Refining the Vapor Intrusion Conceptual Site Model to Account for Unanticipated Sources and Pathways

Chase Holton, Ph.D., P.E.
Senior Environmental Engineer, GSI Environmental Inc.

U.S. EPA "State of VI Science" Workshop

Reliable Ongoing Human Exposure Protection to Vapor Intrusion Using Cleanup as the Simplest Approach

40th Annual Conference on Soil, Water, Energy, and Air, A Hybrid Conference, October 22nd, 2024

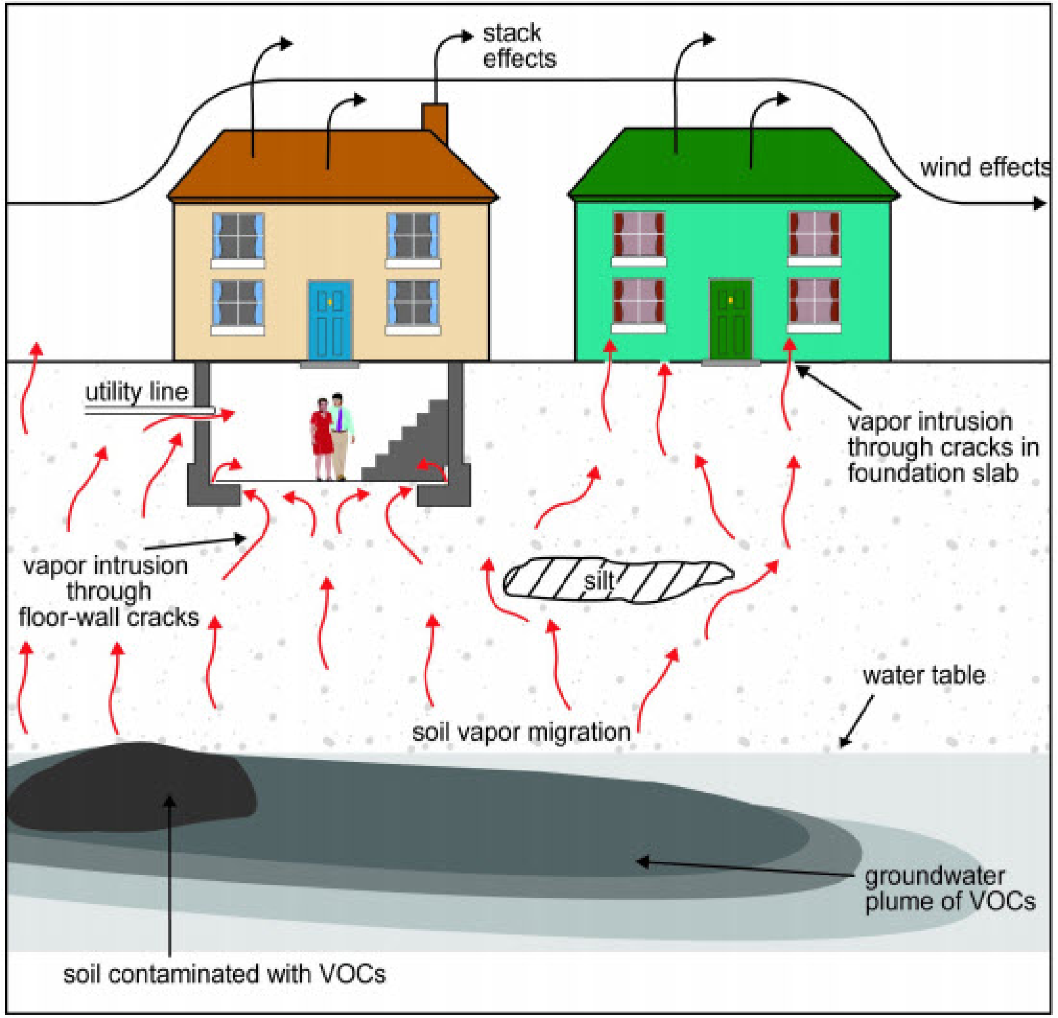
Presentation archived at https://iavi.rti.org/

