Vapor Intrusion Overview

Mike Maddigan (DEP)
Vapor Intrusion Guidance Training

January 10, 2017
Malvern, PA
VI Guidance Training

• Overview: (Mike Maddigan, DEP)
  ✓ New key terms
  ✓ New evaluation options

• Evaluating the VI Pathway (Mike Maddigan, DEP)

• VI Screening (Colleen Costello, GHD)

• Mitigation, remediation, & modeling (Carolyn Fair, DEP)

• VI sampling techniques (Chuck Campbell, Leidos)

• Case Study (David Brown, DEP)
What to Expect from this Training

• Introduction to new terms and concepts
• A general understanding of the process for addressing the VI pathway under Act 2

• Questions will arise as you apply the guidance to your sites
  – Learning through experience
  – Communication is key
Why do we care about VI?

- Volatile substances in soil or groundwater can result in vapor phase intrusion of these substances into inhabited buildings, posing a threat to human health.

- This guidance details how to evaluate the threat under the Statewide Health Standard (SHS) and the Site-Specific Standard (SSS).
What is Vapor Intrusion?

• Vapor Intrusion (VI) is not a medium like soil and groundwater.
• VI is a pathway between contamination of a volatile substance and a receptor in a building.
• VI is primarily associated with volatile organic compounds (VOCs) and some semi-volatile organic compounds (SVOCs)
Indoor Air VI Sources

- Indoor sources (i.e.
  - attached garages,
  - basements, etc.)
- Ambient Air
  - Downwind of VOC source
- Vapor Intrusion
  - Soil
  - Groundwater
Vapor Intrusion Overview

Transport occurs through:
- Concentration gradient
- Pressure gradient
- Temperature gradient
Implementation of New Guidance

- Published in PA Bulletin November 19, 2016
- 60-day implementation period
- Effective January 18, 2017
- How to implement for projects mid-stream?
Implementation of New Guidance

When Use of New Guidance is Expected:

- “…where the RI or SCR is expected to be submitted following the effective date…”

- “If this VI guidance becomes effective prior to the Department receiving an FR or RACR, then the remediator is expected to complete the FR or RACR using this VI guidance.”

(see guidance page 2)
Implementation of New Guidance

When Old Guidance Applies:

• Reports approved by the Department will not need to be resubmitted under new guidance

• An FR or RACR has been received by the Department prior to effective date of new guidance
Implementation of New Guidance

Application of VI guidance is the same for Act 2 sites and for storage tanks sites

- Demonstration of attainment of an Act 2 standard is required under Chapter 245
- RACR should explain how VI pathway was addressed
**Vapor Intrusion Overview**

### Figure 5. Statewide Health Standard Vapor Intrusion Assessment Process

#### 1. APPLY ALTERNATIVE VI ASSESSMENT OPTIONS TO POTENTIAL VI SOURCES

**Assess the VI pathway using modeling**
Calculate and screen modeled indoor air concentrations using soil, groundwater, or near-source soil gas data in accordance with Section G.

**Assess the VI pathway with Statewide health standard soil gas or indoor air screening values**
Perform near-source soil gas, sub-slab soil gas, or indoor air screening using the corresponding SHS screening values in accordance with Section G.

#### 2. MITIGATE, TEST, AND IMPLEMENT AN ENVIRONMENTAL COVENANT

Implement in accordance with Section H.

#### 3. REMEDIATE AND REEVALUATE THE VI PATHWAY

Implement in accordance with Section I.

#### 4. SELECT THE SITE-SPECIFIC STANDARD

Follow the SSS process in accordance with Section K.

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**DELINEATE POTENTIAL VI SOURCES**

If soil and groundwater screening value exceedences and SPL are **NOT** within proximity distances of preferential pathways or current or future inhabited structures, **no further VI analysis is necessary.** Address Chapter 250 requirements in accordance with Section I.

If soil or groundwater screening value exceedences or SPL is within proximity distances to preferential pathways or current or future inhabited structures, choose from the following options:
1. **Alternative VI assessment options.**
2. Mitigation with an Environmental Covenant.
3. Remediation and reevaluation of VI pathway.
4. Evaluation of the VI pathway using the site-specific standard.

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**SCREEN FOR POTENTIAL VI SOURCES**

(Address both screens.)

- **Identify Preferential Pathways**
  Identify potential preferential pathways in accordance with Section D.

- **Apply Proximity Distances**
  Apply petroleum and non-petroleum proximity distances as appropriate in accordance with Section E.

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**AT ANY POINT IN THE VI ASSESSMENT PROCESS THE REMEDIATOR MAY MITIGATE, REMEDIATE, OR CHOOSE THE SITE-SPECIFIC STANDARD TO EVALUATE VI IN ACCORDANCE WITH SECTIONS H, I, AND K, RESPECTIVELY.**

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**ADDRESS CH. 250 REQUIREMENTS**

No further VI analysis is necessary. Address Chapter 250 requirements in accordance with Section I.
Vapor Intrusion Overview

Start Here ➤ Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES
Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES
Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS
Sub-Slab Soil Gas Screening
Near-Source Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling

MITIGATION
Environmental Covenant

REMEDIATION
Reevaluate the VI Pathway

SITE-SPECIFIC STANDARD

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250 REQUIREMENTS
No further VI analysis is necessary.
When Can Mitigation be Done?

Mitigation may be used at any time during the evaluation.

Mitigation eliminates the complete pathway between contamination and the receptor.
Key Terms

- Hydrogeologic Zones
- Point of Application (POA)
- Acceptable Soil
- Preferential Pathway
- Proximity Distance
- Separation Distance
- Separate Phase Liquid (SPL)
- Potential VI Source

(Key terms found in Section B of guidance)
Subsurface zones used to

• Define points of application for screening values
• Define sampling intervals for soil, groundwater, and near-source soil gas

The zones also pertain to the way vapors are transported in the subsurface.
Hydrogeologic Zones

INDOOR AIR

GROUND SURFACE

VAPOR-PHASE ADVECTION

VAPOR-PHASE DIFFUSION

SOIL CONTAMINATION

WATER TABLE

GROUNDWATER FLOW

HEATING SEASON CONVECTION
A POA is the location in buildings and in the hydrogeologic zones where screening values are applied.

POAs guide the selection of sampling locations.
**Point of Application**

- $SV_{SOIL}$: Soil Screening Value (SV)
- $SV_{GW}$: Groundwater SV
- $SV_{IA}$: Indoor Air SV
- $SV_{SS}$: Sub-slab SV
- $SV_{NS}$: Near-source SV
Acceptable Soil or Soil-like Material

- Unconsolidated material in the vadose zone above a potential VI source that does not exceed the saturated hydraulic conductivity of sand or air-filled porosity of silt

- Fill material that is soil-like

- Soils and fill coarser than sand or with air-filled porosity greater than silt may not be acceptable soil
Acceptable Soil

Why is acceptable soil important?

• Impacts the use of groundwater screening values.
• Impacts the use of petroleum vertical proximity distances
• Impacts the application of separation distances for preferential pathways
Warning signs that soil may not be acceptable:

- Show obvious signs of contamination by substances of VI concern such as staining and odor
- Exhibit field screening readings in the headspace above soil samples >100ppmv
- Show evidence of SPL
- Have exceedances of soil screening values
• When applying the petroleum vertical proximity distances, acceptable soil also should exhibit >2% oxygen in soil gas near the building slab.
A natural or man-made feature that enhances vapor migration from a VI source to a building.

The feature must be close to both the contamination and the building and have sufficient volume in order to be a preferential pathway.

Two types:

- External Preferential Pathway
- Significant Foundation Opening
External Preferential Pathway

• A channel or conduit that allows greater vapor flow than ordinary diffusion through vadose zone soil.

• Sewer lines, utility trenches with permeable backfill
Significant Foundation Opening (SFO)

• A breach in the building foundation or basement wall that increases the entry of subsurface vapors.

• Common foundation openings (sumps, French drains, floor drains) are NOT SFOs

• Large foundation cracks, dirt floors, etc. are considered SFOs
Impact of Preferential Pathways

• VI pathway evaluation options are limited if preferential pathways are identified
  – Restricted use of proximity distances
  – Restricted use of some screening values
The minimum distance which a potential VI source must be from a building to not pose a potential unacceptable VI risk.

• Applies to current and planned future buildings

• Cannot be used if a preferential pathway is present
Proximity Distances

Horizontal:
- 30 feet for petroleum substances
- 100 feet for non-petroleum substances

Vertical:
- 5 feet for petroleum adsorbed-phase or dissolved-phase
- 15 feet for petroleum SPL
- None for non-petroleum substances
Separation Distance – The minimum distance which a potential VI source must be from an underground feature for it not to be considered to be a preferential pathway

30 feet horizontal

5 feet vertical

Separation distances are the same for petroleum and non-petroleum constituents
Comprised of non-aqueous phase liquid (NAPL) present in the void space in a contaminated medium such as soil or bedrock

Separate phase liquid (SPL) is physically separate from the portion of the substances that are adsorbed onto or diffused into soil, bedrock, water or air
Importance of SPL

• SPL may be a potential VI source if it contains substances of VI concern.
• SPL can limit the applicability of some screening values within applicable proximity distances.
• SPL limits the use of modeling.
Importance of SPL

SPL limitations to SV use and modeling

• SPL on water table or in associated smear zone – $SV_{GW}$ and modeling unavailable for GW data collected from SPL footprint area

• Residual SPL in soil – $SV_{SOIL}$ and modeling unavailable for data collected from residual SPL impacted soil

• $SV_{GW}$, $SV_{SOIL}$, and modeling can be used on data collected outside limits of the SPL
Importance of SPL

Residual Soil SPL

• Partitioning model used to calculate $SV_{SOIL}$ and soil-to-GW values based on partitioning from soil $\rightarrow$ pore water $\rightarrow$ gas, not directly from SPL

• $SV_{NS}$ can be used for samples collected in soil collected directly above the residual soil SPL
Separate Phase Liquid
Contamination by a substance of VI concern under at least one of the following conditions:

- Soil and/or groundwater exceeding SHS VI screening values within proximity distances
- SPL within proximity distances
- In the presence of a preferential pathway
A Potential VI Source identifies the areas of a site where VI should be addressed.

Can be addressed through alternative assessment options, remediation, mitigation, or an activity and use limitation (AUL).
TRUE or FALSE

1. A gravel or stone bed beneath a foundation would be considered acceptable soil or soil-like material.
TRUE or FALSE

1. A gravel or stone bed beneath a foundation would be considered acceptable soil or soil-like material.

   FALSE

   Gravel or stone exceeds the saturated hydraulic conductivity of sand or the air-filled porosity of silt.
TRUE or FALSE

2. The presence/absence of preferential pathways impacts the use of vertical proximity distances.
TRUE or FALSE

2. The presence/absence of preferential pathways impacts the use of proximity distances.

TRUE

Proximity distances are based on attenuation through soil.
Evaluating the VI Pathway

Key Terms

Where is the Vadose Zone?
Key Terms Review

Where is the Vadose Zone?
Where is the POA for GW?
Key Terms Review

Where is the POA for GW?
Key Terms Review

Where is the POA for NS?
Where is the POA for NS?
Key Terms Review

Where is the POA for SS?
Key Terms Review

Where is the POA for SS?
Is this a Potential VI Source for this building?

- Saturated zone
- 200 Feet
- 3 feet
YES It is outside of the horizontal proximity distance, but there is an external preferential pathway.
Limitations

- Outdated soil and GW VI screening values
- Limited options if data did not screen out
- VI Modeling guidance is limited
- No distinction between petroleum and non-petroleum VI
- Minimal sampling guidance
- Addressed only existing buildings
What Has Changed

• Eliminated 5-ft depth limit for use of screening values when not applicable
• Added detailed guidance for sampling
• Added detailed guidance for modeling
• Added discussion of petroleum VI
• Added alternative assessment options: sub-slab and near-source soil gas screening
What Has Changed

• Introduction of petroleum and vertical proximity distances
• Detailed information on preferential pathways
• Improved method of calculating screening values – accurate, up to date values
• More screening options
  – near-source soil gas,
  – sub-slab soil gas
• Detailed explanation of how to address VI under the SSS
• Guidance for using a combination of standards
• Explanation of how to use AULs/ECs for VI
Ability to Address Future Buildings

- Planned future buildings treated the same as existing buildings – should be addressed
- Can address future VI issues using near-source soil gas sampling, AULs, and modeling
- Unplanned future buildings can be addressed with AUL – at the remediator’s discretion; is not required
Questions?
Evaluating the VI Pathway

Carolyn Fair (DEP)
Vapor Intrusion Training

January 10, 2017
Malvern, PA
Start Here

Conceptual Site Model
Delineate Contamination

DELINATE POTENTIAL
VI SOURCES

Soil and Groundwater Screening

SCREEN FOR POTENTIAL
VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI
ASSESSMENT OPTIONS

Sub-Slab Soil Gas Screening
Near-Source Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling

Mitigation, Remediation, or Use
of the Site-Specific Standard
are Permitted at Any Time

ADDRESS CH. 250
REQUIREMENTS

No further VI analysis
is necessary.

MITIGATION

Environmental Covenant

REMEDIATION

Reevaluate the VI Pathway

SITE-SPECIFIC STANDARD

SHS VI Evaluation Process

Not all steps will be necessary.
The process does not have to be followed sequentially.
Address VI pathway using cumulative risk assessment

NS, SS, IA screen using 1/10th of SHS SVs or EPA RSL values

Mitigation or Remediation to Address VI under the Site-Specific Standard in Accordance with Section K.6 is permitted at any time

Address CH. 250 Requirements
No further VI analysis is necessary.
Start Here

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Delineate Contamination

DELINEATE POTENTIAL
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MITIGATION

Environmental Covenant

REメディATION

Reevaluate the VI Pathway

ADDRESS CH. 250
REQUIREMENTS

No further VI analysis is necessary.

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time
Small Petroleum Releases

- petroleum release to surface or subsurface soil
- full site characterization has not been performed

Remediator may attain the Statewide health standard through § 250.707(b)(1)(iii)

No VI Evaluation
Identify Preferential Pathways
Apply Proximity Distances
SCREEN FOR POTENTIAL VI SOURCES

No further VI analysis is necessary.

ADDRESS CH. 250 REQUIREMENTS
No further VI analysis is necessary.

SHS VI Evaluation

Start Here
Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES
Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES
Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS
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MITIGATION
Environmental Covenant

REMEDICATION
Reevaluate the VI Pathway

SITE-SPECIFIC STANDARD

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

 pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
SHS VI Evaluation

Start Here

Conceptual Site Model
Delineate Contamination

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No further VI analysis is necessary.
Start Here

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Delineate Contamination

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VI SOURCES
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Environmental Covenant

REMEDIATION
Reevaluate the VI Pathway

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ADDRESS CH. 250
REQUIREMENTS
No further VI analysis
is necessary.
CSM Goal:
To describe how site characteristics influence the distribution of VOCs in soil gas and indoor air.

Identify/Delineate whether a potential VI source is present

What is a potential VI source?

[Section C.1]
CSM represents:

- contaminant sources
- migration pathways
- exposure mechanisms
- potential receptors

Determine if a potential VI source is present by investigating proximity distances, external preferential pathways, and significant openings.
This screening step is performed concurrently with the previous step because the proximity distances apply to locations where the soil and groundwater VI screening values are exceeded.
Components of the CSM

• Source description
• Contaminants of Concern
• Soil and Groundwater Data
• Migration pathways
• Preferential pathways
• Fate and transport
• Building construction/characteristics
• Receptors
Additional CSM Considerations

- VOC concentrations decrease as the VOCs move away from the source.
- The degree of decrease is related to:
  - site conditions
  - building characteristics
  - chemical properties

[Section C.1]
Identify Preferential Pathways
Apply Proximity Distances
SCREEN FOR POTENTIAL VI SOURCES
No further VI analysis is necessary.
ADDRESS CH. 250 REQUIREMENTS
No further VI analysis is necessary.

DELINÉATE POTENTIAL VI SOURCES
Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES
Identify Preferential Pathways Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS
Sub-Slab Soil Gas Screening
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MITIGATION
Environmental Covenant

REMEDIATION
Reevaluate the VI Pathway

SITE-SPECIFIC STANDARD
Additional CSM Considerations

• Result in a more rigorous CSM development process than you may be accustomed to

• The level of detail in the CSM should reflect the complexity of the site

• CSM is a **DYNAMIC** tool

  updated as new information becomes available during site characterization
To decide whether VI source is present or not
Proximity Distances

Horizontal:
• 30 feet for petroleum substances
• 100 feet for non-petroleum substances

Vertical:
• 5 feet for petroleum
• 15 feet for petroleum SPL
• None for non-petroleum substances
Petroleum substances are treated differently than non-petroleum substances because of their higher rates of biodegradation.
Acceptable soil

is defined as having greater than 2% oxygen for the purpose of applying proximity distances to petroleum substances – **aerobic condition is required to support biodegradation**

- Not necessary to measure oxygen content unless there is reason to believe it is anaerobic.
  
  (large SPL plume or a very large building over SPL)
Use of Proximity Distances

How Do I Use Them?

• Assess distance from the potential VI source to any existing or planned buildings and

• Assess distance from buildings towards the potential VI source
• Evaluate VI for the *portion* of the exceedances within the proximity distance to the building

the Portion is now your Potential VI Source

• Proximity distances are not applicable if there are no buildings onsite and no future plans for buildings to be constructed
Use of Proximity Distances

Figure 3
SHS VI Evaluation

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL
VI SOURCES
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SCREEN FOR POTENTIAL
VI SOURCES
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MITIGATION
Environmental Covenant

REMEDICATION
Reevaluate the VI Pathway

SITE-SPECIFIC STANDARD

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250
REQUIREMENTS
No further VI analysis is necessary.
Restrictions

• Acceptable soil or soil-like material is needed to be able to use petroleum **vertical** proximity distances

• Proximity distances cannot be used in the presence of an external preferential pathway

• If a significant foundation opening is present, the petroleum **vertical** proximity distances cannot be used
Why are Preferential Pathways Important?

Preferential pathways increase the rate of vapor migration between a source and an inhabited building.

