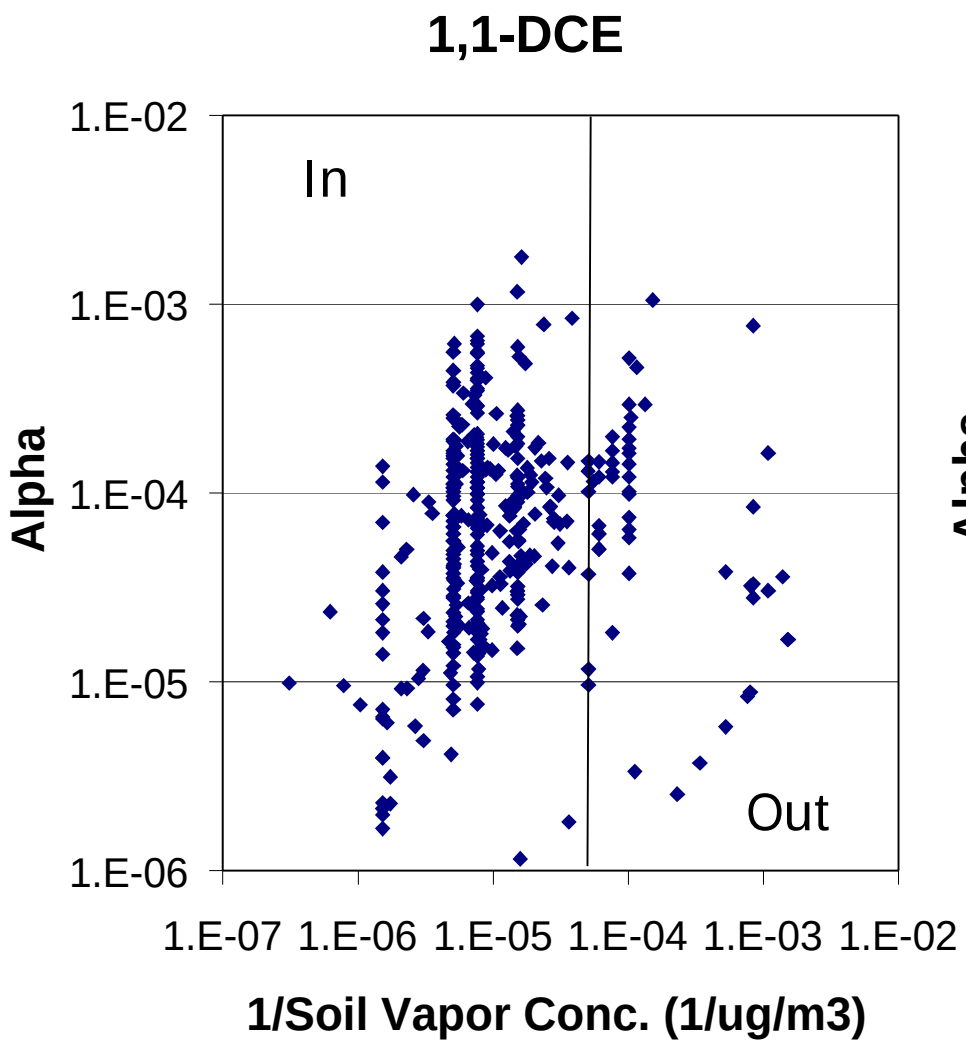


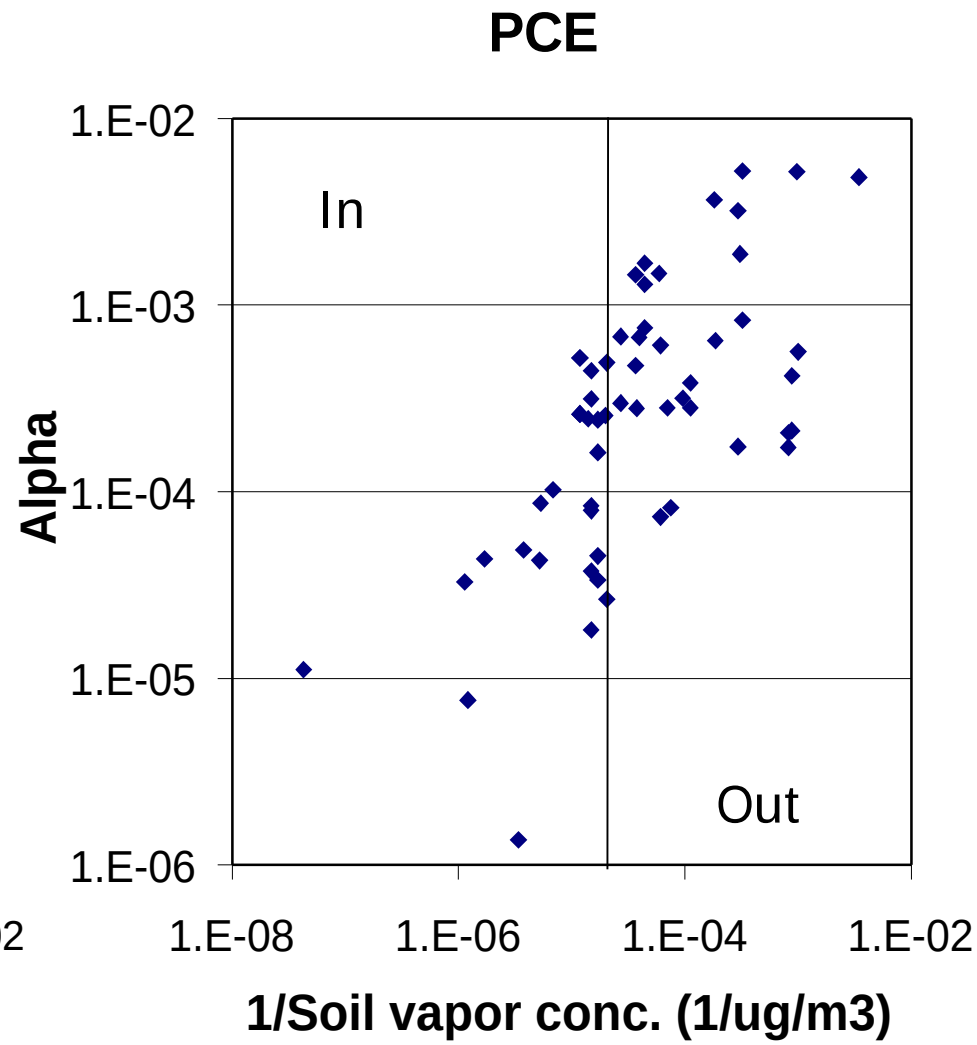
Theoretical Influence Background on Alpha



Filtering Process 11-DCE & PCE

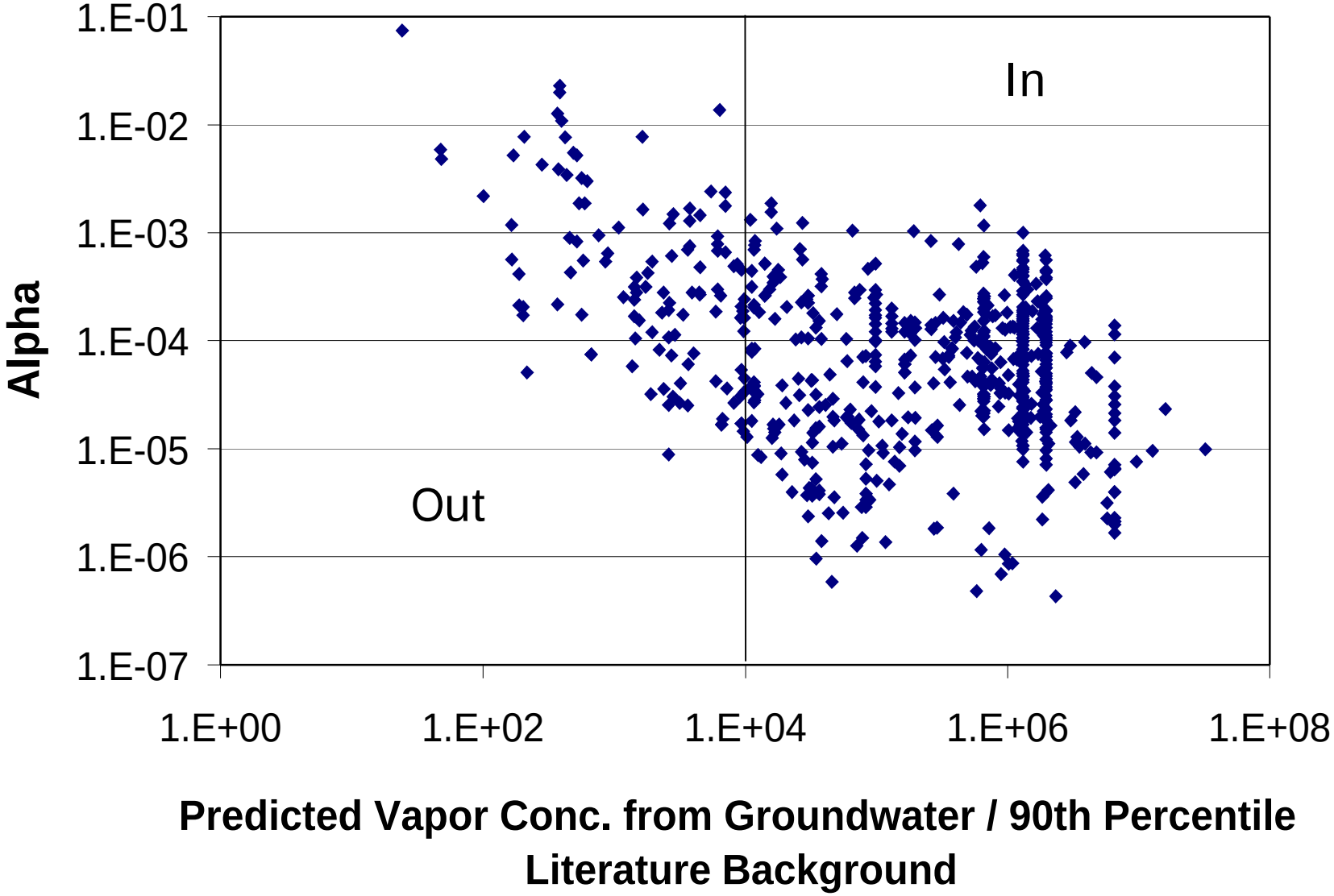
(residential, groundwater alpha's)





