Assessing Variability in Petroleum Vapor Intrusion with PVIScreen

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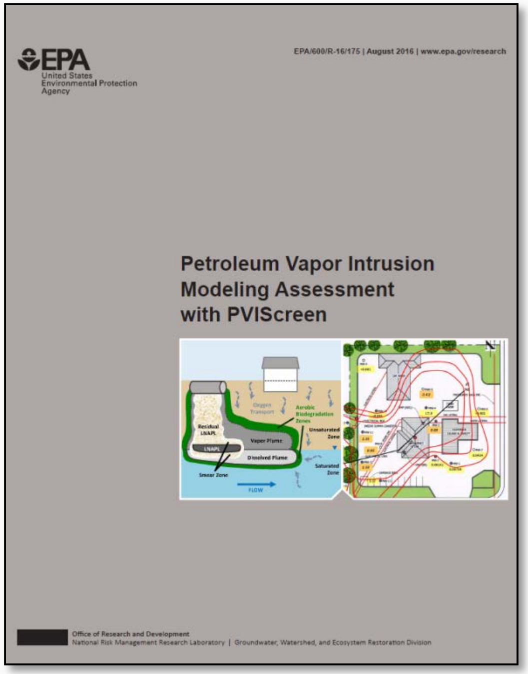
March 14, 2018

Outline

- Characteristics of Environmental Models
- Vapor Intrusion and Petroleum Vapor Intrusion
- PVIScreen model
- Excerpts from examples
  - PVI indicated versus not indicated
- Secrets of PVIScreen
- Summary
- Availability



Why vapor intrusion and models?

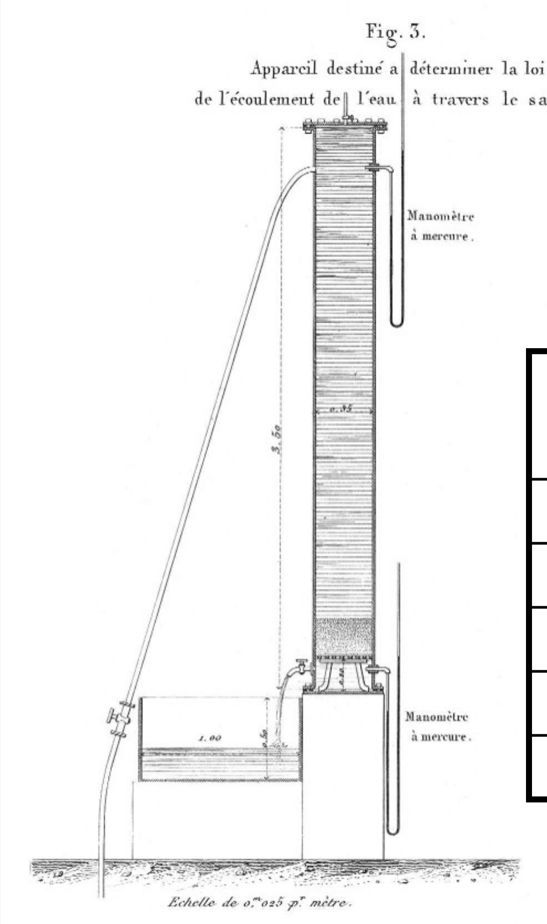
- Technical Challenges
  - ambient air contamination, internal sources/sinks, temporal changes
- Social
  - RP or homeowner reluctance to sample
- In some cases—redeveloping a site—no building exists for testing, so models are relied upon

Vapor Intrusion and Models

- Series of articles in the Denver Post in 2000
  - The vapor intrusion model (Johnson-Ettinger) <u>over-predicted</u> indoor air concentrations sometimes and <u>under-predicted</u> indoor air concentrations sometimes
  - Model used with defaults and very few site specific values

Example: Darcy's Law

- Darcy flux q = -K dh/dl
  - Relationship from Darcy's sand tank experiments
  - Empirical coefficient, the hydraulic conductivity (K), from experiment: measuring the flow (q)

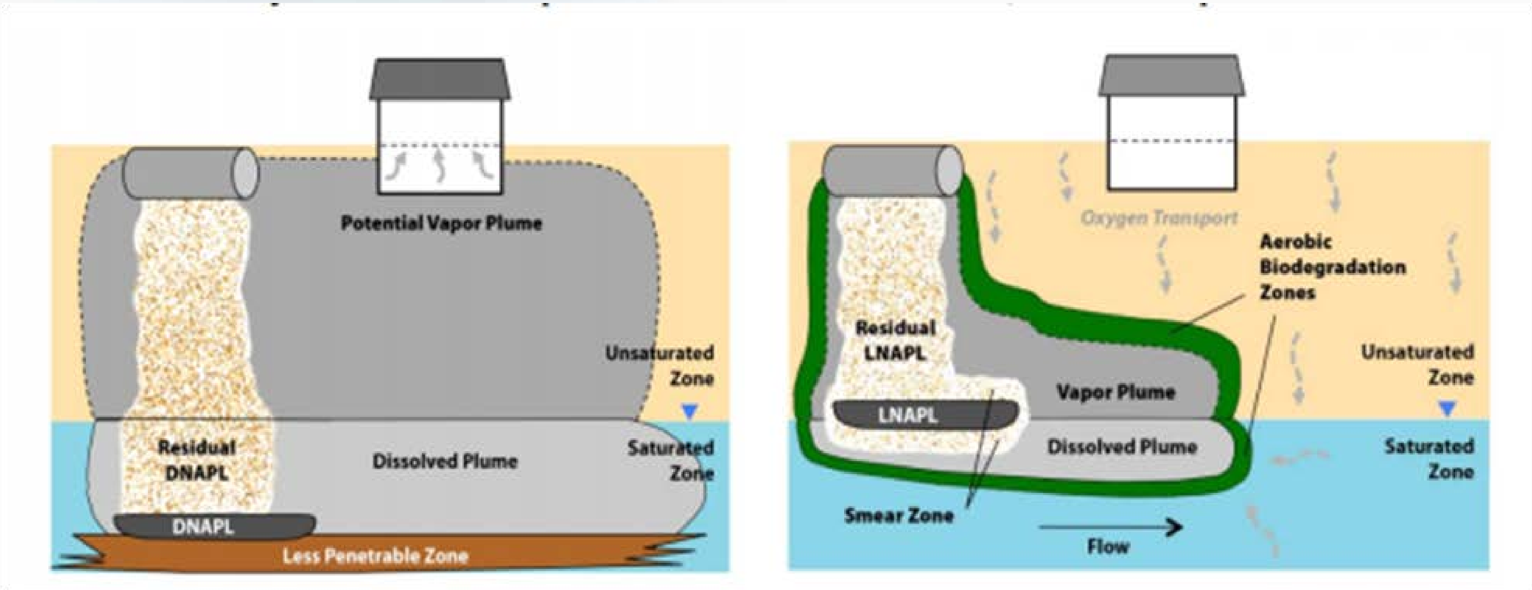


Material	Value (m/d)
Gravel	10^{2} to 10^{4}
Sand	10^{-1} to 10^{3}
Clay	10^{-8} to 10^{-3}
Sandstone	10^{-5} to 10
Basalt	10^{-6} to 10^{-2}

Limits to Predictability

- Note the work of N. Oreskes on ideal applications for models:
  - Weather forecasting
    - Forecast *given* and *received* with uncertainties

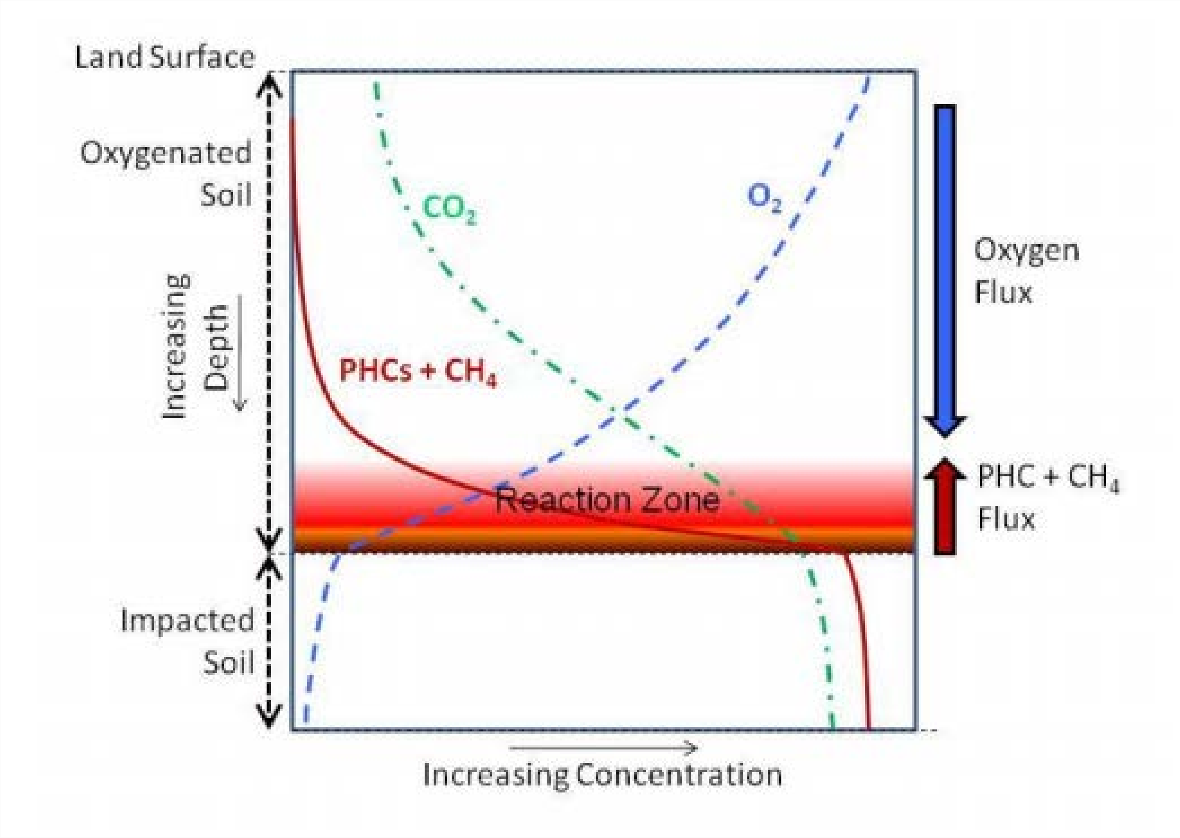
- Oreskes, Naomi, 2003, The role of quantitative models in science, in Models in Ecosystem Science, C.D. Canham and W.K. Lauenroth, eds. Princeton University Press, 13-31



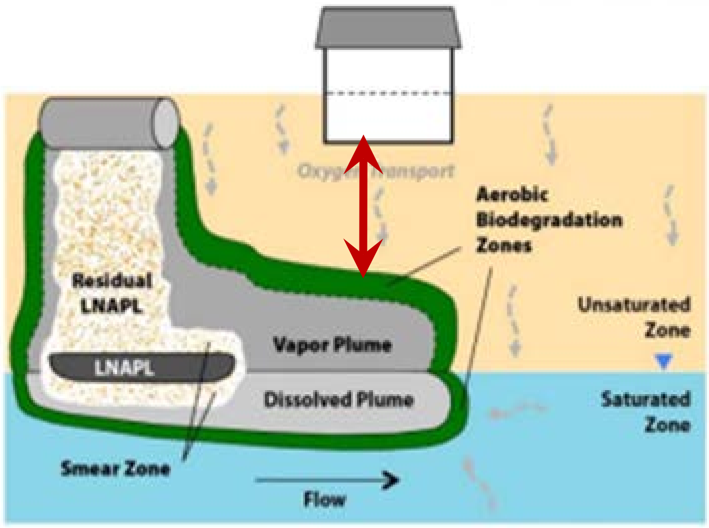
Chlorinated Solvent (left) petroleum (right) are distinguished by prospects for biodegradation