- Less vapor attenuation through soil
- Increased rate of vapor flow to receptors
Professional Judgment and Communication

It is not necessary for remediators to prove the absence of preferential pathways, but a reasonable effort should be made to determine if they are present.

Remediators and PO’s should discuss how preferential pathways should be evaluated at each site.
Some assumptions can be made about buildings and utilities that would allow for an accurate analysis without an overly burdensome intrusive investigation.

- Size and type of utility
- Age of buildings/neighborhoods
- Progressive approach for evaluating external preferential pathways when feasible
Example: High Permeability Backfilled Utility Line

- Remediators **do not** have to **prove the absence** of high-permeability backfill or intact utility lines.
- However, if there is **an indication that these conditions exist** then remediator should evaluate further.
  - Trench for large diameter water line – evaluate further
  - Fiber optic cable line – unlikely to be an issue
Example: Older vs. Newer Housing Development

- Remediators *do not* have to *prove the absence* of dirt floors in a development.
- However, if there is *an indication that these conditions exist* then remediator should evaluate further.
  - Older homes where dirt floors are likely – evaluate further
  - Newer development – dirt floors unlikely to be an issue
TWO TYPES

1. External Preferential Pathway

2. Significant Foundation Opening
External preferential pathway: a channel or conduit that allows for a greater vapor flux than ordinary diffusion through vadose zone soil

✓ Proximity Distances are insufficient to eliminate the source from consideration.

✓ Proximity Distances are based on movement of vapors through soil. In this case, vapors move through material with less attenuation than soil.
Proximity Distance – Measured between potential VI source and building

Separation Distance – Measure between potential VI source and underground feature to determine if that feature is an external preferential pathway
External Preferential Pathways

**Proximity Distance** – Between potential VI source and building
Separation Distance – Between potential VI source and underground feature

➢ to determine if that feature is an external preferential pathway
A feature can be excluded as an external preferential pathway if:

- Any soil or GW contamination exceeding VI screening values is at least 30 horizontal or 5 vertical feet from the feature.
- SPL is at least 30 horizontal or 15 vertical feet from the feature.

OR

- The feature is at least 5 feet away from the foundation.
External Preferential Pathways

Figure 2

Map View
- Exceeds SVs
- Contamination
- Preferential pathway
- Horizontal proximity distance

Side View
- Potential VI Source
- Saturated zone
- 30 ft}

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ft</td>
<td>&lt;5 ft</td>
<td>inhabited building</td>
<td>30 ft</td>
<td>5 ft</td>
</tr>
</tbody>
</table>

Legend:
- A: Exceeds SVs
- B: Contamination
- C: Preferential pathway
- D: Horizontal proximity distance
- E: Saturated zone
- 30 ft: Vertical distance
- <5 ft: Vertical distance

Description:
- A preferential pathway is shown from the potential VI source (A) to the inhabited building (E).
- The horizontal proximity distance is highlighted between the saturated zone and the building.
- The contamination (B) is shown to exceed safe values (SVs) in the vicinity of the building.
**Significant Foundation Openings**

**Significant foundation opening**: enhances vapor entry into buildings

- Large cracks/gaps in the foundation and dirt floors

- **NOT**: Typical cracks, gaps, utility line penetrations – all buildings have them

- **NOT**: Common foundation openings such as sumps, French drains, and floor drains
Significant foundation openings have **one or more** of the following:

- Combined area of openings in foundation surface is \( > 5\% \) of the total foundation area
- Direct indications of contaminant entry into the building (seepage of SPL or groundwater, chemical odors)
- Opening is directly connected to an external preferential pathway (gap around utility line)
VI Evaluation Options when Significant Openings are Present

Visually inspect the foundation and basement walls when possible.

- Sub-slab soil gas samples screened with indoor air screening values (if no dirt floor)
- Indoor air screening – even if contaminated soil, GW, or SPL is in the building

(See Figure 7 for screening value restrictions)
Significant Foundation Openings can be sealed to inhibit the pathway.

Proper Sealing is performed with durable materials so that the former openings are not more transmissive than the rest of the foundation.
**VI Evaluation Options when Significant Openings are Present**

**IF** foundation openings are sealed:

- Soil and GW may be screened with standard screening values
- Near-source soil gas can be screened with near-source screening values
- Sub-slab soil gas can be screened with sub-slab screening values

(See Figure 7 for screening value restrictions)
VI Evaluation Options
When Building Access is Not Possible

• Can still use horizontal proximity distances to evaluate VI even if significant foundation openings are present.
  ✓ This only works if there is no external preferential pathway present.
  ✓ Vertical proximity distances do not apply – based on attenuation across an intact slab.

• Soil data may be screened against generic soil-to-GW values
  (Section D.2, page 18)
VI Evaluation Options
When Building Access is Not Possible

• GW may be screened against used aquifer MSCs
• Near-source soil gas may be screened against Sub-slab values or modeled to predict indoor air
• Modeling may be used by assuming that no slab is present

(Section D.2, page 18)
SSS Evaluation

• Proximity Distances and Preferential Pathways are evaluated in the same manner as under SHS

• SHS screening values still define potential VI source

• Acceptable soil or soil-like materials is also based on SHS screening values
Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES
Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES
Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS
Address VI pathway using cumulative risk assessment
NS, SS, IA screen using 1/10th of SHS SVs or EPA RSL values

MITIGATION
Environmental Covenant

REMEDIATION
Reevaluate the VI Pathway

ADDRESS CH. 250 REQUIREMENTS
No further VI analysis is necessary.

MITIGATION OR REMEDIATION TO ADDRESS VI UNDER THE SITE-SPECIFIC STANDARD IN ACCORDANCE WITH SECTION K.6 IS PERMITTED AT ANY TIME.
SSS Evaluation

- **SHS** $S V_{SOIL}$ and $S V_{GW}$

still define

**potential VI source**
<table>
<thead>
<tr>
<th>Act 2 Standard Used to Address Soil and Groundwater</th>
<th>Use Screening Values in Tables 1–5</th>
<th>Use 1/10 Screening Values in Tables 1–5</th>
<th>Modeling</th>
<th>Risk Assessment</th>
<th>Mitigation with EC (i.e., pathway elimination)</th>
<th>Remediation</th>
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<tr>
<td>Statewide Health Standard (SHS)</td>
<td>✓</td>
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</tbody>
</table>

• Some media and/or substances may attain the SHS while others may attain the SSS.

[Section C.3]
Vapor Intrusion Screening

Colleen Costello (GHD)
C. David Brown (DEP)

Vapor Intrusion Guidance Training

January 10, 2017
Malvern, PA
Identify Preferential Pathways
Apply Proximity Distances

SCREEN FOR POTENTIAL VI SOURCES

No further VI analysis is necessary.

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.

DELINEATE POTENTIAL VI SOURCES

Soil and Groundwater Screening

ALTERNATIVE VI ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION

Environmental Covenant

REMEDIATION

Reevaluate the VI Pathway

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time
• Purpose of vapor intrusion screening:
  - Determine if a Potential VI source is present
  - Screen pathway from source to receptor

• VI Guidance Sections F and G

• Tables 1–5 contain screening values for each of the five POAs
  - Groundwater, Soil, Near-Source Soil Gas, Sub-Slab Soil Gas, and Indoor Air
Main Points (What’s New)

- All screening values have been recalculated
- Most values are now lower
- New, scientifically stronger, methods for determining screening values (SVs)
- New screening value tables for near-source soil gas and sub-slab soil gas
- Site-specific standard SVs established
- New criteria for applying SVs
Overview: Screening Presentation

- General information
- Basis of each type of screening value
- Data requirements
- Limitations
- Application of SVs
- Site-specific standard screening
- Combination of standards
- Site-specific standard RSL tutorial
Appendix A

• Derivation of new Statewide health standard VI screening values (SVs)
• Methodology, equations
• Chemical and toxicological parameters
• New attenuation factors
Some chemicals do not have inhalation toxicity values

- Example: cis-1,2-Dichloroethylene
- VI evaluations are not required
- VI can optionally be addressed with PQLs, mitigation, or remediation
- Remediator might be able to perform a SSS risk assessment (alternative toxicity information)

[Section C.2, Table A-1]
**Attenuation** is the process by which vapor concentrations decrease during migration

- Diffusion in soil
- Soil moisture
- Low-permeability zones in soil
- Biodegradation
- Dilution in indoor air
• **What is an attenuation factor?**
  
  The ratio between a vapor concentration in indoor air and in the subsurface

  \[ \alpha = \frac{C_{IA}}{C_{SG}} \]

  - Concentration units: \( \mu g/m^3 \)
  - Attenuation factors are less than 1
  - Smaller \( \alpha \rightarrow \) more attenuation

• DEP’s SVs are calculated from \( SV_{IA} \) and \( \alpha \)
# VI Screening

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Residential $\alpha_R$</th>
<th>Non-Residential $\alpha_{NR}$</th>
<th>Converted Residential $\alpha_{CR}$</th>
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<tr>
<td>Groundwater</td>
<td>0.0009</td>
<td>0.0003</td>
<td>0.0009</td>
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<tr>
<td>Soil</td>
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<td>0.01</td>
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<td>0.001</td>
<td>0.005</td>
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<td>Sub-slab soil gas</td>
<td>0.026</td>
<td>0.0078</td>
<td>0.026</td>
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</table>

[Table A-4]
Exposure scenarios

- Residential
- Nonresidential
- Converted residential: A building constructed for residential use that is currently used for nonresidential purposes only e.g., a home now used for a shop
- Mixed use: may require using both residential and nonresidential SVs
Data for Screening

• Collect an appropriate amount of data
• Account for spatial, temporal variability
• Use data collection criteria in Table 6
• Recommendations in Appendix C, Section 2
• Satisfy screening conditions in Table 7
• Data may be from characterization, attainment, and/or monitoring
### VI Screening – Figure 7

<table>
<thead>
<tr>
<th>Source</th>
<th>Data Type</th>
<th>Screening Value</th>
<th>Screening Value Use Restriction</th>
<th>Reason for Restriction</th>
</tr>
</thead>
</table>
| Groundwater | Groundwater | SV\textsubscript{GW} | 1. Presence of SPL within appropriate horizontal proximity distance  
2. Presence of a significant foundation opening  
3. Contaminated GW enters an external preferential pathway  
4. GW <$5 \text{ feet below foundation level}$ | 1. SV\textsubscript{GW} values or the used aquifer GW MSCs cannot be used in the presence of SPL because both values assume no SPL is present.  
2. SV\textsubscript{GW} values cannot be used in the presence of significant foundation openings because the calculated SV\textsubscript{GW} values assume the presence of a slab.  
3. SV\textsubscript{GW} values cannot be used when GW enters a preferential pathway because the calculated SV\textsubscript{GW} values assume attenuation through soil.  
4. SV\textsubscript{GW} values cannot be used when GW <$5 \text{ feet below foundation level}$ because the calculated SV\textsubscript{GW} values require at least 5 feet of soil.  
• NOTE: For site-specific standard screening, use 1/10th of the Table 1 or MSC values. |
| Used Aquifer GW MSC | Used Aquifer GW MSC | 1. Presence of SPL within appropriate horizontal proximity distance | | |
| Soil | Soil | SV\textsubscript{SOIL} | 1. Presence of SPL within appropriate horizontal proximity distance  
2. Presence of a significant foundation opening | 1. SV\textsubscript{SOIL} values and the generic soil-to-GW numeric values cannot be used in the presence of SPL because both values assume no SPL is present.  
2. SV\textsubscript{SOIL} values cannot be used in the presence of a significant foundation opening because the calculated SV\textsubscript{SOIL} values assume a slab is present.  
• NOTE: For SSS screening, use 1/10th of the Table 2 or MSC values. |
| Generic Soil-to-GW Numeric Value | Generic Soil-to-GW Numeric Value | 1. Presence of SPL within appropriate horizontal proximity distance | | |
| Near-Source Soil Gas | Near-Source Soil Gas | SV\textsubscript{NS} | 1. Contaminated GW or SPL enters a preferential pathway  
2. Presence of a significant foundation opening  
3. External preferential pathway penetrates the building foundation  
4. Potential VI source is <$5 \text{ feet below foundation level}$ | 1. SV\textsubscript{NS} values cannot be used when contaminated GW or SPL enters an external preferential pathway because the SV\textsubscript{NS} values assume attenuation through soil.  
2. SV\textsubscript{NS} values cannot be used in the presence of a significant foundation opening because the SV\textsubscript{NS} values assume the presence of a slab.  
3. SV\textsubscript{NS} values cannot be used if an external preferential pathway penetrates the building foundation because the SV\textsubscript{NS} values assume the presence of a slab.  
4. SV\textsubscript{NS} values cannot be used if the potential VI source is <$5 \text{ feet below foundation}$ because the SV\textsubscript{NS} values require 5 feet of soil between the source and the foundation.  
5. A comparison of near-source soil gas data to SV\textsubscript{NS} values cannot be performed if the potential VI source is <$5 \text{ feet below grade}$ because shallow soil gas data can be unreliable.  
• NOTE: For SSS screening, use 1/10th of the Table 3 values or use EPA indoor air RSLs with an appropriate attenuation factor. |
| Sub-Slab Soil Gas | Sub-Slab Soil Gas | SV\textsubscript{SS} | 1. Presence of a significant foundation opening  
2. Preferential pathway penetrates the building foundation | 1. The comparison of sub-slab data to SV\textsubscript{SS} is not available in the presence of a significant foundation opening because the calculation of the SV\textsubscript{SS} values assumes the presence of an intact slab.  
2. The comparison of sub-slab data to SV\textsubscript{SS} is not available if an external preferential pathway penetrates the building foundation because the SV\textsubscript{SS} values assume the presence of soil between the source and foundation.  
• NOTE: For SSS screening, use 1/10th of the Table 4 values or use EPA indoor air RSLs with an appropriate attenuation factor. |
| Indoor Air | Indoor Air | SV\textsubscript{IA} | No Restrictions |  |
Basis of Groundwater SVs

- Attenuation factors from EPA’s VI database
- Groundwater VI screening values are no lower than Ch. 250 used aquifer MSCs
- Calculated values or MSCs for \( \geq 5 \) feet depth
- If GW < 5 feet below foundation, only MSCs
- *Note: Table 1 VI SVs have changed since July 2015 draft!*

[Table 1; Appendix A, Section 5]
Data Requirements

• Properly constructed monitoring wells
• Well screens cross the water table
• Wetted length of screen $\leq 10$ feet
• Acceptable soil or soil-like material present vertically between groundwater and building
• At least two rounds of data
Screening Limitations

- No SPL (NAPL) is present
- If groundwater enters an external preferential pathway:
  - Use groundwater MSCs only
- If a significant foundation opening is present:
  - Use groundwater MSCs only

[Section F, Figure 7]
Groundwater Screening Values—$SV_{GW}$

- SPL present – no
- Preferential pathway w/in 5 ft of building – no
- Preferential pathway penetrates building – no
- Significant foundation opening – no
- Less than 5 ft depth to plume – no

**NO RESTRICTIONS** – GW screening values based on HIGHER of the Ch. 250 Used Aquifer MSC or the Calculated $SV_{GW}$ (which is based on EPA attenuation factors from GW to indoor air)
You cannot use *any* GW screening value \((SV_{GW})\) within SPL areas but you can use alternative assessment options.
Groundwater Screening Values—$SV_{GW}$

- SPL present — no
- Contamination inside preferential pathway w/in 5 ft of building — YES
- Preferential pathway penetrates building — no
- Significant foundation opening — no
- Less than 5 ft depth to plume — no

You cannot use the calculated GW screening value ($SV_{GW}$) but you can use GW Used Aquifer MSC.
Groundwater Screening Values—$SV_{GW}$

SPL present – no
Preferential pathway w/in 5 ft of building – no
Preferential pathway penetrates building – YES
Significant foundation opening – YES
Less than 5 ft depth to plume – no

You cannot use the calculated GW screening value ($SV_{GW}$) but you can use GW Used Aquifer MSC.
Groundwater Screening Values—$SV_{GW}$

- SPL present – no
- Preferential pathway w/in 5 ft of building – no
- Preferential pathway penetrates building – no
- Significant foundation opening – no
- Less than 5 ft depth to plume – YES

You cannot use the calculated GW screening value ($SV_{GW}$) but you can use GW Used Aquifer MSC.
Application of SVs

• With characterization data: no exceedences
• Suitable statistical tests of attainment data
  ➢ Statewide health standard only
  ➢ 75%/10x and/or 75%/2x or 95% UCL tests
  ➢ No exceedences if less than eight rounds
• Remember—groundwater screening is performed at appropriate POAs, not POC!

[Section F.2, Table 7]
Basis of Soil SVs

• Attenuation factors derived from Johnson & Ettinger model simulations
• Soil VI screening values are no lower than generic soil-to-groundwater numeric values
• Note: Table 2 VI SVs have changed since July 2015 draft!