RTI INTERNATIONAL Jacobs AEHS Foundation GSI ENVIRONMENTAL PRAXIS ENVIRONMENTAL TECH. INC

Agenda

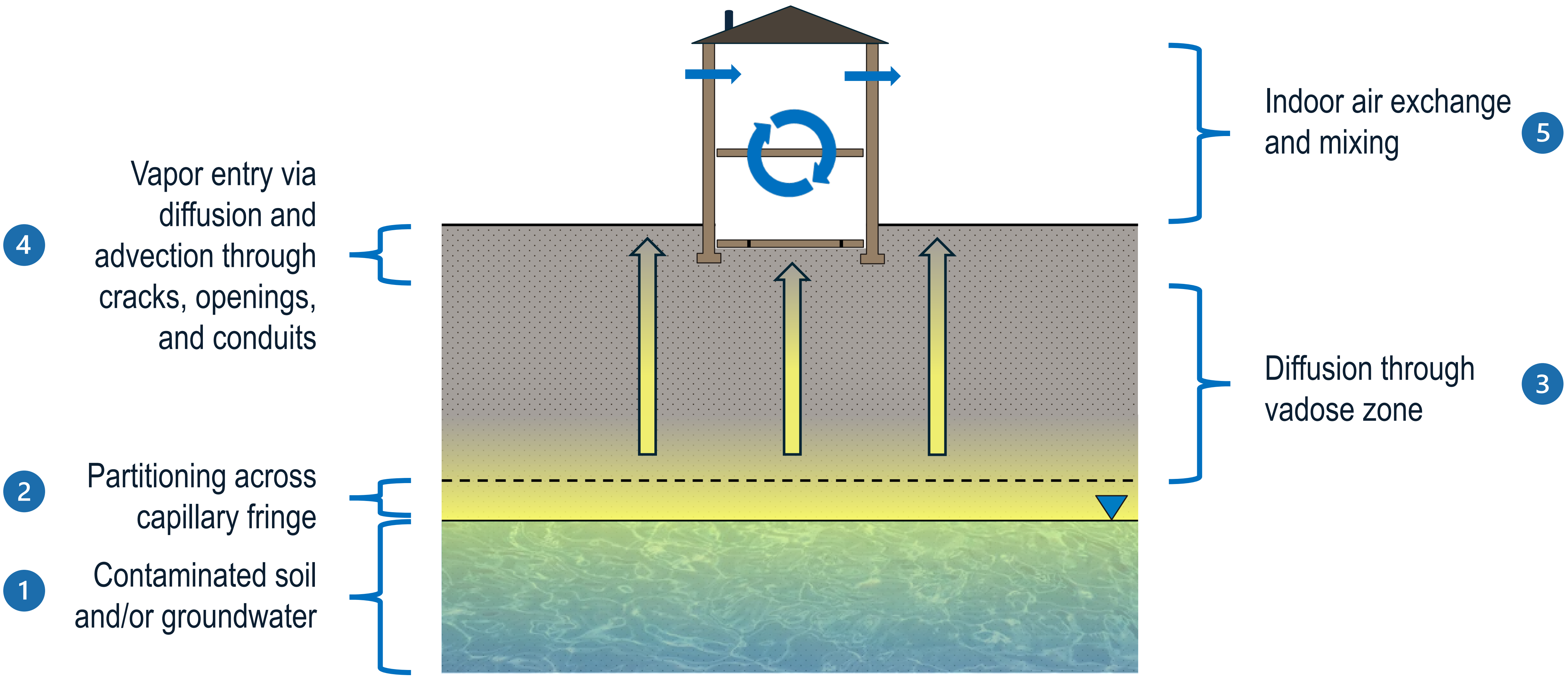
Vapor Intrusion Conceptual Site Models

- Sources
- Pathways



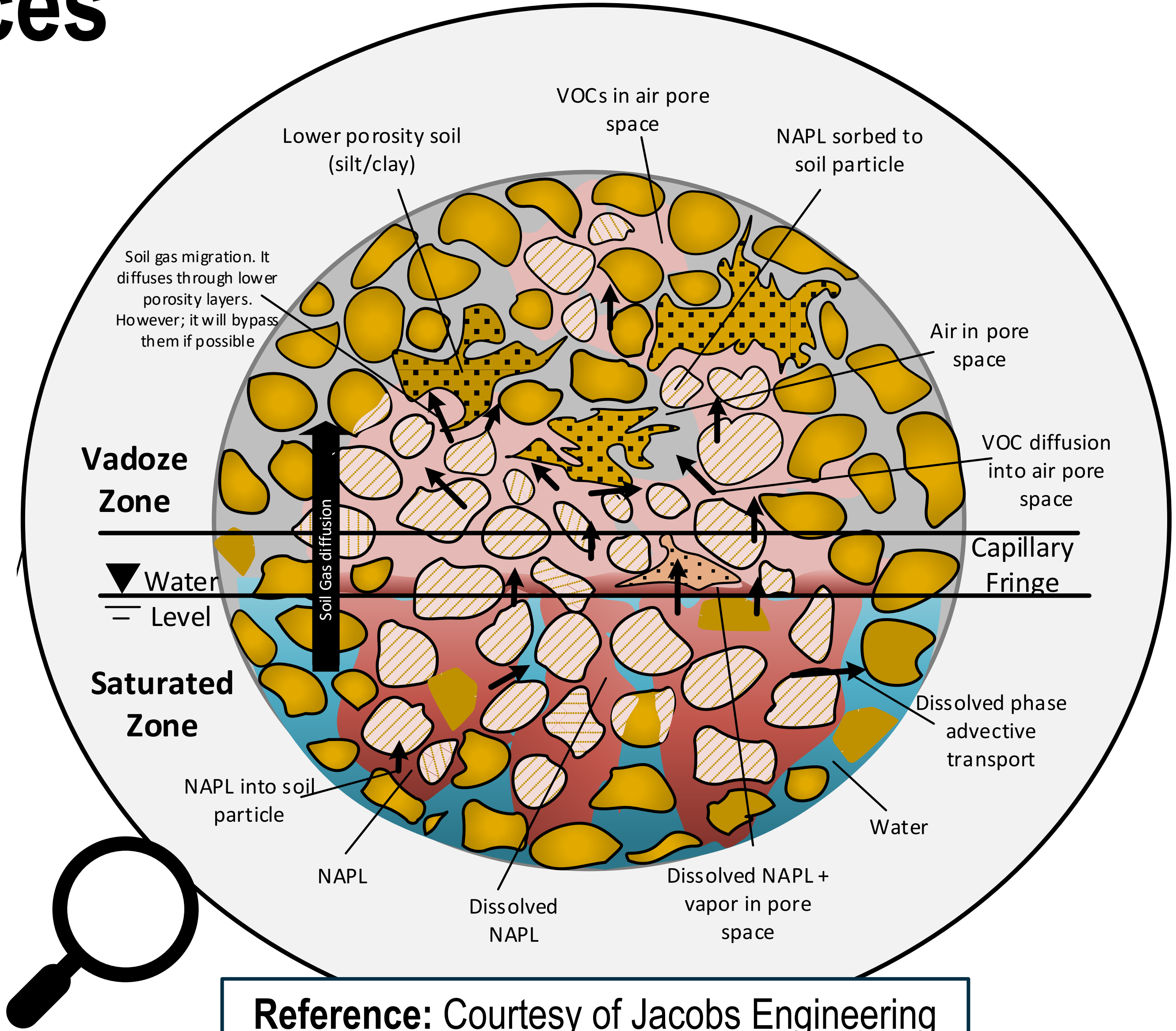
Reference: USEPA, 2015

Vapor Intrusion Conceptual Site Model



Vapor Intrusion Sources

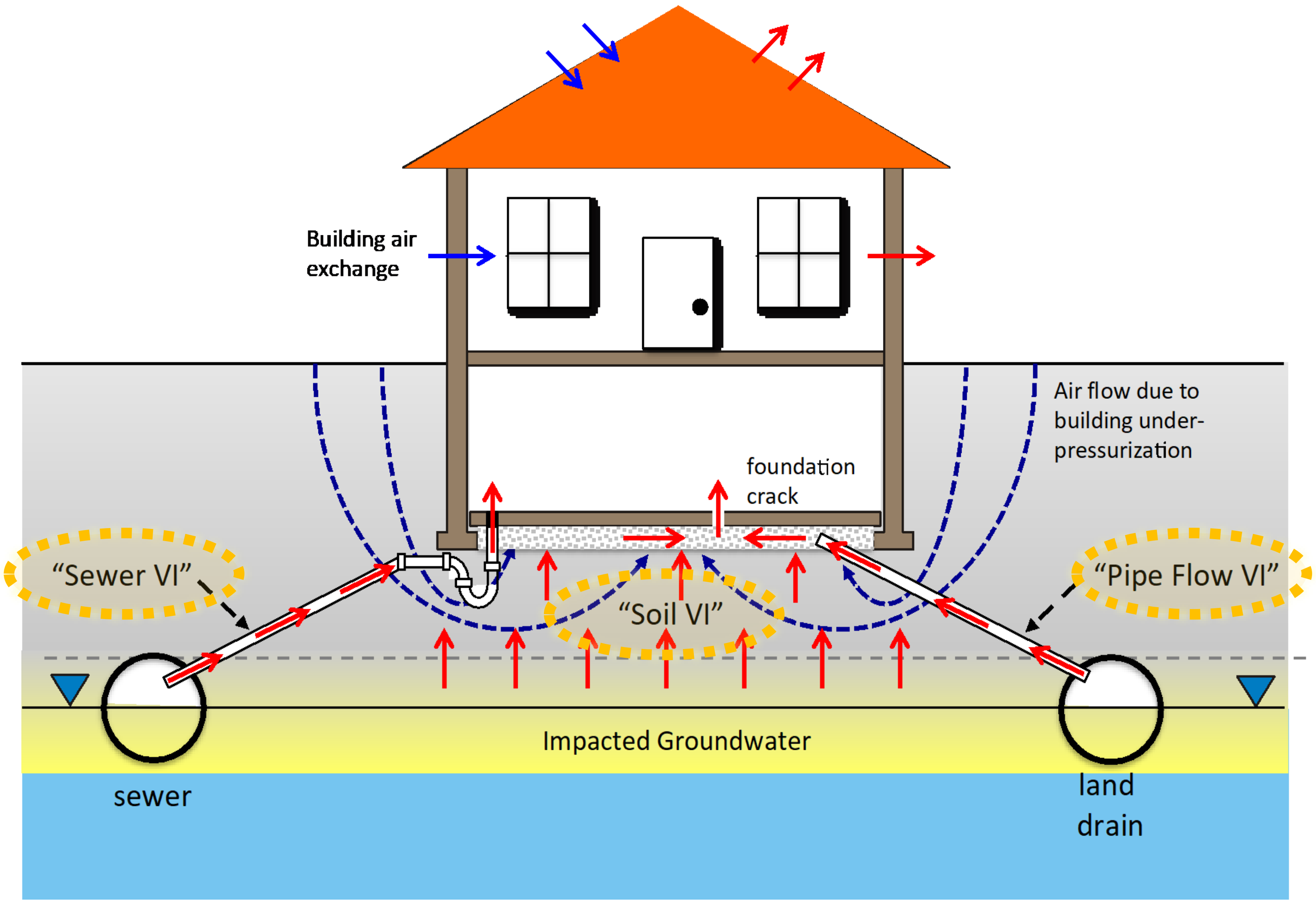
- Site characteristics to consider:
  - Site history
  - Concentration of COPCs
  - Geology and hydrogeology
  - Differences COPC properties
  - Vertical and lateral distance to source material