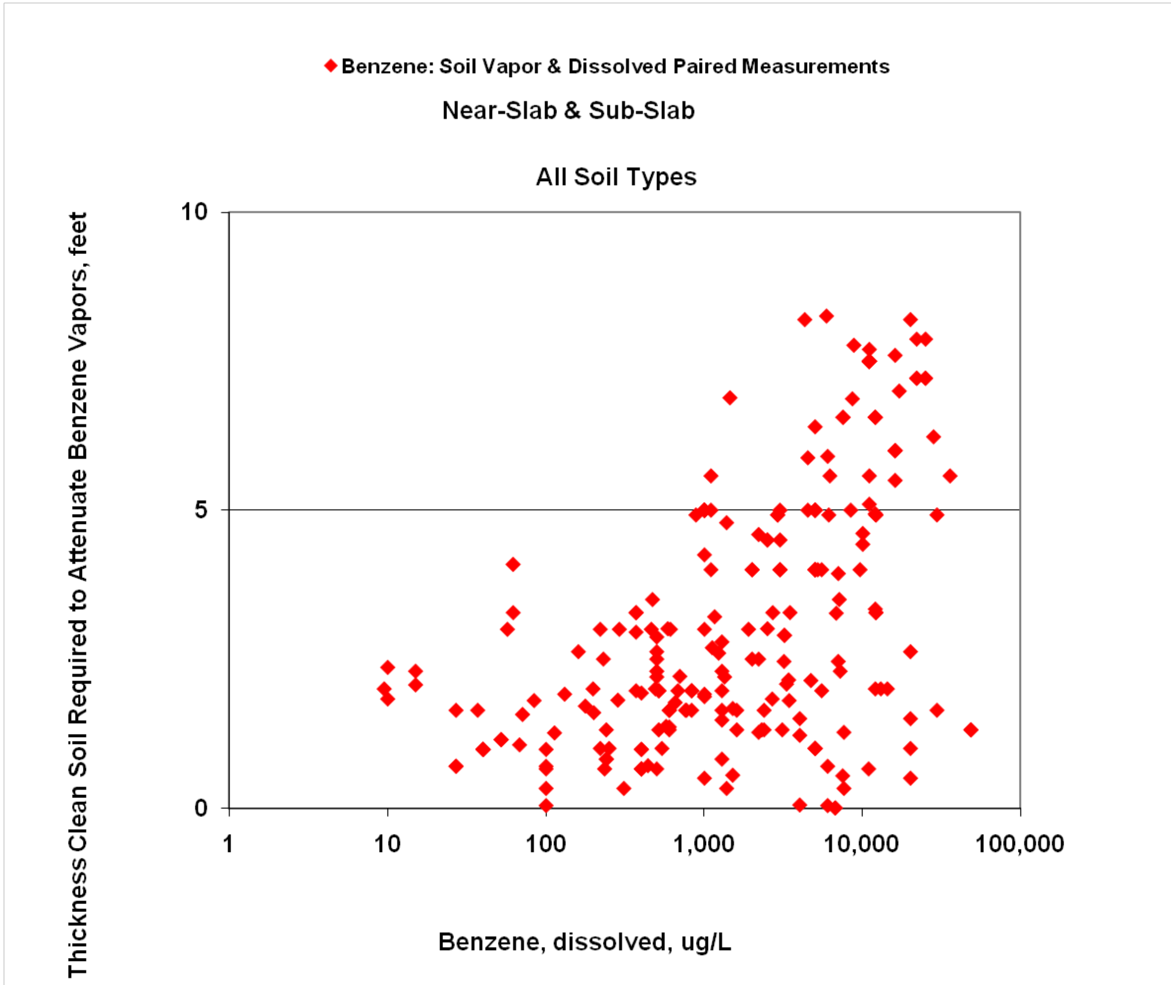
U.S. EPA, 2012, Petroleum Hydrocarbons And Chlorinated Hydrocarbons Differ In Their Potential For Vapor Intrusion, U.S. Environmental Protection Agency, Washington, DC., March.

Petroleum Vapor Intrusion and biodegradation:

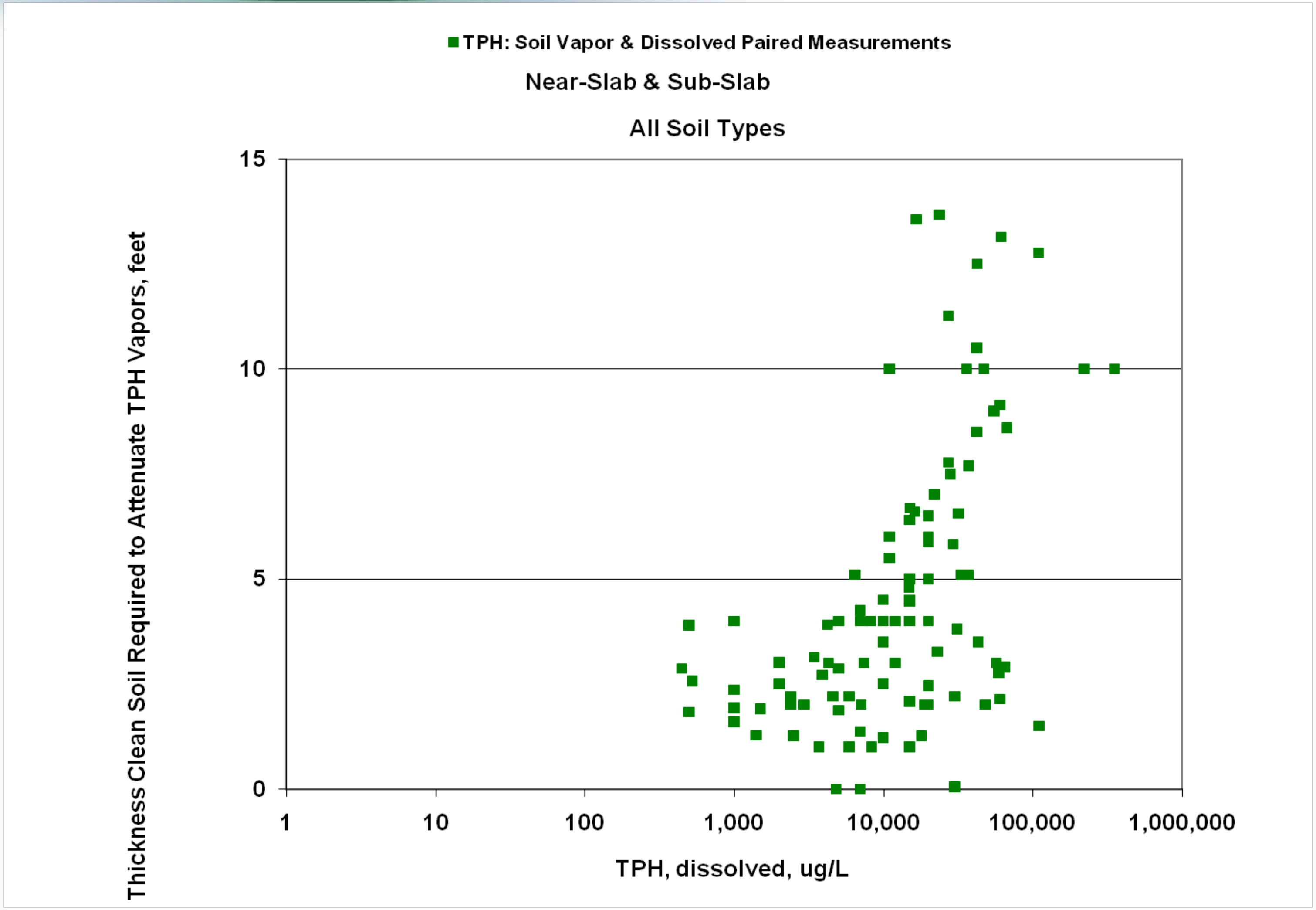


PVIScreen rests on a foundation of field data:





Robin V. Davis, 2009, Update on Recent Studies and Proposed Screening Criteria for the Vapor-Intrusion Pathway, LUSTLine Bulletin 61, pp 11-14.


TPH: Soil Vapor & Dissolved Paired Measurements
Near-Slab & Sub-Slab
All Soil Types
Thickness Clean Soil Required to Attenuate TPH Vapors, feet
15
10
5
0
1
10
100
1,000
10,000
100,000
1,000,000
TPH, dissolved, ug/L

United States Environmental Protection Agency

EPA 510-R-15-001

Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites

U.S. Environmental Protection Agency
Office of Underground Storage Tanks
Washington, D.C.

June 2015

Site assessment flow chart from OUST guide on PVI

Model Use:

- NOT without mitigating immediate threats
- NOT without site characterization
- As a line of evidence for related to determination of vertical separation distance*

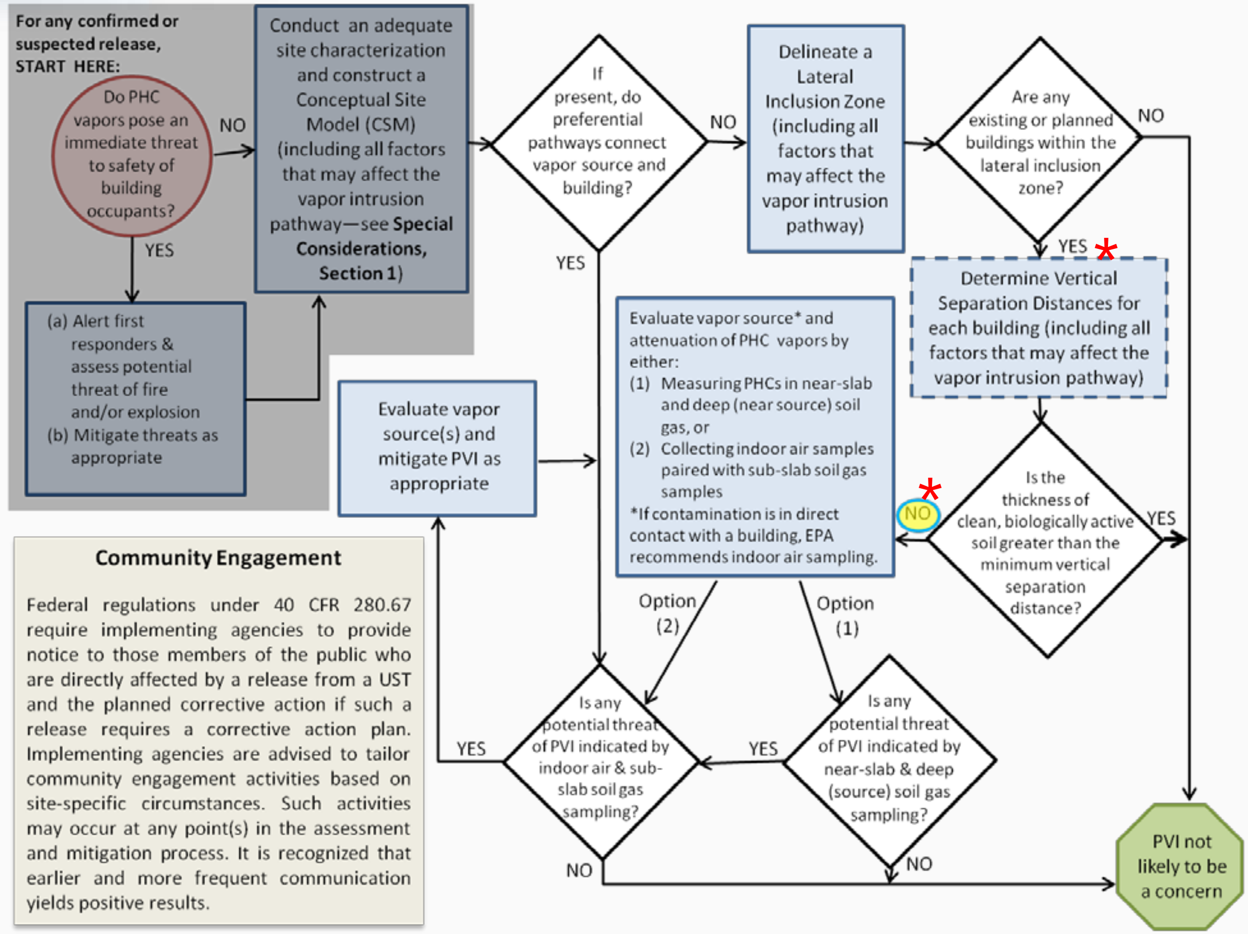
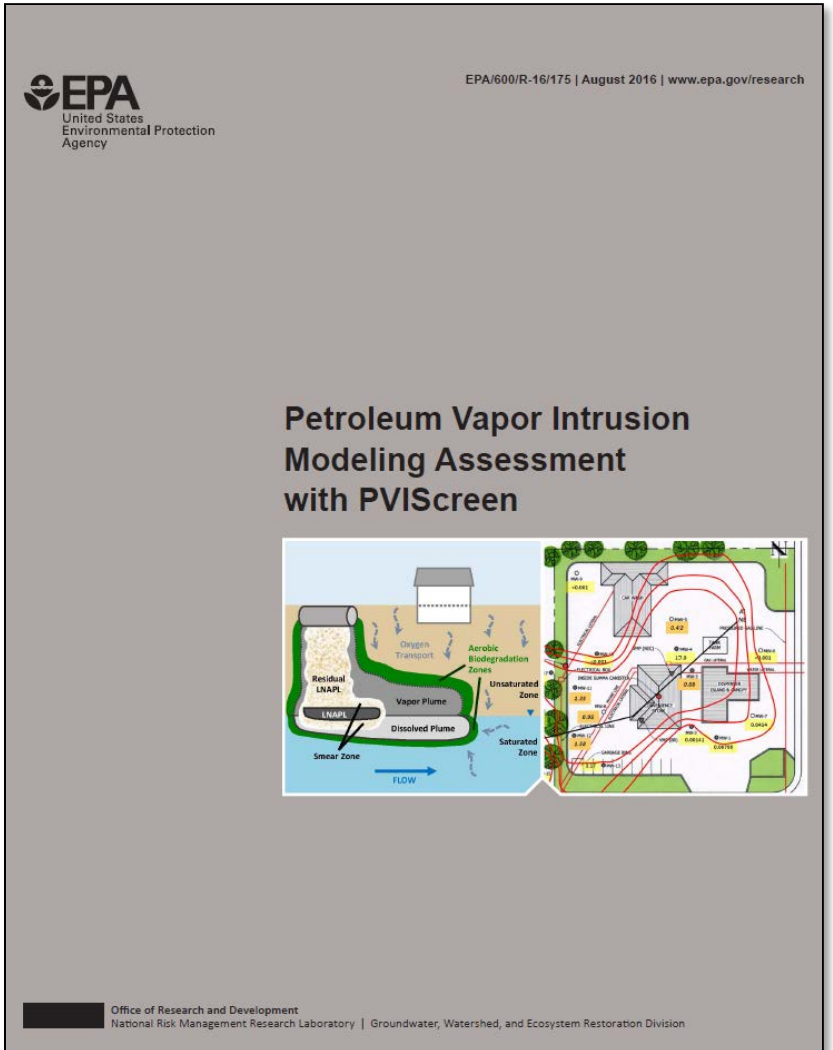


Table 3. Recommended Vertical Separation Distance Between Contamination And Building Basement Floor, Foundation, Or Crawlspace Surface.