[Table 2; Appendix A, Section 4]
Data Requirements

• Samples collected in unsaturated zone

[Table 6]
Screening Limitations

• No SPL (NAPL) is present
• If a significant foundation opening is present:
  ➢ Use generic soil-to-groundwater numeric values only
• *There is no 5-foot depth limitation!*
  ➢ Soil screening values apply to shallow soil (e.g., immediately below foundation)

[Section F, Figure 7]
Soil Screening Values—SV$_{SOIL}$

SPL Present – no
Preferential pathway w/in 5 ft of building – no
Preferential pathway penetrates building – no
Significant foundation opening – no
5 ft depth – not applicable to soil

NO RESTRICTIONS – Soil Screening values based on HIGHER of the Ch. 250 Generic Soil-to-GW values or the Calculated SV$_{SOIL}$ (which is based on attenuation factors derived from J&E model)
You cannot use *any* soil screening value ($SV_{SOIL}$) but you can use alternative assessment options.
Soil Screening Values—$SV_{SOIL}$

SPL Present – no
Preferential pathway w/in 5 ft of building – YES
Preferential pathway penetrates building – YES
Significant foundation opening – no
5 ft depth – not applicable to soil

NO RESTRICTIONS – Soil Screening values based on HIGHER of the Ch. 250 Generic Soil-to-GW values or the Calculated $SV_{SOIL}$ (which is based on attenuation factors derived from J&E model)
Soil Screening Values—$SV_{SOIL}$

- SPL Present – no
- Preferential pathway w/in 5 ft of building – no
- Preferential pathway penetrates building – no
- Significant foundation opening – YES
- 5 ft depth – not applicable to soil

You cannot use the calculated soil screening value ($SV_{SOIL}$) but you can use generic soil-to-GW numeric values.
Application of SVs

- With characterization data: no exceedences
- Suitable statistical tests of attainment data
  - Statewide health standard only
  - 75%/10x or 95% UCL tests
- POA for soil screening is throughout the volume of soil contamination
  - Base and sidewalls of excavation (attainment)

[Section F.2, Table 7]
Basis of Near-Source Soil Gas SVs

• Attenuation factors derived from Johnson & Ettinger model simulations
• Near-source data is preferred because of variability in shallower soil gas concentrations
• $SV_{NS}$ available for evaluation of future use

[Table 3; Appendix A, Section 3]
Data Requirements

• Sample about 1 foot above the source
  ➢ Above capillary fringe
  ➢ Above bedrock
• Sample at least 5 feet below ground surface
• Acceptable soil or soil-like material present vertically between source and building
• At least two sample locations and two rounds
  ➢ Sample events ≥ 45 days apart

[Table 6, Appendix C]
Near-Source Soil Gas SVs

Screening Limitations

- $SV_{NS}$ not available if:
  - SPL or contaminated groundwater present in an external preferential pathway
  - External preferential pathway penetration
  - Significant foundation opening present
  - Potential VI source is < 5 feet below foundation

- Alternatively, use $SV_{SS}$ if any of the above conditions occur

[Section G, Figure 7]
Screening Limitations

• **Important:** If soil gas data is not near-source, then use of $SV_{NS}$ values is not allowed
  ➢ Under certain circumstances, $SV_{SS}$ might be acceptable
  ➢ But the samples still must be collected at least 5 feet below ground surface
Near-Source Screening Values—SV\textsubscript{NS}

- SPL Present – no
- Preferential pathway w/in 5 ft of building – no
- Preferential pathway penetrates building – no
- Significant foundation opening – no
- Less than 5 ft depth to plume – no

NO RESTRICTIONS – Near-source soil gas screening values based on attenuation factors derived from J& E model simulations
Near-Source Screening Values—\(SV_{NS}\)

- SPL Present – **no**
- Preferential pathway w/in 5 ft of building – **YES**
- Preferential pathway penetrates building – **no**
- Significant foundation opening – **no**
- Less than 5 ft depth to plume – **no**

**NO RESTRICTIONS** – You can use near-source soil gas screening value (\(SV_{NS}\))
Near-Source Screening Values—$SV_{NS}$

- SPL or GW > MSCs present in a preferential pathway w/in 5 ft of building – YES
- Preferential pathway penetrates building – no
- Significant foundation opening – no
- Less than 5 ft depth to plume – no

You cannot use the near-source soil gas screening value ($SV_{NS}$) but you can compare to sub-slab screening value ($SV_{SS}$)
Near-Source Screening Values—$SV_{NS}$

- SPL Present – no
- Preferential pathway w/in 5 ft of building – no
- Preferential pathway penetrates building – YES
- Significant foundation opening – YES
- Less than 5 ft depth to plume – no

You cannot use the near-source soil gas screening value ($SV_{NS}$) but you can compare to sub-slab screening value ($SV_{SS}$).
Near-Source Screening Values—$SV_{NS}$

SPL Present – no  
Preferential pathway w/in 5 ft of building – no  
Preferential pathway penetrates building – no  
Significant foundation opening – no  
Less than 5 ft depth to plume – YES

You cannot use the near-source soil gas screening value ($SV_{NS}$) but you can compare to sub-slab screening value ($SV_{SS}$).
The Basis of Sub-Slab Soil Gas SVs

- Attenuation factors based on EPA’s analysis of their VI database
- $SV_{SS}$
- Sub-slab soil gas is closer to receptors
  - More indicative of potential exposures
  - Avoids conflicting background sources

[Table 4; Appendix A, Section 2]
Data Requirements

• At least two sample locations and two rounds
  ➢ Sample events ≥ 45 days apart
• Bias sample points towards areas of greatest expected impact
• Sample collection immediately below slab
  ➢ Basement walls may be appropriate
  ➢ Large, intact outdoor paved areas acceptable

[Table 6, Appendix C]
Screening Limitations

• $S_{\text{SV}}$ not available if:
  ➢ An external preferential pathway penetrates the building foundation
  ➢ A significant foundation opening is present

• Alternatively, use $S_{\text{VA}}$ if either of the above conditions occur

[Section G, Figure 7]
Sub-Slab Screening Values — $S_{SS}$

- Preferential pathway w/in 5 ft of building – YES
- Preferential pathway penetrates building – no
- Significant foundation opening – no

Source: $GW > S_{GW}$

NO RESTRICTIONS – You can use sub-slab soil gas screening value ($S_{SS}$)
Sub-Slab Screening Values—$SV_{ss}$

- SPL or GW > MSCs present in a preferential pathway w/in 5 ft of building — YES
- Preferential pathway penetrates building — no
- Significant foundation opening — no

NO RESTRICTIONS – You can use sub-slab soil gas screening value ($SV_{ss}$)
Sub-Slab Screening Values—$SV_{SS}$

- Preferential pathway w/in 5 ft of building – no
- Preferential pathway penetrates building – YES
- Significant foundation opening – YES

You cannot use the sub-slab soil gas screening value ($SV_{SS}$) but you can compare to indoor air screening value ($SV_{IA}$).
Basis of Indoor Air SVs

• Calculated $SV_{IA}$ from EPA’s standard inhalation risk equations
• Input DEP’s toxicological values
• Select lower of carcinogenic, non-carcinogenic, and mutagenic SVs
• POA is the breathing zone in the lowest occupied level of the building

[Table 5; Appendix A, Section 1]
Data Requirements

• At least two sample locations and two rounds
  ➢ Sample events ≥ 45 days apart
• Sample on lowest floor (e.g., basement)
• Daily average outdoor temperature should be at least 15°F below the minimum indoor temperature of the occupied space
  ➢ More likely to be representative of long-term

[Table 6, Appendix C]
Screening Limitations

• No restrictions on indoor air sampling
• However, important to be aware of potential indoor sources and outdoor background

[Section G, Appendix C]

• Note that modeled indoor air concentrations may also be screened (SHS only)

[Section G.3]
Application of SVs: Near-Source, Sub-Slab, and Indoor Air

• No exceedences of characterization data
• May perform long-term monitoring
  ➢ Once or twice per quarter
  ➢ Statistical tests allowed if there is a combination of at least eight locations and rounds (SHS only)
  ➢ May apply 75%/10x and/or 75%/2x or 95% UCL tests
  ➢ Otherwise no exceedences (SSS)

[Section G.2, Table 7]
Summary of Restrictions with SPL

- $SV_{GW}$ and groundwater MSCs not available
- $SV_{SOIL}$ and generic soil-to-groundwater numeric values not available
- $SV_{NS}$ not available if SPL enters a preferential pathway
- Modeling of soil and groundwater data not available
Use of Site-Specific Standard SVs

• Default SSS screening values are one-tenth the tabulated SHS screening values
• May use EPA’s regional screening levels as basis for SSS SV_{IA}, SV_{SS}, and SV_{NS}
• Pass only with no exceedences
  ➢ SHS statistical tests are not available
• SSS alternatives are modeling and/or risk assessment

[Section K.4]
SSS Potential VI Source

• **Important:** A potential VI source is defined by exceedences of *Statewide health standard* screening values (\(SV_{GW}\) and \(SV_{SOIL}\))

• The SSS soil and groundwater SVs based on one-tenth of SHS SVs will rarely be used
  
  ➢ Example: evaluation of SSS post-remediation attainment data

[Section B, Section K.3]
• Background standard does not require VI
• VI pathway must be evaluated along with all of the other requirements of each standard
• Act 2 standards are attained only for soil or groundwater, not vapor
  ➢ VI is a pathway, not an environmental medium
  ➢ If the site-specific standard is selected, then the remediator *cannot* use the SHS VI process
• Screening values from Tables 1 to 5 for SHS
  ➢ But $SV_{GW}$ and $SV_{SOIL}$ allowed for SSS (VI source)
  ➢ $SV_{NS}$, $SV_{SS}$, $SV_{IA}$ must be adjusted for SSS
• Can evaluate VI under SHS only when attaining the SHS for soil and groundwater
• Can evaluate VI under SSS when attaining either the SHS or SSS for soil and groundwater
• Differences with modeling output

[Section C.3]
Combination of Standards

Example: Chlorinated VOC Plume with Offsite Impacts

- Saturated zone
- Groundwater flow
- MW-1
- MW-2
- MW-3
- Vapor
- POC

Example: Chlorinated VOC Plume with Offsite Impacts
## Groundwater Attainment (MSCs)

<table>
<thead>
<tr>
<th>Substance</th>
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<th>MW-2</th>
<th>MW-3</th>
<th>MSC</th>
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</thead>
<tbody>
<tr>
<td>TCE (μg/L)</td>
<td>8000</td>
<td>400</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>1,1-DCE (μg/L)</td>
<td>90</td>
<td>5</td>
<td>ND</td>
<td>7</td>
</tr>
</tbody>
</table>

TCE—site-specific standard  
DCE—Statewide health standard
Vapor Intrusion Groundwater Screening

<table>
<thead>
<tr>
<th>Substance</th>
<th>MW-1</th>
<th>SV&lt;sub&gt;GW&lt;/sub&gt;</th>
<th>MW-2</th>
<th>MW-3</th>
<th>SV&lt;sub&gt;GW&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCE (μg/L)</td>
<td>8000</td>
<td>110</td>
<td>400</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>1,1-DCE (μg/L)</td>
<td>90</td>
<td>3800</td>
<td>5</td>
<td>ND</td>
<td>300</td>
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</table>

TCE does not screen out of VI
DCE does screen out (GW)
## Vapor Intrusion Near-Source Soil Gas Screening

<table>
<thead>
<tr>
<th>Substance</th>
<th>SG-1</th>
<th>SV_{NS}</th>
<th>SG-3</th>
<th>SV_{NS}</th>
</tr>
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<tr>
<td>TCE (µg/m³)</td>
<td>1,000,000</td>
<td>880*</td>
<td>300</td>
<td>42*</td>
</tr>
<tr>
<td>1,1-DCE (µg/m³)</td>
<td>50,000</td>
<td>880,000</td>
<td>40</td>
<td>42,000</td>
</tr>
</tbody>
</table>

*SSS SV_{NS} = one-tenth SHS SV_{NS}*

**TCE does not screen out of VI (NS)**
Example Conclusions

• The TCE plume is a potential VI source
  ➢ But 1,1-DCE is not based on $SV_{GW}$

• Must apply one-tenth $SV_{NS}$ for screening of TCE soil gas data

• What are alternatives for addressing TCE?
  ➢ Risk calculation (offsite TCE HQ < 1)
  ➢ Sub-slab soil gas sampling
  ➢ Indoor air sampling
  ➢ Mitigation
Representative Process to Evaluate Vapor Intrusion With a Combination of Standards

For each substance that is a potential VI source:

**Statewide Health Standard VI Path**

Does the substance attain the SHS for both soil and groundwater MSCs (as per Chapter 250, Subchapter G)?

- **yes**: Use SHS SVs (Tables 3–5)
  - **pass**: Model VI (screen output with $SV_{IA}$)
  - **fail**: Mitigate (test system)
  - **fail**: Remediate (resample)

- **no**: Use SSS SVs ($\frac{1}{10}$ SHS SVs or RSLs)
  - **pass**: Complete cumulative risk assessment (VISL or J&E)
  - **pass**: Remediate (resample)
  - **fail**: Mitigate (test system)

**Site-Specific Standard VI Path**

- **fail**: Mitigate (test system)
- **no** and **yes**: reevaluate

**Done**
Questions?
Tutorial: Calculation of Site-Specific Standard Vapor Intrusion Screening Values from EPA Indoor Air RSLs

Colleen Costello (GHD)
C. David Brown (DEP)

Vapor Intrusion Guidance Training

January 10, 2017
Malvern, PA
• EPA RSLs are available online at: www.epa.gov/risk/regional-screening-levels-rsls
• RSLs are revised approximately every 6 months (May and November)
• Click the “Generic Tables” link
• Access the “Resident Air” and “Composite Worker Air” tables for THQ = 0.1
Regional Screening Levels (RSLs) – Generic Tables (May 2016)

For assistance/questions please use the Regional Screening Levels (RSLs) contact us page.

You will need Adobe Reader to view some of the files on this page. See EPA’s About PDF page to learn more.

The screening level (SL) tables are available for download in Excel and PDF formats. All tables are presented with target cancer risk (TR) of 1E-06, however, tables are presented with target hazard quotients (THQ) of 1.0 and 0.1. Use the tables appropriate for your region. These tables are considered ready for use. The tables contain both SL calculations and the toxicity values that were used. The download tables do not include the ingestion of fish exposure pathway, the outdoor worker and the indoor worker exposure to soil exposure pathway that are presented in the User’s Guide. These exposure pathways can be considered on a site-specific basis in the Calculator.

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</tbody>
</table>
• RSLs for soil and water do not account for VI and are not available for SSS VI evaluations
• Use residential and worker indoor air RSLs
• RSLs may be converted to soil gas and sub-slab SVs using DEP’s attenuation factors:

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Attenuation Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residential</td>
</tr>
<tr>
<td>Sub-slab soil gas</td>
<td>0.026</td>
</tr>
<tr>
<td>Near-source soil gas</td>
<td>0.005</td>
</tr>
</tbody>
</table>

[Table A-4]
• RSLs are calculated for a cancer risk of $10^{-6}$
• But if VI is the only complete exposure pathway for the receptor, then a cancer risk of $10^{-5}$ is acceptable
• Must use RSLs for a hazard quotient (HQ) of 0.1
• Intent of screening is to maintain a factor of 10 risk margin relative to SSS cumulative thresholds (cancer risk $\leq 10^{-4}$ & hazard index $\leq 1.0$)
• Some substances are carcinogens, some are noncarcinogens, some are both
• The lower of the cancer and non-cancer RSLs is used as the screening value
• EPA residential RSLs are calculated with a 26-yr exposure duration in contrast to DEP’s 30 yr
• For the SSS, substances that don’t screen out are carried through a risk assessment
### Example for Four Substances

#### EPA Residential Indoor Air RSLs

<table>
<thead>
<tr>
<th>Substance</th>
<th>Cancer $10^{-6}$</th>
<th>HQ = 0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>0.36</td>
<td>3.1</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.083</td>
<td>0.31</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.48</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Note: All concentration units in this and subsequent tables are $\mu g/m^3$
### Example for Four Substances

#### EPA Residential Indoor Air RSLs

Select lower of the two RSLs

<table>
<thead>
<tr>
<th>Substance</th>
<th>Cancer $10^{-6}$</th>
<th>HQ = 0.1</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Trichloroethylene</td>
<td>0.48</td>
<td>0.21</td>
</tr>
</tbody>
</table>
Example for Four Substances

Compare to DEP’s SSS SVs

<table>
<thead>
<tr>
<th>Substance</th>
<th>EPA RSL</th>
<th>DEP SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>0.36</td>
<td>0.31</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.083</td>
<td>0.072</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>0.73</td>
<td>0.73</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.21</td>
<td>0.21</td>
</tr>
</tbody>
</table>

- DEP’s site-specific standard SVs are one-tenth of Statewide health standard SVs
- Pick higher of two values
### EPA Residential IA RSLs @ $10^{-5}$ Risk

<table>
<thead>
<tr>
<th>Substance</th>
<th>Cancer $10^{-5}$</th>
<th>HQ = 0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>3.6</td>
<td>3.1</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.83</td>
<td>0.31</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>0.73</td>
<td>0.73</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>4.8</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Use cancer risk of $10^{-5}$ when vapor intrusion is the only complete exposure pathway for the receptor.
**Compare to DEP’s SSS SVs (residential)**

<table>
<thead>
<tr>
<th>Substance</th>
<th>EPA RSL</th>
<th>DEP SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>3.1&lt;sub&gt;NC&lt;/sub&gt;</td>
<td>0.31&lt;sub&gt;C&lt;/sub&gt;</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.31&lt;sub&gt;NC&lt;/sub&gt;</td>
<td>0.072&lt;sub&gt;C&lt;/sub&gt;</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>0.73&lt;sub&gt;NC&lt;/sub&gt;</td>
<td>0.73&lt;sub&gt;NC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.21&lt;sub&gt;NC&lt;/sub&gt;</td>
<td>0.21&lt;sub&gt;NC&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

- RSLs selected with $10^{-5}$ cancer risk
- DEP’s SSS SVs are one-tenth of SHS SVs
- Notation: $C$—cancer
  $NC$—noncancer
Exercise Objective

• Determine RSL-based site-specific standard vapor intrusion screening values for several common contaminants
• We will use RSL-based SVs in a case study this afternoon
### Abbreviated lookup table of EPA indoor air RSLs

**Group Exercise**  
**US EPA Indoor Air Regional Screening Levels (RSLs)**  
**Residential**  
**May 2016**

Key:  
I = IRIS;  
P = PPRTV;  
A = ATSDR;  
C = Cal EPA;  
X = APPENDIX PPRTV SCREEN (See FAQ #27);  
H = HEAST;  
F = See FAQ;  
J = New Jersey;  
O = EPA Office of Water;  
E = see user guide Section 2.3.5;  
L = see user guide on lead;  
M = mutagen;  
S = see user guide Section 5;  
V = volatile;  
R = RBA applied (See User Guide for Arsenic notice);  
c = cancer;  
n = noncancer;  
* = where: n SL < 100x c SL;  
** = where n SL < 10x c SL;  
SSL values are based on DAF=1;  
m = Concentration may exceed ceiling limit (See User Guide);  
s = Concentration may exceed Csat (See User Guide)

<table>
<thead>
<tr>
<th>IUR (µg/m³)⁻¹</th>
<th>k e y</th>
<th>RICᵢ (mg/m³)</th>
<th>k e y</th>
<th>mutagen</th>
<th>Analyte</th>
<th>CAS No.</th>
<th>Carcinogenic SL TR=1E-06 (µg/m³)</th>
<th>Noncarcinogenic SL THI=0.1 (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.8E-06 I</td>
<td>3.0E-02 I V</td>
<td></td>
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<td>Benzene</td>
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<td>3.6E-01</td>
<td>3.1E+00</td>
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<td>4.0E-01 I V</td>
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<td></td>
<td>Cumele</td>
<td>98-82-8</td>
<td>4.2E+01</td>
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<td>6.0E-04 I</td>
<td>9.0E-03 I V</td>
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<td></td>
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<td>Dichloroethylene, 1,1-</td>
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<td>5.0E+00 I V</td>
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<tr>
<td>1.6E-06 I</td>
<td>2.0E-03 I V</td>
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<td></td>
<td></td>
<td>Trichloroethylene, 1,1,2-</td>
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<td>4.1E-06 I</td>
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<td>Trichloroethylene</td>
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<td>1.8E-01</td>
<td>2.1E-02</td>
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<tr>
<td>5.0E-03 P V</td>
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<td></td>
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<td>Trimethylbenzene, 1,2,3-</td>
<td>79-01-6</td>
<td>4.8E-01</td>
<td>2.1E-01</td>
</tr>
<tr>
<td>7.0E-03 P V</td>
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<td>Trimethylbenzene, 1,2,4-</td>
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<tr>
<td>4.4E-06 I</td>
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<tr>
<td>1.0E-01 I V</td>
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</tr>
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</table>
### Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

**Note:** RSLs at a $10^{-5}$ cancer risk are acceptable only when VI is the sole potential exposure pathway.

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<th>Regulated Substance</th>
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</tr>
<tr>
<td></td>
<td>Carcinogenic</td>
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</tr>
<tr>
<td></td>
<td>$10^{-6}$ Risk</td>
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</tr>
<tr>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Common Chlorinated VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene (PCE)</td>
<td></td>
<td></td>
</tr>
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<td>0.48</td>
<td>4.8</td>
</tr>
<tr>
<td>Dichloroethylene, cis-1,2-</td>
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<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
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</tr>
</tbody>
</table>

1. **Look up RSLs**
**Group Exercise: RSL-Based Site-Specific Standard VI Screening Values**

Note: RSLs at a $10^{-5}$ cancer risk are acceptable only when VI is the sole potential exposure pathway.