Reference: Courtesy of Jacobs Engineering

**COPC = chemicals of potential concern*

Vapor Intrusion Pathways

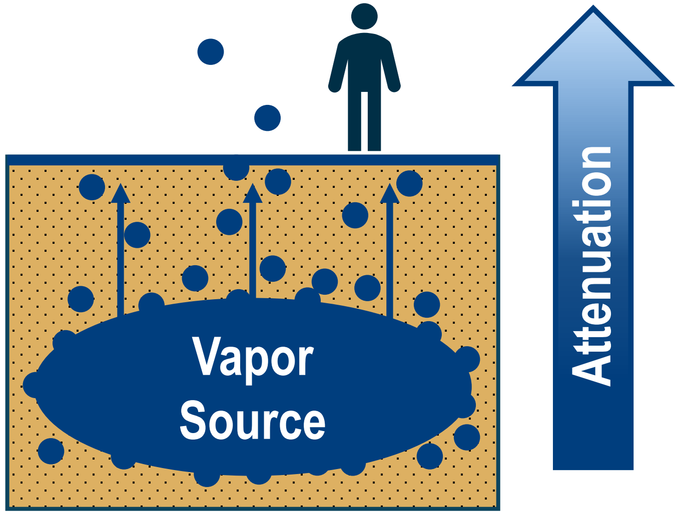


Reference: Adapted from Guo et al. (2015), *Environmental Science & Technology*

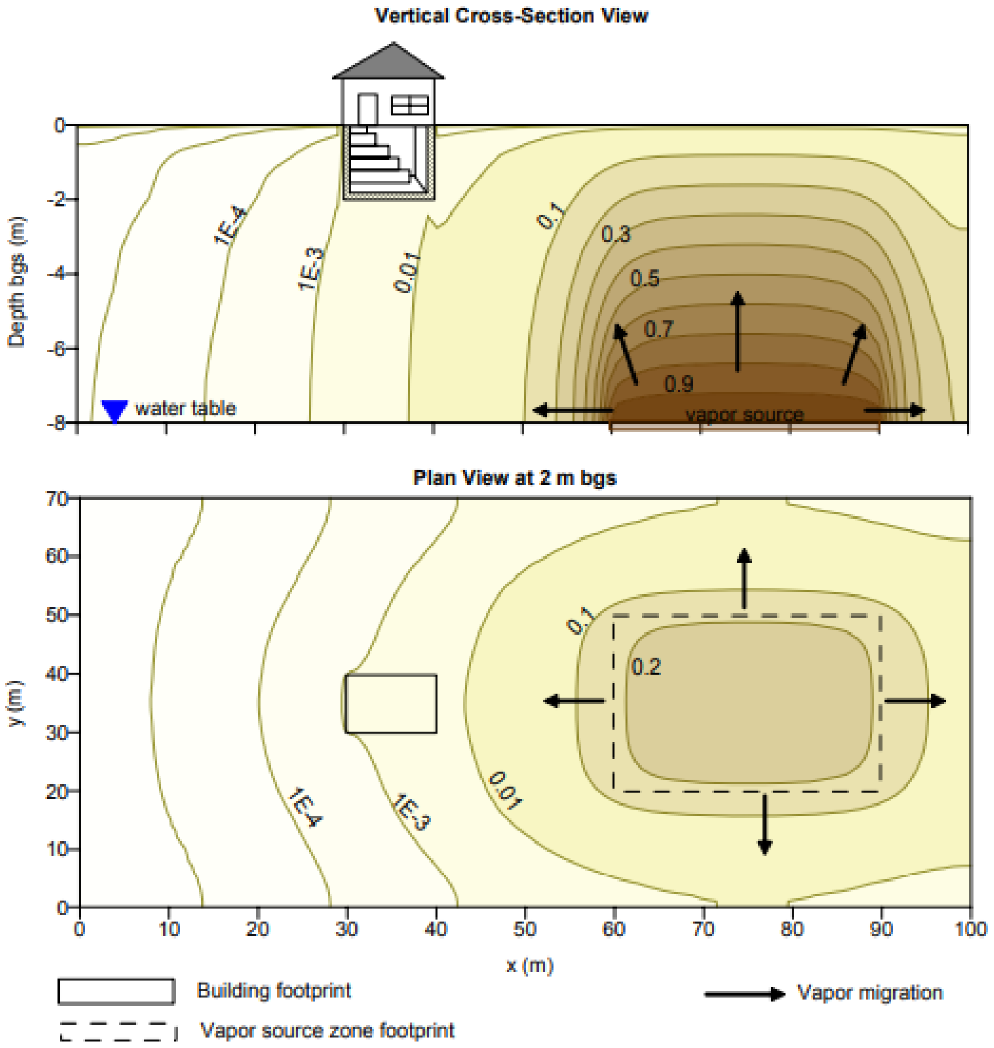
Vapor Intrusion Attenuation

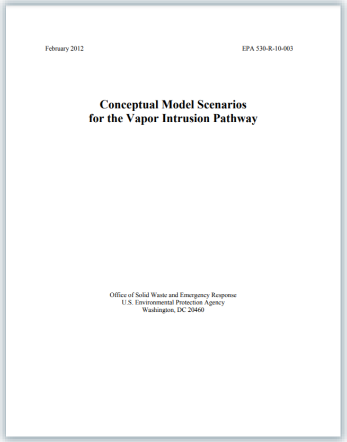
The **vapor attenuation factor** (AF or *α*) "*…defined as the ratio of the indoor air concentration arising from vapor intrusion ([IA]) to the subsurface soil vapor concentration ([SV]) at a point or depth of interest in the vapor migration pathway.*" (USEPA, 2012)

$$AF = \frac{[IA]}{[SV]} \quad \text{or} \quad [SV_{SL}] = \frac{[IA_{SL}]}{AF}$$