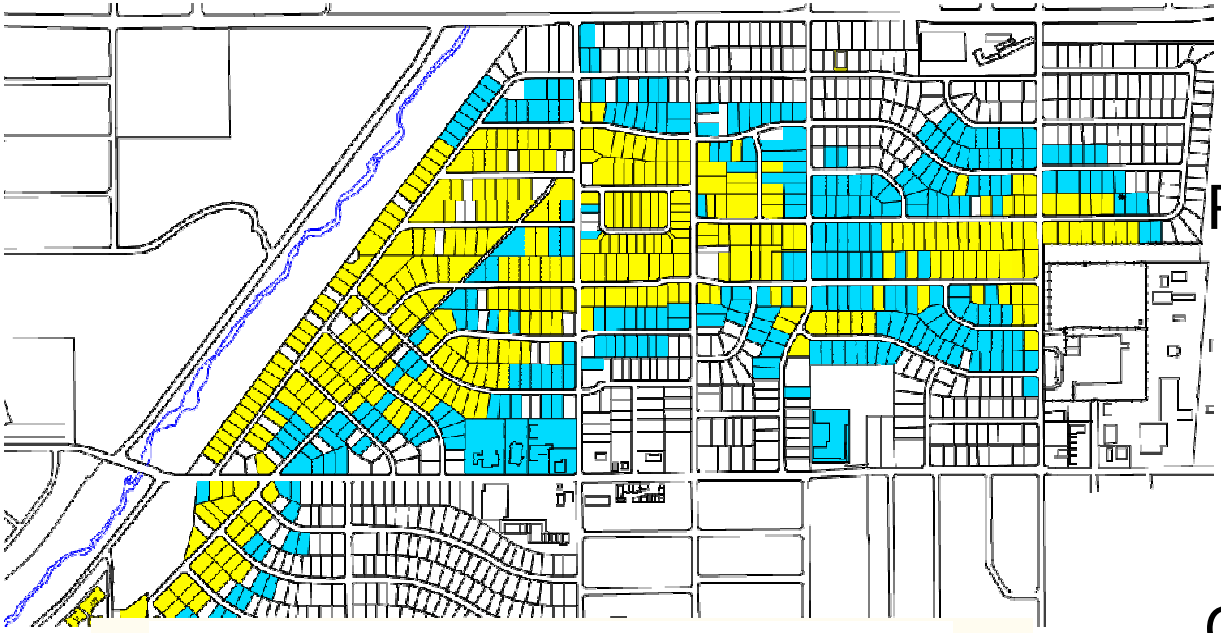
Filtering Process All Data

(residential, groundwater alpha's)



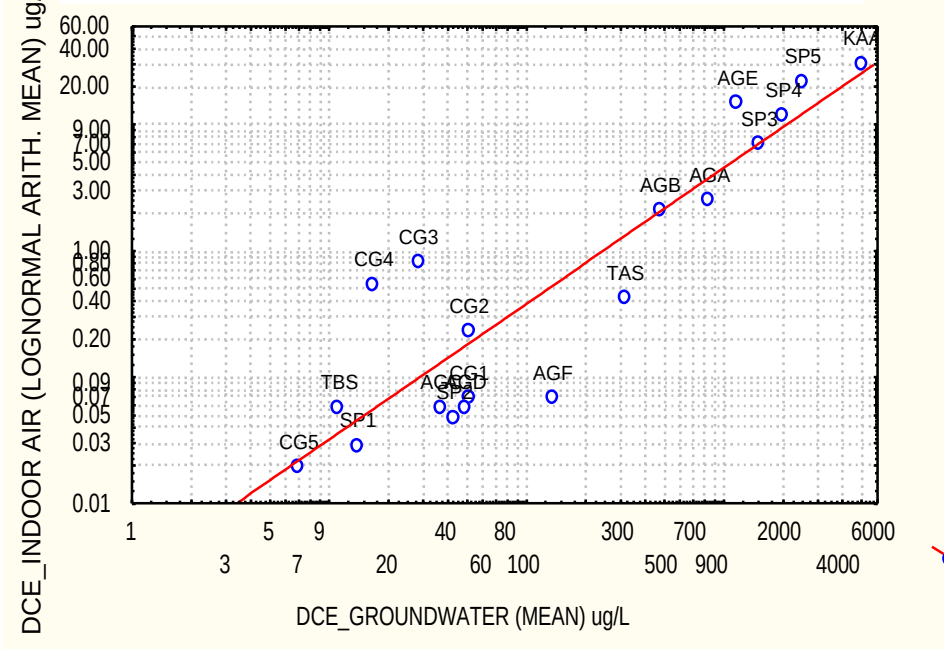
Data Consistency/Reliability/ Usefulness Assessment

- Evaluate data relationships ("Vapor Pathway Analysis")
  - Correlations between groundwater, soil vapour and indoor air concentrations
  - Consistent spatial relationships between impacted homes and plume
  - Consistent concentration ratios for chemicals with similar fate and transport properties
- Compare indoor air to background data (literature, control study)