Media	Benzene	TPH	Vertical Separation Distance (feet)*
Soil (mg/Kg)	≤10	≤ 100 (unweathered gasoline), or ≤ 250 (weathered gasoline, diesel)	6
	>10 (LNAPL)	> 100 (unweathered gasoline) >250 (weathered gasoline, diesel)	15
Groundwater (mg/L)	≤5	≤30	6
	>5 (LNAPL)	>30 (LNAPL)	15

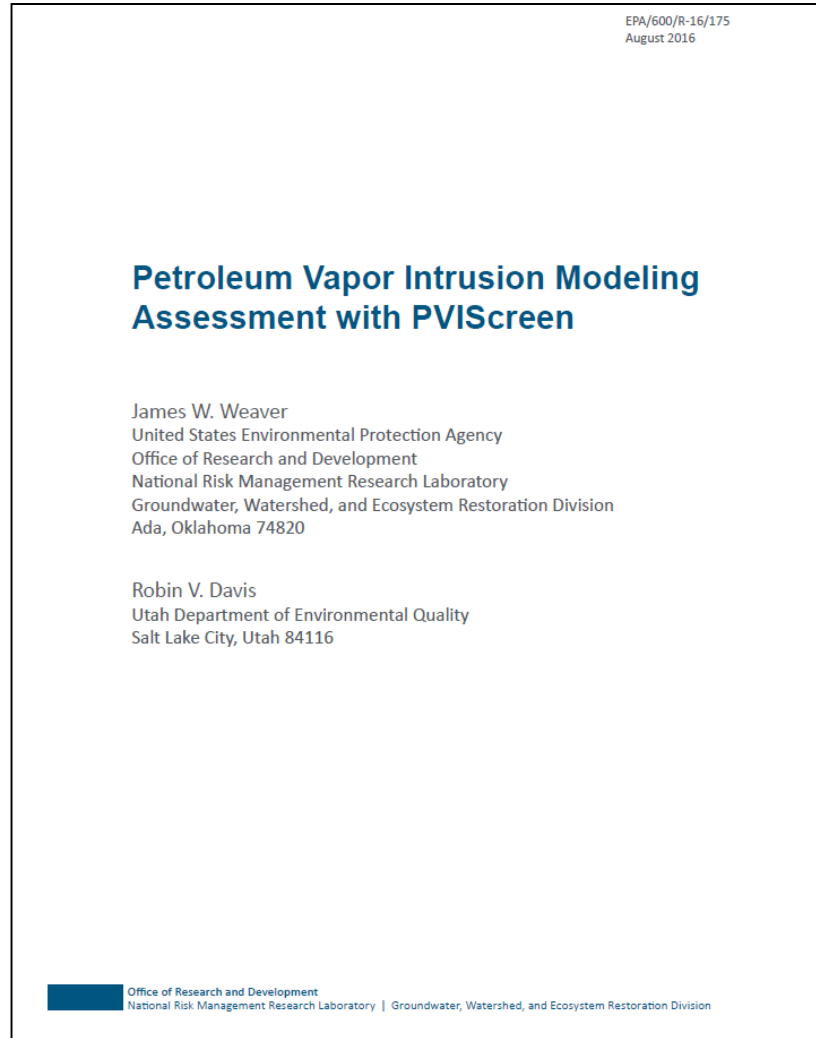
Consider PVIScreen usage in marginal cases as a second line of evidence


EPA United States Environmental Protection Agency

EPA/600/R-16/175 | August 2016 | www.epa.gov/research

Petroleum Vapor Intrusion Modeling Assessment with PVIScreen

Office of Research and Development
National Risk Management Research Laboratory | Groundwater, Watershed, and Ecosystem Restoration Division


EPA/600/R-16/175
August 2016

Petroleum Vapor Intrusion Modeling Assessment with PVIScreen

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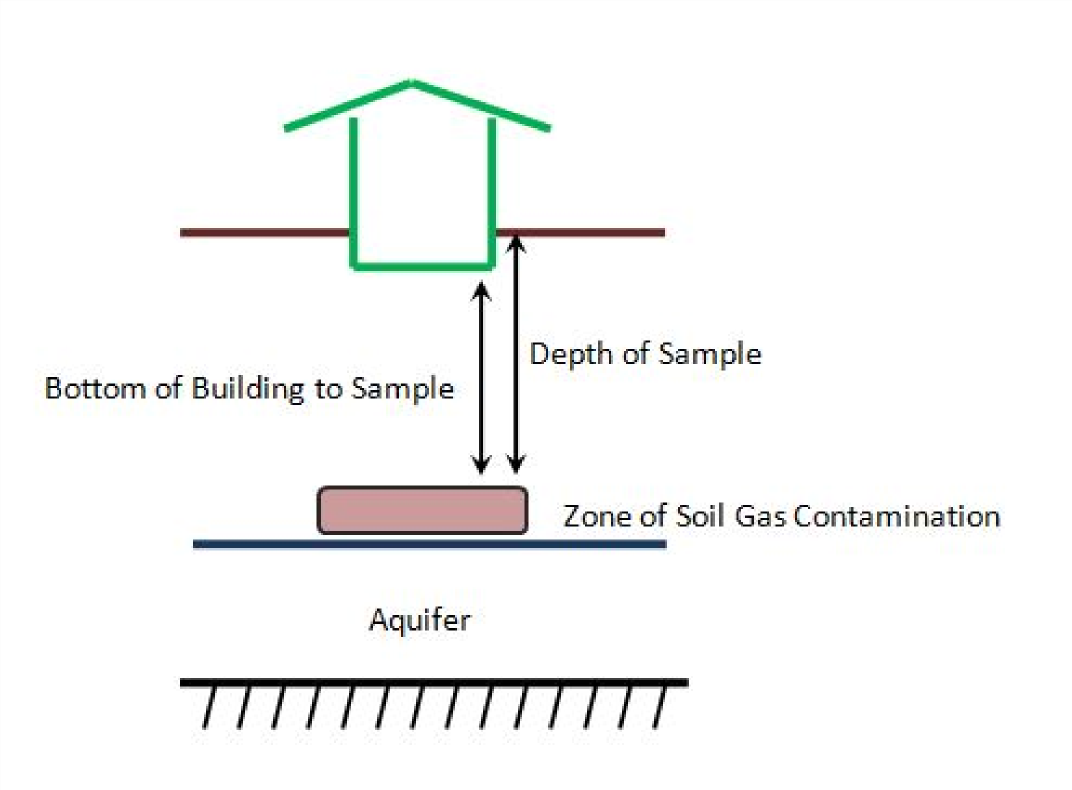
http://www.epa.gov/land-research/pviscreen

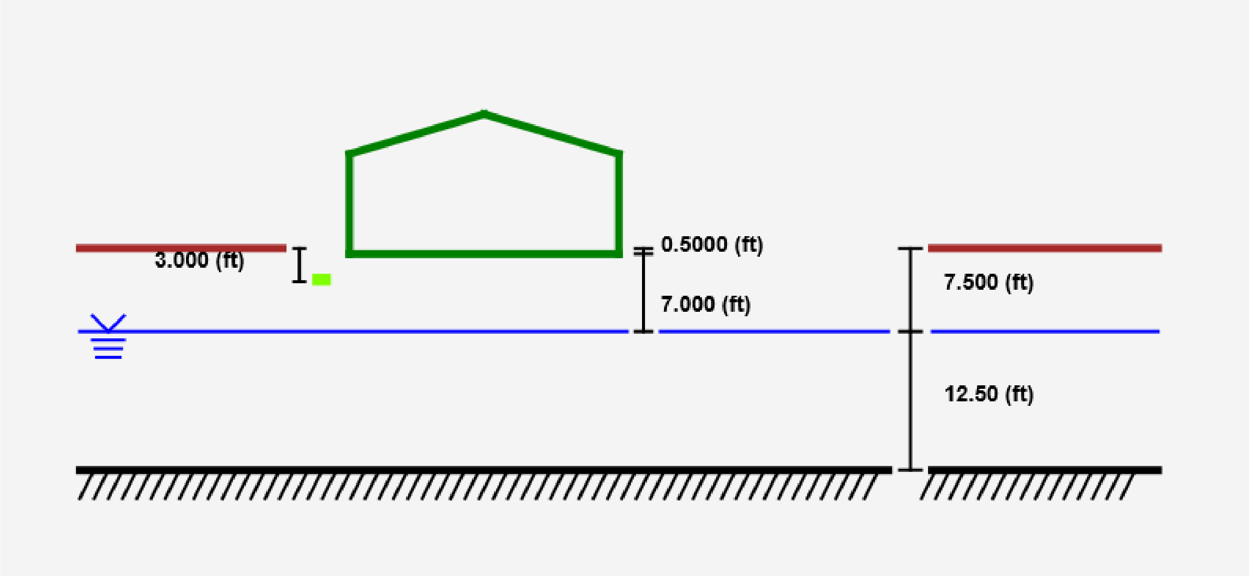
PVIScreen

- PVIScreen includes:
  - BioVapor equations, recoded in Java
  - Automated Monte Carlo uncertainty analysis
  - Soil gas or ground water source
  - Comparison to screening levels
  - Flexible and customizable unit choices
  - Automated Report
- Primary focus:
  - To add line of evidence for site assessment and closure decisions
  - To make uncertainty analysis practical by giving a prediction and estimate of its uncertainty