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<td>Carcinogenic 10⁻⁶ Risk</td>
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<td></td>
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<tr>
<td>Ethylbenzene</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
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</tr>
</tbody>
</table>

### Pick lower value

**3**
**Group Exercise: RSL-Based Site-Specific Standard VI Screening Values**

Note: RSLs at a $10^{-5}$ cancer risk are acceptable only when VI is the sole potential exposure pathway.

<table>
<thead>
<tr>
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</tr>
<tr>
<td>Ethylbenzene</td>
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<td></td>
</tr>
<tr>
<td>Xylenes (total)</td>
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<td></td>
</tr>
<tr>
<td>Methyl tert-Butyl Ether (MTBE)</td>
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<tr>
<td>Naphthalene</td>
<td>0.083</td>
<td>0.83</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,2,4- (1,3,4-TMB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimethylbenzene, 1,3,5-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dibromoethane, 1,2- (ethylene dibromide) (EDB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichloroethane, 1,2- (EDC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Chlorinated VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene (PCE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>0.48</td>
<td>4.8</td>
</tr>
<tr>
<td>Dichloroethylene, cis-1,2-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 5*
# Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

**Note:** RSLs at a $10^{-5}$ cancer risk are acceptable only when VI is the sole potential exposure pathway

<table>
<thead>
<tr>
<th>Regulated Substance</th>
<th>EPA Residential Indoor Air RSLs (µg/m³)</th>
<th>PA DEP IA SVs (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carcinogenic 10⁻⁶ Risk</td>
<td>Carcinogenic 10⁻⁵ Risk</td>
</tr>
<tr>
<td>Petroleum Short List</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>0.36</td>
<td>3.6</td>
</tr>
<tr>
<td>Toluene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xylenes (total)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl tert-Butyl Ether (MTBE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumene (isopropylbenzene)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.083</td>
<td>0.83</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,2,4- (1,3,4-TMB)</td>
<td></td>
<td>0.73</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,3,5-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dibromoethane, 1,2- (ethylene dibromide) (EDB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichloroethane, 1,2- (EDC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Chlorinated VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene (PCE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>0.48</td>
<td>4.8</td>
</tr>
<tr>
<td>Dichloroethylene, cis-1,2-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise Instructions

• You have a sheet of excerpted residential indoor air RSLs from EPA’s table
• You have an exercise sheet to fill in RSLs

1. Look up and enter the RSLs for cancer ($10^{-6}$) and noncancer (0.1) toxicity
2. Adjust cancer RSLs to a $10^{-5}$ risk
3. Determine the lower RSL
4. Compare to DEP’s SSS screening values
5. Pick higher value
RSL Exercise: RSL-Based Site-Specific Standard VI Screening Values

Note: RSLs at a $10^{-5}$ cancer risk are acceptable only when VI is the sole potential exposure pathway

<table>
<thead>
<tr>
<th>Regulated Substance</th>
<th>EPA Residential Indoor Air RSLs (µg/m³)</th>
<th>PA DEP IA SVs (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carcinogenic</td>
<td>10⁻⁶ Risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleum Short List</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>0.36</td>
<td>3.6</td>
</tr>
<tr>
<td>Toluene</td>
<td><strong>520</strong></td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>1.1</td>
<td>11</td>
</tr>
<tr>
<td>Xylenes (total)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Methyl tert-Butyl Ether (MTBE)</td>
<td>11</td>
<td>110</td>
</tr>
<tr>
<td>Cumene (isopropylbenzene)</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.083</td>
<td>0.83</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,2,4-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1,3,4-TMB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimethylbenzene, 1,3,5-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dibromoethane, 1,2-</td>
<td><strong>0.0047</strong></td>
<td>0.047</td>
</tr>
<tr>
<td>(ethylene dibromide) (EDB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichloroethane, 1,2- (EDC)</td>
<td>0.36</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Chlorinated VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene (PCE)</td>
<td>11</td>
<td>110</td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>0.48</td>
<td>4.8</td>
</tr>
<tr>
<td>Dichloroethylene, cis-1,2-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>0.17</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Answers
Example for Four Substances

Residential Sub-Slab Soil Gas

<table>
<thead>
<tr>
<th>Substance</th>
<th>EPA RSL</th>
<th>DEP SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>120</td>
<td>12</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>12</td>
<td>2.8</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>8.1</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Divide indoor air RSL by attenuation factor

\[ \alpha_{SS} = 0.026 \text{ (SV units } \mu g/m^3) \]
Residential Near-Source Soil Gas

<table>
<thead>
<tr>
<th>Substance</th>
<th>EPA RSL</th>
<th>DEP SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>620</td>
<td>62</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>62</td>
<td>14</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>

Divide indoor air RSL by attenuation factor
\[ \alpha_{NS} = 0.005 \text{ (SV units } \mu \text{g/m}^3) \]
Process to Determine Site-Specific Standard Vapor Intrusion Screening Values

For each site-specific standard substance:

1. Obtain current EPA IA RSLs (CR = 10⁻⁶, HQ = 0.1)
2. Obtain the PA DEP SHS IA SV (Table 5)
3. Is VI the only potentially complete exposure pathway for the receptor?
   - Yes: Multiply the cancer RSL by 10 (CR = 10⁻⁵)
   - No:
     - Divide the DEP SV_{IA} by 10 to obtain the default SSS SV
     - Select the lower of the cancer and noncancer RSLs
4. Select the higher of the RSL-based SV and DEP’s SSS SV
5. Divide by the near-source soil gas attenuation factor:
   - α_R, α_NR, or α_CR (Table A.4)
6. Divide by the sub-slab soil gas attenuation factor
7. Site-specific standard indoor air screening value
8. Site-specific standard near-source soil gas screening value

START
Site-Specific Standard Vapor Intrusion Screening Values Based on EPA RSLs

**Residential** Conditions for a $10^{-5}$ Screening Value Cancer Risk

*Note: May 2016 RSL values*

<table>
<thead>
<tr>
<th>Substance</th>
<th>CAS No.</th>
<th>Cancer RSL ($\mu g/m^3$)</th>
<th>Non-Cancer RSL ($\mu g/m^3$)</th>
<th>Indoor Air RSL-Based SV ($\mu g/m^3$)</th>
<th>Sub-Slab Soil Gas RSL-Based SV ($\mu g/m^3$)</th>
<th>Near-Source Soil Gas RSL-Based SV ($\mu g/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk Basis</strong></td>
<td></td>
<td>CR = $10^{-6}$ and HQ = 0.1</td>
<td>CR = $10^{-5}$ and HQ = 0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>71-43-2</td>
<td>3.6E-01</td>
<td>3.1E+00</td>
<td>3.1</td>
<td>120</td>
<td>620</td>
</tr>
<tr>
<td>Cumene</td>
<td>98-82-8</td>
<td>4.2E+01</td>
<td>9.4E-01</td>
<td>42</td>
<td>1,600</td>
<td>8,400</td>
</tr>
<tr>
<td>Dibromoethane, 1,2-</td>
<td>106-93-4</td>
<td>4.7E-03</td>
<td>9.4E-01</td>
<td>0.047</td>
<td>1.8</td>
<td>9.4</td>
</tr>
<tr>
<td>Dichloroethane, 1,1-</td>
<td>75-34-3</td>
<td>1.8E+00</td>
<td></td>
<td>18</td>
<td>690</td>
<td>3,600</td>
</tr>
<tr>
<td>Dichloroethane, 1,2-</td>
<td>107-06-2</td>
<td>1.1E-01</td>
<td>7.3E-01</td>
<td>0.73</td>
<td>28</td>
<td>150</td>
</tr>
<tr>
<td>Dichloroethylene, 1,1-</td>
<td>75-35-4</td>
<td>2.1E+01</td>
<td></td>
<td>21</td>
<td>810</td>
<td>4,200</td>
</tr>
<tr>
<td>Dichloroethylene, 1,2-cis-</td>
<td>156-59-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichloroethylene, 1,2-trans-</td>
<td>156-60-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>100-41-4</td>
<td>1.1E+00</td>
<td>1.0E+02</td>
<td>11</td>
<td>420</td>
<td>2,200</td>
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<tr>
<td>Methyl tert-Butyl Ether (MTBE)</td>
<td>1634-04-4</td>
<td>1.1E+01</td>
<td>3.1E+02</td>
<td>110</td>
<td>4,200</td>
<td>22,000</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>91-20-3</td>
<td>8.3E-02</td>
<td>3.1E-01</td>
<td>0.31</td>
<td>12</td>
<td>62</td>
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<tr>
<td>Tetrachloroethylene (PCE)</td>
<td>127-18-4</td>
<td>1.1E+01</td>
<td>4.2E+00</td>
<td>4.2</td>
<td>160</td>
<td>840</td>
</tr>
<tr>
<td>Toluene</td>
<td>108-88-3</td>
<td></td>
<td>5.2E+02</td>
<td>520</td>
<td>20,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Trichloroethane, 1,1,1-</td>
<td>71-55-6</td>
<td></td>
<td>5.2E+02</td>
<td>520</td>
<td>20,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Trichloroethane, 1,1,2-</td>
<td>79-00-5</td>
<td>1.8E-01</td>
<td>2.1E-02</td>
<td>0.021</td>
<td>0.81</td>
<td>4.2</td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>79-01-6</td>
<td>4.8E-01</td>
<td>2.1E-01</td>
<td>0.21</td>
<td>8.1</td>
<td>42</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,2,3-</td>
<td>526-73-8</td>
<td></td>
<td>5.2E-01</td>
<td>0.52</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,2,4-</td>
<td>95-63-6</td>
<td></td>
<td>7.3E-01</td>
<td>0.73</td>
<td>28</td>
<td>150</td>
</tr>
<tr>
<td>Trimethylbenzene, 1,3,5-</td>
<td>108-67-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>75-01-4</td>
<td>1.7E-01</td>
<td>1.0E+01</td>
<td>1.7</td>
<td>65</td>
<td>340</td>
</tr>
<tr>
<td>Xylenes</td>
<td>1330-20-7</td>
<td></td>
<td>1.0E+01</td>
<td>10</td>
<td>380</td>
<td>2,000</td>
</tr>
</tbody>
</table>
Summary: RSL Screening Values

- Use current EPA RSL tables
- Adjust cancer RSL to $10^{-5}$ if VI only pathway
- Minimum of cancer/noncancer RSL
- RSL-based screening values may be higher than one-tenth of DEP’s SVs—advantage
- Calculate soil gas RSL-based screening values using DEP’s attenuation factors
Questions?
Mitigation, Remediation, Modeling

Charles Campbell (Leidos)
Vapor Intrusion Training

January 10, 2017
Malvern, PA
Evaluating the VI Pathway

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES
Soil and Groundwater Screening

ALTERNATIVE VI ASSESSMENT OPTIONS
- Sub-Slab Soil Gas Screening
- Near-Source Soil Gas Screening
- Indoor Air Screening
- Vapor Intrusion Modeling

MITIGATION
- Environmental Covenant

REMITEDICATION
- Reevaluate the VI Pathway

SCREEN FOR POTENTIAL VI SOURCES
Identify Preferential Pathways
Apply Proximity Distances

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250 REQUIREMENTS
No further VI analysis is necessary.
When Can Mitigation be Done?

At any time during the evaluation

Eliminates the complete pathway between contamination and the receptor

Most Common Systems:

• Sub-Slab Depressurization System
• Vapor Barrier
• Clay Barrier

[Section H]
Performing Mitigation

• Protective regardless of changes in subsurface concentrations or screening values

• Performance testing requirements in Appendix C
  – Indoor air confirmation sampling not required

• EC needed to ensure maintenance of the system

[Section H]
Sub-Slab Depressurization System
(commonly called a radon mitigation system)

The vent pipe is routed up the side of the structure to a location above the roof line.

A fan is used to draw soil vapor from beneath the slab.

A liquid gauge, or manometer is used to verify that the system is operating properly.

Sub-Slab Soil Vapor

A sub-slab depressurization system vents contaminated soil vapor before it enters a structure. The fan draws vapor from beneath the building outside to the roof line where it is released to the outside air.
Background

• Former dry cleaner
• Commercial and residential building
• Petroleum and PCE soil impacts
• PCE and TCE groundwater impacts
Soil Investigation

- Two heating oil USTs removed
  - January 2013
  - corrosion holes and soil staining
  - closure sampling
  - silt/clay soil
  - trimethylbenzene exceedences
  - maximum PCE 79 mg/kg
  - residential $SV_{SOIL} = 0.43$ mg/kg
max PCE: 22 mg/kg

max PCE: 79 mg/kg

Soil Investigation @ USTs

30 feet
Soil Investigation

- Soil borings to characterize and delineate
- Remedial actions: additional soil excavated around each former UST
  - May 2013
- Eight attainment samples at each
- Statewide health standard attained for fuel oil short list, but not for PCE
  - No exceedences of petroleum soil SVs
Example: Soil VI Non-Attainment

PCE in soil (mg/kg)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.37</td>
<td>9.6</td>
<td>0.31</td>
<td>0.54</td>
<td>0.37</td>
<td>0.38</td>
<td>0.024</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Soil-to-groundwater \[ \text{MSC} \] 0.50 mg/kg
Vapor intrusion \[ \text{SV}_{\text{SOIL}} \] 0.43 mg/kg

Result: **Fails** 75%/10x test
because 9.6 mg/kg is >10x MSC and >10x \[ \text{SV}_{\text{SOIL}} \]
Example: Soil VI **Attainment**

PCE in soil (mg/kg)

<table>
<thead>
<tr>
<th></th>
<th>A2-1</th>
<th>A2-2</th>
<th>A2-3</th>
<th>A2-4</th>
<th>A2-5</th>
<th>A2-6</th>
<th>A2-7</th>
<th>A2-8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.001</td>
<td>0.0028</td>
<td>0.030</td>
<td>0.31</td>
<td>0.32</td>
<td>0.22</td>
<td><strong>0.61</strong></td>
<td>0.015</td>
</tr>
</tbody>
</table>

Soil-to-groundwater MSC 0.50 mg/kg
Vapor intrusion SV\text{SOIL} 0.43 mg/kg

Result: **Passes** 75%/10x test
Groundwater Investigation

- Four overburden monitoring wells installed
  - 20 feet deep, 15-foot screens
  - Depth to water ~9 feet
  - Wetted length of well screen ~10 feet or less
  - No NAPL observed


<table>
<thead>
<tr>
<th>Substance</th>
<th>Data (μg/L)</th>
<th>$SV_{GW}$ (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>40–130</td>
<td>110</td>
</tr>
<tr>
<td>TCE</td>
<td>~80</td>
<td>9</td>
</tr>
</tbody>
</table>
Groundwater Investigation

maximum concentrations:
PCE 130 µg/L
TCE ~80 µg/L

30 feet
Soil Gas Investigation

• Two soil gas samples
  ➢ collected beneath the building
  ➢ 5 feet deep
  ➢ helium leak tests
  ➢ 1-hr samples
  ➢ collected 1-month apart
  ➢ March–April 2013

• Appropriate screening is with sub-slab SVs, not near-source SVs
Soil Gas Investigation

Results:

<table>
<thead>
<tr>
<th>Substance</th>
<th>March ($\mu$g/m$^3$)</th>
<th>April ($\mu$g/m$^3$)</th>
<th>RSL/SV$_{SS}$ ($\mu$g/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>100,000</td>
<td>2,200,000</td>
<td>160</td>
</tr>
<tr>
<td>TCE</td>
<td>2,200</td>
<td>5,700</td>
<td>8.0</td>
</tr>
</tbody>
</table>

(Site-specific standard residential screening values)
Mitigation System Installation

- Sub-slab depressurization system
  - Installed by certified radon mitigator
  - Two vapor collection sumps placed at back end of building
  - One blower
  - June 2013
  - Indoor air testing instead of differential pressure testing
SSD Mitigation System