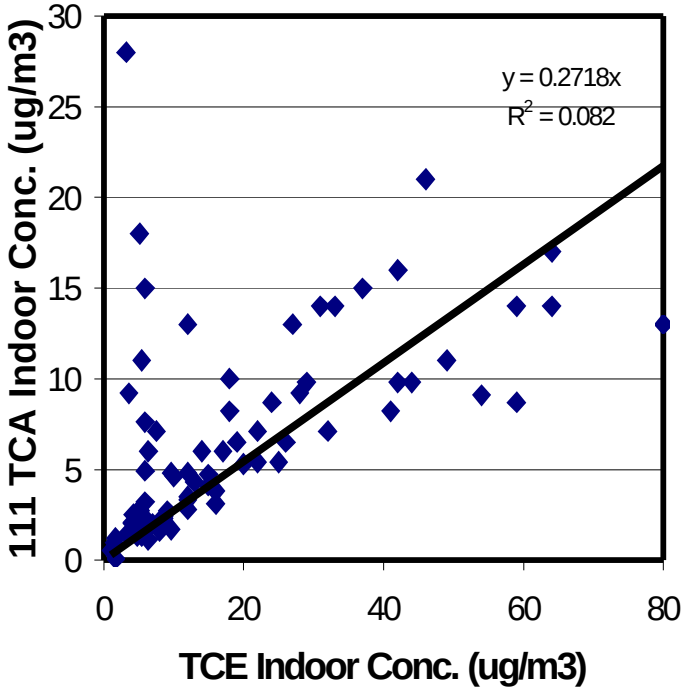


Redfields Site 11 DCE
> 0.49 µg/m³

CDOT Indoor Air vs.
Gdw for 11 DCE



Canadian Site TCA vs.
TCE Indoor Air



Data Consistency/Reliability/ Usefulness Assessment

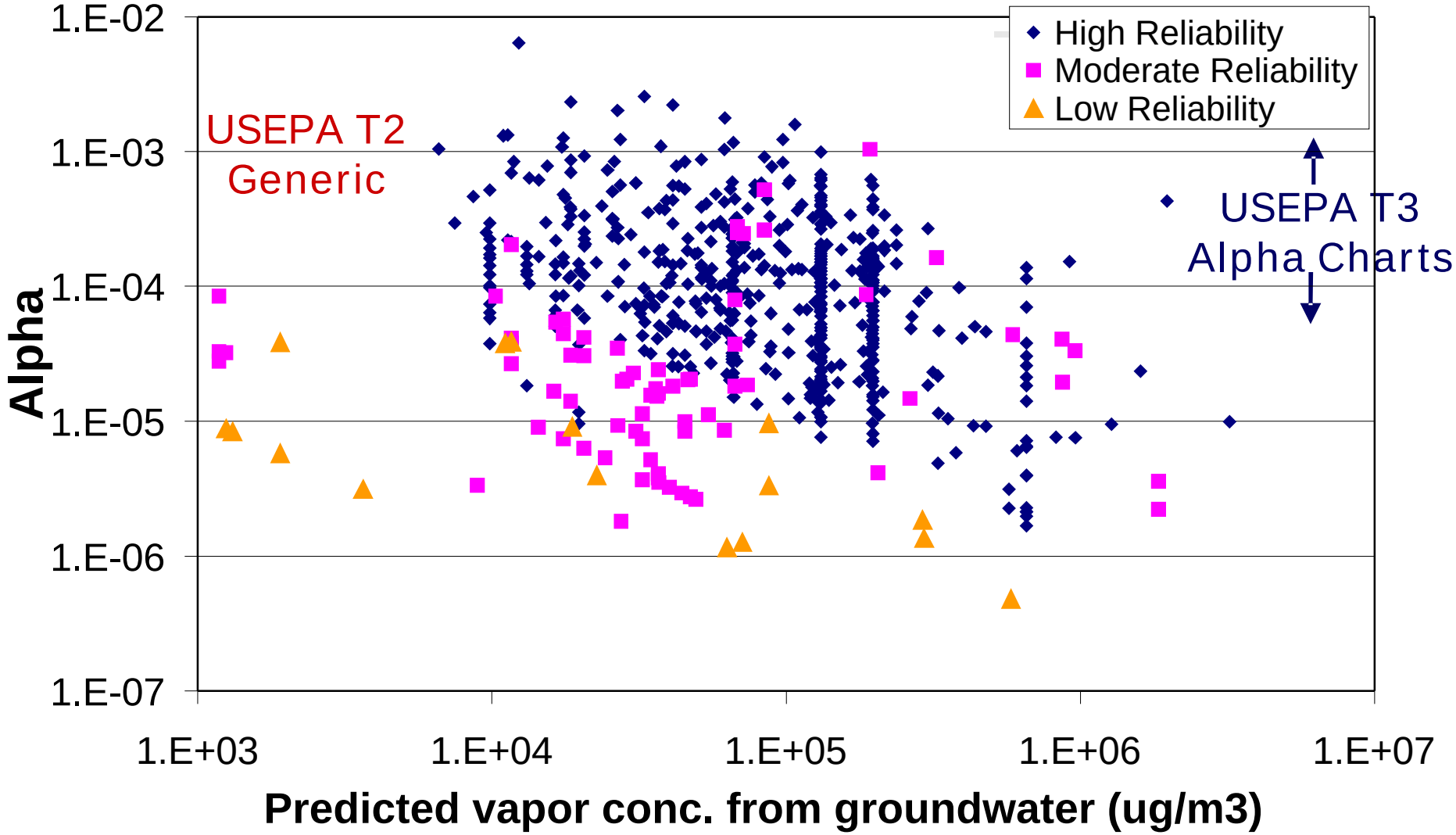
Higher consistency	Evidence for VI based on pathway analysis and indoor air > 90 % background
Moderate consistency	No conclusive evidence for VI based on pathway analysis, but indoor air > 90 % background
Lower consistency	No evidence for VI based on pathway analysis and indoor air < 90 % background[1]

[1] These alpha's represent upper bound values and are likely biased high

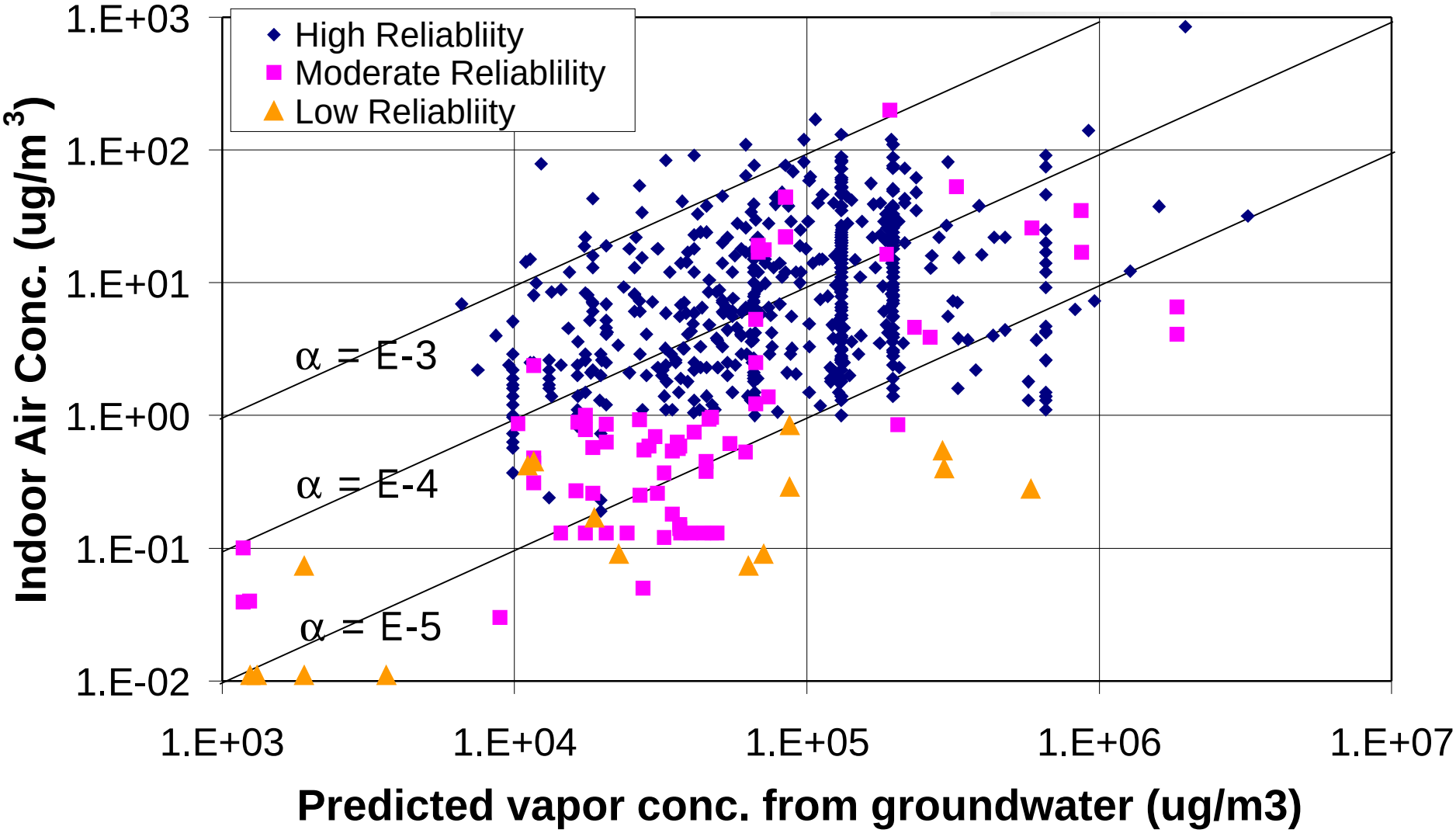
Chlorinated Solvent Sites

- Nineteen residential sites analyzed
- Data for one to several hundred buildings per site
- Most sites: Evidence for vapor intrusion
- Particularly for 11 DCE and TCE, indoor air concentrations well above typical background levels
- After source strength filter, variation in chemical concentration ratios in almost all cases less than 10X