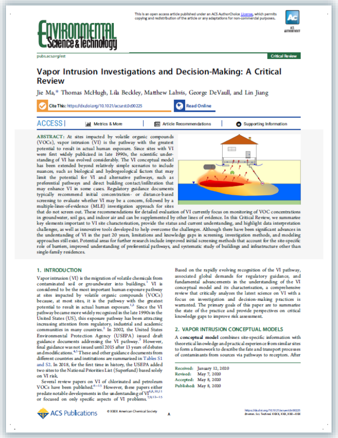


Groundwater to Indoor Air

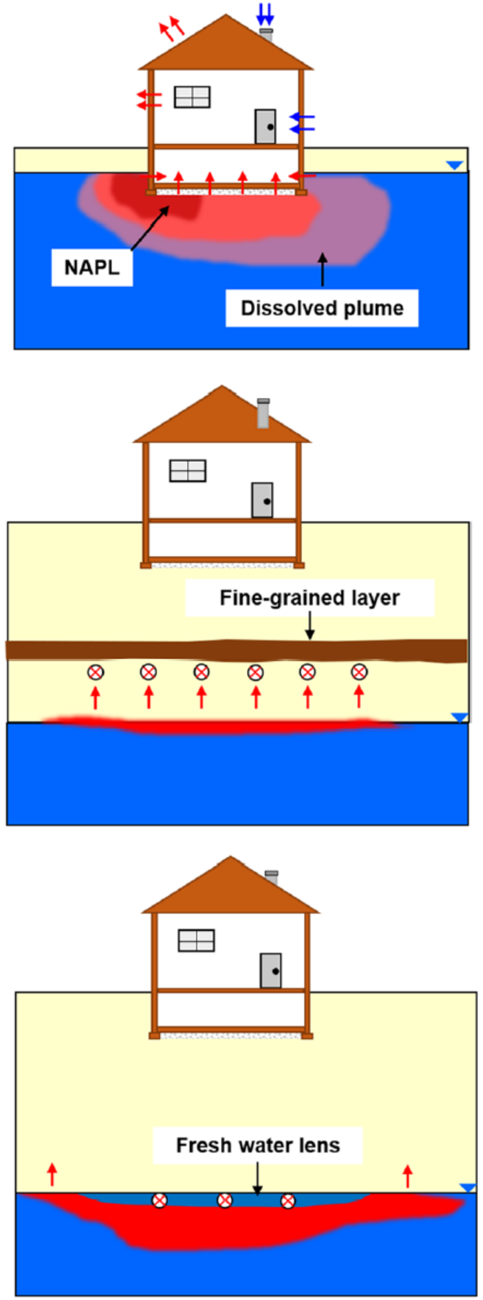




Reference: USEPA, 2012



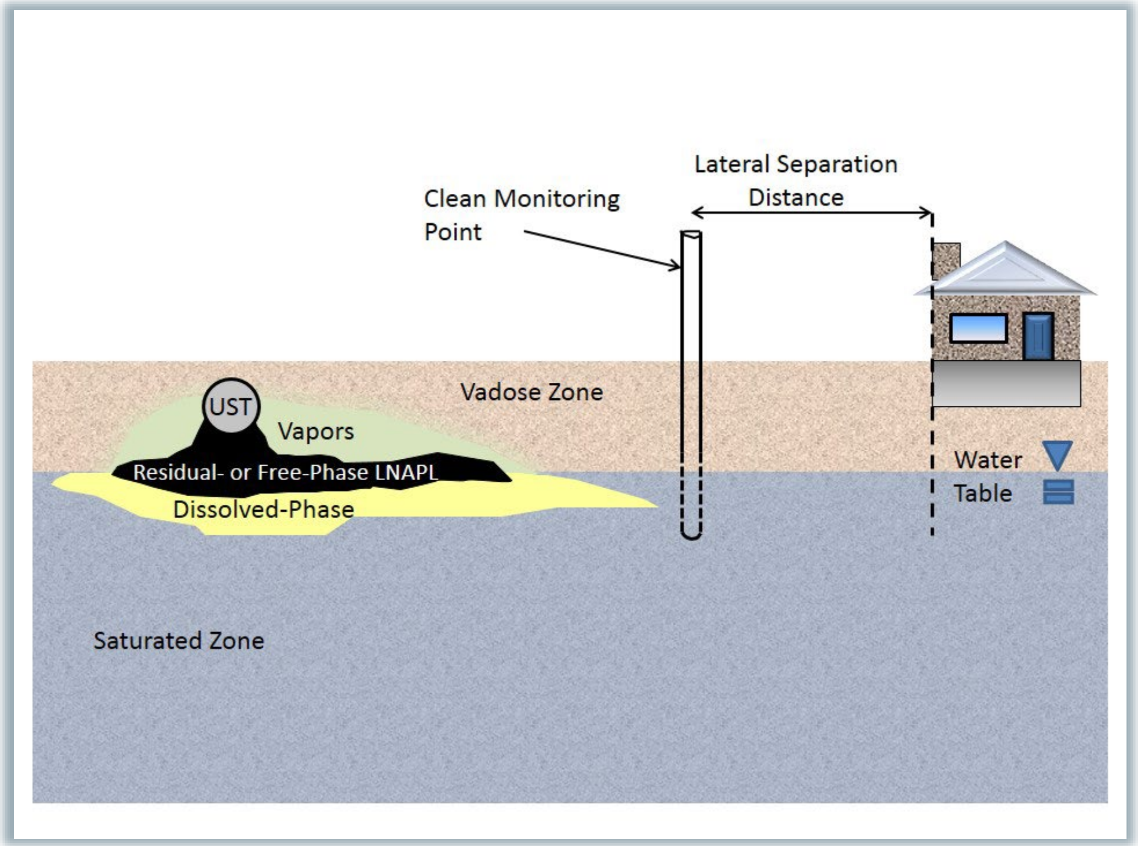
Reference: Ma et al., 2020, *Figure 1C, 2B, 2C*



Reference: USEPA, 2012, Conceptual Model Scenarios of the Vapor Intrusion Pathway

Lateral Separation Distance

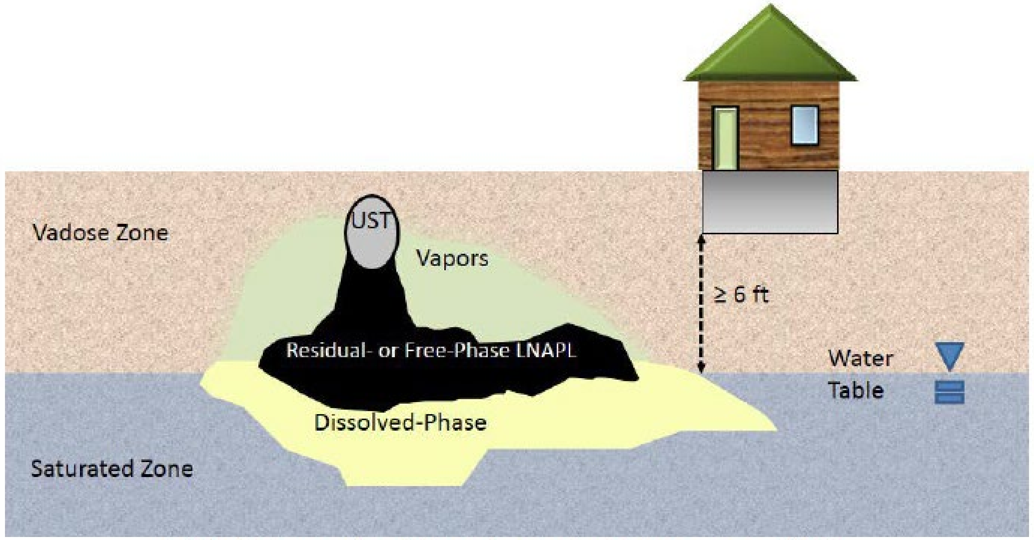
- The lateral separation zone for some PVI* scenarios is **30 feet** from vapor plume edge or a clean monitoring point to building foundation.
- What about chlorinated solvents and other recalcitrant compounds? Is **100 feet** sufficient?



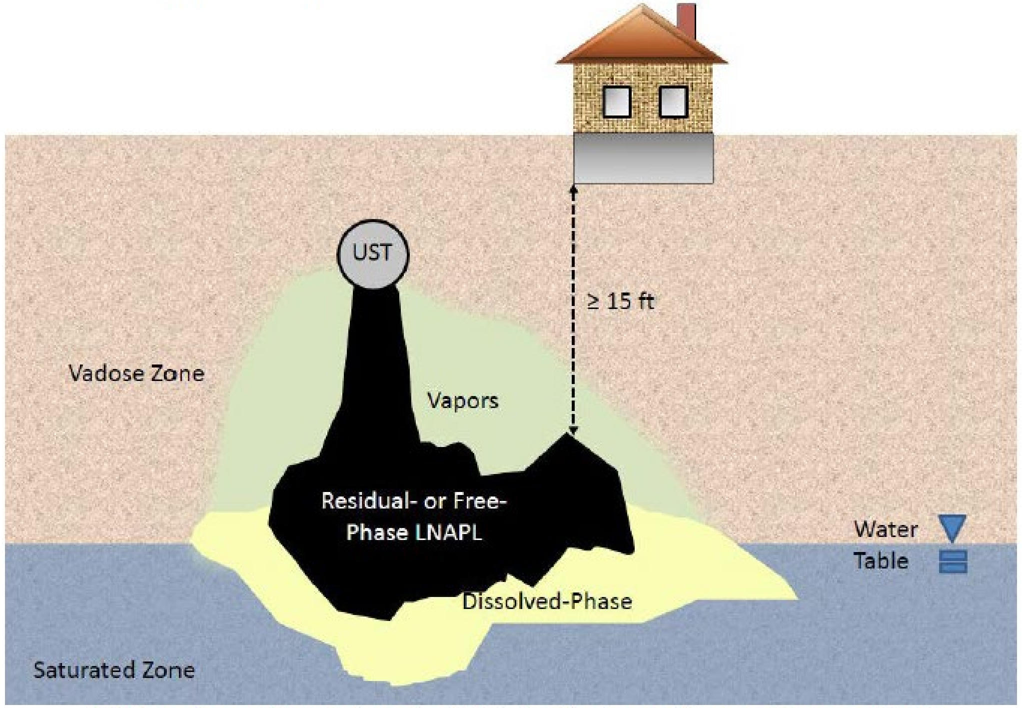
Reference: USEPA (2015), Technical Guide For Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites

Vertical Separation Distance

- Vertical separation distance for PVI* of **6 to 15 feet** from subsurface impacts to building foundation based on source type.
- What about more recalcitrant compounds?