30 feet
Mitigation System Testing

• Initial indoor air testing round
  ➢ June 2013
  ➢ two indoor locations
  ➢ one outdoor ambient sample
  ➢ 24-hr samples
Mitigation System Testing

Results of initial indoor air testing round:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Indoor 300 (µg/m³)</th>
<th>Garage (µg/m³)</th>
<th>Outdoor (µg/m³)</th>
<th>RSL/SV₁₈ IA (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>4.7</td>
<td>&lt; 3.4</td>
<td>&lt; 3.4</td>
<td>4.2</td>
</tr>
<tr>
<td>TCE</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>0.21</td>
</tr>
</tbody>
</table>

(Site-specific standard residential screening values)

PCE concentration of 4.7 µg/m³ *alone* does not pose an excess risk (VISL)
Mitigation System Testing

• Second indoor air testing round
  ➢ July 2013
  ➢ Same three indoor/outdoor locations

<table>
<thead>
<tr>
<th>Substance</th>
<th>Indoor 300 (μg/m³)</th>
<th>Garage (μg/m³)</th>
<th>Outdoor (μg/m³)</th>
<th>RSL/SV_{IA} (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>56</td>
<td>&lt; 3.4</td>
<td>&lt; 3.4</td>
<td>4.2</td>
</tr>
<tr>
<td>TCE</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>0.21</td>
</tr>
</tbody>
</table>

PCE concentration of 56 μg/m³ does pose an excess risk (HQ = 1.3)
Mitigation System Testing

- Third indoor air testing round
  - August 2013
  - Three indoor locations
  - Sealed cracks, floor drain before sampling

<table>
<thead>
<tr>
<th>Substance</th>
<th>Indoor 300 (µg/m³)</th>
<th>Indoor 302 (µg/m³)</th>
<th>Garage (µg/m³)</th>
<th>RSL/SV_{IA} (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>250</td>
<td>&lt; 3.4</td>
<td>14</td>
<td>4.2</td>
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<tr>
<td>TCE</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>0.21</td>
</tr>
</tbody>
</table>
Indoor Air Sampling

- **Indoor air (garage)**
  - PCE **ND–14 µg/m³**
  - Soil gas point max PCE: **2,200,000 µg/m³**

- **Indoor air (302)**
  - PCE **ND–14 µg/m³**

- **Indoor air (300)**
  - PCE **4.9–250 µg/m³**

- **Outdoor air**
  - PCE **nondetect**

30 feet
Mitigation System Modification

- Expanded SSD system
  - Two additional vapor collection sumps, in tenant space adjacent to dry cleaner
  - One additional blower
  - September 2013
indoor air PCE < 3.4 µg/m³
# VI Case Study

## Mitigation System Testing

- Fourth indoor air testing round
  - October 2013
  - Two indoor, one outdoor locations

<table>
<thead>
<tr>
<th>Substance</th>
<th>Indoor 300 (μg/m³)</th>
<th>Garage (μg/m³)</th>
<th>Outdoor (μg/m³)</th>
<th>RSL/SV$_{IA}$ (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>&lt; 3.4</td>
<td>&lt; 3.4</td>
<td>&lt; 3.4</td>
<td>4.2</td>
</tr>
<tr>
<td>TCE</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>&lt; 2.7</td>
<td>0.21</td>
</tr>
</tbody>
</table>

**No exceedences**
Conclusions

- Mitigation system designs may be deficient
  - Needs to be installed in a location where it is most effective
  - Even in a relatively small building
- Some substances (e.g., TCE, naphthalene) have very low indoor air screening values
  - Consultants should communicate with labs on options for analysis
When Can Remediation be Done?

At any time during the evaluation

Remediation should result in resampling and reevaluation
Performing Remediation

• Remediator may choose soil and/or GW remediation.

• Data must be collected following remediation for VI screening.

• Remediator must implement interim measures to protect human health if remediation will be a long-term activity.
Environmental Covenants

Institutional Controls – prevent exposure
(can be used to maintain the Statewide Health Standard, but NOT to attain it)

Engineering Controls – contain or control migration
Environmental Covenants

Is An Environmental Covenant Needed

• Required for active mitigation (engineering control)

• Required for institutional controls for future use:
  ➢ prohibiting new buildings or basements
  ➢ requiring a VI evaluation for new construction
  ➢ requiring mitigation for new construction
  ➢ for the ongoing applicability of an OSHA program

[Sections H and J]
When Evaluating Indoor Air:

- Difficult to evaluate the effect of the VI source when the same chemicals are being used in the building.

- Remediator may choose to use OSHA program to address VI because the PEL values are much higher than indoor air screening values.

Using OSHA to Address VI:

- May use OSHA program to address VI under Act 2 only if:
  1. COC in GW or soil is currently used in on-site industrial processes
  2. OSHA regulations are fully implemented and documented in ALL areas of the building for ALL possible receptors

- Quantitative analysis of indoor air data using occupational screening values is expected

- EC required if using OSHA program to evaluate VI

[Section K.7]
Demonstrating that OSHA regulations are fully implemented:

• Appendix D
  – Checklist of elements to document the OSHA program on the site
  – All elements on the checklist should be present in the report to prove the OSHA program is adequately implemented for all receptors
Appendix D: OSHA Program Vapor Intrusion Checklist

List the chemical(s) of concern that the facility uses:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>CAS Registry Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- [ ] Facility provided Material Safety Data Sheet(s) (MSDS) or Safety Data Sheet(s) (SDS) for the chemical(s) of concern listed above that they have identified as using.

- [ ] Facility identified where the chemical(s) are used in the facility and how they are used.

- [ ] The facility has performed air monitoring (industrial hygiene) of the identified chemical(s) of concern.

- [ ] The facility has provided the results of the air monitoring to the Department.

- [ ] The air monitoring has been conducted in all areas of the plant or facility.

- [ ] The facility has provided documentation showing that all employees in the facility have completed safety training associated with the chemicals of concern.
OSHA Checklist

List the chemical(s) of concern that the facility uses:

<table>
<thead>
<tr>
<th>Chemical:</th>
<th>CAS Registry Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

– Regulated substances in the VI pathway must also be used in the workplace
Facility provided Material Safety Data Sheet(s) (MSDS) or Safety Data Sheet(s) (SDS) for the chemical(s) of concern listed above that they have identified as using.

Facility identified where the chemical(s) are used in the facility and how they are used.

The facility has performed air monitoring (industrial hygiene) of the identified chemical(s) of concern.
The facility has provided the results of the air monitoring to the Department.

The air monitoring has been conducted in all areas of the plant or facility.

The facility has provided documentation showing that all employees in the facility have completed safety training associated with the chemicals of concern.
OSHA Checklist

- Pictures provided by the facility show PPE and signage use associated with the chemicals of concern.
  - Include Annual assessments and medical clearances
Occupational Exposure Values for Chemicals of Concern

Occupational Safety and Health Administration Permissible Exposure Limits (OSHA PEL) or American Conference of Governmental Industrial Hygienist Threshold Limit Values (ACGIH TLV).

<table>
<thead>
<tr>
<th>Chemical of Concern</th>
<th>OSHA PEL</th>
<th>ACGIH TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OSHA exposure limits are available at: 29 CFR Subpart Z; 29 CFR 1910.1000–1052


ACGIH TLVs are available from the purchased publication. All of these values should be available from the MSDS/SDS.

Status: (All of the above items must be included in order for the facility to qualify to use an OSHA program to address VI.)

☐ Qualified
☐ Not Qualified

Consultant or Reviewer:

(Print)______________________________________

(Signature)________________________________ Date:_________________
Appendix B

• Description of DEP’s modeling expectations
• SHS and SSS modeling approaches
• Report contents—what information the consultant should submit
Why use Modeling?

➤ Screening of predicted indoor air
  – For SHS
  – Indoor air measurements may not be possible:
    • Access Issues
    • Presence of chemicals indoors that will interfere with measurement
    • Undeveloped sites or areas

[Section G.3]
Why use Modeling?

- Screening of predicted indoor air
  - Model generates a predicted indoor air concentration
  - Predicted indoor air concentration is compared to the indoor air screening value

[Section G.3]
Why use Modeling?

- Calculate predicted inhalation risks (Risk Assessment)
  - For SSS ONLY

[Section K.5]
Models Available

- J&E Model
- BioVapor model
  - Best for petroleum VI sites because J&E does not account for bioattenuation of petroleum

[Section G.3]
Restrictions for J&E Model

- Can’t model Soil/ GW data when external preferential pathway or SPL is present
- Can’t model Near-Source soil gas data when external preferential pathway is present

[Section G3]
J&E Model

- Should only use DEP versions of J&E
  - Posted on the DEP website on the Vapor Intrusion page
  - PA versions have the DEP default input parameters, physical/chemical properties, and toxicological values

[Appendix B]
J&E Model

• Six PA DEP J&E models, based on source data and land use:
  ➢ Groundwater Residential and Non-residential
  ➢ Soil Residential and Non-residential
  ➢ Soil Gas Residential and Non-residential

[Appendix B]
Modeling Under SHS

• Predicted Indoor Air concentration on RESULTS tab
• Compared to the indoor air screening value

[Appendix B]
VI Modeling

Modeling Under SSS

• Inhalation Risks (carcinogenic and noncarcinogenic) on the RESULTS tab are added with all risks for the given receptor

• Compared to the Act 2 thresholds

[Appendix B]
RESULTS

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

<table>
<thead>
<tr>
<th>Indoor exposure groundwater conc., (µg/L)</th>
<th>Indoor exposure groundwater conc., (µg/L)</th>
<th>Risk-based indoor exposure groundwater conc., (µg/L)</th>
<th>Pure component water solubility, S (µg/L)</th>
<th>Final indoor exposure groundwater conc., (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1.10E+06</td>
<td>NA</td>
</tr>
</tbody>
</table>

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: Mutagenic adjustment factor applied to cancer risk calculation.

Groundwater Results

INCREMENTAL RISK CALCULATIONS:

<table>
<thead>
<tr>
<th>Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)</th>
<th>Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2E-04</td>
<td>2.5E+01</td>
</tr>
</tbody>
</table>

INDOOR AIR CALCULATIONS:

| Infinite source bldg. conc., Cbuilding (µg/m³) |
|-----------------------------------------------|---------------------------------------------|
| 5.3E+01                                       |                                             |

SSS: Inhalation risks

SHS: Indoor air concentration
### Calculate Risk-Based Groundwater Concentration

Enter "X" in "YES" box.

**YES**

Not available for PA DEP models.

**OR**

Calculate Incremental Risks from Actual Groundwater Concentration (enter "X" in "YES" box and initial groundwater conc. below)

**YES**

Entries highlighted in yellow should be verified and updated with site-specific information by the user, if appropriate. (Other parameters may also be modified.) Refer to the PA DEP Technical Guidance Manual for Vapor Intrusion, Appendix B.

---

**Chemical**

**CAS No.**

**79016**

**Initial conc., (μg/L)**

**1.00E+03**

**TRICHLOROETHYLENE (TCE)**

#### Parameters

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<th>Parameter</th>
<th>Value</th>
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<td>Temperature</td>
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<td>Soil stratum B thickness</td>
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<tr>
<td>Soil stratum C bulk density</td>
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</table>

#### Additional Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Average vapor rate into bldg.</td>
<td>5</td>
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</tbody>
</table>

---

**Residential Exposure Factors** Use default residential or nonresidential values for Statewide health standard models.
### Soil Properties Lookup Table

<table>
<thead>
<tr>
<th>SCS Soil Type</th>
<th>$K_r$ (cm/h)</th>
<th>$\alpha_1$ (1/cm)</th>
<th>N (unitless)</th>
<th>M (unitless)</th>
<th>n (cm$^3$)/mg</th>
<th>$\theta_1$ (cm$^3$)/mg</th>
<th>Mean Grain Diameter (cm)</th>
<th>Bulk Density $\rho_b$ (g/cm$^3$)</th>
<th>$\theta_b$ (cm$^3$)/mg</th>
<th>SCS Soil Name</th>
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<td>C</td>
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<td>CL</td>
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<td>0.0039</td>
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<td>1.62</td>
<td>0.100 Sandy Loam</td>
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</tr>
</tbody>
</table>
Addressing Chapter 250 Requirements

• Final step necessary to demonstrate compliance

• Ch. 250 VI requirements can be achieved by:
  1. Soil and GW screening within proximity distances
  2. Using one or more of the alternative assessment options
  3. Mitigation with an Environmental Covenant (EC)
  4. A Risk Assessment that demonstrates that the health risks are within acceptable limits

• Remediation should result in resampling and reevaluation to meet one of the requirements listed above
Addressing Chapter 250 Requirements

- Final step necessary to demonstrate compliance
- Ch. 250 VI requirements can be achieved by:

1. Soil and GW screening within proximity distances
2. Using one or more of the alternative assessment options
3. Mitigation with an Environmental Covenant (EC)
4. A Risk Assessment that demonstrates that the health risks are within acceptable limits

[Section J]
Addressing Chapter 250 Requirements

• Final step necessary to demonstrate compliance

• Ch. 250 VI requirements can be achieved by:

  1. Soil and GW screening within proximity distances
  2. Using one or more of the alternative assessment options
  3. Mitigation with an Environmental Covenant (EC)
  4. A Risk Assessment that demonstrates that the health risks are within acceptable limits

[Section J]
SHS

Soil and GW screening within proximity distances

✓ Screen data that is within the proximity distance from the contamination

✓ If data is below screening values then no Potential VI source is identified

✓ Diagrams showing data points, buildings, proximity distances should be included in report
Using Alternative Assessment Options

✓ Screening Near-Source, Sub-slab, and/or indoor air data
✓ Modeling indoor air
Using Alternative Assessment Options

- If data is below screening values then no further analysis is required
- Diagrams showing sampling points, buildings, Potential VI Sources should be included in report

[Section J]
SHS

Mitigation with EC

- Install mitigation system
- Installer certification, manufacturer’s specifications, plans should be included in report
- Testing of the system should be performed and results documented

[Section J]
SSS (Compared to SHS)

- Screening values are different
- Risk Assessment may be required
### Addressing Ch. 250 Requirements

<table>
<thead>
<tr>
<th>Act 2 Standard Used to Address Soil and Groundwater</th>
<th>VI Evaluation Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use Screening Values in Tables 1–5</td>
</tr>
<tr>
<td>Statewide Health Standard (SHS)</td>
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<tr>
<td>Site-Specific Standard (SSS)</td>
<td>✔️</td>
</tr>
<tr>
<td>Combination of Standards*</td>
<td>✔️</td>
</tr>
</tbody>
</table>

- Some media and/or substances may attain the SHS while others may attain the SSS.

[Section C.3]
SSS

VI evaluation performed under SSS when:

- Substances of VI concern in soil and/or groundwater are evaluated under the SSS
- Soil and groundwater meet SHS, but VI pathway does not meet SHS
- Choosing to evaluate substances such as mercury, cyanide or organics with no inhalation toxicity values

[Section K.1]
Risk Assessment demonstrating that health risks are within acceptable limits

- Sum risks for all substances and for **all pathways** for each receptor

- Compare cumulative risk to acceptable thresholds: $10^{-4}$ cancer risk, hazard index 1.0
Questions?
VI Sampling

Charles Campbell (Leidos)
Vapor Intrusion Training

January 10, 2017
Malvern, PA
Appendix C

❖ Information and recommendations on sampling methods

➢ Best practices

➢ **Not requirements**
Sampling Guidance

- Variability of Data
- Sampling Locations
- Sampling Methods
  - Oxygen content
  - SPL
  - Leak testing
  - Sub-slab depressurization testing
Variability of Data

• In Soil gas, Sub-slab, and Indoor air measurements

• Should be considered in sampling

• Variability range can be an order of magnitude, or more
Variability of Data

- Spatial variability
- Temporal variability

[Appendix C]
Spatial variability

Non-uniform concentrations at different locations within or beneath a building

- Source distribution, building structure, oxygen content of soil

[Appendix C]
TCE in Soil Gas—Layton, Utah Study Site

Source: Johnson et al. [2011]
Temporal variability

Concentrations that change from one sampling event to the next.

- Pressure and temperature differences, building ventilation, sampling leaks

[Appendix C]
Sub-Slab TCE—Layton, Utah Study Site
Concentrations at four times

Source: Holton [2015]
Variability of VI Data

How do we address variability?

• Install sufficient sample points—at least two per building
• Perform enough sampling rounds—at least two
• Indoor air sampling during heating season
• VI sampling plan should reflect CSM

Professional judgment

• If DEP’s review concludes that sampling is insufficient, discuss doing more

[Appendix C]
Sampling Locations:

- Near-source soil gas
- Sub-slab soil gas
- Indoor Air

[Appendix C]
Near-source soil gas

- At least five feet below foundation level to use $SV_{NS}$
- For a GW source, within one foot of the top of the capillary fringe, or soil-bedrock interface
- Permanent points recommended
- Minimize disturbance to formation

[Section G2, Appendix C]
Sub-slab soil gas

- Perform pre-sampling survey
- In areas of the building with the greatest expected VI impact
- Intact areas of the slab
- Avoid perimeter (> 5 ft)

[Appendix C]
Indoor Air

• Perform pre-sampling survey
  ➢ Visual review of lowest level
  ➢ Conditions of floor slab, floor cracks
  ➢ Heating & Ventilation systems
  ➢ VOC sources in lowest level – paint, solvents, fuel containers
  ➢ VOC sources outside – mowing, paving
  ➢ Occupant activities – painting, smoking

[Appendix C]
Sampling Locations

Indoor Air

• Sample from the lowest occupied level
• Beware of background and indoor sources
• Collect a concurrent ambient air sample
• Use 6-L Summa canisters
  ➢ Sample rate < 200 mL/min; duration 8 or 24 hr

[Appendix C]
Indoor Air

- The indoor temperature should be at least 15°F greater than the outdoor temperature.
- Samples collected in warmer seasons should be used for information only and not to screen.
- If building is not heated, samples can be collected in any season.