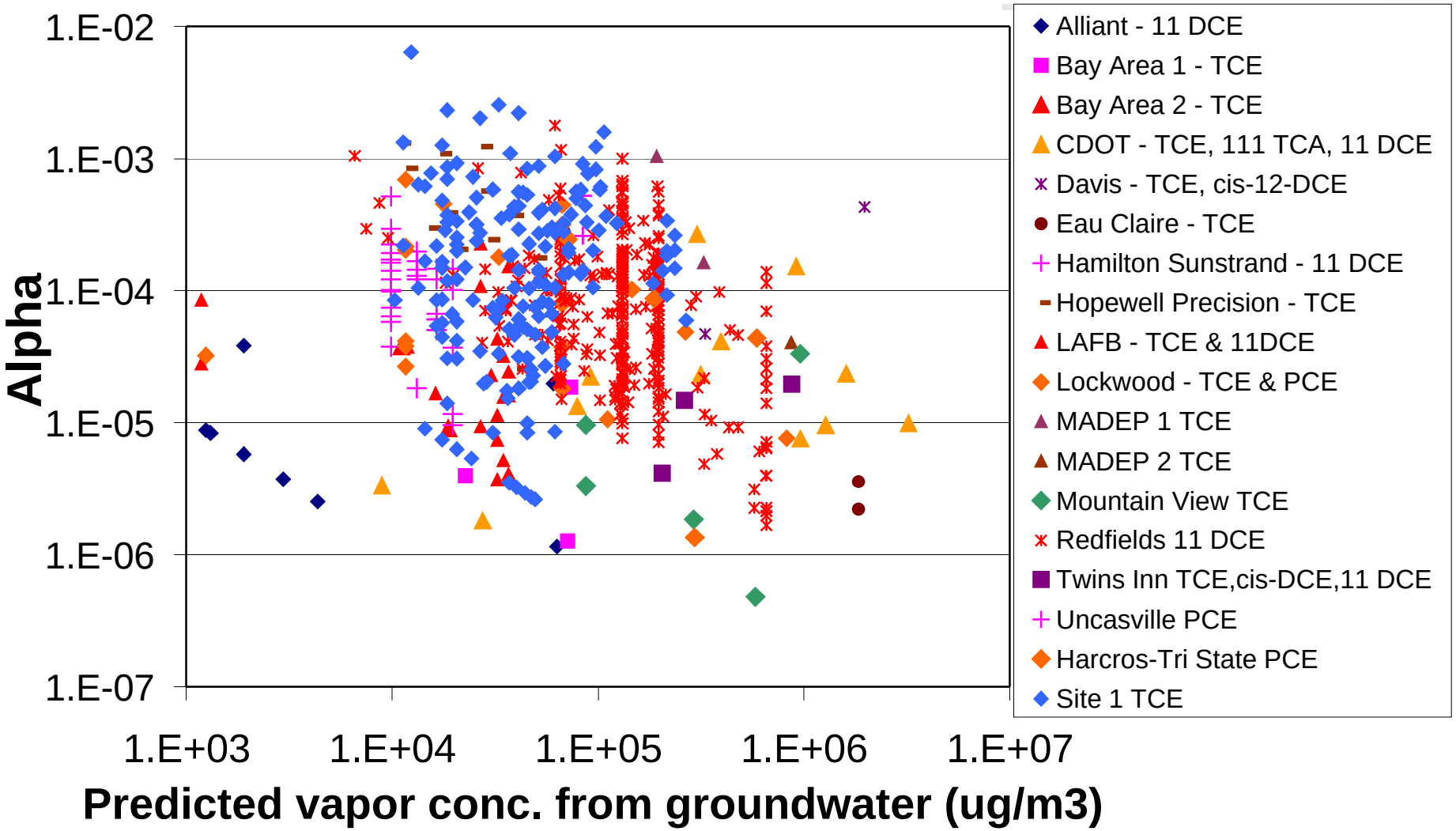
Groundwater Alpha - Residential - Chlorinated Solvents - Filtered



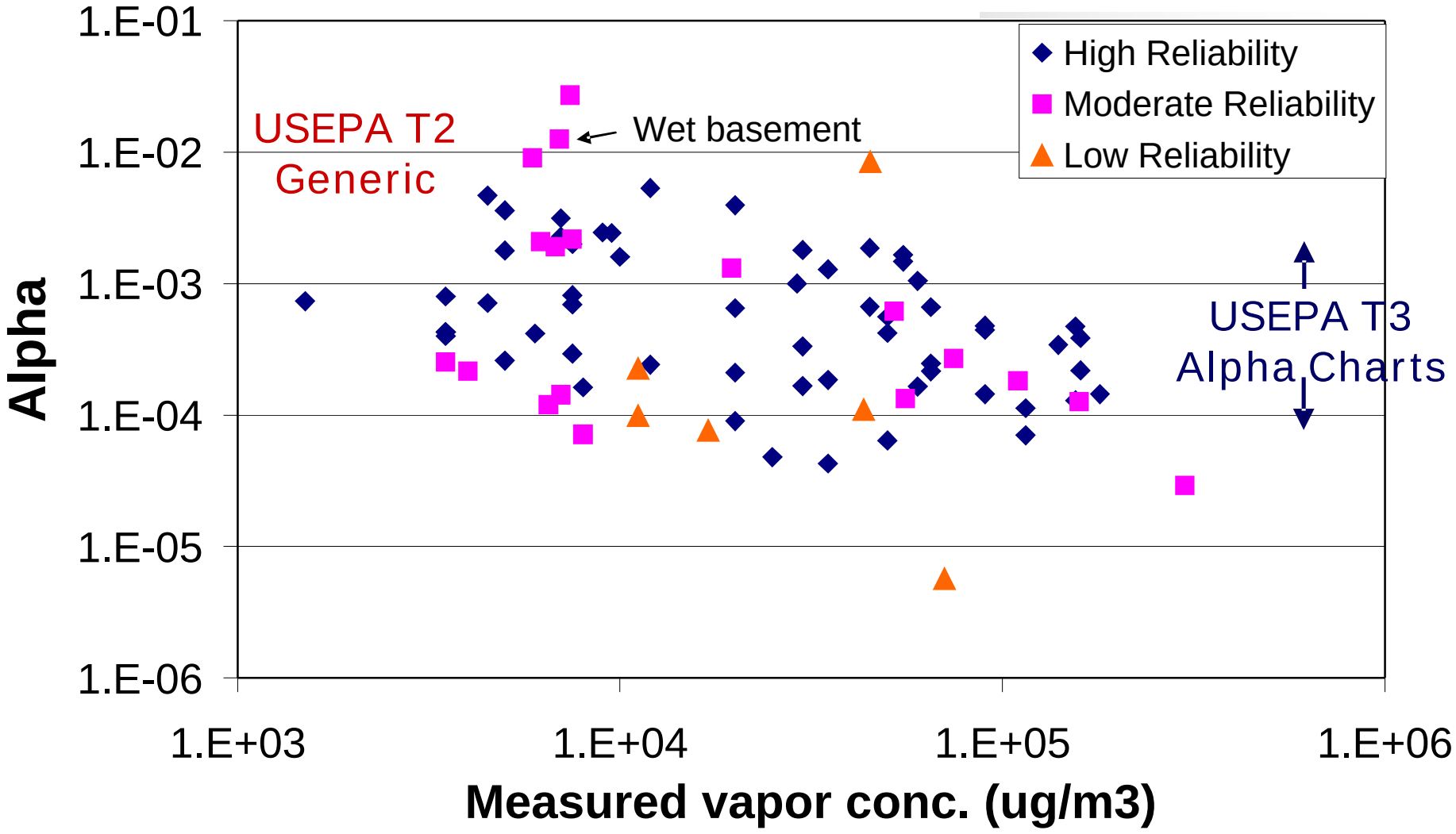
Groundwater Alpha - Residential - Chlorinated Solvent - Filtered



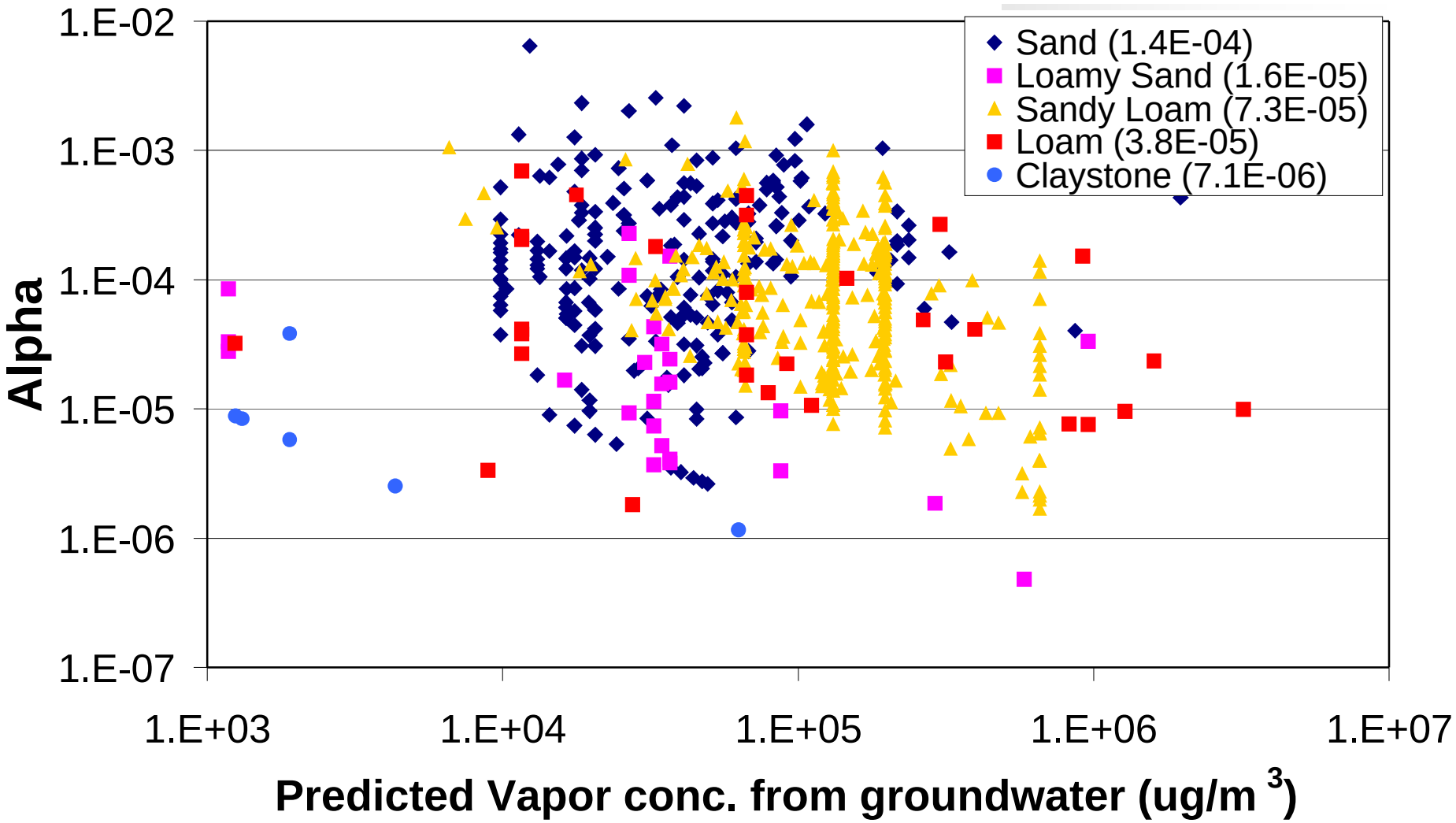
All Site Data
Gdw Alpha - CS - Residential