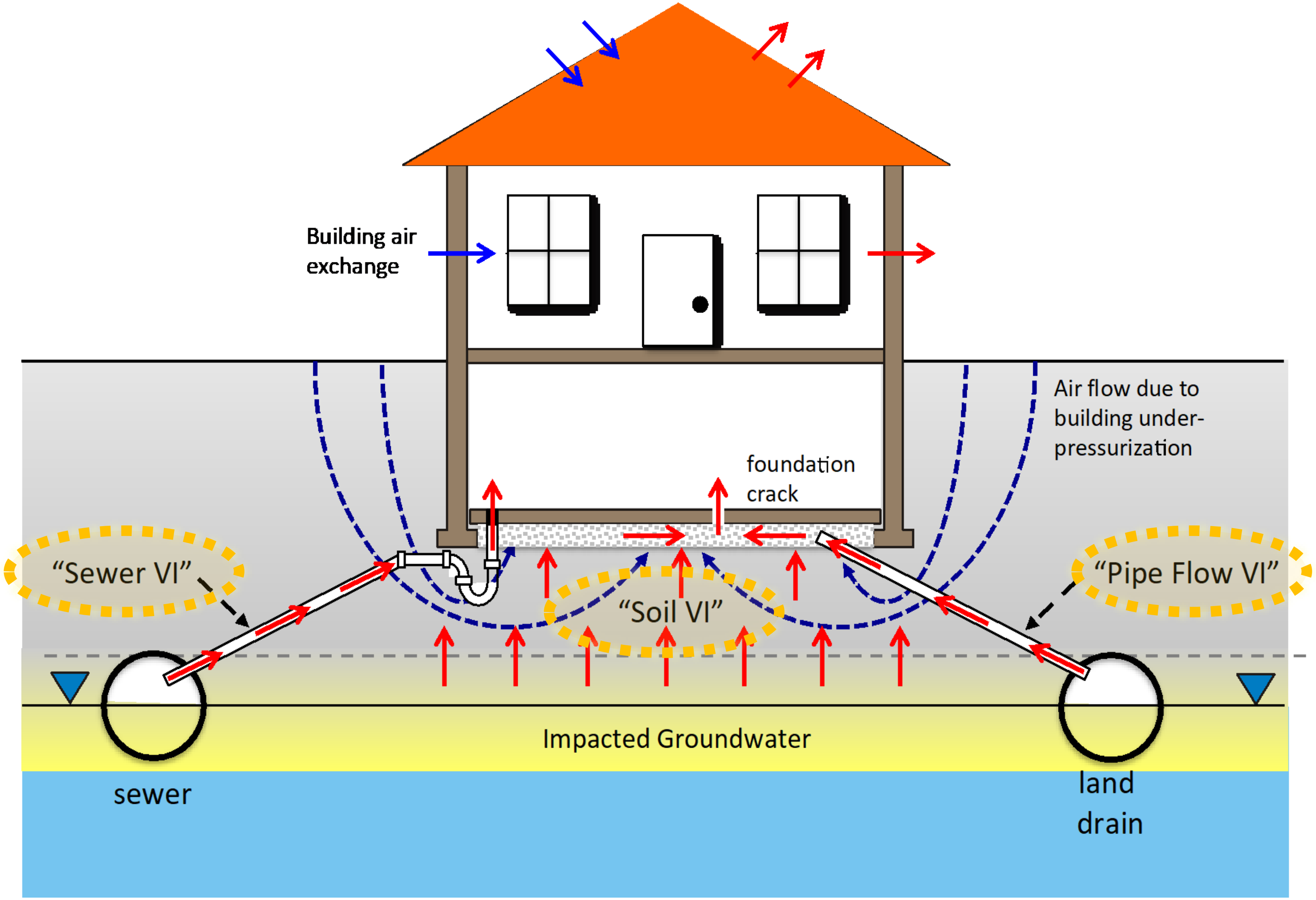
(a) Vertical separation distance for dissolved-phase source of PHCs.



(b) Vertical separation distance for LNAPL (residual or mobile phase) source of PHCs.

Reference: USEPA (2015), Technical Guide For Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites

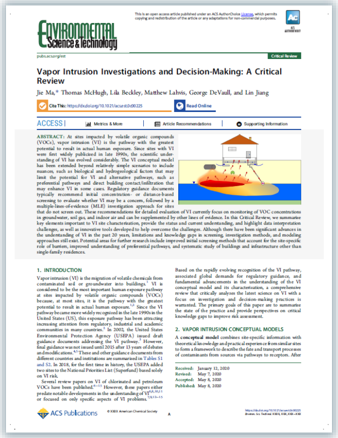
Vapor Intrusion Pathways



Reference: Adapted from Guo et al. (2015), *Environmental Science & Technology*

Conduit Pathways

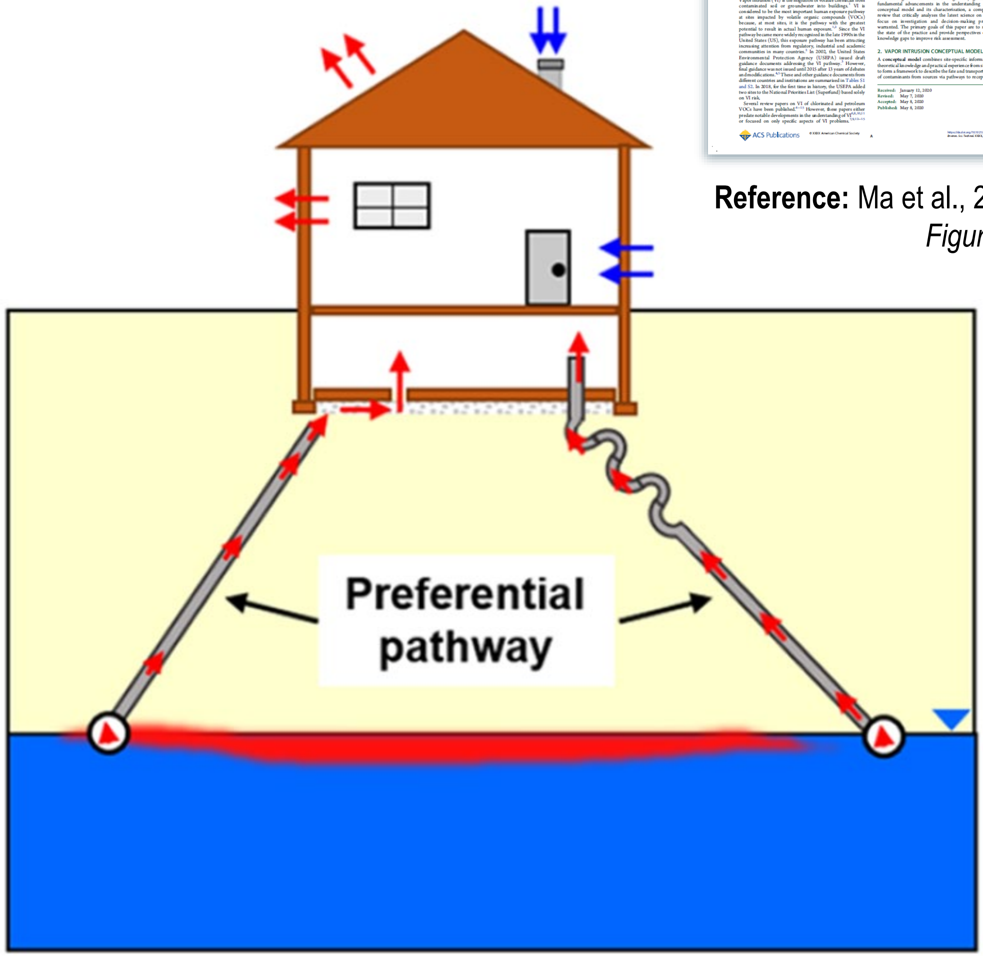
- Preferential or ***conduit pathways***, such as sanitary sewers, can serve as VI pathways and can be difficult to identify using conventional investigation tools.