[Section G2]
Sampling Locations

Key:

- Vapor pathway
- Groundwater sample
- Soil sample
- Air sample

Saturated zone

30 feet

Pennsylvania Department of Environmental Protection
Sampling Locations
Soil Gas

- At least two locations per building
- At least two rounds, at least 45 days apart
Soil Gas

- Use appropriate, nonreactive materials
  - No polyethylene tubing
- Point must equilibrate after construction 2-24 hr
- Use passivated canisters (Summa)
  - 1-L volume normally adequate
- Purge about three volumes; Flow rate < 200 mL/min; Sample duration ~30 min

[Appendix C]
Using Statistical Tests to screen data: **SHS only**

- At least eight data points
- Combination of sampling locations and sampling rounds
- All eight points from one type of sample (NS, SS, IA)
- Sampling rounds performed in subsequent quarters or twice per quarter – At least 45 days apart.

[Section G2]
Oxygen Content

○ Demonstrates Acceptable Soil (greater than 2% oxygen content)
Oxygen Content

- Recommended when the soil is suspected to be anaerobic
  - Petroleum substances will not biodegrade at expected rates

- Only needed when using vertical proximity distances for petroleum substances

[Appendix C]
Oxygen Content

- Sub-slab sample \( \sim 12 \) inches below the slab
- Near-slab no farther than 10 feet from the building (if Sub-slab is not possible)
- One grab sample at one location

[Appendix C]
SPL Sampling

- SPL places limitations on screening, modeling, and use of proximity distances
- Can perform testing of SPL for presence of VOCs that pose a VI risk
- Concentrations of VOCs are evaluated with Near-source screening values to determine if a VI risk is present

[Appendix C]
Leak Testing – recommended

- Leaking during soil gas sampling may dilute samples with ambient air
  - Shut-in test
    - Demonstrates integrity of the sampling assembly using vacuum
  - Leak check
    - Demonstrates surface seal integrity using helium shroud

[Appendix C]
Sub-slab Depressurization Systems

- Differential pressure measurements across the slab
  - More than one location, corners and edges
  - Use a digital micromanometer
  - Demonstrate vacuum of ≥ 0.004” H₂O (1 Pa)

- Alternative: indoor air sampling – not required

[Appendix C]
Questions?
Vapor Intrusion Case Study
Urban Petroleum Site

C. David Brown (DEP)
Vapor Intrusion Guidance Training

January 10, 2017
Malvern, PA
VI Case Study

- Application of the VI evaluation process
- Conceptual site model
- Preferential pathways
- Proximity distances
- Combination of standards
- Soil and groundwater screening
- Soil gas sampling and screening
- SSS risk assessment
- VI modeling
Background

- Former gas station; closed in 1998
- USTs removed in 2006
- Notification of release, soil & groundwater
- Incomplete site characterization
- Potential vapor intrusion receptors
- DEP state lead tank site 2013–
Vapor Intrusion Evaluation Process

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES

Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

MITIGATION

Environmental Covenant

REMEDIATION

Reevaluate the VI Pathway

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
Soil Sampling Data

**SB-5**
- 10.0–10.5
- 12/17/13
  - Benzene: 57
  - Ethylbenzene: 270
  - Naphthalene: 87
  - Toluene: 1200
  - 1,2,4-TMB: 790
  - 1,3,5-TMB: 220
  - Xylene (Total): 1800

**SB-8**
- 10.0–10.5
- 12/17/13
  - Benzene: 15
  - Ethylbenzene: 210
  - Naphthalene: 59
  - Toluene: 670
  - 1,2,4-TMB: 640
  - 1,3,5-TMB: 170
  - Xylene (Total): 1500

**SB-7**
- 9.0–9.5
- 12/17/13
  - Benzene: 2.5
  - Ethylbenzene: 180
  - Naphthalene: 76
  - Toluene: 260
  - 1,2,4-TMB: 830
  - 1,3,5-TMB: 240
  - Xylene (Total): 1400

**SB-10**
- 9.0–9.5
- 12/18/13
  - Benzene: 17
  - Ethylbenzene: 150
  - Naphthalene: 67
  - Toluene: 480
  - 1,2,4-TMB: 540
  - 1,3,5-TMB: 170
  - Xylene (Total): 1300

**MW-1**
- 12/11/15
  - 7.5–8.0
  - 12.5–13.0
  - Benzene: 5.2
  - Ethylbenzene: 73
  - Naphthalene: 26
  - Toluene: 150
  - 1,2,4-TMB: 210
  - 1,3,5-TMB: 59

**SB-9**
- 9.0–9.5
- 12/18/13
  - Benzene: 2.5
  - Ethylbenzene: 89
  - Naphthalene: 38
  - Toluene: 140
  - 1,2,4-TMB: 330
  - 1,3,5-TMB: 100

**SB-2**
- 10.0–10.5
- 12/17/13
  - Benzene: 18
  - Ethylbenzene: 210
  - Naphthalene: 63
  - Toluene: 810
  - 1,2,4-TMB: 510
  - 1,3,5-TMB: 170
  - Xylene (Total): 1200

**MW-3**
- 10.5–11.0
- 12/12/13
  - Benzene: 18
  - Ethylbenzene: 210
  - Naphthalene: 63
  - Toluene: 810
  - 1,2,4-TMB: 510
  - 1,3,5-TMB: 170
  - Xylene (Total): 1200

**SB-5**
- 10.0–10.5
- 12/16/13
  - Benzene: 51
  - Ethylbenzene: 190
  - Naphthalene: 50
  - Toluene: 870
  - 1,2,4-TMB: 480
  - 1,3,5-TMB: 140
  - Xylene (Total): 1200

**SB-11**
- 15.5–16.0
- 12/18/13
  - 1,2,4-TMB: 39
  - 1,3,5-TMB: 10

**SB-3**
- 9.5–10.0
- 12/13/13
  - Naphthalene: 52
  - 1,2,4-TMB: 530
  - 1,3,5-TMB: 160

**SB-4**
- 10.0–10.5
- 12/16/13
  - Benzene: 2
  - Toluene: 210
  - 1,2,4-TMB: 110
  - 1,3,5-TMB: 33
Groundwater Elevation Data

April 2014
Groundwater Sampling Data

MW-1
4/10/2014
Benzene 3000
MTBE 300
1,2,4-TMB 160
1,3,5-TMB 25

MW-2
4/10/2014
Benzene 270
1,2,4-TMB 51

MW-3
4/10/2014
Benzene 260

Cross Section
Cross Section

WNW Residential property

SB-3 SB-2 SB-6 MW-8D Passyunk Avenue MW-1 SB-9 SB-2 MW-3

601 Christian Street property

fill

silt/clay

sand

(DTW June 2016)

vertical exaggeration 2x

10 ft

20 ft
Conceptual Site Model

- Gasoline released at least 18 years ago
- Urban fill, silt/clay soil, deeper sand unit
- Groundwater ~27 feet deep
- Groundwater flow to south and southeast
- Soil impact ~7–16 feet deep in silt/clay
- Direct contact MSC exceedences
- Significant groundwater impact in southwest
- No mobile LNAPL; possibly residual LNAPL
CSM (continued)

- Water, sewer, and gas utility lines
- Some subsurface electric and telephone lines
- Combined sewer main to south of property
- Property is a vacant lot
- But unrestricted access
- No groundwater use in area
- No nearby surface water
- Potential VI at neighboring buildings
Site Characterization Deficiencies

- Further characterization is required
- Extent of soil impact under sidewalks and streets is unknown
- Groundwater plume is not delineated
- Cleanup standard(s) must be selected
- Vapor intrusion pathway requires evaluation
Screen Soil Data for Vapor Intrusion

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL
VI SOURCES

Soil Screening

ALTERNATIVE VI
ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION

Environmental Covenant

REMEDICATION

Reevaluate the VI Pathway

SCREEN FOR POTENTIAL
VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250
REQUIREMENTS

No further VI analysis is necessary.
Exercise Objective: Soil Screening

• Soil is characterized on the source property
• Are there potential VI sources in soil?
• Are any substances in soil excluded from further VI evaluation?
• Remember: a potential VI source is defined by exceedences of SHS screening values
  ➢ Soil screening doesn’t depend on standard used
  ➢ Refer to Table 2 screening values
Conditions for Soil Screening

Conditions from VI Guidance Table 6:

☑ Collect sufficient samples to characterize source(s)
☑ Samples are from unsaturated soil
☑ No SPL has been observed
Restrictions on Soil Screening

Restrictions from VI Guidance Figure 7:

- SPL not identified within horizontal proximity distance
- Significant foundation openings not present—property is undeveloped

If VI screening values are exceeded, then these restrictions may not pertain
<table>
<thead>
<tr>
<th>Regulated Substance</th>
<th>CAS No.</th>
<th>Residential (mg/kg)</th>
<th>Type</th>
<th>Nonresidential (mg/kg)</th>
<th>Type</th>
<th>Converted Residential (mg/kg)</th>
<th>Type</th>
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<td>SGN</td>
<td>9.6</td>
<td>SV</td>
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<td>8.0</td>
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<td>CRESOL(S)</td>
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**Exercise #1: Soil Vapor Intrusion Screening (Case Study)**

**SB-2—Analytical Data**

<table>
<thead>
<tr>
<th>Substance</th>
<th>CAS No.</th>
<th>SB-2</th>
<th>SHS MSCs</th>
<th>VI Screening Values</th>
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<td>Soil Screening Value</td>
</tr>
<tr>
<td>Depth (ft)</td>
<td>10.0–10.5</td>
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<td></td>
<td>mg/kg</td>
</tr>
<tr>
<td>Date Collected</td>
<td>12/16/2013</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Type (USCS)</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units</td>
<td>mg/kg</td>
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<td>57</td>
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<td><strong>1,2-Dibromoethane</strong></td>
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<td>0.74</td>
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<td><strong>810</strong></td>
<td>100</td>
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<td><strong>1,2,4-Trimethylbenzene</strong></td>
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<td><strong>Xylene (Total)</strong></td>
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</table>

**Bolded** data entries indicate exceedences of Statewide health standard MSCs.
Exercise Instructions

• You have soil data from one sample (SB-2)
• Determine the residential soil VI screening value for each substance
• Are there potential VI sources in soil?
• Which substances exceed?
• Which don’t?
### Exercise #1: Soil Vapor Intrusion Screening (Case Study)

<table>
<thead>
<tr>
<th>Substance</th>
<th>CAS No.</th>
<th>SB-2</th>
<th>SHS MSCs</th>
<th>VI Screening Values</th>
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<td>Soil–Ground-</td>
<td>Direct Contact (0–15 ft)</td>
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<td></td>
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<td>water mg/kg</td>
<td>mg/kg</td>
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<td>Soil Type</td>
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<td>ML</td>
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**Exercise #1 Answers**

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<tr>
<th>Substance</th>
<th>CAS No.</th>
<th>SB-2</th>
<th>SHS MSCs</th>
<th>VI Screening Values</th>
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<td>Cumene</td>
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<td>26</td>
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<tr>
<td>Methyl tert-Butyl Ether</td>
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<td>Toluene</td>
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<td>1,2,4-Trimethylbenzene</td>
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<td>1,3,5-Trimethylbenzene</td>
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<td>Xylene (Total)</td>
<td>1330-20-7</td>
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<td>1,000</td>
<td>1,900</td>
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</table>

**Exceed?**

- Benzene: yes
- 1,2-Dibromoethane: yes
- 1,2-Dichloroethane: yes
- Ethylbenzene: yes
- Cumene: no
- Methyl tert-Butyl Ether: yes
- Naphthalene: yes
- Toluene: yes
- 1,2,4-Trimethylbenzene: yes
- 1,3,5-Trimethylbenzene: yes
- Xylene (Total): yes
VI Soil Screening Results

• There is a potential VI source in soil
  ➢ Benzene, toluene, ethylbenzene, xylenes, naphthalene, 1,2,4-TMB, 1,3,5-TMB
• Cumene is not a potential VI source
• The method detection limits for three substances exceed $SV_{SOIL}$
  ➢ MTBE, EDB, EDC
  ➢ They must be retained in the VI evaluation
Area of Potential VI Source in Soil

Sketch this on your figure labeled “Exercise #3”
Questions/Discussion
Consider Preferential Pathways

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES

Soil Screening

ALTERNATIVE VI ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION

Environmental Covenant

REMEDICATION

Reevaluate the VI Pathway

SCREEN FOR POTENTIAL VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
External Preferential Pathway Evaluation

- Sewer, water, and electric utilities
- No connections at source property
- Utility lines/vaults likely present within 30 feet horizontally of soil exceeding SVs
- Utility lines/vaults likely present within 5 feet vertically of soil exceeding SVs
- Therefore, utilities are potential external preferential pathways
Utilities Within 30 feet of Soil Exceedences
City Combined Sewer Plan
Preferential Pathways, continued

- Reinforced concrete sewer main to south
- Box culvert, ~10 x 10 feet
- Depth to top ~10 feet
  depth to bottom ~20 feet
- Groundwater plume > 5 feet below sewer
  ➢ Not a preferential pathway for groundwater
- Soil exceedences are present within 30 feet horizontally and 5 feet vertically of sewer
Preferential Pathway Options

- Near-source soil gas sampling
- Soil gas sampling in trenches
- Sample vapor in sewer line
- Residential sub-slab sampling
- Inspect residences for utility penetrations
- Residential indoor air sampling

[See VI Guidance Section D.1]
External Preferential Pathway Evaluation: One Option

Prospective Soil Gas Point
Preferential Pathway Considerations

- No mobile LNAPL present
- Only petroleum contaminants of concern
- Utility line trenches likely backfilled with soil-like material → vapor attenuation
  - From site observations and utility contractor info
- Volume of sewer main is large relative to area of contamination
  - Petroleum vapors would be substantially diluted
Significant Foundation Openings

- Residences have not been accessed to inspect basements
- Nonintrusive evaluation options:
  - Horizontal proximity distance
  - Soil and groundwater screening
  - Near-source soil gas sampling
  - VI modeling

[See VI Guidance Section D.2]
Preferential Pathway Status

- Site data does not indicate a heightened concern for preferential pathways
- Further investigation could be performed for potential external preferential pathways
  - For example, soil gas sampling
- Further assessment of potential significant openings should also be conducted
  - Offsite soil, groundwater, soil gas sampling
Further Groundwater Characterization

**Start Here**

**Conceptual Site Model**
Delineate Contamination

**Delineate Potential VI Sources**
Soil and Groundwater Screening

**Screen for Potential VI Sources**
Identify Preferential Pathways
Apply Proximity Distances

**Alternative VI Assessment Options**
Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

**Mitigation**
Environmental Covenant

**Remediation**
Reevaluate the VI Pathway

**Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time**

**Address CH. 250 Requirements**
No further VI analysis is necessary.
Groundwater Sampling Data

**MW-8D**  
6/5/2015  
<table>
<thead>
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<th>Analyte</th>
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<td>Naphthalene</td>
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6/4/2015  
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6/4/2015  
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6/4/2015  
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**MW-7D**  
6/5/2015  
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**MW-6D**  
6/4/2015  
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June 2015
Conceptual Site Model Update

- There is a potential VI source in soil onsite
- Another source property exists to the west
  - Also a former gas station, closed Act 2 site
  - VI was mitigated in new construction (2004)
- Soil samples from the offsite wells do not indicate impacts from the source property
  - Soil contamination is delineated
CSM Update (continued)

• The groundwater plume has been delineated
  ➢ Extends to the south, beneath offsite residences
  ➢ Is it a potential VI source?
• Significant foundation openings remain a potential pathway offsite
• Vapor intrusion requires further evaluation
Screen Groundwater Data for VI

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES

Groundwater Screening

ALTERNATIVE VI ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION

Environmental Covenant

REMEDIATION

Reevaluate the VI Pathway

SCREEN FOR POTENTIAL VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
Exercise Objective: Groundwater Screening

- Is the groundwater plume a potential VI source? Where?
- Are any substances in groundwater excluded?
- Remember: a potential VI source is defined by exceedences of SHS screening values
  - Independent of standard
  - Refer to Table 1 screening values
Conditions for Groundwater Screening

Conditions from VI Guidance Table 6

- Install sufficient monitoring wells
- Properly construct monitoring wells
- MW screens cross the water table
- Wetted length ≤ 10 feet
- Groundwater > 5 feet from buildings
- Acceptable soil or soil-like material present
- No SPL is present
Restrictions on Groundwater Screening

Restrictions from VI Guidance Figure 7:

- No SPL observed in monitoring wells within horizontal proximity distance
- Significant foundation openings—not suspected (could screen with MSCs)
- Contamination does not enter external preferential pathways—GW too deep
- Groundwater is > 5 feet below foundations
### Table 1: Groundwater Statewide Health Standard Vapor Intrusion Screening Values (SV\textsubscript{GW})

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<tr>
<th>Regulated Substance</th>
<th>CAS No.</th>
<th>Residential (µg/L)</th>
<th>Type</th>
<th>Nonresidential (µg/L)</th>
<th>Type</th>
<th>Converted Residential (µg/L)</th>
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<td>Sol.</td>
<td>20,000,000</td>
<td>Sol.</td>
<td>20,000,000</td>
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Exercise #2: Groundwater Vapor Intrusion Screening (Case Study)

MW-7D—Analytical Data

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<th>Benzene</th>
<th>Ethylbenzene</th>
<th>Cumene</th>
<th>MTBE</th>
<th>Naphthalene</th>
<th>Toluene</th>
<th>1,2,4-TMB</th>
<th>1,3,5-TMB</th>
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<td>108-67-8</td>
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<tr>
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<td>374</td>
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<td>95</td>
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<td>298</td>
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<td>1210</td>
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<td>3/8/2016</td>
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<td>444</td>
<td>76</td>
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<td>371</td>
<td>4.9</td>
<td>1170</td>
<td>346</td>
<td>1405</td>
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<tr>
<td>6/9/2016</td>
<td>889</td>
<td>1900</td>
<td>202</td>
<td>25</td>
<td>778</td>
<td>7.8</td>
<td>2670</td>
<td>794</td>
<td>4710</td>
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<tr>
<td>9/14/2016</td>
<td>802</td>
<td>1390</td>
<td>161</td>
<td>0.5 U</td>
<td>602</td>
<td>6.4</td>
<td>1700</td>
<td>510</td>
<td>2954</td>
</tr>
</tbody>
</table>