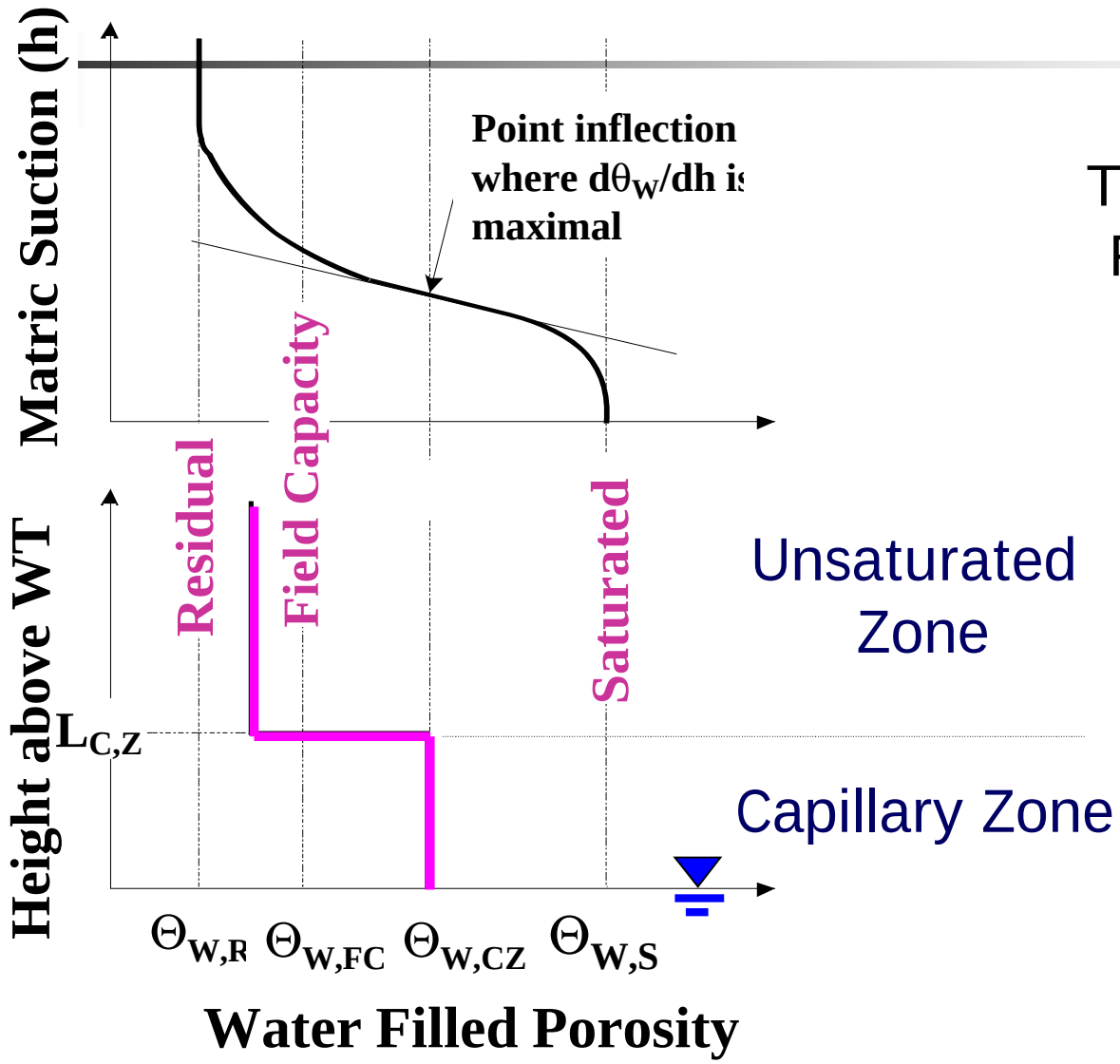
Soil Vapor Alpha - Residential - Chlorinated Solvents - Filtered



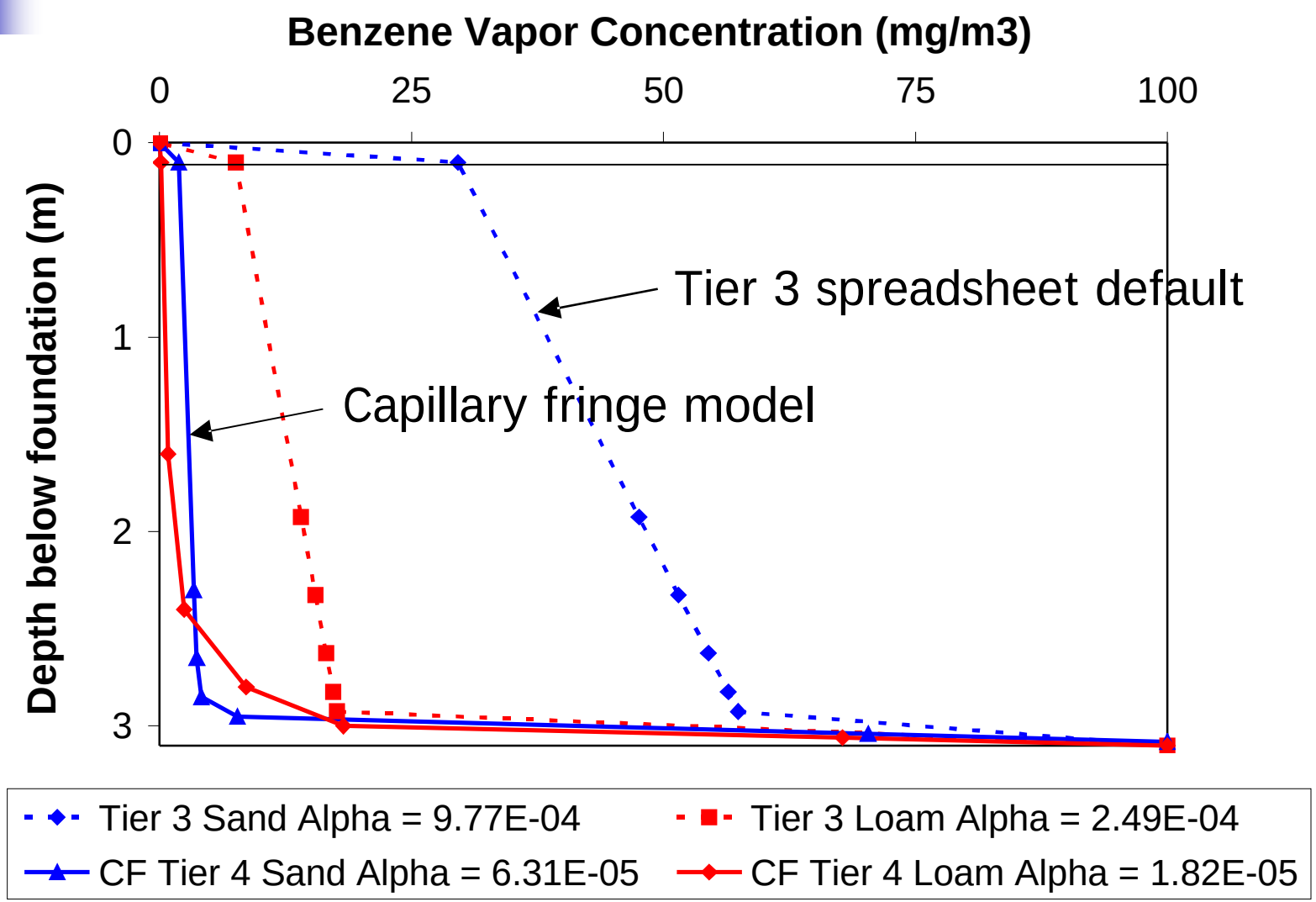
Influence of Soil Type
Gdw Alpha - CS - Residential