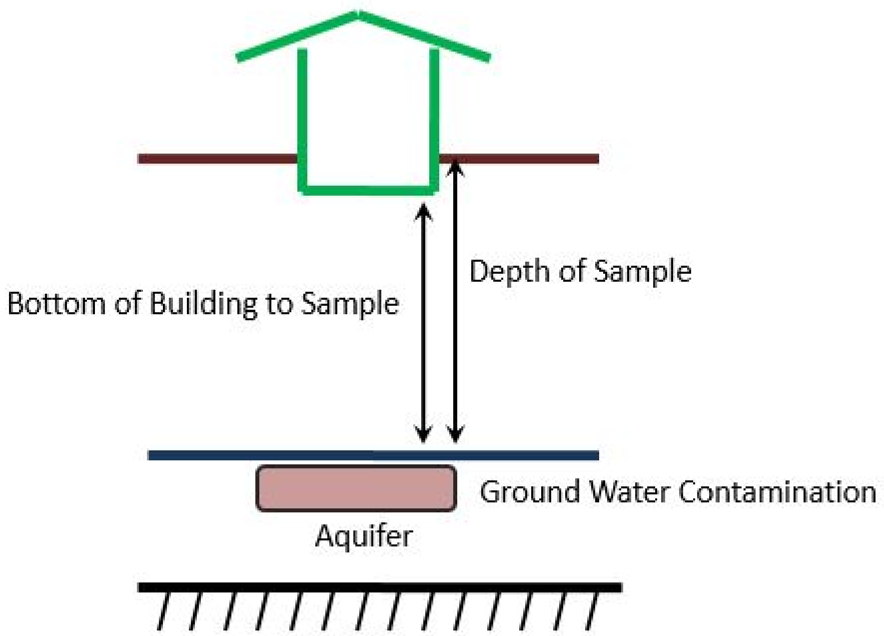
PVIScreen Sources: Soil Gas Data



PVIScreen generates schematic



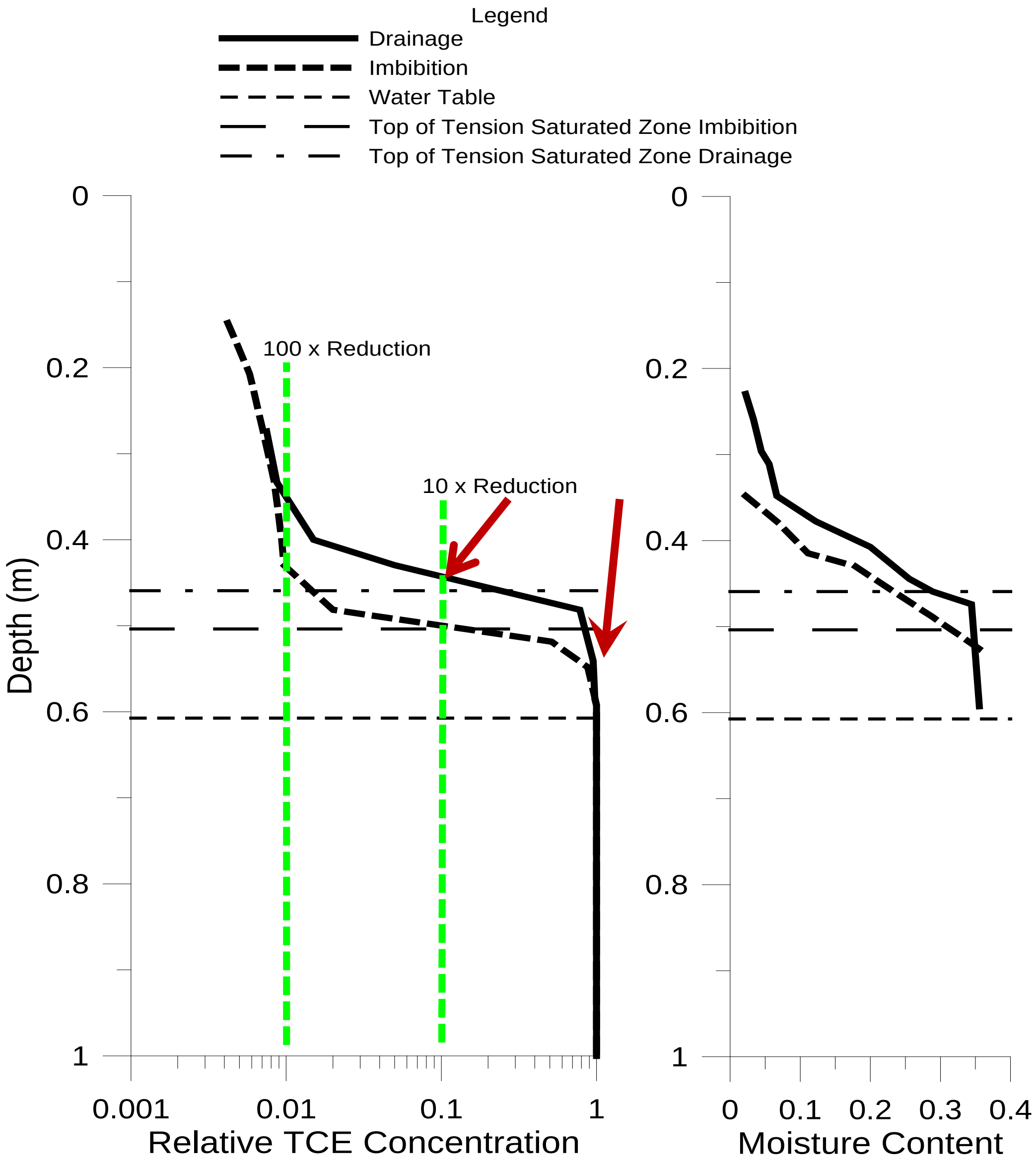
PVIScreen Sources: Ground Water Data



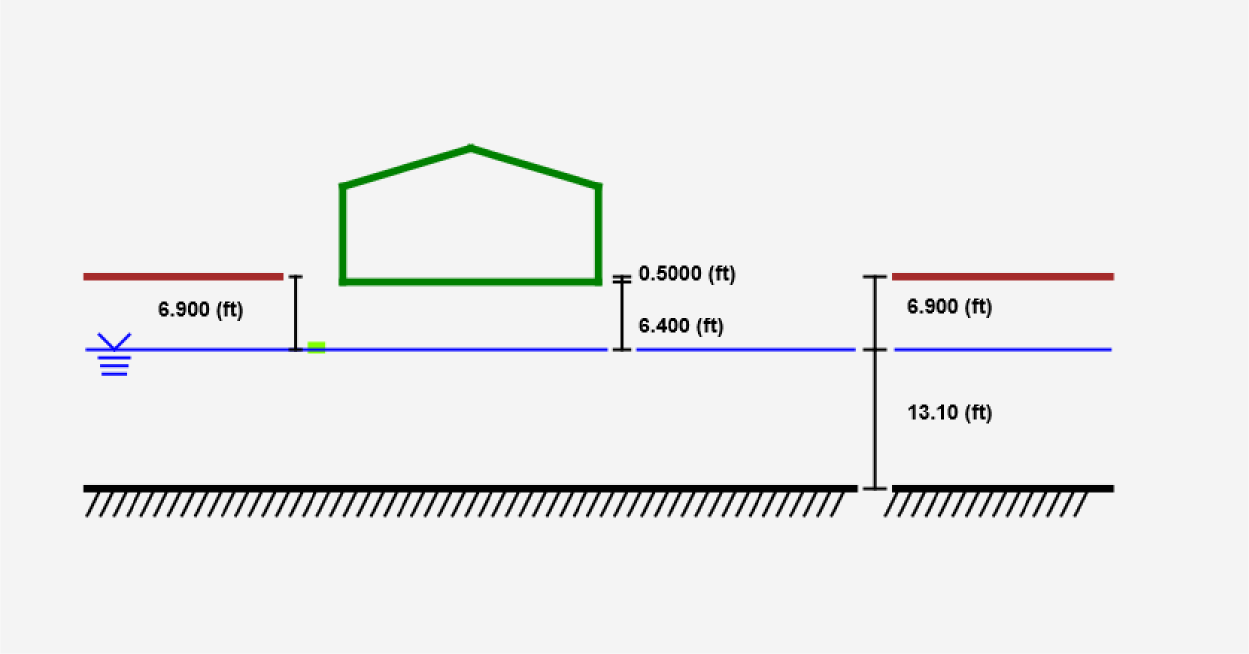
Concentration relationships in the capillary fringe: from one data set*

•Concentration reduction by ~1/10 through the capillary fringe

*McCarthy, K.A. and Johnson, R.L., 1993, Transport of volatile organic compounds across the capillary fringe, Water Resources Research, 29(6) 1675-1683.



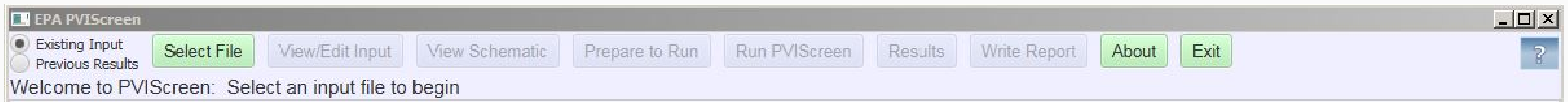
Schematic showing ground water source



How does it work?

- PVIScreen is written in Java
- The interface: JavaFX
- All inputs and outputs saved in text files:
  - File extensions managed by User Interface:
    - Input: *ProblemName*.pvi
    - Output: ProblemName-DateTime.PVIScreen.Result.csv
    - Input and output files are ASCII text files in comma-separated value format—direct editing not advised.
- Runs from Windows Directory (double click)

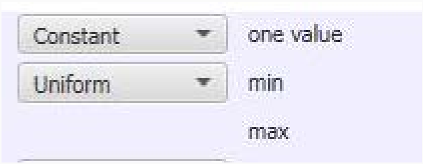
PVIScreen Interface:



The options run from right to left, and buttons become active when the option is available

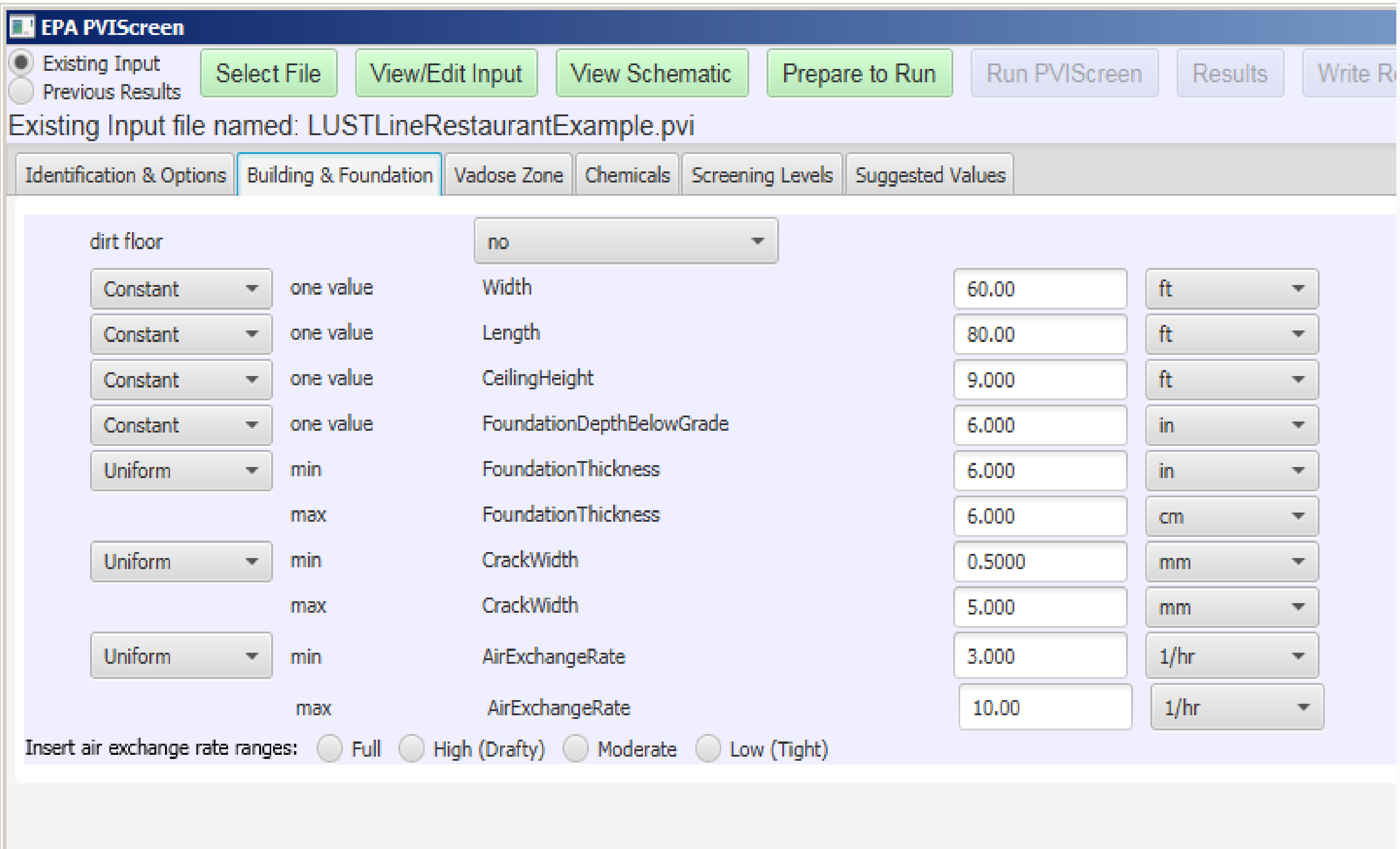
Approach to uncertainty: allow parameters to be treated as uncertain, *but incorporate all known parameter values*

- GUI allows
    - Constant
    - min to max range



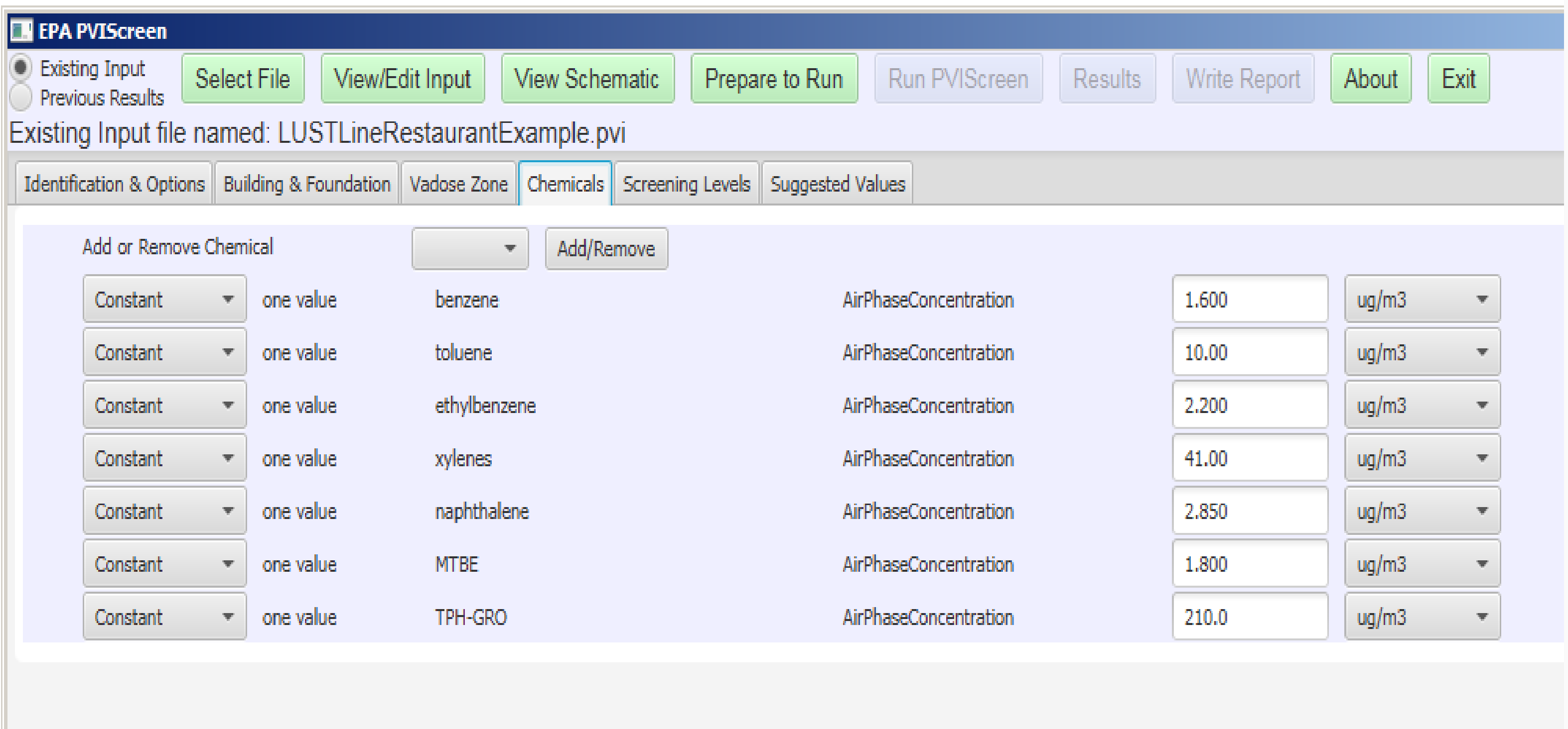
- Command line also allows empirical and parametric distributions
    - (not included in GUI or today's presentation)