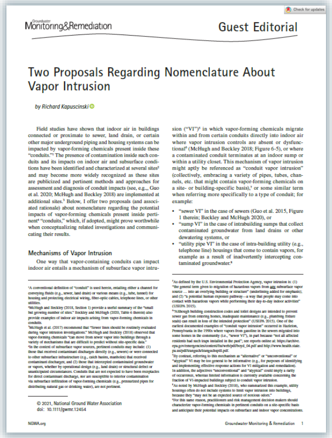

Environmental Science & Technology

Critical Review

Vapor Intrusion Investigations and Decision-Making: A Critical Review

Reference: Ma et al., 2020, *Figure 1B*




Groundwater Monitoring&Remediation

Guest Editorial

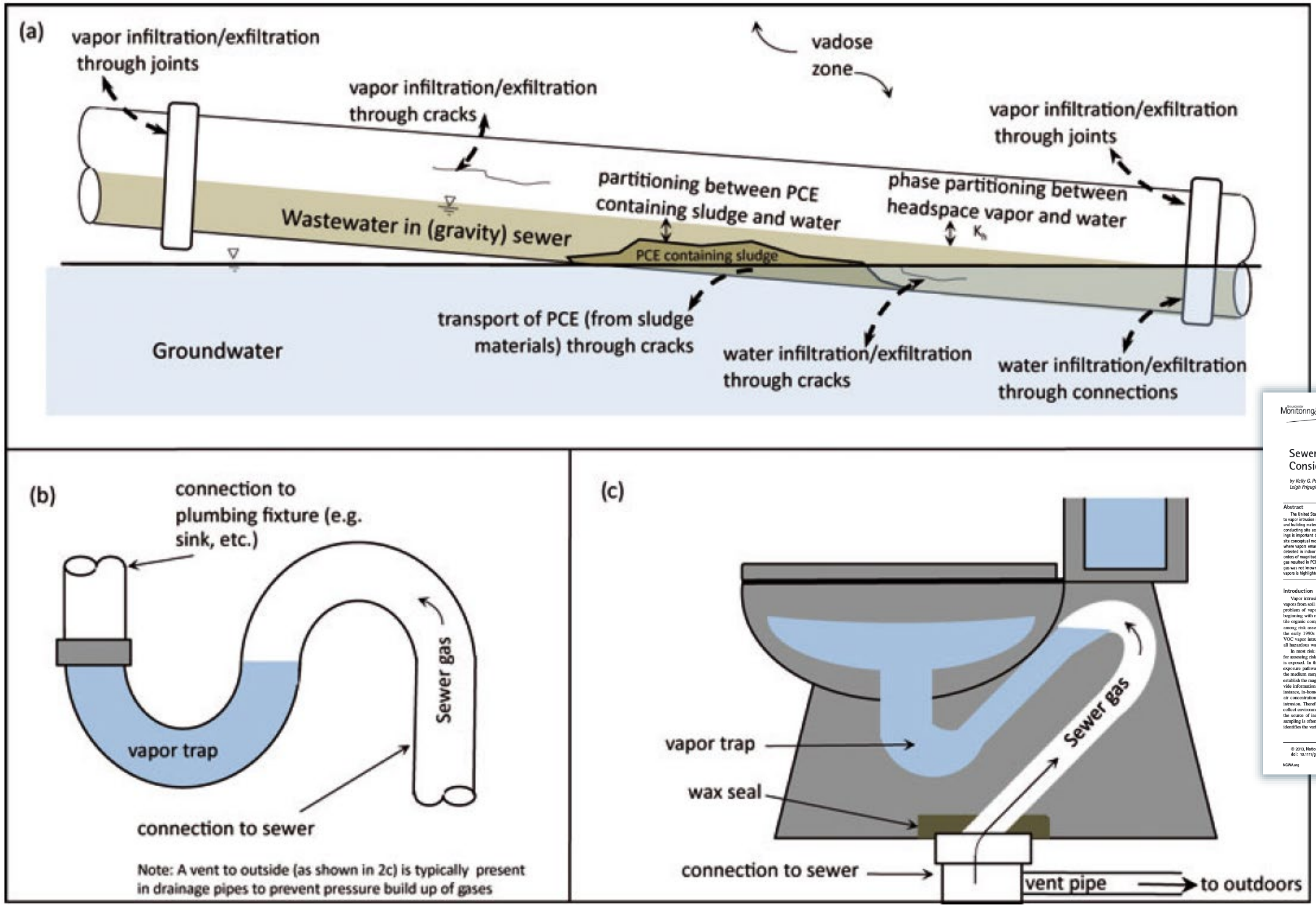
Two Proposals Regarding Nomenclature About Vapor Intrusion

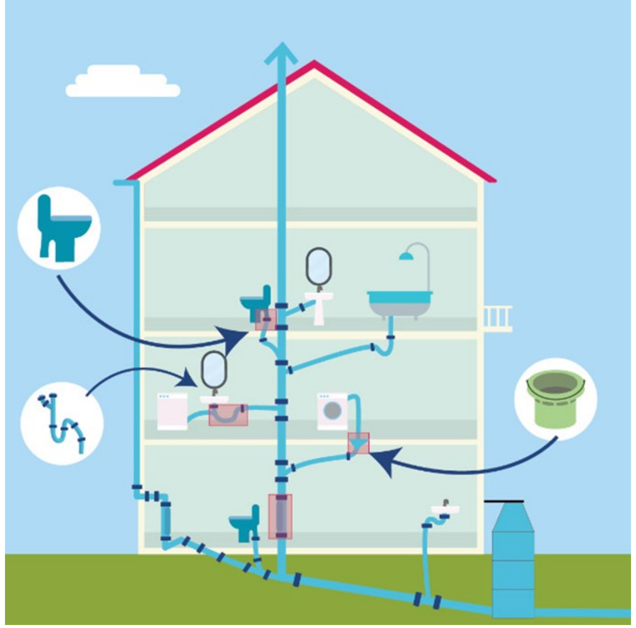
by Richard Kapuscinski

Conduit vapor intrusion "*refer[s] specifically to instances where vapor-forming chemicals migrate within and from conduits directly into indoor air.*"

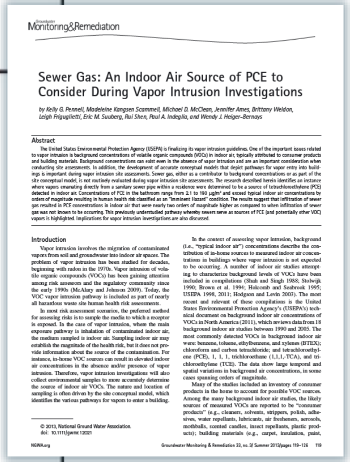
Reference: Kapuscinski, 2021

Sewer Vapor Intrusion





Reference: Nielsen and Hvidberg, 2017


Monitoring&Remediation

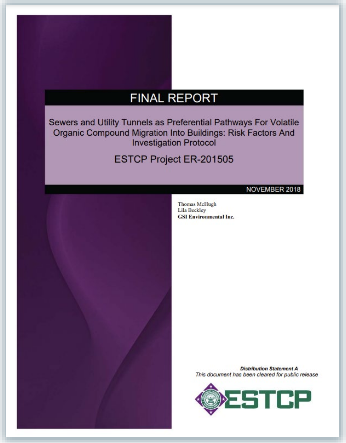
Sewer Gas: An Indoor Air Source of PCE to Consider During Vapor Intrusion Investigations

Reference: Figure 2, Pennell et al., 2013, Sewer Gas: An Indoor Air Source of PCE to Consider During Vapor Intrusion Investigations.

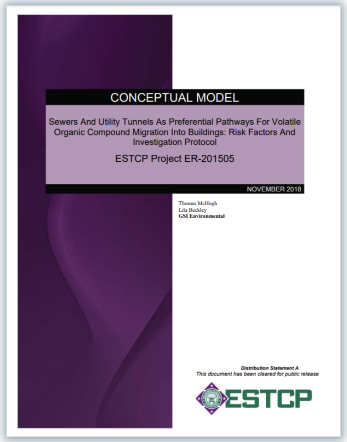
Sewer Vapor Intrusion

Results from ESTCP Project ER-201505:

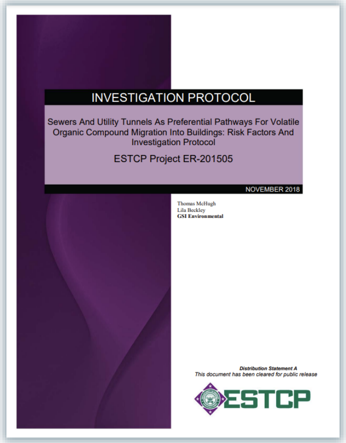
“Sewers and Utility Tunnels as Preferential Pathways for Volatile Organic Compound Migration Into Buildings: Risk Factors and Investigation Protocol”