VI Screening Values

| Groundwater Screening Value |     |     |     |     |     |     |     |     |     |
| Exceed? (yes/no)           |     |     |     |     |     |     |     |     |

**Bolded** data entries indicate exceedences of Statewide health standard MSCs.
Exercise Instructions

• You have VOC analytical data from one monitoring well (MW-7D)
• Determine the residential groundwater VI screening value for each substance
• Are there potential VI sources in groundwater?
• Which substances exceed?
• Which don’t?
**Exercise #2: Groundwater Vapor Intrusion Screening (Case Study)**

**MW-7D—Analytical Data**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Benzene (CAS No.)</th>
<th>Ethylbenzene</th>
<th>Cumene</th>
<th>MTBE</th>
<th>Naphthalene</th>
<th>Toluene</th>
<th>1,2,4-TMB</th>
<th>1,3,5-TMB</th>
<th>Xylenes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHS MSC</td>
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<td>108-88-3</td>
<td>95-63-6</td>
<td>108-67-8</td>
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<td>623</td>
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<td>1170</td>
<td>346</td>
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<td>6/9/2016</td>
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**VI Screening Values**

<table>
<thead>
<tr>
<th>Groundwater Screening Value</th>
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<th>700</th>
<th>1,900</th>
<th>6,300</th>
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<tbody>
<tr>
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<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
VI Groundwater Screening Results

- There is a potential VI source in groundwater
  - Benzene, ethylbenzene, naphthalene, TMBs
  - Extends offsite
- Cumene, MTBE, toluene, and xylenes are not potential VI sources
- Characterization samples from three onsite wells were analyzed for EDB and EDC
  - Data did not exceed $SV_{GW}$
Areas of Potential VI Source in Groundwater

Mark these wells on your figure labeled “Exercise #3”
## Intermittent Screening Value Exceedences

<table>
<thead>
<tr>
<th>Date</th>
<th>Benzene (μg/L)</th>
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<tbody>
<tr>
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<td>22</td>
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<tr>
<td>4/10/2014</td>
<td><strong>260</strong></td>
</tr>
<tr>
<td>7/21/2014</td>
<td><strong>109</strong></td>
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<tr>
<td>10/7/2014</td>
<td>15</td>
</tr>
<tr>
<td>1/21/2015</td>
<td>6.9</td>
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<tr>
<td>6/4/2015</td>
<td>22</td>
</tr>
<tr>
<td>9/16/2015</td>
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</tr>
<tr>
<td>12/16/2015</td>
<td>0.9</td>
</tr>
<tr>
<td>3/9/2016</td>
<td>8.9</td>
</tr>
<tr>
<td>6/9/2016</td>
<td>0.8</td>
</tr>
<tr>
<td>SHS R SV\textsubscript{GW}</td>
<td>23</td>
</tr>
</tbody>
</table>
If this is an interior well, and GW attains the SHS at the POC, then the last eight quarters of data pass the 75%/10x test for VI screening.

<table>
<thead>
<tr>
<th>Date</th>
<th>Benzene (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/23/2014</td>
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</tr>
<tr>
<td>4/10/2014</td>
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<tr>
<td>7/21/2014</td>
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<tr>
<td>10/7/2014</td>
<td>15</td>
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<tr>
<td>1/21/2015</td>
<td>6.9</td>
</tr>
<tr>
<td>6/4/2015</td>
<td>22</td>
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<tr>
<td>9/16/2015</td>
<td>20</td>
</tr>
<tr>
<td>12/16/2015</td>
<td>0.9</td>
</tr>
<tr>
<td>3/9/2016</td>
<td>8.9</td>
</tr>
<tr>
<td>6/9/2016</td>
<td>0.8</td>
</tr>
<tr>
<td>SHS R SV&lt;sub&gt;GW&lt;/sub&gt;</td>
<td>23</td>
</tr>
</tbody>
</table>
If this is a **POC** well, the last eight quarters of data does **not** pass the 75%/10x test for the MSC → SSS

<table>
<thead>
<tr>
<th>Date</th>
<th>Benzene (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/23/2014</td>
<td>22</td>
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<tr>
<td>4/10/2014</td>
<td>260</td>
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<td>7/21/2014</td>
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<td>10/7/2014</td>
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<td>6/4/2015</td>
<td>22</td>
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<td>9/16/2015</td>
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<td>12/16/2015</td>
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<td>8.9</td>
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<td>6/9/2016</td>
<td>0.8</td>
</tr>
<tr>
<td>SHS MSC</td>
<td>5</td>
</tr>
</tbody>
</table>
For the SSS, screening of attainment data requires use of one-tenth $SV_{GW}$, no 75%/10x test → alternative assessment options

### VI Case Study

<table>
<thead>
<tr>
<th>Date</th>
<th>Benzene (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>22</td>
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<td>4/10/2014</td>
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<tr>
<td>10/7/2014</td>
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<td>1/21/2015</td>
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<td>6/4/2015</td>
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<td>0.8</td>
</tr>
<tr>
<td>SHS MSC</td>
<td>2.3</td>
</tr>
</tbody>
</table>
GW Screening Considerations

• What if GW concentrations only intermittently exceed the screening value?
  ➢ Any exceedence of the SHS $SV_{GW}$ indicates a potential VI source

• Refer to VI Guidance Table 7—for SHS only
  ➢ No exceedences for characterization data
  ➢ Options for statistical tests for attainment data

• Site-specific standard
  ➢ No exceedence rule for all data
Questions/Discussion
Apply Petroleum Proximity Distances

Start Here

Conceptual Site Model Delineate Contamination

Delineate Potential VI Sources

Soil and Groundwater Screening

Screen for Potential VI Sources

Identify Preferential Pathways
Apply Proximity Distances

Note: It is acceptable to apply proximity distances after delineating to MSCs without performing VI screening

Alternative VI Assessment Options

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

Mitigation

Environmental Covenant

Remediation

Reevaluate the VI Pathway
Proximity Distances

Map View

- Contamination exceeds SVs in the proximity of inhabited building A.
- Horizontal proximity distance is measured between A and inhabited building.

Side View

- Saturated zone D and E are near the contaminated area C.
- Vertical proximity distance is measured from the saturated zone to the contaminated area.
- Tree is placed near the saturated zone to indicate location.
Exercise Objective: Proximity Distances

- Determine if proximity distances allow any potential receptors to be excluded for VI
- Apply petroleum proximity distances:
  - 30 feet horizontally
  - 5 feet vertically, no NAPL
  - 15 feet vertically, NAPL
- Evaluate potential VI sources in soil and groundwater
Exercise #3: Proximity Distances (Case Study)
Exercise Instructions

• Use the previously determined areas of potential VI sources
• Apply proximity distances around potential VI sources in soil and groundwater
• Consider the source property and neighboring properties
• For which properties is soil/groundwater contamination a potential VI source?
Exercise #3: Answer

- Horizontal Proximity Distance
  - 30 ft horizontal proximity distance
  - Interpolated extent of contamination
  - Homes mitigated
  - Potential receptors

- Scale in feet: 0, 30, 60, 90, 120, 150
Proximity Distance Considerations

• Is LNAPL present onsite?
• No LNAPL observed soil or wells
• But maximum benzene ~50 mg/kg
• EPA’s petroleum VI guidance indicates potential residual LNAPL presence for:
  ➢ Benzene > 10 mg/kg
  ➢ TPH > 100/250 mg/kg (gasoline)
• Don’t forget potential preferential pathways
These homes have been mitigated

Separate source

(DTW June 2016)
Proximity Distance Results

- Soil at the former gas station property is a potential VI source
  - Planned development includes a basement
  - So whether NAPL is present or not doesn’t matter

- Groundwater is not a potential VI source
  - *If there are no significant foundation openings*
  - More than 5 feet of acceptable soil is present above the water table and below foundations
  - No mobile LNAPL
  - Both onsite and offsite
Questions/Discussion
Soil Gas Investigation

Start Here

Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES

Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION

Environmental Covenant

REMEDIATION

Reevaluate the VI Pathway

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
Soil Gas Sample Points
Soil Gas Investigation

• Four soil gas points
• Screened ~9 feet deep (clayey silt unit)
• Sampled in two quarterly rounds
• Shut-in vacuum tightness test and helium tracer gas leak test at each point
• Collected 30-min samples in 1-L Summas
• Outdoor ambient air samples
• No EDB or EDC analyses
Exercise Objective: Soil Gas Screening

• Apply appropriate screening values to the soil gas data
• Combination of standards
• Does the VI pathway screen out with the soil gas data?
Conditions for Soil Gas Screening

Conditions from VI Guidance Table 6

- Account for spatial variability
- Minimum two rounds, two locations
- Representative of sources and pathways
- Sample within 1 foot of source
- Sample at least 5 feet below grade
- Acceptable soil or soil-like material present
Restrictions on Soil Gas Screening

Restrictions from VI Guidance Figure 7:

- ☑ Contamination does not enter external preferential pathway—GW too deep
- ☐ Significant foundation openings not suspected—should confirm
- ☐ Preferential pathway foundation penetrations not suspected—should confirm
- ☑ Potential VI source is > 5 feet below foundations
Proposed Soil & Groundwater Standards

• Only **cumene** will attain the Statewide health standard for both soil and groundwater
• The site-specific standard with pathway elimination will be used for all other substances in soil
• The site-specific standard with pathway elimination will be used for groundwater
  - Benzene, ethylbenzene, MTBE, naphthalene, trimethylbenzenes
### Table 3. Near-Source Soil Gas Statewide Health Standard Vapor Intrusion Screening Values (SV$_{NS}$)

<table>
<thead>
<tr>
<th>Regulated Substance</th>
<th>CAS No.</th>
<th>Residential ($\mu g/m^3$)</th>
<th>Nonresidential ($\mu g/m^3$)</th>
<th>Converted Residential ($\mu g/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACETALDEHYDE</td>
<td>75-07-0</td>
<td>1,900</td>
<td>39,000</td>
<td>7,900</td>
</tr>
<tr>
<td>ACETONE</td>
<td>67-64-1</td>
<td>6,500,000</td>
<td>140,000,000</td>
<td>27,000,000</td>
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<tr>
<td>ACETONITRILE</td>
<td>75-05-8</td>
<td>13,000</td>
<td>260,000</td>
<td>53,000</td>
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<tr>
<td>ACROLEIN</td>
<td>107-02-8</td>
<td>4.2</td>
<td>88</td>
<td>18</td>
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<tr>
<td>ACRYLAMIDE</td>
<td>79-06-1</td>
<td>19</td>
<td>1,200</td>
<td>250</td>
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<tr>
<td>ACRYLIC ACID</td>
<td>79-10-7</td>
<td>210</td>
<td>4,400</td>
<td>880</td>
</tr>
<tr>
<td>ACRYLONITRILE</td>
<td>107-13-1</td>
<td>72</td>
<td>1,800</td>
<td>360</td>
</tr>
<tr>
<td>ALLYL ALCOHOL</td>
<td>107-18-6</td>
<td>21</td>
<td>440</td>
<td>88</td>
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<tr>
<td>AMMONIA</td>
<td>7664-41-7</td>
<td>21,000</td>
<td>440,000</td>
<td>88,000</td>
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<tr>
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<td>16,000</td>
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<td>500</td>
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<tr>
<td>BETA PROPIONOLACTONE</td>
<td>57-57-8</td>
<td>1.2</td>
<td>31</td>
<td>6.1</td>
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<tr>
<td>BIPHENYL, 1,1-</td>
<td>92-52-4</td>
<td>83</td>
<td>1,800</td>
<td>350</td>
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</tbody>
</table>

### Table 4. Sub-Slab Soil Gas Statewide Health Standard Vapor Intrusion Screening Values (SV$_{SS}$)

<table>
<thead>
<tr>
<th>Regulated Substance</th>
<th>CAS No.</th>
<th>Residential ($\mu g/m^3$)</th>
<th>Nonresidential ($\mu g/m^3$)</th>
<th>Converted Residential ($\mu g/m^3$)</th>
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<tbody>
<tr>
<td>ACETALDEHYDE</td>
<td>75-07-0</td>
<td>360</td>
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<td>17,000,000</td>
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<td>75-05-8</td>
<td>2,400</td>
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<td>10,000</td>
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<td>17</td>
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<tr>
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<td>56,000</td>
<td>17,000</td>
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<tr>
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<td>40</td>
<td>560</td>
<td>170</td>
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<td>BENZENE</td>
<td>71-43-2</td>
<td>120</td>
<td>2,000</td>
<td>610</td>
</tr>
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<td>100-44-7</td>
<td>19</td>
<td>320</td>
<td>96</td>
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<tr>
<td>BETA PROPIONOLACTONE</td>
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<td>0.23</td>
<td>3.9</td>
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<tr>
<td>BIPHENYL, 1,1-</td>
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<td>16</td>
<td>220</td>
<td>67</td>
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</table>
### Site-Specific Standard Vapor Intrusion Screening Values Based on EPA RSLs

**Residential Conditions for a $10^{-5}$ Screening Value Cancer Risk**

*Note: May 2016 RSL values*

<table>
<thead>
<tr>
<th>Substance</th>
<th>CAS No.</th>
<th>Cancer RSL (µg/m³)</th>
<th>Non-Cancer RSL (µg/m³)</th>
<th>Indoor Air RSL-Based SV (µg/m³)</th>
<th>Sub-Slab Soil Gas RSL-Based SV (µg/m³)</th>
<th>Near-Source Soil Gas RSL-Based SV (µg/m³)</th>
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</thead>
<tbody>
<tr>
<td><strong>Risk Basis</strong></td>
<td></td>
<td><strong>CR = 10^{-6}</strong></td>
<td><strong>HQ = 0.1</strong></td>
<td><strong>CR = 10^{-5} and HQ = 0.1</strong></td>
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<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>71-43-2</td>
<td>3.6E-01</td>
<td>3.1E+00</td>
<td>3.1</td>
<td>120</td>
<td>620</td>
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<tr>
<td>Cumene</td>
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<td>4.2E+00</td>
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<td>1,600</td>
<td>8,400</td>
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<td>Dibromoethane, 1,2-</td>
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<td>4.7E-03</td>
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<td>0.047</td>
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Exercise #4: Soil Gas VI Screening
### Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

**SG-5—Analytical Data** (sample depth 9.5')

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<th>Benzene</th>
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<tbody>
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**Outdoor Ambient Sample Data**

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**VI Screening Values**

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Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5’)

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<th>Substance</th>
<th>Benzene</th>
<th>Ethylbenzene</th>
<th>Cumene</th>
<th>MTBE</th>
<th>Naphthalene</th>
<th>Toluene</th>
<th>1,2,4-TMB</th>
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<tbody>
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<td>100-41-4</td>
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<td>1634-04-4</td>
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<td>108-67-8</td>
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Outdoor Ambient Sample Data

| Date          |         |               |        |       |             |         |           |           |         |
| 6/5/2015      | 1.5     | J             | 2.0    | J     | 2.0         | U       | 1.4       | U         | 5.2     | U       | 2.7     | J         | 2.0      | 2.0      | U         | 6.3      | J       |
| 9/16/2015     | 1.0     | J             | 8.1    | 1.0   | U           | 2.1     | J         | 2.6       | U       | 7.6     | 2.1     | J         | 1.0      | U         | 33       |

VI Screening Values

| Standard            | SSS | SSS | SHS | SSS | SSS | SSS | SSS | SSS | SSS | SSS | SSS | SSS |
|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Statewide Health Standard SV |     |     |     |     |     |     |     |     |     |     |     |     | **120** |
| Site-Specific Standard SV |     |     |     |     |     |     |     |     |     |     |     |     |     |
| RSL-based Site-Specific Standard SV |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Exceed? (yes/no)    |     |     |     |     |     |     |     |     |     |     |     |     |     |

1 Look up SHS SV_{ss}
Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5′)

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VI Screening Values

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Divide by 10 for SSS SV_{ss}
Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5’)

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Outdoor Ambient Sample Data

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| 6/5/2015       | 1.5   | J   | 2.0     | J     | 2.0     | U       | 1.4     | U       | 5.2     | U       | 2.7     | J       | 2.0     | U       | 6.3     | J       |
| 9/16/2015      | 1.0   | J   | 8.1     | 1.0   | 2.1     | J       | 2.6     | U       | 7.6     | 2.1     | J       | 1.0     | U       | 33      |         |

VI Screening Values

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<td>RSL-based Site-Specific Standard SV</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
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</table>

Exceed? (yes/no)
**Exercise #4: Soil Gas Vapor Intrusion Screening** (Case Study)

**SG-5—Analytical Data** (sample depth 9.5')

<table>
<thead>
<tr>
<th>Substance</th>
<th>Benzene</th>
<th>Ethyl-benzene</th>
<th>Cumene</th>
<th>MTBE</th>
<th>Naphthalene</th>
<th>Toluene</th>
<th>1,2,4-TMB</th>
<th>1,3,5-TMB</th>
<th>Xylenes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS No.</td>
<td>71-43-2</td>
<td>100-41-4</td>
<td>98-82-8</td>
<td>1634-04-4</td>
<td>91-20-3</td>
<td>108-88-3</td>
<td>95-63-6</td>
<td>108-67-8</td>
<td>1330-20-7</td>
</tr>
<tr>
<td>Units</td>
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<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
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<tr>
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<td>7.5</td>
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<td>8.1</td>
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<td>3.2</td>
<td>J</td>
<td>8.9</td>
<td>J</td>
<td>31</td>
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<tr>
<td>9/16/2015</td>
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**Outdoor Ambient Sample Data**

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<thead>
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<th>Cumene</th>
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<th>Naphthalene</th>
<th>Toluene</th>
<th>1,2,4-TMB</th>
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<td>U 6.3 J</td>
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**VI Screening Values**

<table>
<thead>
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<th>SHS</th>
<th>SSS</th>
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<th>SSS</th>
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<th>SSS</th>
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<tr>
<td>RSL-based Site-Specific Standard SV</td>
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Select higher of values