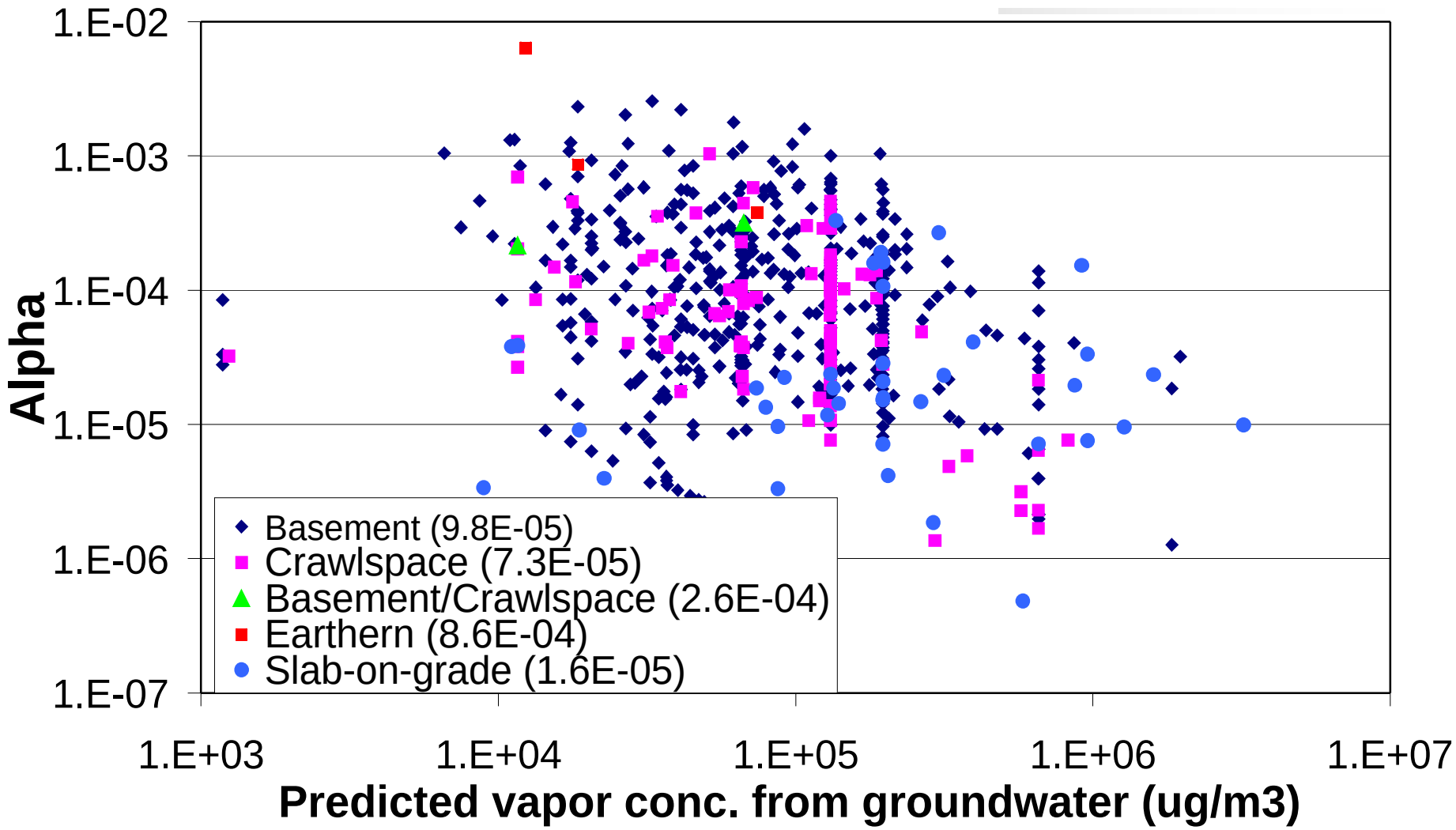
Water-Filled Porosity



Vapor Profile Predicted by J&E Model



Influence of Foundation
Gdw Alpha - CS - Residential



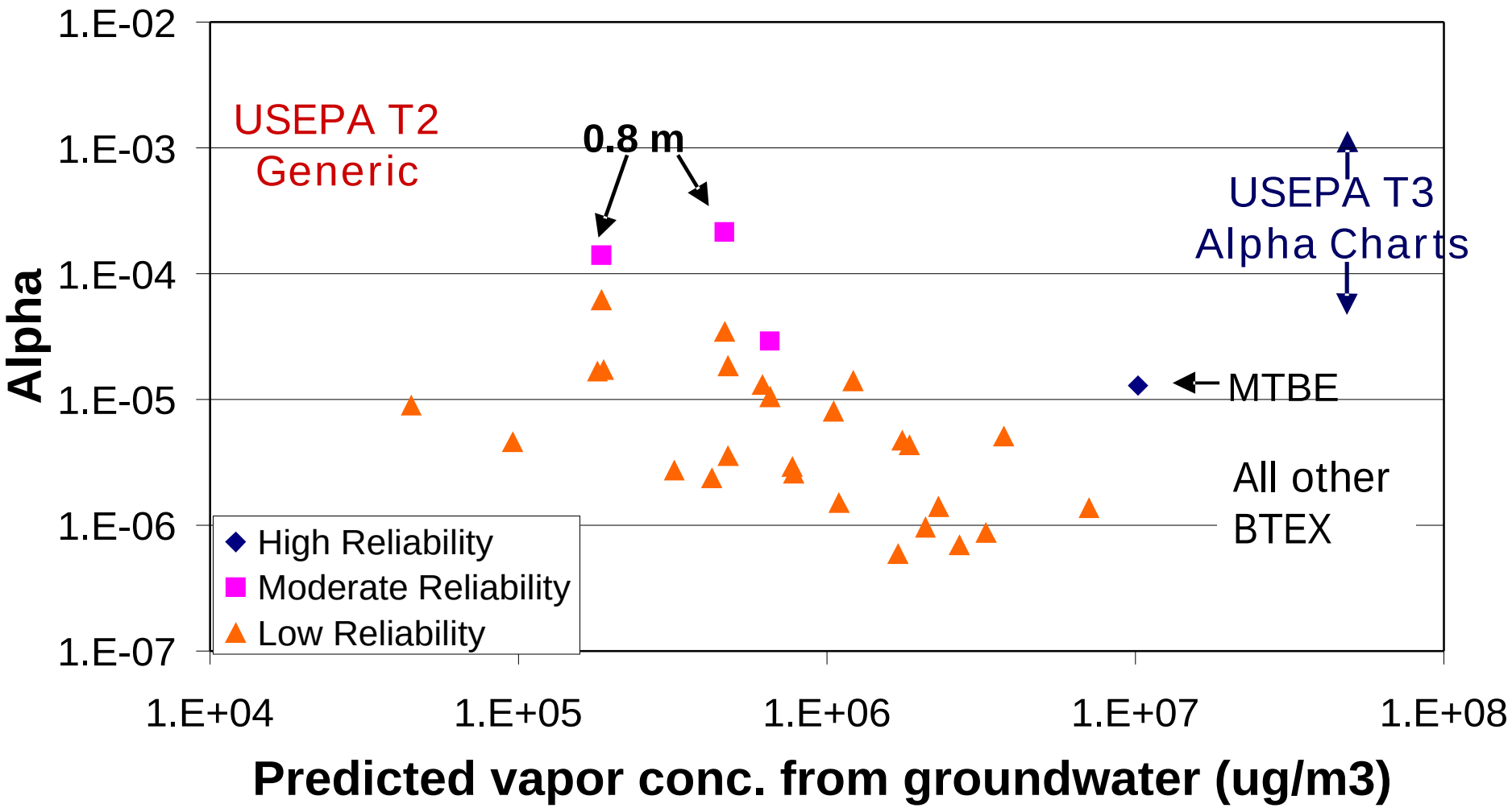
Chlorinated Solvent Sites Conclusions

- Groundwater alpha: Max 90th individual sites = 8E-04, few buildings as high as 1E-3
- Soil vapor alpha: Max 90th individual sites = 2.4E-03, few buildings as high as 1E-2
- Empirical data suggests USEPA generic groundwater (0.001) and soil vapor (0.01) alpha's are reasonable
- Groundwater alpha's correlated to soil type
- Foundation type has little influence on alpha's (except perhaps earthern foundations) – Suggests transport controlled primarily by soil properties

Petroleum Hydrocarbon Sites

- Twelve residential sites analyzed
- Data for 1 to 8 buildings per site (many sites 1 to 2) (short plumes)
- For all but two sites, measured indoor air concentrations could not be distinguished from background
- BTEX chemical ratios often highly variable