Final Report ESTCP Project ER-201505, Beckley and McHugh, 2018



Conceptual Model ESTCP Project ER-201505, Beckley and McHugh, 2018

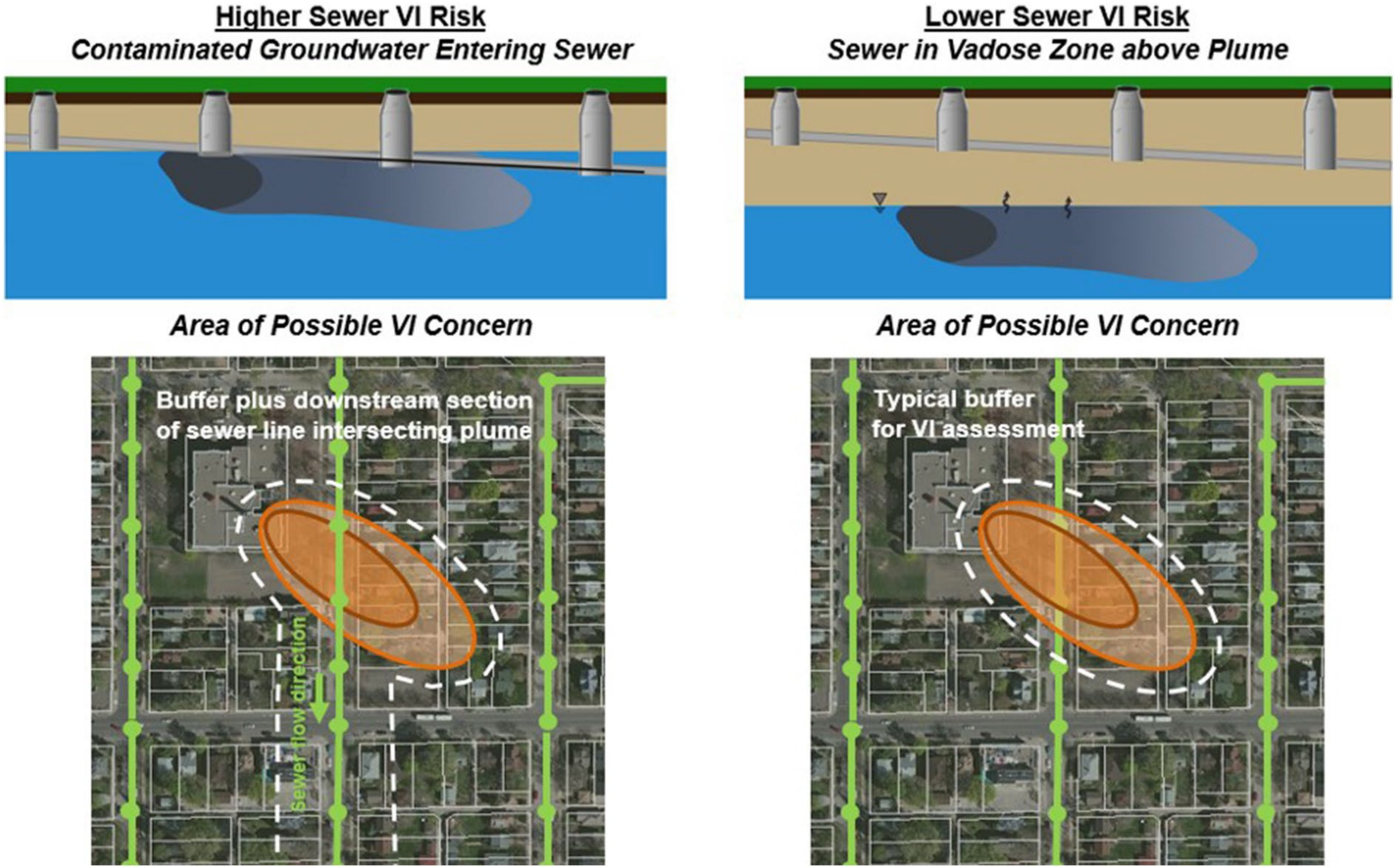


Investigation Protocol ESTCP Project ER-201505, Beckley and McHugh, 2018

A Conceptual Model for VI from Groundwater through Sewer Lines: Beckley and McHugh 2020

Sewer Vapor Intrusion

Higher and Lower VI Risk Scenarios

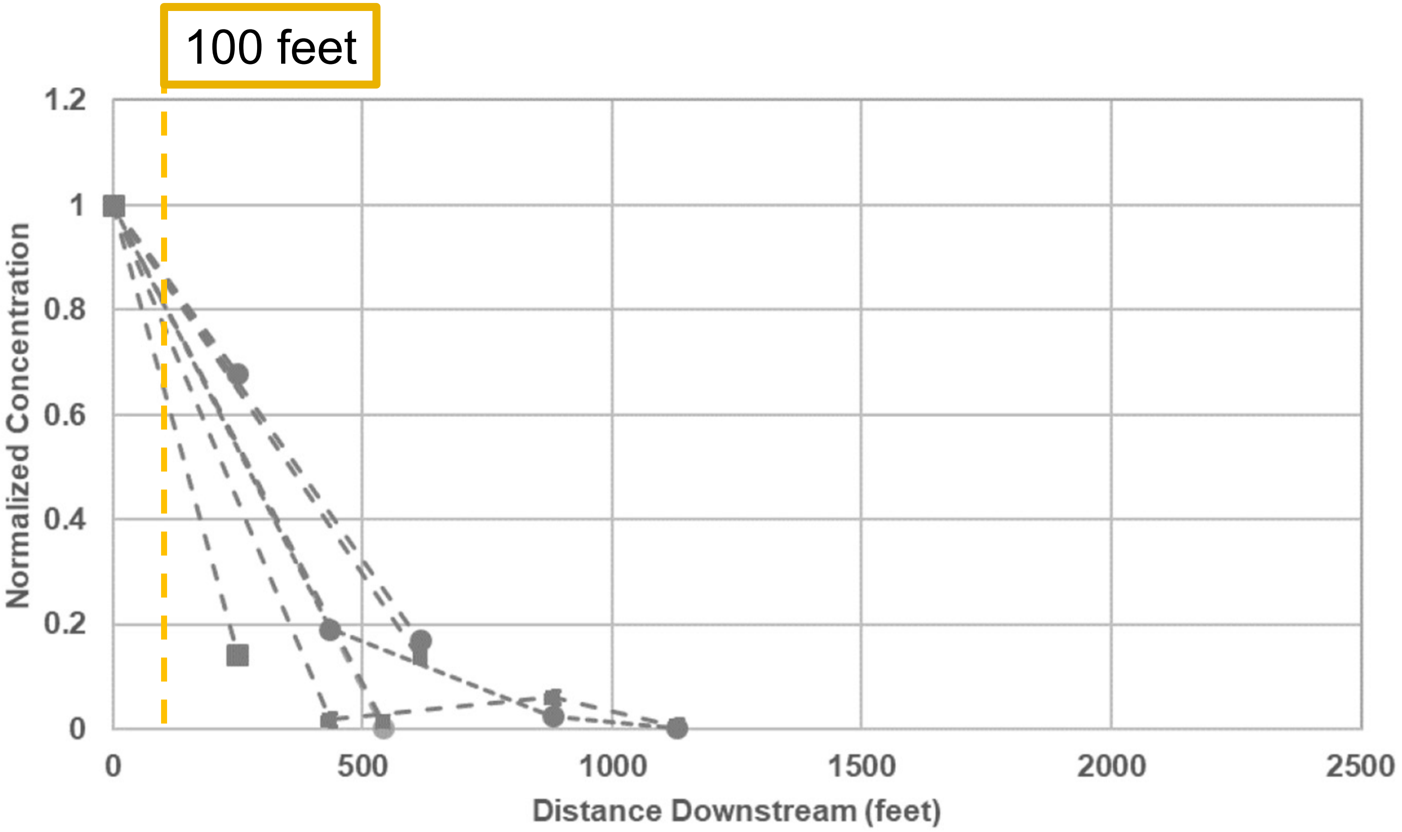


Reference: Figure 2, Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Sewer Vapor Intrusion

Downstream Attenuation – Sewer Line Above Water Table

(indirect interaction)