Example inputs: constants or ranges

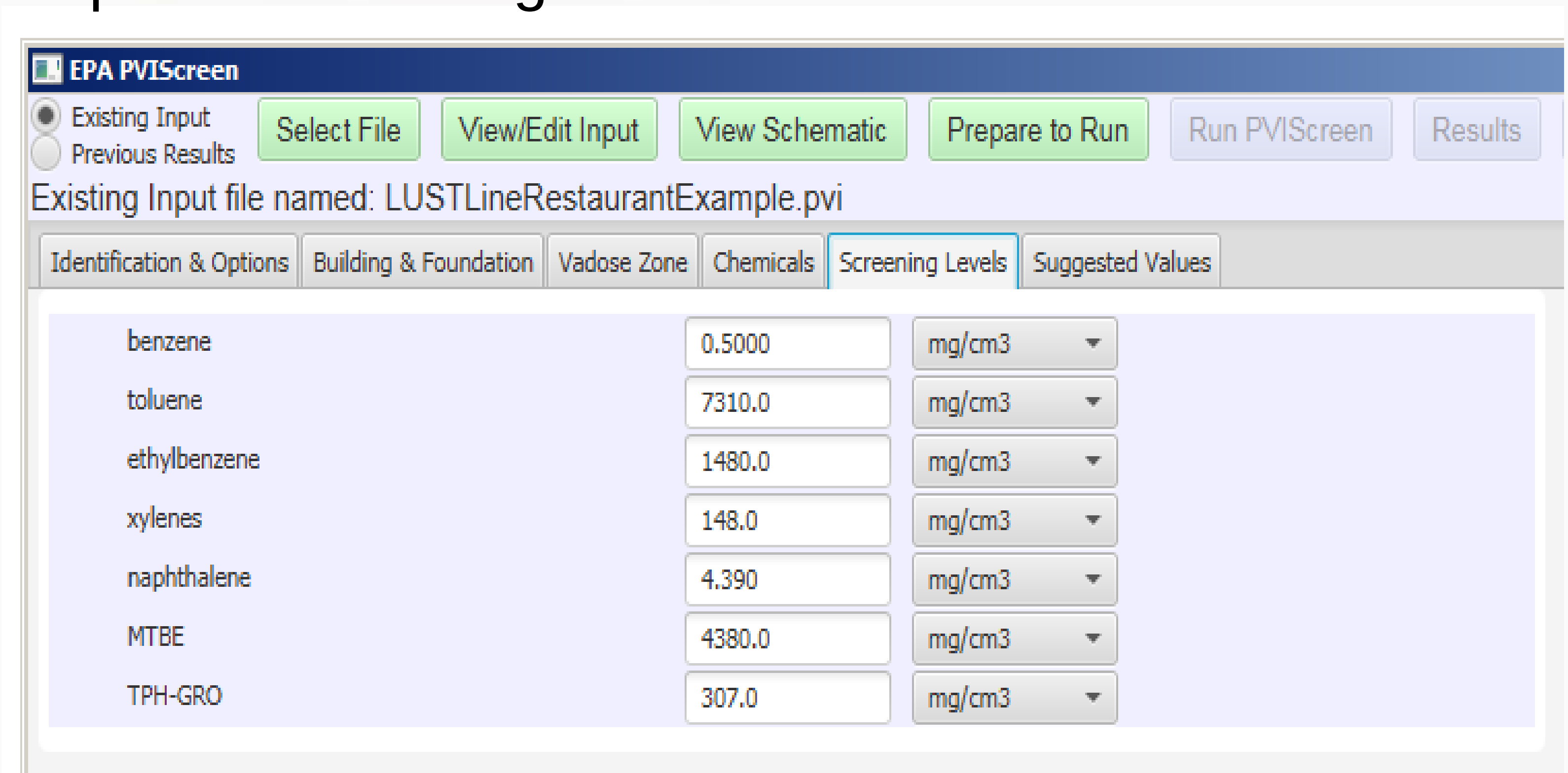


Inputs of multiple constituents

- all oxygen should NOT go to degrade only benzene



Input of Screening Levels:

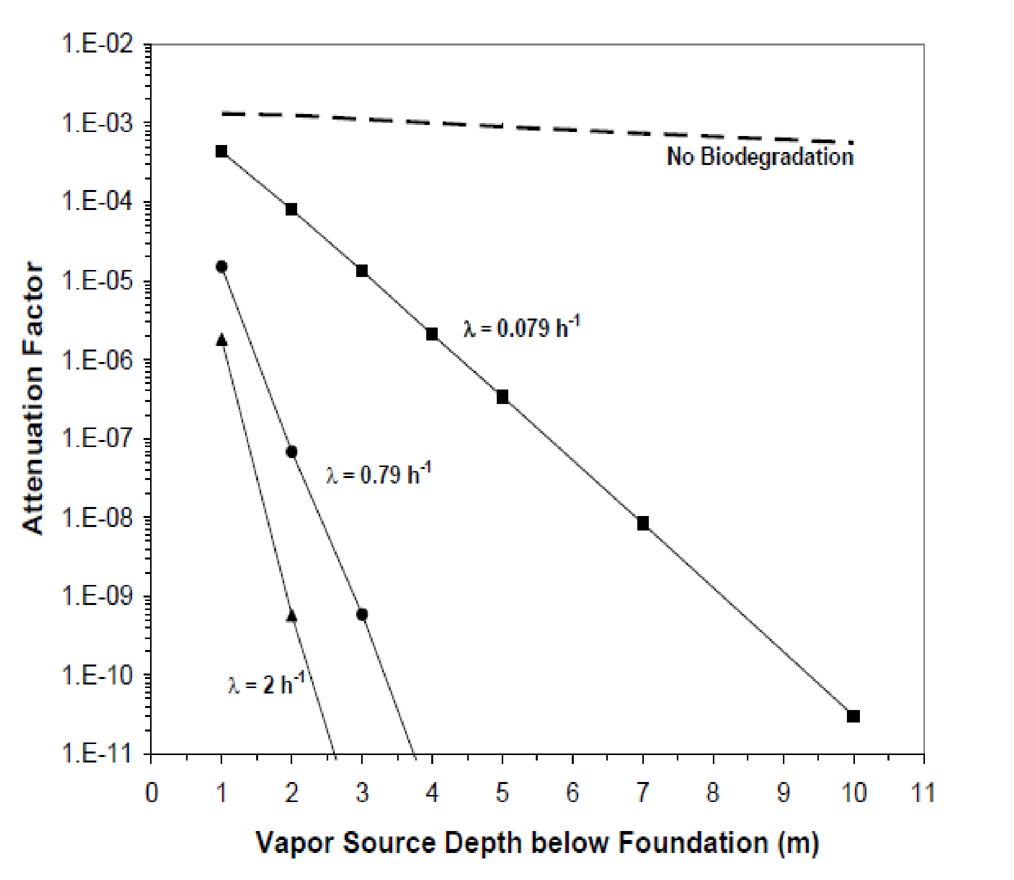


State-specific or EPA RSL

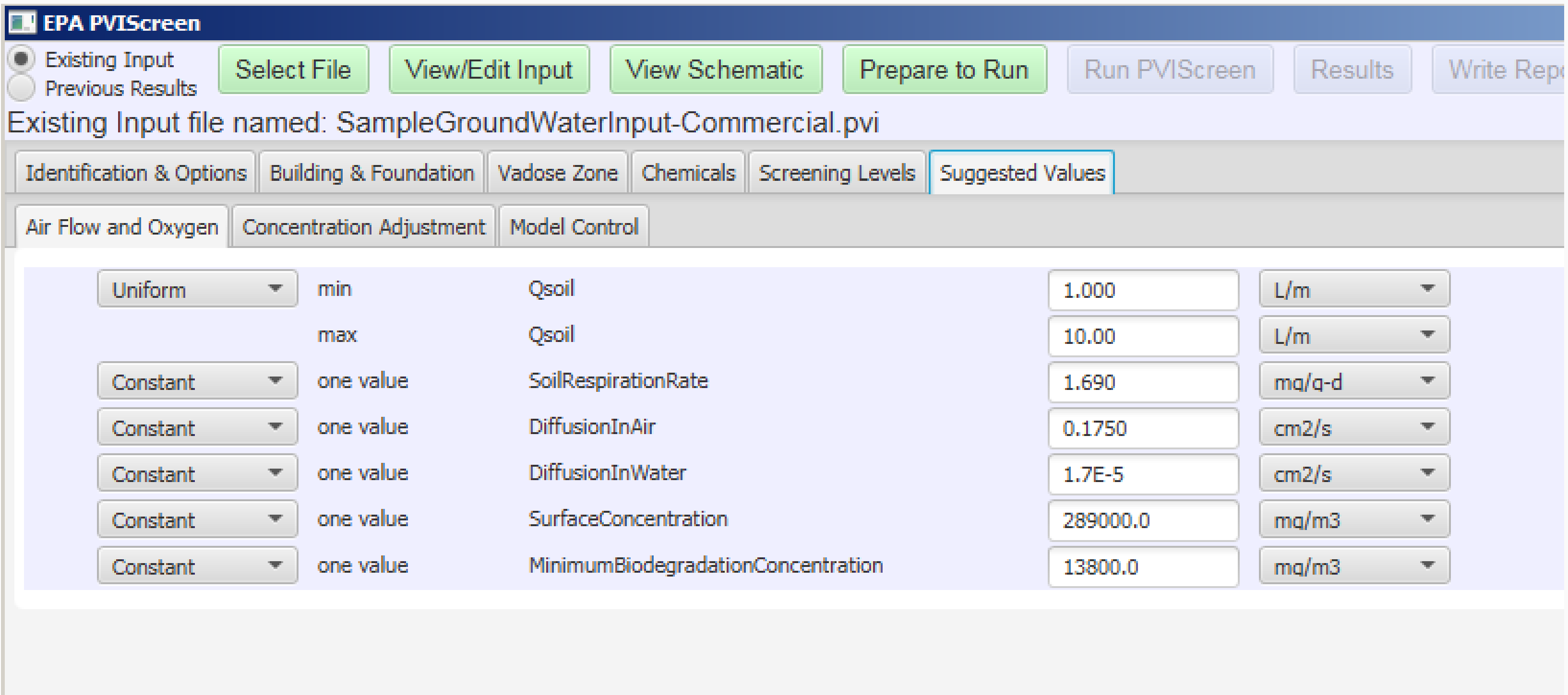
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2017