4
Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5’)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Benzene</th>
<th>Ethyl-benzene</th>
<th>Cumene</th>
<th>MTBE</th>
<th>Naphthalene</th>
<th>Toluene</th>
<th>1,2,4-TMB</th>
<th>1,3,5-TMB</th>
<th>Xylenes</th>
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</thead>
<tbody>
<tr>
<td>CAS No.</td>
<td>71-43-2</td>
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<td>1330-20-7</td>
</tr>
<tr>
<td>Units</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
<td>µg/m³</td>
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<td>µg/m³</td>
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<tr>
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<td>480</td>
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Outdoor Ambient Sample Data

| Date             |         |       |       |       |           |         |           |           |         |
| 6/5/2015         | 1.5     | 2.0   | 2.0   | 1.4   | 5.2       | 2.7     | 2.0       | 2.0       | U       |
| 9/16/2015        | 1.0     | 8.1   | 1.0   | 2.1   | 2.6       | 7.6     | 2.1       | 1.0       | U       |

VI Screening Values

<table>
<thead>
<tr>
<th>Standard</th>
<th>SSS</th>
<th>SSS</th>
<th>SHS</th>
<th>SSS</th>
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<tbody>
<tr>
<td>Statewide Health Standard SV</td>
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<tr>
<td>Site-Specific Standard SV</td>
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</table>

<table>
<thead>
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<th>Exceed? (yes/no)</th>
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</table>

Screen soil gas data
Exercise Instructions

• You have VOC analytical data from soil gas sampling at one location (SG-5)
• Determine the appropriate VI residential SVs
  ➢ Statewide health or site-specific standard?
  ➢ Near-source soil gas or sub-slab soil gas?
  ➢ Utilize RSL-based screening values
• Which substances exceed? Which don’t?
• Are there receptors of concern for VI?
Soil Gas Screening Considerations

• Can you screen soil gas data that isn’t from a near-source sample point?
  ➢ Yes, but you must use **sub-slub screening values**
  ➢ Sample data is used to assess receptor exposure

• The deeper the point the better
  ➢ Concern with temporal variability of shallow data
  ➢ Surface pavement is beneficial

• Be aware of basements so screens are installed at proper depths
Soil Gas Considerations (continued)

- Use of sub-slab screening values presumes the absence of significant foundation openings
  - Alternative: Screen with $SV_{IA}$
  - Or determine if significant foundation openings are present
  - This will be assessed next
**Exercise #4: Soil Gas Vapor Intrusion Screening** (Case Study)

**SG-5—Analytical Data** (sample depth 9.5')

<table>
<thead>
<tr>
<th>Substance</th>
<th>Benzene</th>
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<th>1,3,5-TMB</th>
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<tr>
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<tr>
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<td>8.1</td>
<td>J</td>
<td>3.2</td>
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<td>200</td>
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<td>7.6</td>
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**Outdoor Ambient Sample Data**

<table>
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<th>Date</th>
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<th>9/16/2015</th>
</tr>
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<tbody>
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**VI Screening Values**

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<thead>
<tr>
<th>Standard</th>
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<th>SSS</th>
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<tbody>
<tr>
<td>Statewide Health Standard SV</td>
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</table>

**Exceed? (yes/no)**

|                 | no  | no  | no  | no  | no  | no  | yes | yes | yes | yes |

---

**Answers**

---
Soil Gas Screening Exceedences

Impacted by an offsite source; existing mitigation
Questions/Discussion
Perform a VI Risk Assessment

Start Here → Conceptual Site Model
Delineate Contamination

DELINEATE POTENTIAL VI SOURCES
Soil and Groundwater Screening

SCREEN FOR POTENTIAL VI SOURCES
Identify Preferential Pathways
Apply Proximity Distances

ALTERNATIVE VI ASSESSMENT OPTIONS
Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION
Environmental Covenant

REMEDICATION
Reevaluate the VI Pathway

ADDRESS CH. 250 REQUIREMENTS
No further VI analysis is necessary.

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time
Vapor Intrusion Risk Assessment

- Evaluate VI inhalation risks using EPA’s VISL Calculator spreadsheet
- Input maximum soil gas concentrations
- Data is *not* near-source soil gas, so use sub-slab attenuation factor (0.03)—conservative
  - **Valid if no significant foundation openings**
VI Risk Assessment (continued)

• EPA updated trimethylbenzene toxicity information in IRIS (September 2016)
  ➢ New RfC = 0.06 μg/m³
  ➢ This is less stringent than the toxicity value used for DEP’s screening values
  ➢ Modify RfC in VISL

• User can sum TMB concentrations in VISL
  ➢ 1,3,5-TMB not available in current VISL
VI Risk Assessment (continued)

• Determine if significant foundation openings are present
  ➢ Surveyed property owner
  ➢ In-person inspection not required
  ➢ Response: no dirt floor, foundation in good condition, no basement seepage or odors
  ➢ Conclude that it is appropriate to assume no significant foundation openings
BUILDING SURVEY FORM

Survey Completed by: _____________________________ Date: __________________

Site Name: 601 Christian Street Corrective Action Site Case No.: 51-18770

PA DEP Contact: C. David Brown (484.250.5796) cdbrown@pa.gov

Part I — Occupants

Building Address: ________________________________________________________________________________

Property Contact: _____________________________ Owner / Renter / other: _____________________________

Contact’s Phone: ________________________________

Part II — Building Characteristics

Building type: single-family residential / multi-family residential / office / strip mall / commercial / industrial

Describe building: ________________________________________________________________________________

Number of floors—below grade: ______ (full basement / crawl space / slab) at or above grade: ______

Basement floor: concrete / dirt / floating / other (specify): _________________________________

Foundation type: poured concrete / cinder block / stone / other (specify): _________________________________

Condition of foundation and floor (e.g., large cracks, gaps, or other openings): _________________________________

Basement sump present? Yes / No Sump pump? Yes / No Standing water? Yes / No

Basement French drain present? Yes / No Basement floor drain present? Yes / No

Basement used as living space? Yes / No Describe: _________________________________

Existing sub-slab depressurization (radon) system in place? Yes / No Operating? Yes / No

Part III — Miscellaneous Items

Have the occupants noticed any unusual odors in the building? Yes / No

Describe (with location): _________________________________

Is there any seepage of water or other liquid in the basement? Yes / No

Describe (with location): _________________________________

Any known spills of a fuel or chemical immediately outside or inside the building? Yes / No

Describe (with location): _________________________________

— Thank you for taking the time to fill out this survey form. —
VI Case Study

VISL Example Results—SG-5

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Sub-slab or Exterior Soil Gas Concentration to Indoor Air Concentration (SGC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Scenario</td>
<td>Scenario</td>
<td>Residential</td>
<td>Select residential or commercial scenario</td>
</tr>
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<td>Target Risk for Carcinogens</td>
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</tr>
<tr>
<td>Target Hazard Quotient for Non-Carcinogens</td>
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<table>
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<tr>
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<th>RFC</th>
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<td>71-43-2</td>
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<td></td>
</tr>
</tbody>
</table>

Notes: Cumulative Risks: 8.0E-06 0.39
(Note Afss_R = 0.026)
Risk Assessment Results—SG-5

- VISL demonstrates acceptable cumulative inhalation risks for receptors near SG-5
  - Cancer risk is $8.0 \times 10^{-6} < 1.0 \times 10^{-4}$ limit
  - Hazard index is 0.39 < 1.0 limit
Risk Assessment Modeling

• What if presence of significant foundation openings can’t be determined?
• Alternatives:
  ➢ VISL with sub-slab data input as indoor air data
  ➢ J&E model with assumption of dirt floor
• Example: Residences adjacent to SG-7
• Determine if VI risk is acceptable at homes
Soil Gas Modeling Example
### VI Case Study

#### VISL Example Results—SG-7

**EPA-OLEM VAPOR INTRUSION ASSESSMENT**
Indoor Air Concentration to Risk (IAC-Risk) Calculator Version 3.5.1 (May 2016 RSLs)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Scenario</td>
<td>Scenario</td>
<td>Residential</td>
<td>Select residential or commercial scenario from pull down list</td>
</tr>
<tr>
<td>Target Risk for Carcinogens</td>
<td>TCR</td>
<td>1.00E-05</td>
<td>Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column E)</td>
</tr>
<tr>
<td>Target Hazard Quotient for Non-Carcinogens</td>
<td>THQ</td>
<td>0.1</td>
<td>Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column F)</td>
</tr>
</tbody>
</table>

### Site Indoor Air Concentration

<table>
<thead>
<tr>
<th>CAS</th>
<th>Chemical Name</th>
<th>Cia (ug/m³)</th>
<th>VI Carcinogenic Risk</th>
<th>VI Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>71-43-2</td>
<td>Benzene</td>
<td>3.7</td>
<td>1.0E-05</td>
<td>1.2E-01</td>
</tr>
<tr>
<td>98-82-8</td>
<td>Cumene</td>
<td>2.0</td>
<td>No IUR</td>
<td>4.8E-03</td>
</tr>
<tr>
<td>100-41-4</td>
<td>Ethylbenzene</td>
<td>15</td>
<td>1.3E-05</td>
<td>1.4E-02</td>
</tr>
<tr>
<td>1634-04-4</td>
<td>Methyl tert-Butyl Ether (MTBE)</td>
<td>1.4</td>
<td>1.3E-07</td>
<td>4.5E-04</td>
</tr>
<tr>
<td>91-20-3</td>
<td>Naphthalene</td>
<td>5.2</td>
<td>6.3E-05</td>
<td>1.7E+00</td>
</tr>
<tr>
<td>108-88-3</td>
<td>Toluene</td>
<td>47</td>
<td>No IUR</td>
<td>9.0E-03</td>
</tr>
<tr>
<td>95-63-6</td>
<td>Trimethylbenzene, 1,2,4-</td>
<td>24</td>
<td>No IUR</td>
<td>3.8E-01</td>
</tr>
<tr>
<td>108-67-8</td>
<td>Trimethylbenzene, 1,3,5-</td>
<td>19</td>
<td>No IUR</td>
<td>3.0E-01</td>
</tr>
<tr>
<td>1330-20-7</td>
<td>Xylenes</td>
<td>85</td>
<td>No IUR</td>
<td>8.2E-01</td>
</tr>
</tbody>
</table>

**Cumulative Risks:** 8.7E-05 3.31

---

- **Soil gas data as indoor air data for potential significant foundation opening**
- **Modeling for chemicals with HQ > 0.1**
SG-7 Soil Gas Modeling

- Johnson & Ettinger models of soil gas data
  - Zero slab thickness (dirt floor)
- Use PA DEP version of spreadsheet
- Modify for current TMB toxicity
- Select site-specific inputs
- Use conservative default values where appropriate
# J&E Model Input Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_F$</td>
<td>240 cm</td>
<td>basement 8’</td>
</tr>
<tr>
<td>$L_s$</td>
<td>274 cm</td>
<td>SG-7 9.0’</td>
</tr>
<tr>
<td>$T_s$</td>
<td>18°C</td>
<td>default</td>
</tr>
<tr>
<td>$T_s$</td>
<td>SI</td>
<td>silt</td>
</tr>
<tr>
<td>$L_B$</td>
<td>550 cm</td>
<td>measured (18’)</td>
</tr>
<tr>
<td>$W_B$</td>
<td>580 cm</td>
<td>measured (19’)</td>
</tr>
<tr>
<td>$H_B$</td>
<td>210 cm</td>
<td>basement 7’</td>
</tr>
<tr>
<td>$Q_{soil}$</td>
<td>2.8 L/min</td>
<td>scaled by perimeter</td>
</tr>
</tbody>
</table>
**Soil Gas Concentration Data**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>CAS No.</th>
<th>Soil gas conc., $C_a$ (µg/m$^3$)</th>
<th>Soil gas conc., $C_q$ (ppmv)</th>
<th>Chemical</th>
<th>CAS No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIMETHYLBENZENE, 1,3,4-</td>
<td>95636</td>
<td>2.40E+01</td>
<td>N/A for PA DEP Model</td>
<td>TRIMETHYLBENZENE, 1,2,4-</td>
<td></td>
</tr>
</tbody>
</table>

Entries highlighted in yellow should be verified and updated with site-specific information by the user, if appropriate. (Other parameters may also be modified.)

Refer to the PA DEP Technical Guidance Manual for Vapor Intrusion, Appendix B.

---

### Soil Gas Parameters

<table>
<thead>
<tr>
<th>Depth below grade to bottom</th>
<th>Soil gas sampling Average depth soil below grade, temperature, $(L_f, T_f)$</th>
<th>Soil gas depth, thickness of soil, $(h_a, h_b, h_C)$</th>
<th>Soil steam, permeability, $(k_m)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>274</td>
<td>18</td>
<td>SI</td>
</tr>
</tbody>
</table>

### Soil Type and SCS

<table>
<thead>
<tr>
<th>User-defined soil type, or soil vapor permeability, $(n)$</th>
<th>Used to estimate soil vapor permeability, $(k)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL 1.62, 0.387, 0.1</td>
<td>SL 1.62, 0.387, 0.1</td>
</tr>
</tbody>
</table>

### Enclosed Spaces

<table>
<thead>
<tr>
<th>Enclosed Soil-bldg. space, floor thickness, $(h)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

### Indoor Air Exchange

<table>
<thead>
<tr>
<th>Indoor Floor-wall, air exchange rate, $(Q_{ei})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8</td>
</tr>
</tbody>
</table>

### Averaging Time

<table>
<thead>
<tr>
<th>Averaging time for carcinogens, $(AT_C)$ (yrs)</th>
<th>Averaging time for noncarcinogens, $(AT_{NC})$ (yrs)</th>
<th>Exposure duration, $(ED)$ (days/yr)</th>
<th>Exposure frequency, $(EF)$ (hr/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>30</td>
<td>30</td>
<td>350</td>
</tr>
</tbody>
</table>

### Zero slab thickness

1.35

---

**Residential Exposure Factors**

Use default residential or nonresidential values for Statewide health standard models.
Near-Source Soil Gas Results

### INCREMENTAL RISK CALCULATIONS:

<table>
<thead>
<tr>
<th>Incremental risk from vapor intrusion to indoor air, carcinogen</th>
<th>Hazard quotient from vapor intrusion to indoor air, noncarcinogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>2.9E-02</td>
</tr>
</tbody>
</table>

### INDOOR AIR CALCULATIONS:

- Infinite source bldg. conc., $C_{building}$ (µg/m³)
- 1.8E+00

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
## VI Case Study

### SG-7 Risk Assessment Modeling Results

<table>
<thead>
<tr>
<th>Substance</th>
<th>Cancer Risk</th>
<th>Hazard Quotient</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>$1.3 \times 10^{-5}$</td>
<td>$9.0 \times 10^{-3}$</td>
<td>VISL</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>$1.3 \times 10^{-5}$</td>
<td>0.014</td>
<td>VISL</td>
</tr>
<tr>
<td>Cumene</td>
<td>$4.8 \times 10^{-3}$</td>
<td>VISL</td>
<td></td>
</tr>
<tr>
<td>MTBE</td>
<td>$1.3 \times 10^{-7}$</td>
<td>$4.5 \times 10^{-4}$</td>
<td>VISL</td>
</tr>
<tr>
<td>Benzene</td>
<td>$1.3 \times 10^{-6}$</td>
<td>0.013</td>
<td>J&amp;E</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>$5.5 \times 10^{-6}$</td>
<td>0.13</td>
<td>J&amp;E</td>
</tr>
<tr>
<td>1,2,4-TMB</td>
<td></td>
<td>0.029</td>
<td>J&amp;E</td>
</tr>
<tr>
<td>1,3,5-TMB</td>
<td></td>
<td>0.023</td>
<td>J&amp;E</td>
</tr>
<tr>
<td>Xylenes</td>
<td></td>
<td>0.084</td>
<td>J&amp;E</td>
</tr>
<tr>
<td><strong>Cumulative</strong></td>
<td>$2.0 \times 10^{-5}$</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

*With assumption of a significant foundation opening*
Risk Assessment Modeling Results

- At residences adjacent to SG-7, predicted risks are acceptable even with significant foundation openings
  - Conservative assumption in VISL (soil gas as IA)
  - Simulated in J&E with a slab thickness of zero
  - Property access or owner surveys were not needed
Preferential Pathway Conclusions: Potential Offsite Receptors

- External preferential pathways are unlikely to be a concern at the site
- Trench fill attenuates hydrocarbon vapors
- Absence of significant foundation openings was verified at two properties
Risk Assessment Conclusions: Potential Offsite Receptors

- Risk assessments performed with attenuation factors (VISL) and modeling (J&E)
- Accounted for potential significant foundation openings
- There do not appear to be excess inhalation risks from vapor intrusion at residences
Planned Mitigation of Onsite Property

Start Here

Conceptual Site Model
Delineate Contamination

DELINATE POTENTIAL VI SOURCES

Soil and Groundwater Screening

ALTERNATIVE VI ASSESSMENT OPTIONS

Near-Source Soil Gas Screening
Sub-Slab Soil Gas Screening
Indoor Air Screening
Vapor Intrusion Modeling
SSS Risk Assessment

MITIGATION

Environmental Covenant

REMEDICATION

Reevaluate the VI Pathway

SCREEN FOR POTENTIAL VI SOURCES

Identify Preferential Pathways
Apply Proximity Distances

Mitigation, Remediation, or Use of the Site-Specific Standard are Permitted at Any Time

ADDRESS CH. 250 REQUIREMENTS

No further VI analysis is necessary.
Conclusions: Onsite Receptors

• Presently no occupied building
• Developer intends to construct a mixed-use building with a basement
• Signed consent order & agreement
  ➢ Requires installation of a vapor mitigation system
  ➢ Requires performance testing of the system
  ➢ Requires implementation of an environmental covenant to maintain engineering control
Vapor Intrusion Evaluation Summary

proximity distances

mitigated

VISL and J&E

future mitigation; covenant

no significant openings; VISL
Some Key Points

• The VI evaluation process may be iterative and cyclic, not linear—Refine the CSM
• Petroleum less a concern than LNAPL, CVOCs
• “Reasonable” preferential pathway assessment; may be qualitative
  ➢ Property access not required
• Many tools available, may be combined
  ➢ Screening, proximity distances, VISL, J&E
Questions/Discussion