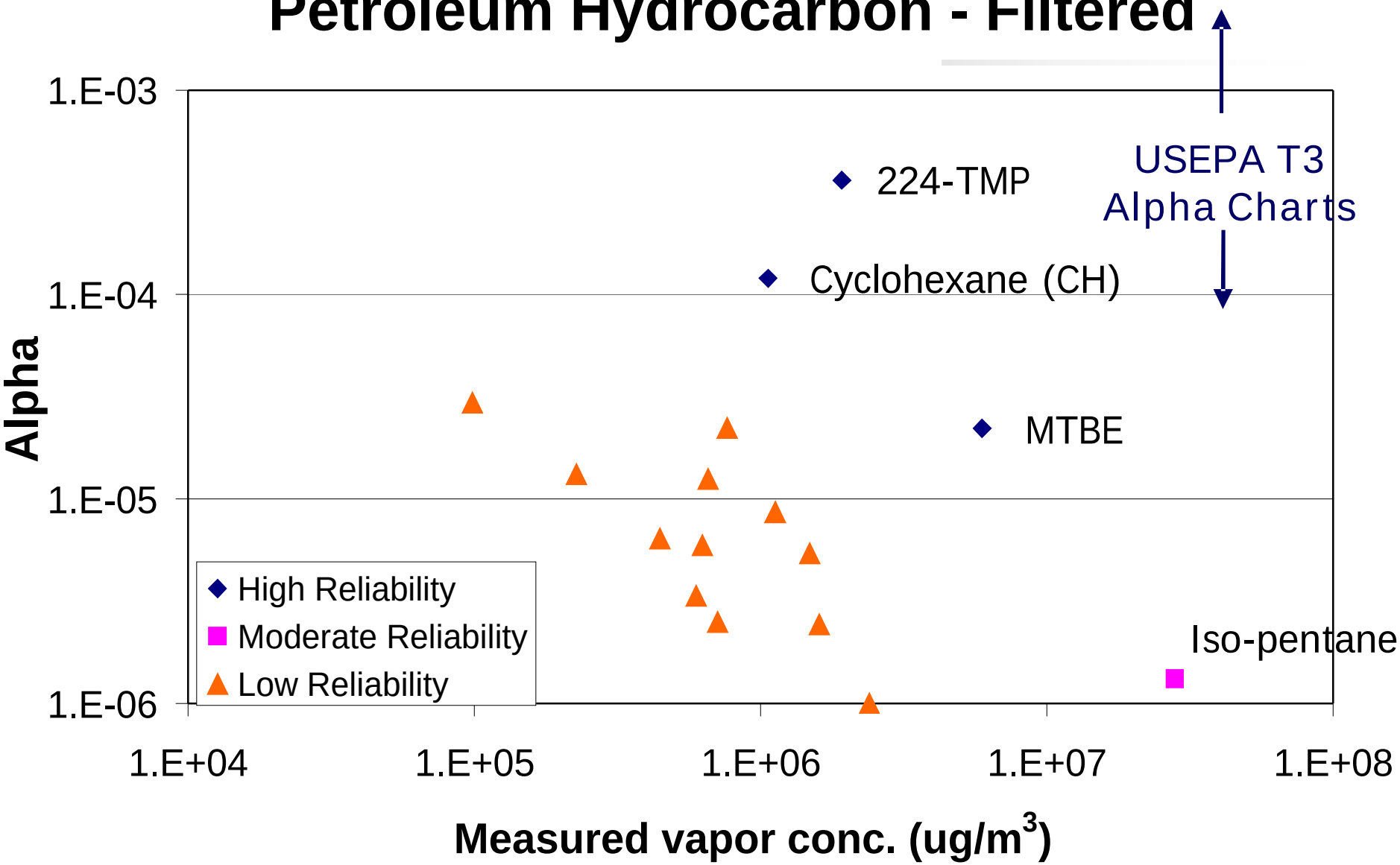
Groundwater Alpha - Residential - Petroleum Hydrocarbon- Filtered



Low reliability = < alpha shown

USEPA T2
Generic

Soil Vapor Alpha - Residential - Petroleum Hydrocarbon - Filtered



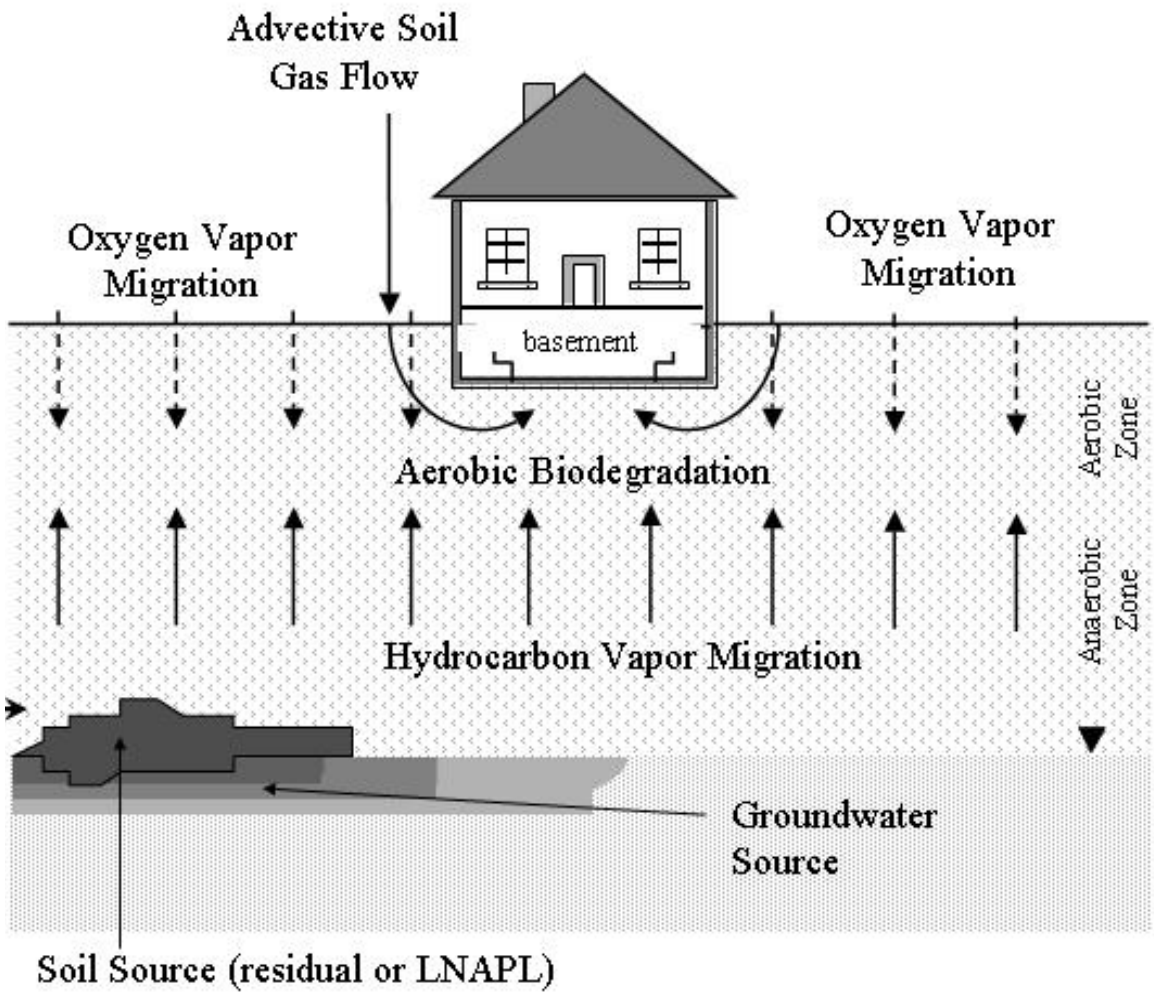
Petroleum Hydrocabon Sites Conclusions

- Groundwater alpha:
  - Max BTEX = 2E-04 (this was for 0.8 m depth)
- Soil vapor alpha:
  - Max BTEX = 3E-05
  - Max 224-TMP = 4E-04 (less degradation 224-TMP, CH)
- Although data reliability low and data is limited, empirical data suggests :
  - Alpha's for PHC's lower than for chlorinated solvents
  - USPEA generic alpha's are conservative for petroleum hydrocarbons

Petroleum Hydrocarbon – Closer Look at Biodegradation

- Empirical data would appear to support lower alpha's for petroleum hydrocarbons
- Aerobic biodegradation of BTEX vapors is rapid and can occur over thin soil layers – Key is whether there is sufficient O_2 below buildings!