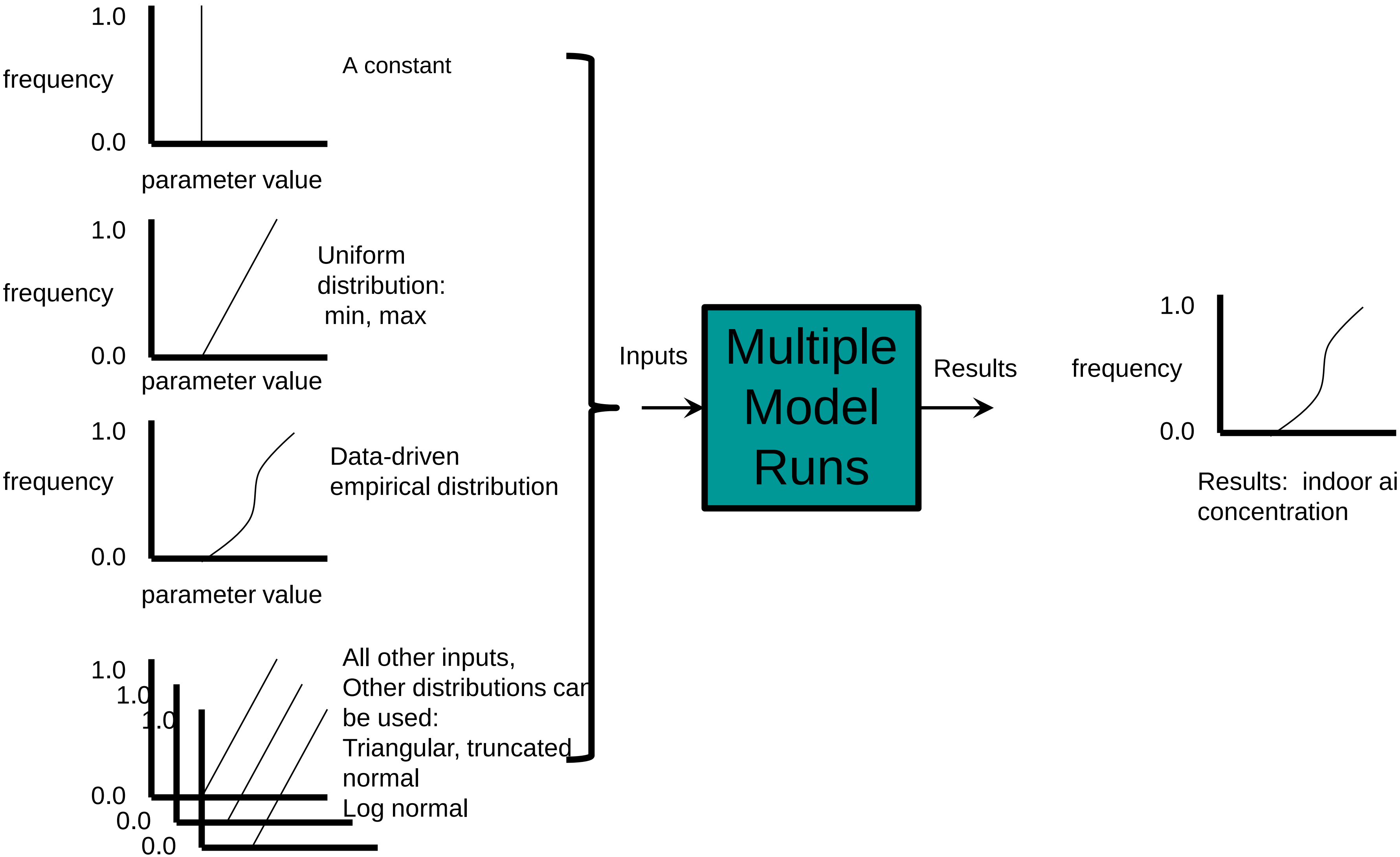
Factors controlling biodegradation are uncertain, variable

- Hydrocarbon degradation rates vary by factor of 100
- How does this impact PVI?

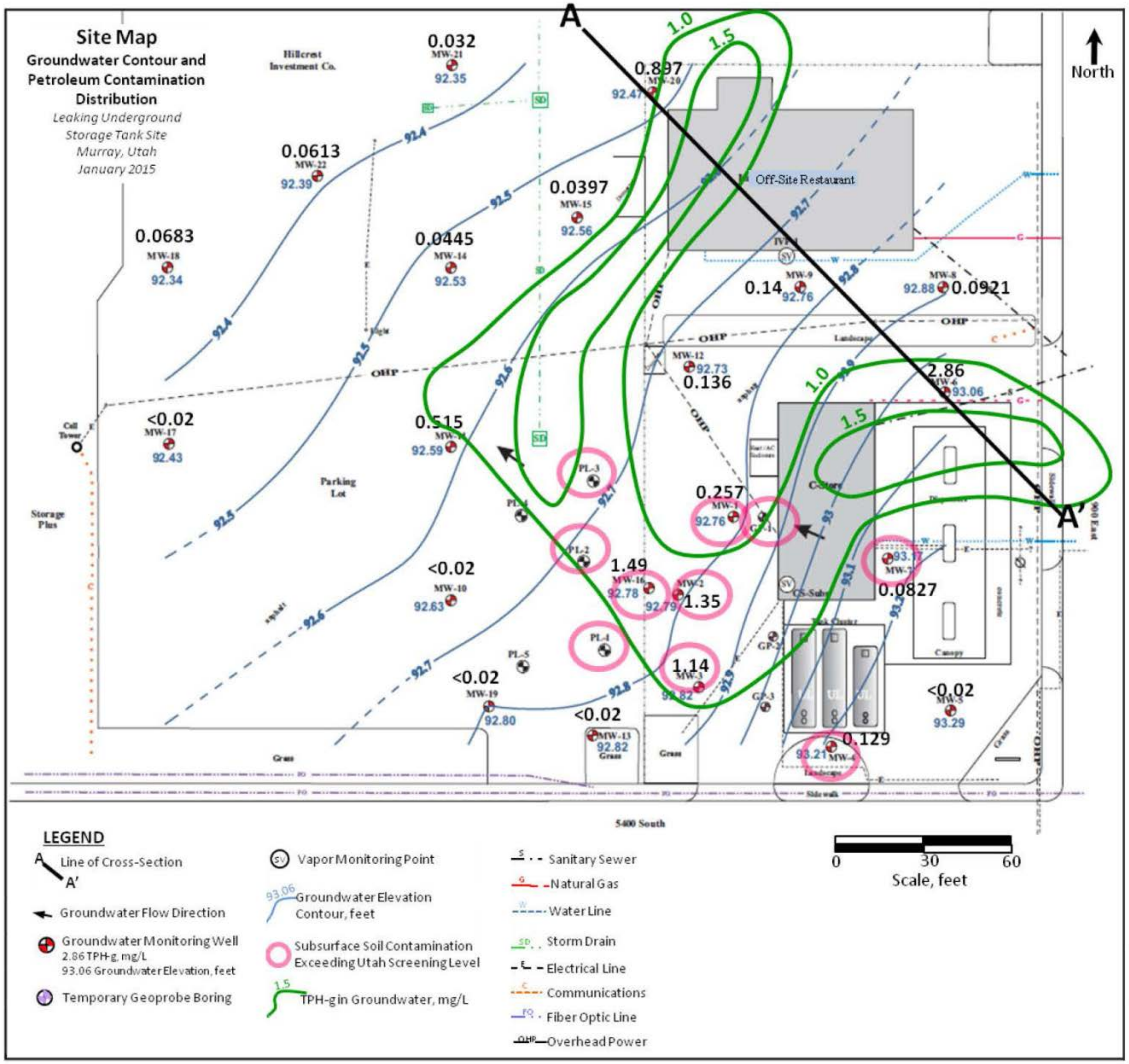


“Suggested” Values

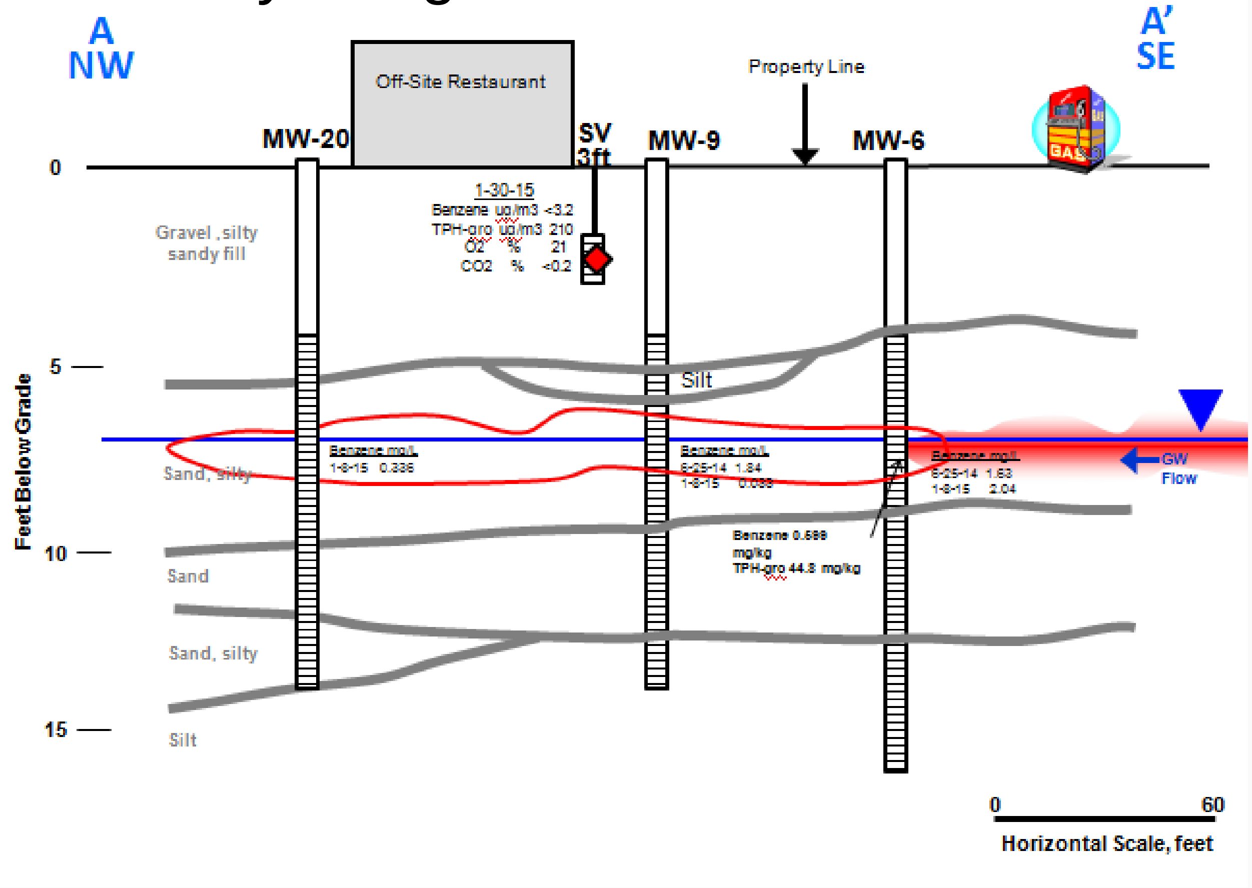



1.0
frequency
0.0
parameter value
A constant
1.0
frequency
0.0
parameter value
Uniform distribution: min, max
1.0
frequency
0.0
parameter value
Data-driven empirical distribution
1.0
1.0
1.0
0.0
0.0
0.0
All other inputs, Other distributions can be used: Triangular, truncated normal Log normal
Inputs
Multiple Model Runs
Results
1.0
frequency
0.0
Results: indoor air concentration

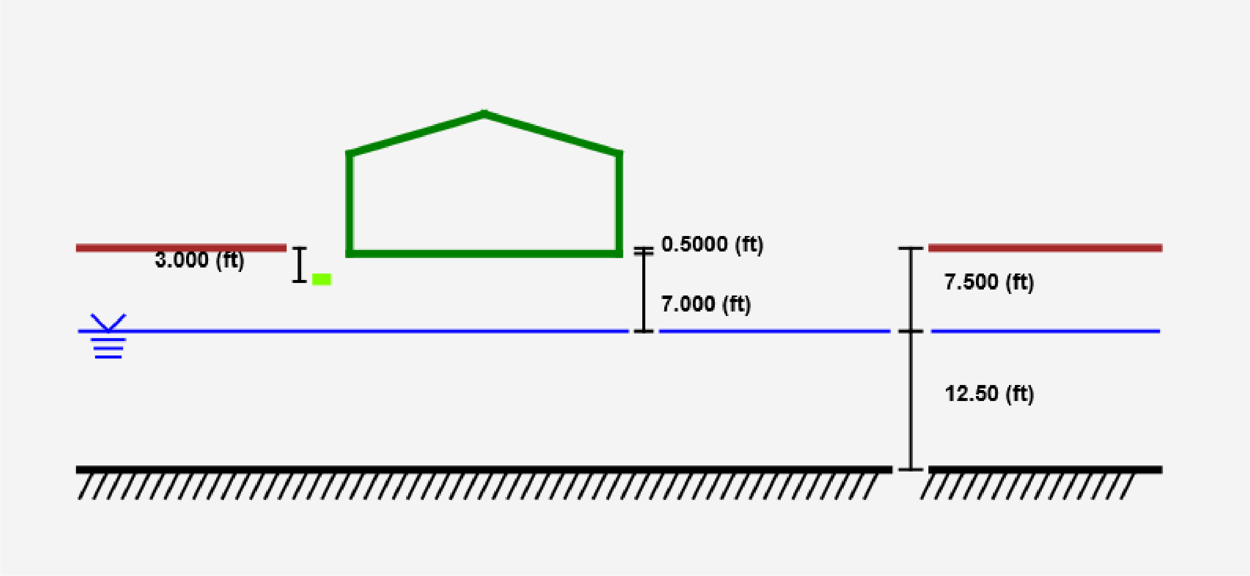
Soil gas input data example from a site in Utah:



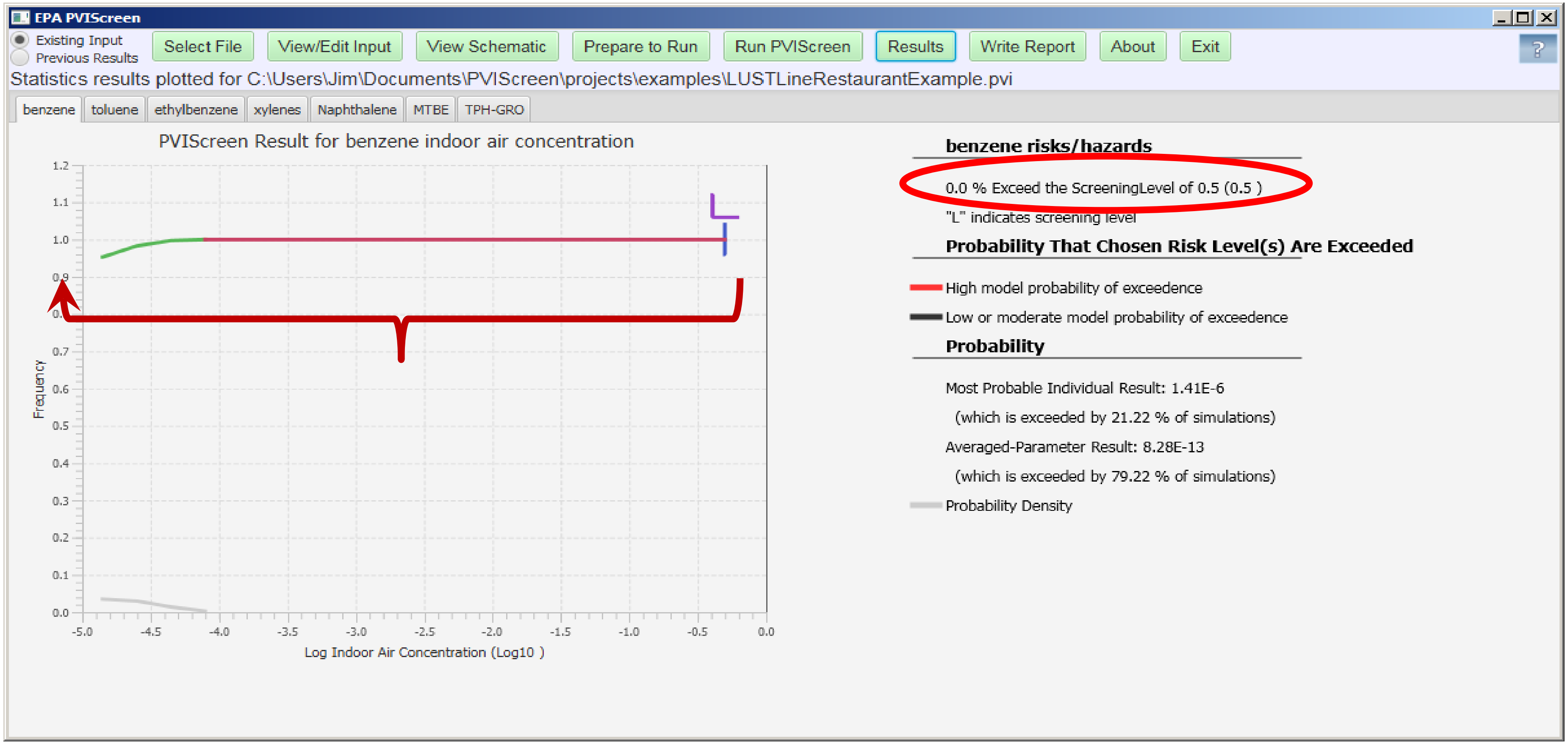
Impacts to Off-Site Restaurant? PVIScreen ‘driven’ by soil gas data at 3’ below the surface



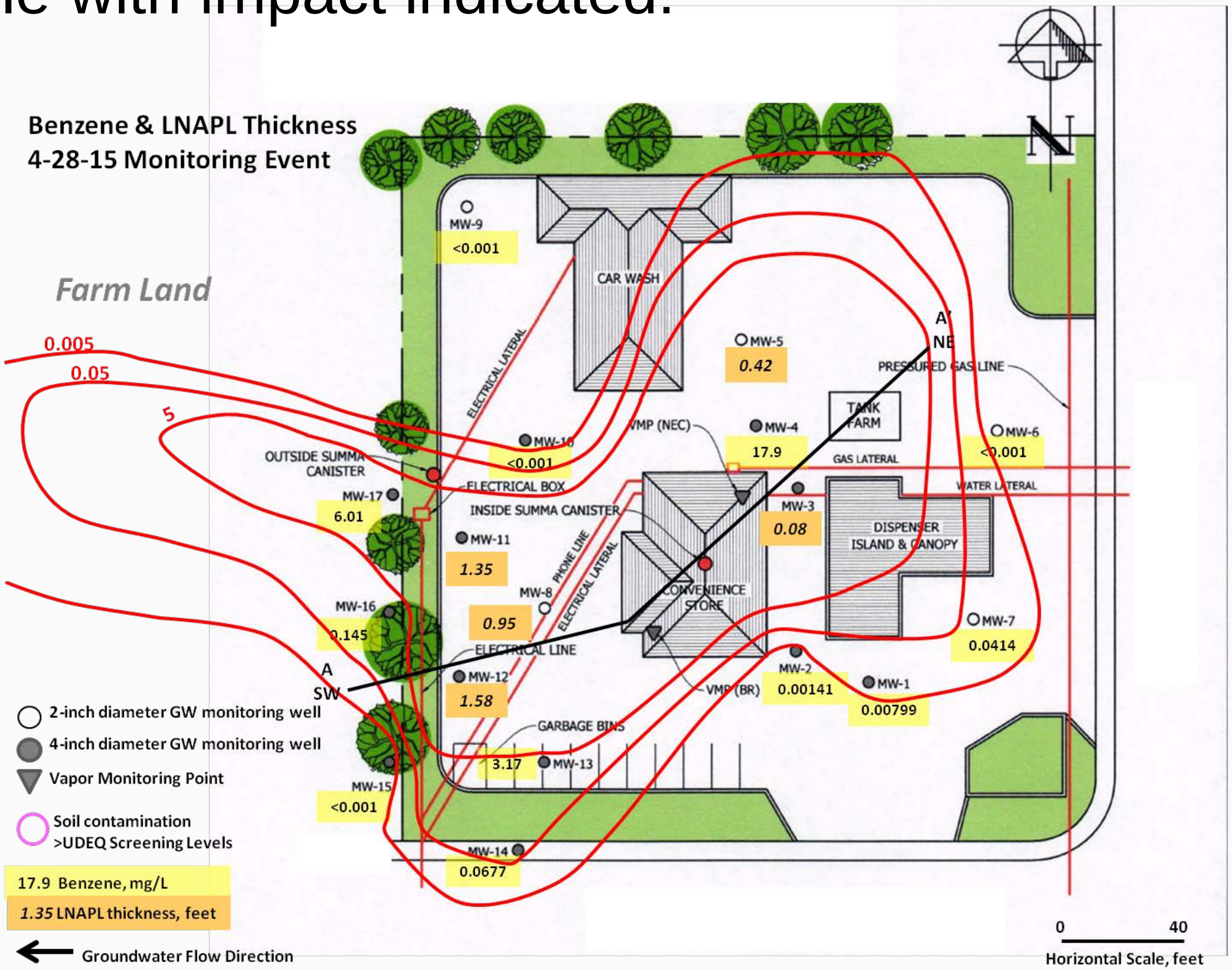
PVIScreen generates schematic

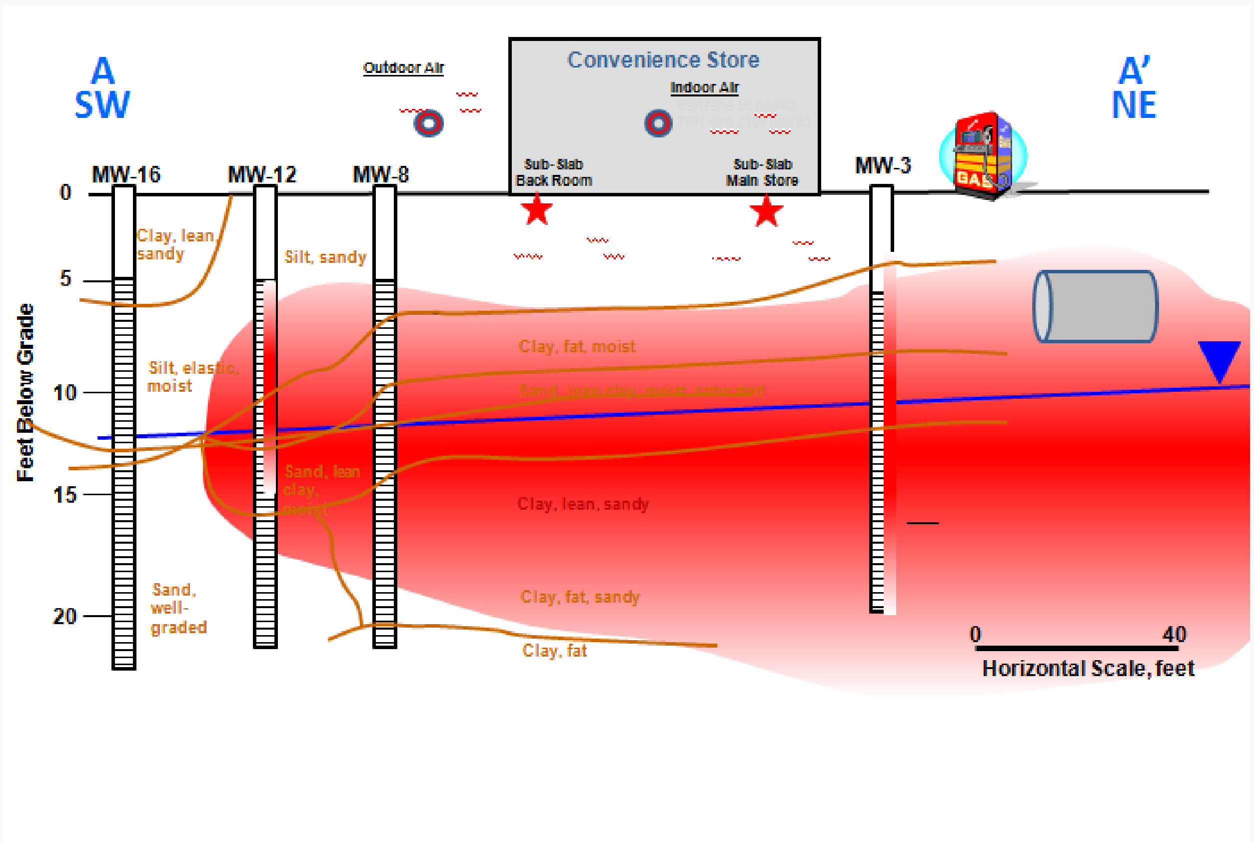


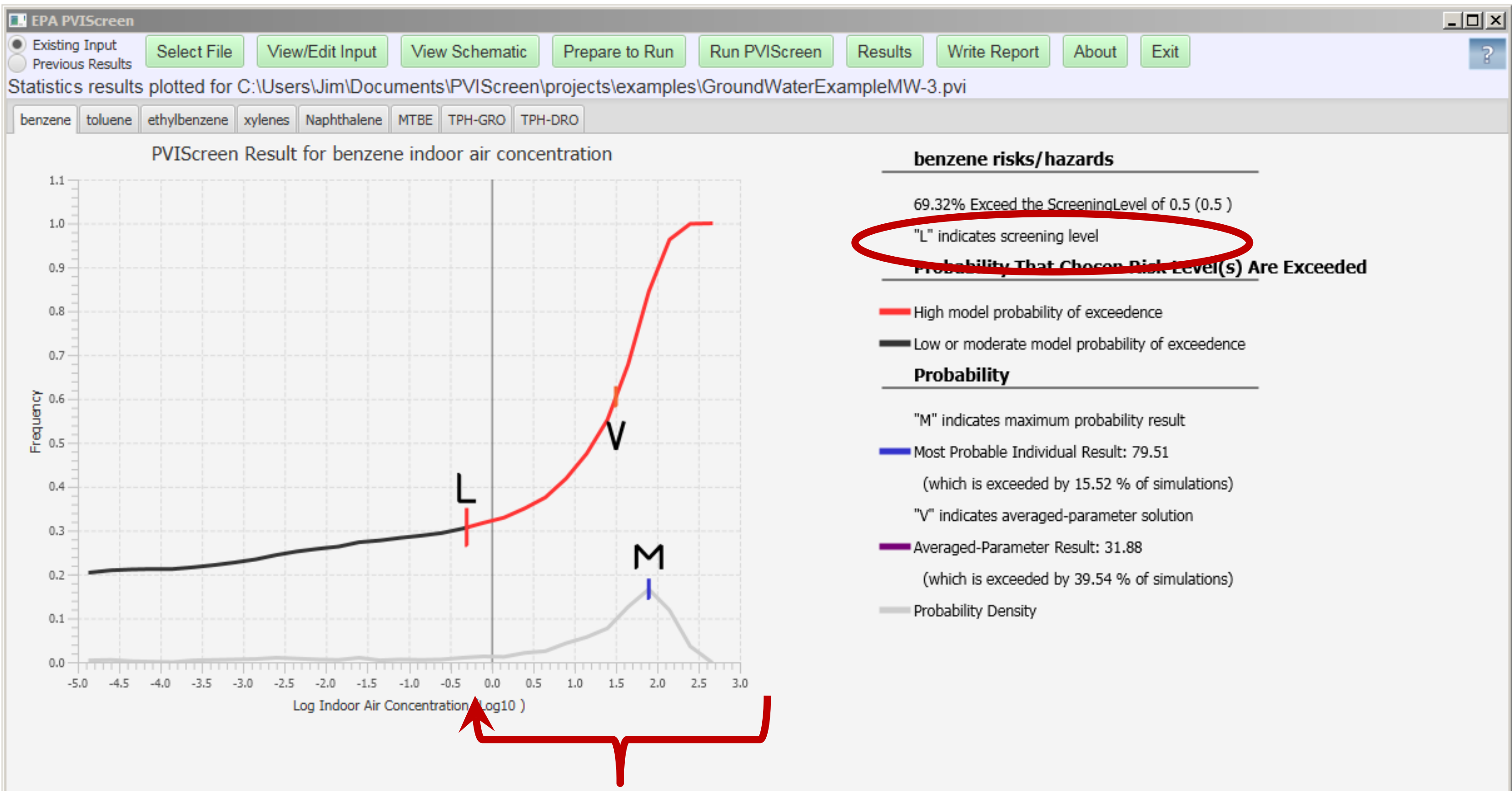
Results: PVIScreen model runs indicate no impact