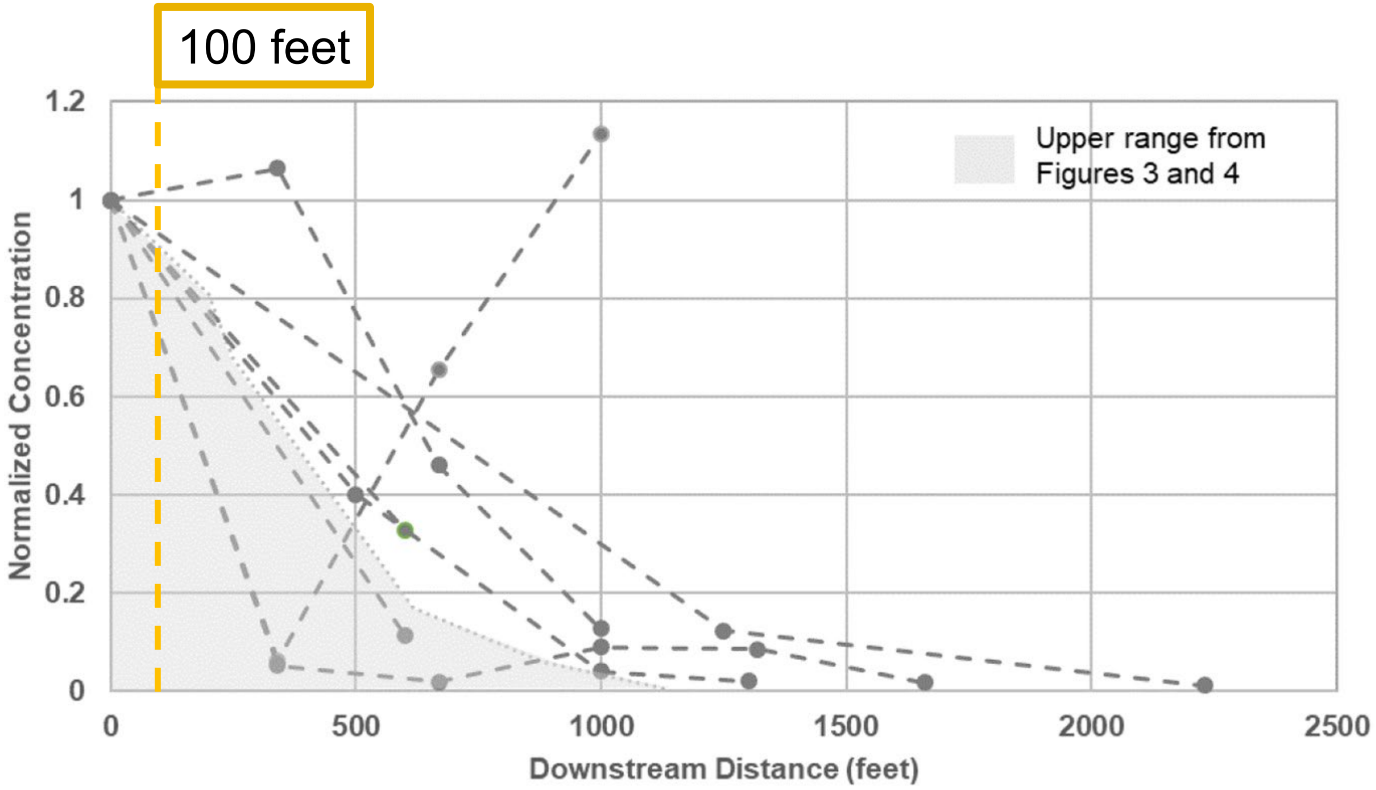


Reference: Figure 3, Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Sewer Vapor Intrusion

Downstream Attenuation – Sewer Line Below Water Table

(direct interaction)



Reference: Figure 5, Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Sewer Vapor Intrusion

Groundwater-to-sewer attenuation factors

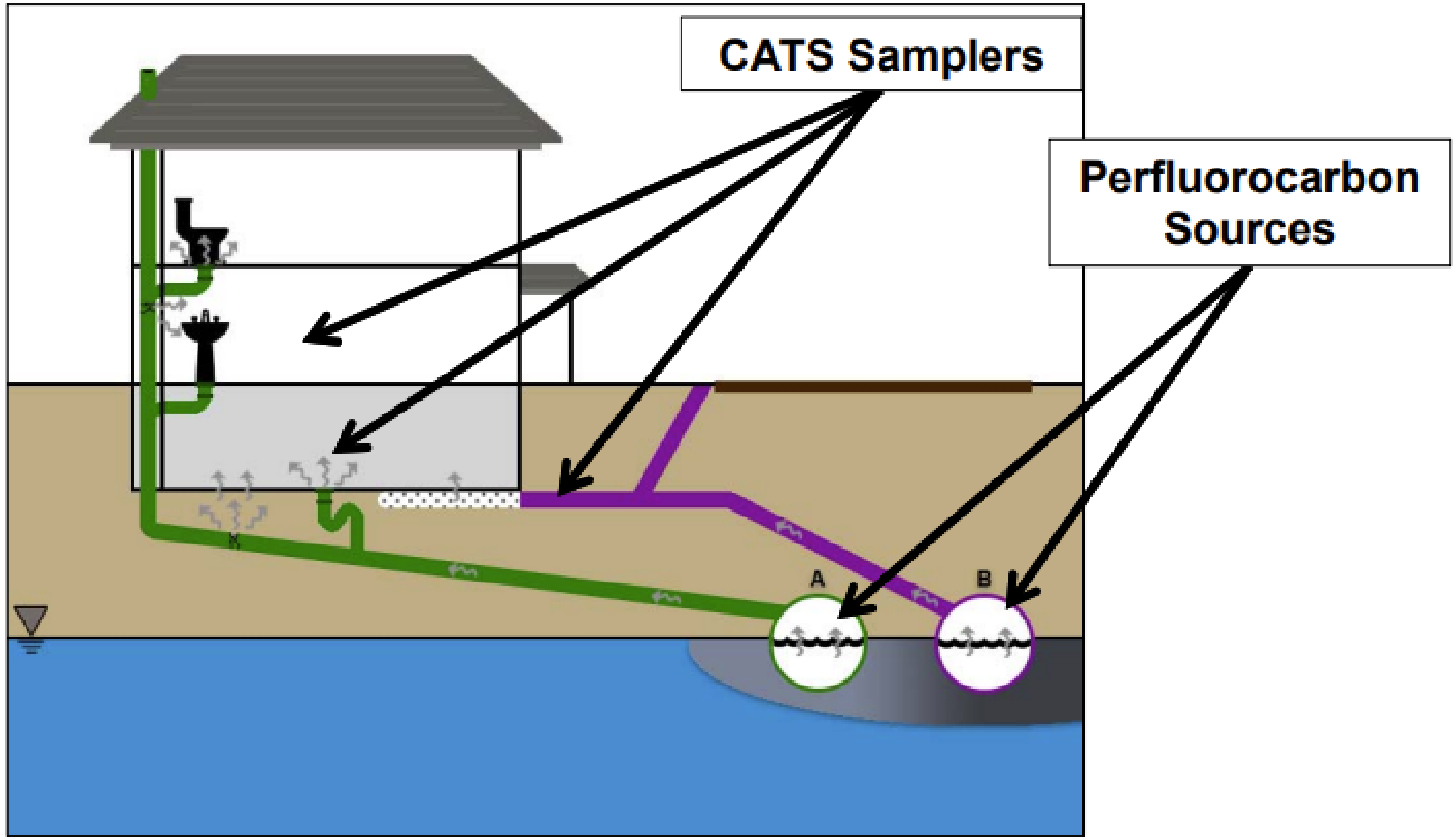
Site category	No. plumes	No. AFs	Attenuation factor	Attenuation
			Median (10th – 90th percentiles) [Note 1]	Median (10th – 90th percentiles) [Note 2]
A: direct interaction (sewer at or below water table)	6	59	1.3E−02 (6.7E−05–7.3E−02)	80× (15,000×–14×)
B: indirect interaction (sewer above water table)	28	137	1.3E−04 (1.9E−06–5.5E−03)	7900× (520,000×–180×)

Notes: 1) Attenuation factor calculated as sewer vapor concentration divided by equilibrium groundwater concentration. 2) Attenuation is the inverse of attenuation factor.

Reference: Table 4, Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Sewer Vapor Intrusion

Sewer-to-indoor air attenuation factors



Sewer Vapor Intrusion

Sewer-to-indoor air attenuation factors

Table 5
Sewer to building attenuation.

Sewer type	Building type	Range of attenuation [Note 1]
Buildings with known sewer preferential pathways (specific pathway in italics)		
Land drain (upstream)	*Residence (ASU VI research house)*	*40–70×*
Sanitary sewer (upstream)	*Residence (ASU VI research house)*	*40–60×*
Storm/sanitary sewer (upstream)	Residence (USEPA VI research duplex)	160–>1000×
Storm/sanitary sewer (downstream)	*Residence (USEPA VI research duplex)*	*50–100×*
Buildings without known or suspected sewer pathways		
Sanitary sewer	Residence (Houston duplex #1)	150–790×
Sanitary sewer	Residence (Houston duplex #2)	470–590×
Sanitary sewer (upstream)	Residence (San Rafael house #1)	90–110×
Sanitary sewer (upstream)	Residence (San Rafael house #2)	20–50×
Sanitary sewer (downstream)	Residence (San Rafael house #1)	>1000×
Sanitary sewer (downstream)	Residence (San Rafael house #2)	>1000×
Sanitary sewer	Residence (NASCC area 1 apartment)	>1000×
Sanitary sewer	Office/storage building (Moffett bldg 107)	>1000×
Sanitary sewer	Office/lab building (San Diego)	>1000×
Sanitary sewer	Hospital (NASCC area 2)	>1000×
Sanitary sewer	Office building (NASCC area 3)	>1000×
Sanitary sewer	Shop building (NASCC area 3)	>1000×
Sanitary sewer	Office building (NASCC area 4)	>1000×
Sanitary sewer	Office building (Burlingame)	550–>1000×
Sanitary sewer	Warehouse (Houston)	50–470×

Reference: Table 5, Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Sewer Vapor Intrusion

Sewer-to-indoor air attenuation factors:
Sun Devil Manor, residential house, Layton, UT

Sewer/Building Combination Tested:	***Land Drain Manhole to House***	***Sanitary Sewer Manhole to House***
Attenuation	20x – 40x	60x – 80x

Reference: Table 5**,** Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Summary

- Consider all source types
- Consider conduit pathways before application of lateral and vertical separation distances
- VOCs may migrate >100 feet via conduit pathways
- Attenuation of >33x generally expected from sewer vapor to indoor air based on tracer studies

Questions and Discussion

Email: *cwholton@gsi-net.com*

Extra Slides

Conduit Vapor Intrusion