Factors Affecting Aerobic Biodegradation



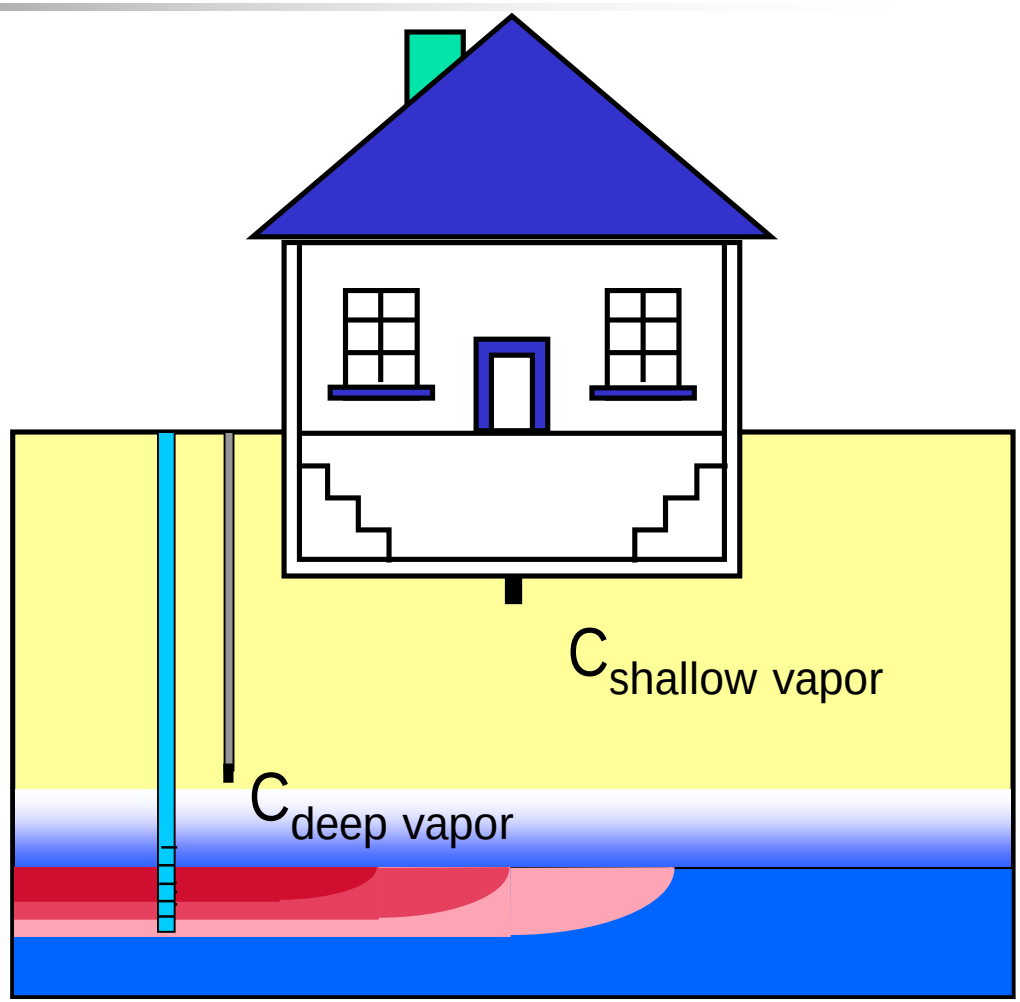
- Source concentrations
  - Dissolved versus NAPL above water table
- Depth to contamination
- Building size (or depth/size ratio)
- Soil type
- Barometric pumping, wind-induced movement air
- Surface capping effect

Petroleum Hydrocarbon – Closer Look at Biodegradation

- Challenge is in quantifying conditions when would or would not expect biodegradation below buildings
- Try to answer this question through:
  - Field studies that include below building soil gas sampling
  - Modeling studies – source concentrations, capillary fringe important factors

Vadose Zone Attenuation Factor (VZAF...!)

- Groundwater VZAF = $C_{subslab\ vapor}$ / $C_{predicted\ deep\ vapor}$
- Soil Vapor VZAF = $C_{subslab\ vapor}$ / $C_{measured\ deep\ vapor}$



Groundwater VZAF

(Mission Valley, Logan, Rental Property, Hal's: compiled Robin Davis, Utah DEP)

Site	Chemical	Simplified Soil Type	Foundation type	Depth to groundwater below foundation (m)	Predicted Deep Soil Vapor (mg/m3)	Groundwater VZAF	Comment
Mission Valley	Benzene	Sand & Gravel	Slab-on-grade	2.1 to 6.1	3680	8.7E-07	
Logan	Benzene	Silt	Slab-on-grade	3.81	420	2.4E-05	
Rental Property	Benzene	Sandy Loam	Slab-on-grade	5.65 to 6.55	1652	5.1E-07	
Mount Holly	Benzene	Loamy Sand	1/2 Basement	0.8	49.28	1.5E-04	
Stafford	Benzene	Sand	Basement	1.5	2040	< 1.7E-04	
Stafford	MTBE	Sand	Basement	1.5	12036	1.5E-03	
BP	Benzene	Loamy Sand	Basement	3.2	1070	2.4E-01	0.75 m below slab
Hal's	Benzene	Silt	Basement	2.74	0.7	1.0E-01	0.9 m below slab
Hal's	Benzene	Silt	Basement	2.74	0.7	2.0E-01	0.9 m below slab
Hal's	Benzene	Silt	Basement	2.74	25.2	1.2E-04	0.9 m below slab

Soil Vapor VZAF

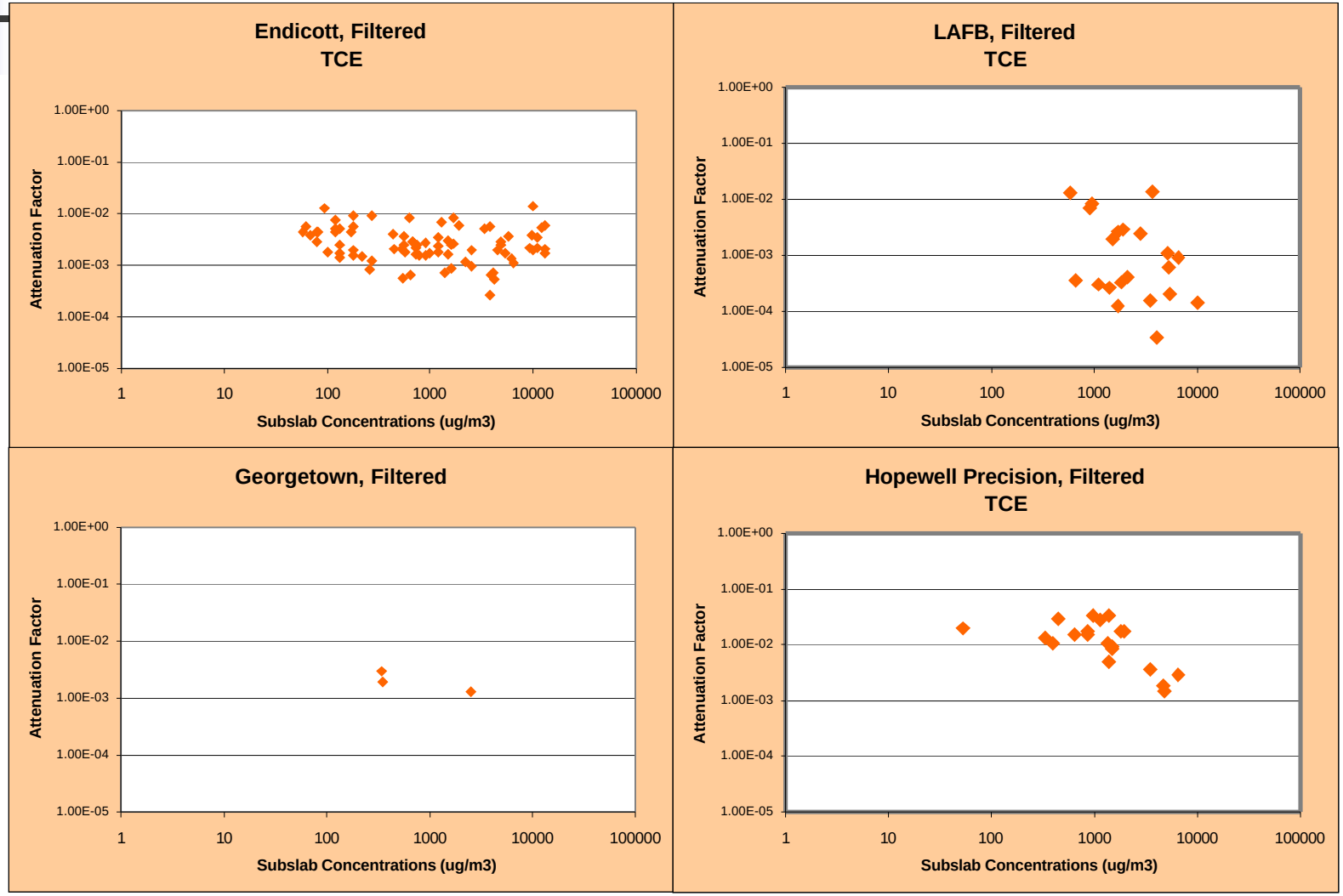
(Hal's: compiled by Robin Davis,Utah DEP data)

Site	Chemical	Simplified Soil Type	Foundation type	Depth to Measured Deep Soil Vapor (m)	Measured Deep Soil Vapor (mg/m3)	Soil Vapor VZAF	Comment
Alameda	Benzene	Coarse	Slab-on-grade	0.7	200	4.5E-03	
Alameda	Isopentane	Coarse	Slab-on-grade	0.7	28000	8.9E-04	
Chatterton	Benzene	Coarse	Slab-on-grade	1.5	20000	5.0E-05	$\Delta P <= 2.5$ Pa
Chatterton	Benzene	Coarse	Slab-on-grade	1.5	20000	5.0E-01	$\Delta P > 10$ Pa
Stafford	Benzene	Coarse	Basement	1.5	656	< 5.3E-04	
Stafford	224-TMP	Coarse	Basement	1.5	2512	7.4E-03	
BP	Benzene	Coarse	Basement	3.2	595	4.4E-01	
Hal's	Benzene	Fine	Basement	2.13	0.2	3.5E-01	0.9 m below slab
Hal's	Benzene	Fine	Basement	2.13	1	1.4E-01	0.9 m below slab
Hal's	Benzene	Fine	Basement	2.13	35	8.6E-05	0.9 m below slab

Final Thoughts

- VZAF analysis for nine sites
- Significant BTEX bioattenuation seven sites
- Limited BTEX bioattenuation two sites
- For sites with limited bioattenuation still assessing why, but may be related to O_2 limitations due to basement, relatively shallow depth to contamination and finer-grained soils

Filtered Subslab, Individual Sites



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