Example with impact indicated:

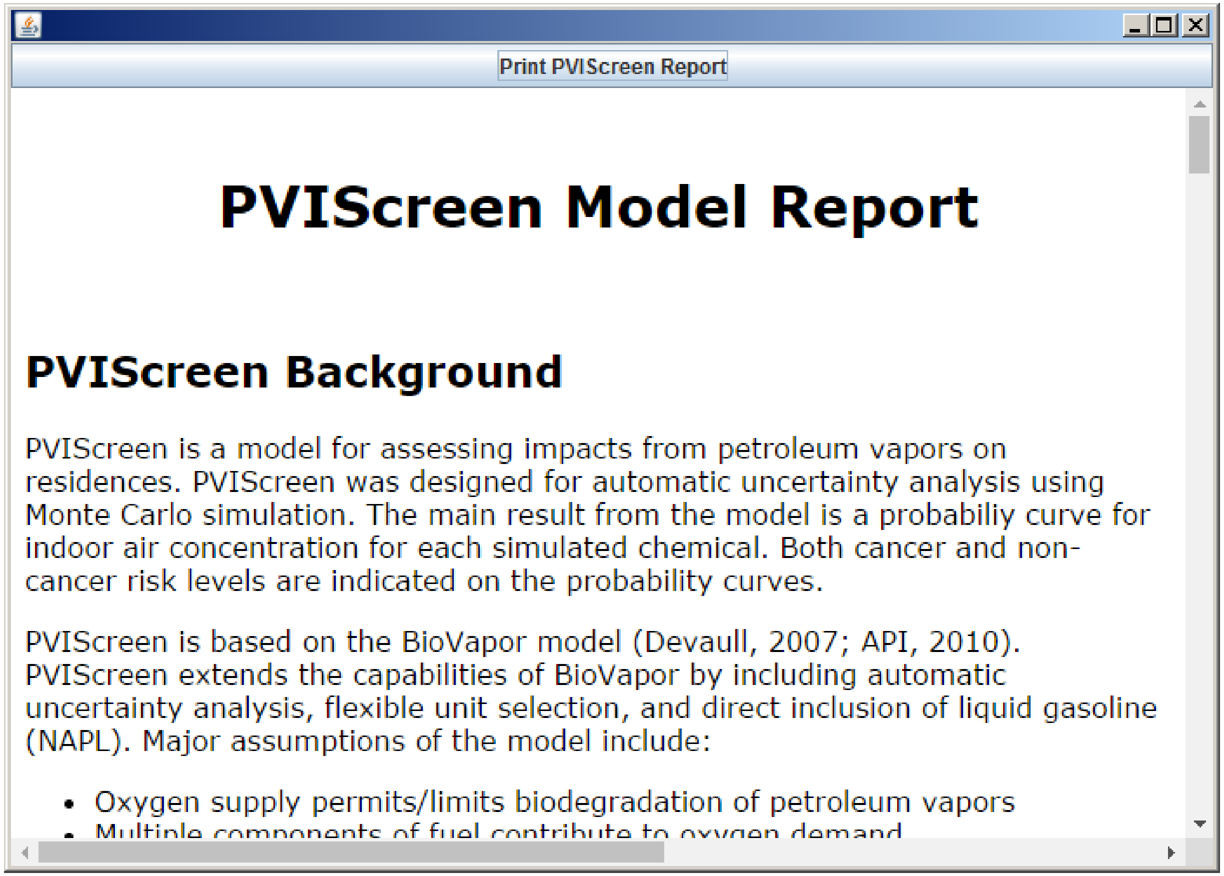



A
SW
A'
NE
Outdoor Air
Convenience Store
Indoor Air
Sub-Slab
Back Room
Sub-Slab
Main Store
MW-16
MW-12
MW-8
MW-3
GAS
0
5
10
15
20
Feet Below Grade
Clay, lean, sandy
Silt, sandy
Silt, elastic, moist
Clay, fat, moist
Clay, lean, sandy
Sand, well-graded
Clay, fat, sandy
Clay, fat
0
40
Horizontal Scale, feet



Impact indicated by ~69% of runs

Automated Report:



Print PVIScreen Report

PVIScreen Model Report

PVIScreen Background

PVIScreen is a model for assessing impacts from petroleum vapors on residences. PVIScreen was designed for automatic uncertainty analysis using Monte Carlo simulation. The main result from the model is a probabiliy curve for indoor air concentration for each simulated chemical. Both cancer and non-cancer risk levels are indicated on the probability curves.

PVIScreen is based on the BioVapor model (Devaull, 2007; API, 2010). PVIScreen extends the capabilities of BioVapor by including automatic uncertainty analysis, flexible unit selection, and direct inclusion of liquid gasoline (NAPL). Major assumptions of the model include:

- Oxygen supply permits/limits biodegradation of petroleum vapors
- Multiple components of fuel contribute to oxygen demand

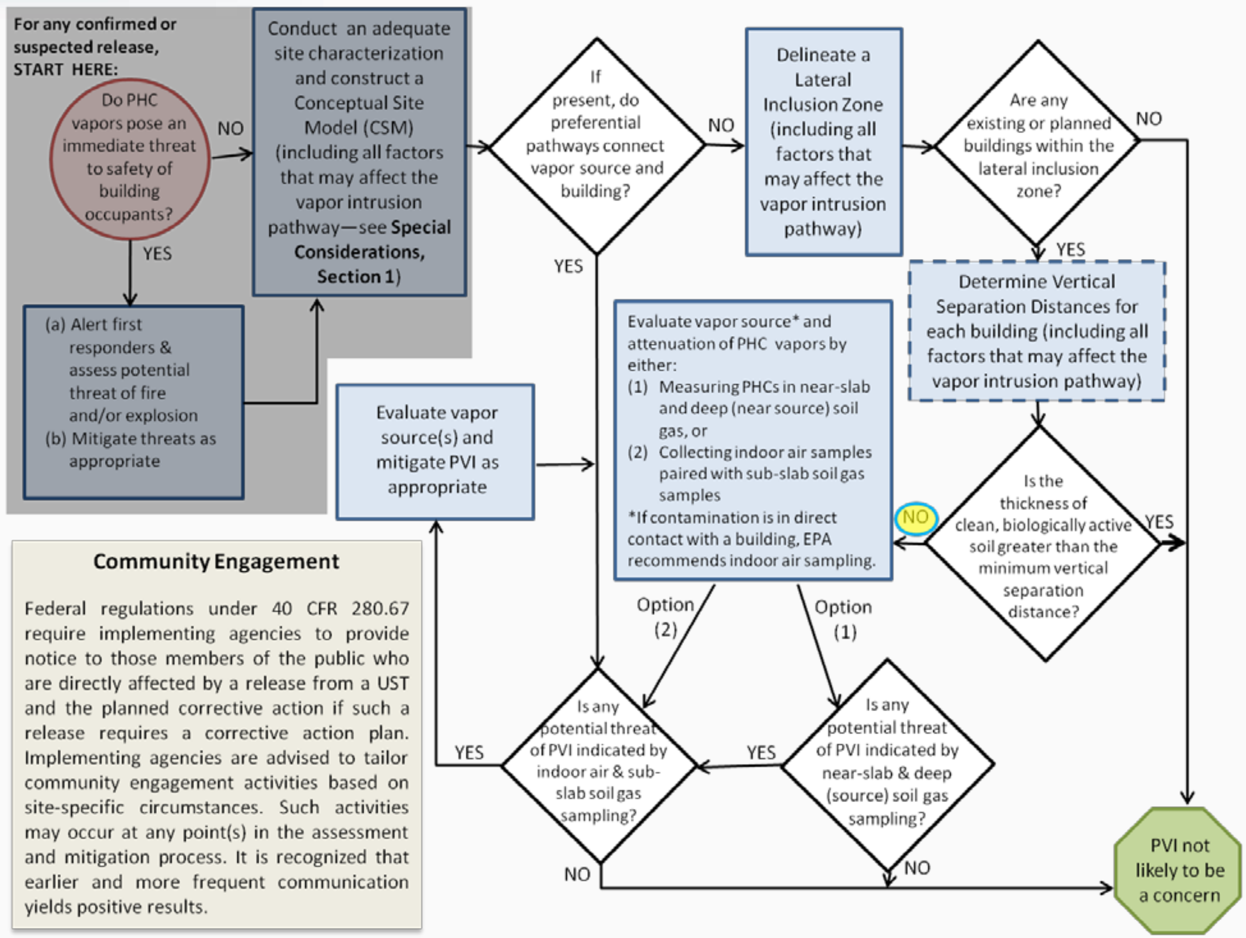
Model Output – all parameter values saved with results
Method to display parameter values which exceed risk levels is being developed

	A	B	C	D	E	F	G	H	I	J
1	Control	Statistics								
2	EPA-PetroleumVaporIntrusion									
3	Post-Processed Output: Statistics-Histograms-Cumulative Probabilities									
4	Input Data File: C:\Users\Jim\workspace\PVIScreen\RFG-25Ft-NYC2003-Leached-f1000-None-Fixed half foot.csv									
5	Output File Name: RFG 25Ft NYC2003 Leached f1000 half foot PVIScreen 2013-Sep-6 4h-59m-19.0s.csv									
6	Sorted Output File Name (this file): RFG 25Ft NYC2003 Leached f1000 half foot PVIScreen 2013-Sep-6 4h-59m-19.0s Statistics.csv									
7										
8										
9	Result	Heading	building AirExchangeRate	building MixingZ	building \	building L	building [	building FoundationThicl	building CrackWic	building
10	Result	Unit/Cour	(1/s)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm3/s)
1001	Result	653	4.96E-05	450.0480365	1000	1000	15	19.91185664	0.282173926	28.3
1002	Result	940	7.81E-05	452.0850911	1000	1000	15	14.06168026	0.113904141	96.7
1003	Result	688	2.79E-05	344.1029533	1000	1000	15	16.17564898	0.226845316	53.3
1004	Result	300	2.95E-05	385.8951733	1000	1000	15	18.97272857	0.416460407	42.0
1005	Result	133	6.97E-05	277.8792118	1000	1000	15	12.38464698	0.235393048	34.5
1006	Result	211	4.03E-05	411.0058471	1000	1000	15	19.81538962	0.273654733	18.6
1007	Result	180	1.19E-04	254.5569291	1000	1000	15	16.0461374	0.173825781	1
1008	Result	50	3.59E-05	476.6361125	1000	1000	15	17.24209519	0.229550274	18.9
1009	Result	307	3.44E-05	459.0581482	1000	1000	15	14.0713416	0.28272131	31.9
1010	Result	[illegible]	7.97E-05	269.9006984	1000	1000	15	18.11253617	0.258305466	125.
1011										
1012	Simple Statistics:									

Secrets of PVIScreen…

- *Java must be enabled.*
- *Always* start PVIScreen by opening an existing file (examples or templates).
  - Template files regenerate every time the model is run—save under different name.
  - Create project directories for each project.
  - All files are saved with date/time stamp (can pile up).
  - If results are not displayed, exit and restart PVIScreen.
- Concentrations needed to drive model.
- Biodegradation is always treated as being uncertain.
- When an impact is shown…
  - Because of randomness, % will very with each simulation
  - If result has marginal exceedances (say <10%) consider refining ranges of parameters.

Results fit within PVI guidance framework --one line of evidence



Summary

- Immediate threats must be handled first.
- Site characterization and development of a Conceptual Site Model next.
- Model use (including PVIScreen) should be embedded with site assessment.
- PVIScreen incorporates parameter. uncertainty into PVI modeling.
- Results can add a line of evidence to an assessment.

Availability at http://www.epa.gov/land-research/pviscreen

- Email: weaver.jim@epa.gov
- *The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency*