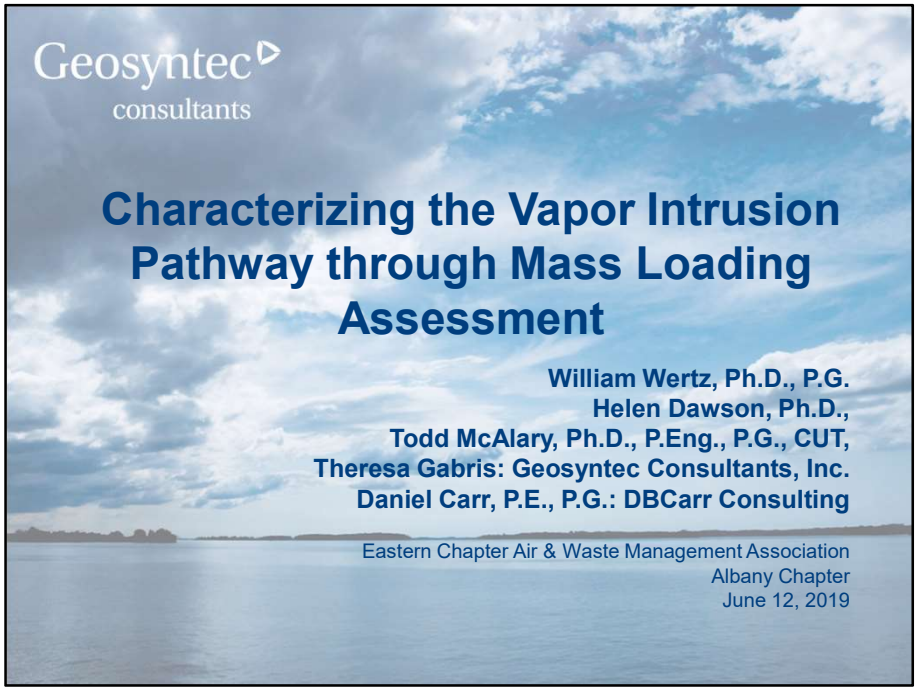

Approach to assessing VI in short time frame, 1-2 days
Provides data that allows you to be more confident about your risk management decisions.

Outline

- Concept
- Experimental approach
- Case studies
  - Small (~2,000 ft^2) commercial building
  - Medium-sized (~11,000 ft^2) commercial building
- Lessons learned
- Proposed protocol

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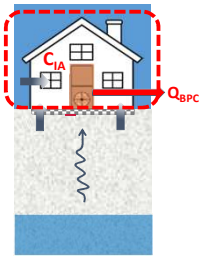
Mass Loading (ML) Assessment

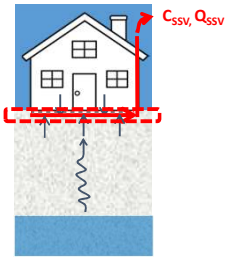
Mass Discharge through Building



$ML_{BPC} = C_{IA} Q_{BPC}$

(BPC = building pressure control)

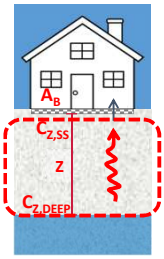
Mass Capture through Sub-Slab Venting



$ML_{SSV} = C_{SSV}\ Q_{SSV}$

(SSV = subslab venting)

Mass Transport through Vadose Zone



$ML_{Vadose} = - D^{eff} A_B \Delta C_Z / \Delta Z$

- Mass Loading (ML) = mass flux times building footprint area

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SERDP-ESTCP VI Research: ER-201503

3

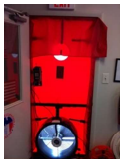
Experimental Approach

ML_{Vadose}: Vadose Zone Characterization

- Collect soil cores for laboratory analysis of soil properties and VOCs.
- Collect soil vapor samples at multiple levels.
- Collect groundwater samples at the water table

ML_{SSV}: Subslab Venting

- Measure soil vapor flow rate and collect soil vapor sample from permanent sub-slab venting systems or via high volume subslab sampling (HVS).



ML_{BPC}: Building Pressure Control

- Induce negative pressure with door fans.
- Collect indoor air samples using individually-certified 6L Summa canisters when pressure is consistently negative and after 3-4 building air exchanges.
- Monitor cross-slab and cross-building pressure differentials with a micromanometer/data logger.
- Repeat tests under positive pressure to evaluate background contribution of VOCs.

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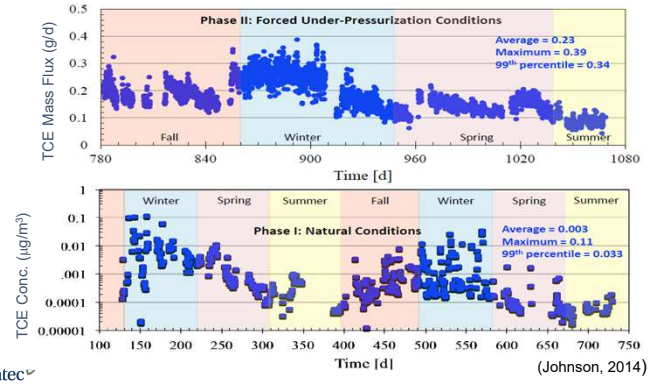
Benefits of Considering Mass Loading

- Mass loading has been shown to be much less variable than indoor air and subsurface concentrations.
- Mass loading characterization may expedite risk management decisions and reduce the need for long-term indoor air monitoring.



(Johnson, 2014)

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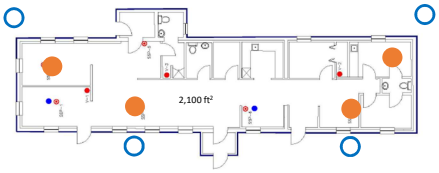
Demonstration Sites

Exterior sampling location
Interior sampling location

Raritan Arsenal, NJ

- Building 200
- Medical office
- Area: 2,100 ft^2,
- Height: 8 ft
- Volume: 16,800 ft^3



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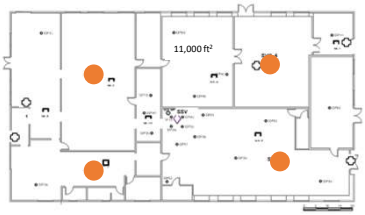
Vandenberg AFB, CA

- Building 11193
- Former dry cleaner facility & gym
- Area: 11,000 ft^2
- Height: 13.2 ft
- Volume: 145,000 ft^3



August 2016 ML Vadose Zone Field Activities

- **Groundwater**
  - **Sampled existing wells using PDBs**
  - **Collected Grab Samples at Four New Locations**
- **Soil**
  - **Physical and Chemical profiling from ground surface to water table at four locations**
- **Soil Gas**
  - **Sampled Exterior Soil Gas at 7, 12, 19 ft bgs**
  - **Sampled Interior Soil gas at SS and 3.5 ft**

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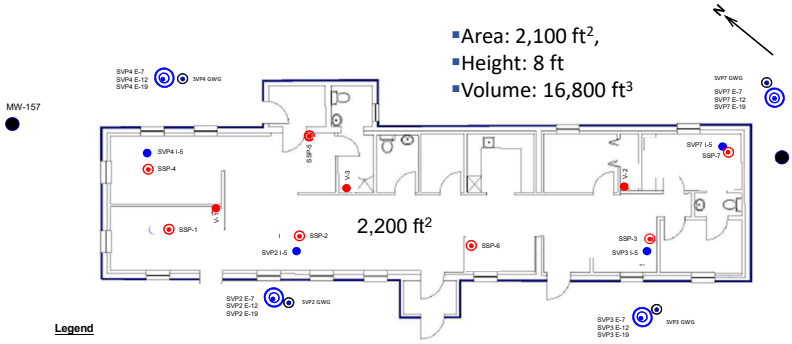
Building 200 Former Raritan Arsenal Sampling Locations

- Area: 2,100 ft^2,
- Height: 8 ft
- Volume: 16,800 ft^3



Legend

- SSV Extraction Point (existing)
- Sub-slab Probe (existing)
- New Soil Vapor Probe (3.5 ft deep)
- Multi-level Soil Vapor Probe (7, 12, 19 ft deep)
- Groundwater Grab Sample
- Groundwater Monitoring Well (location approximate)

MW-155

Scale (feet)

0 5 10 15

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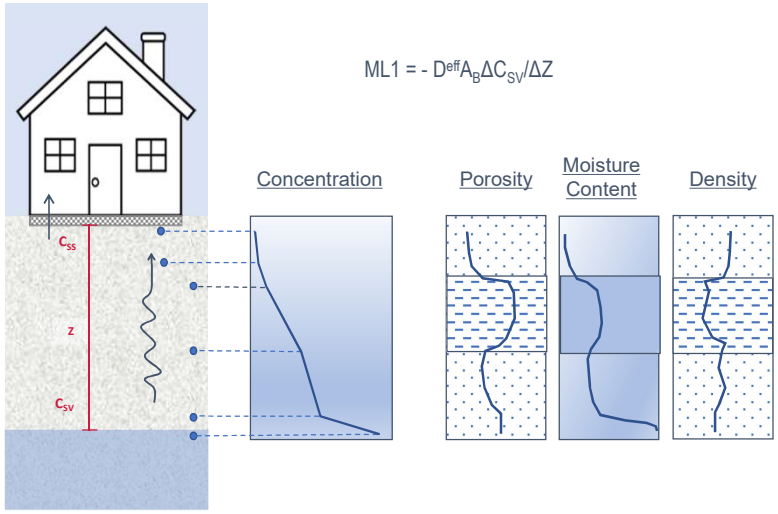
ML1: Diffusive Mass Loading

$$ML1 = - D^{eff} A_B \Delta C_{SV} / \Delta Z$$



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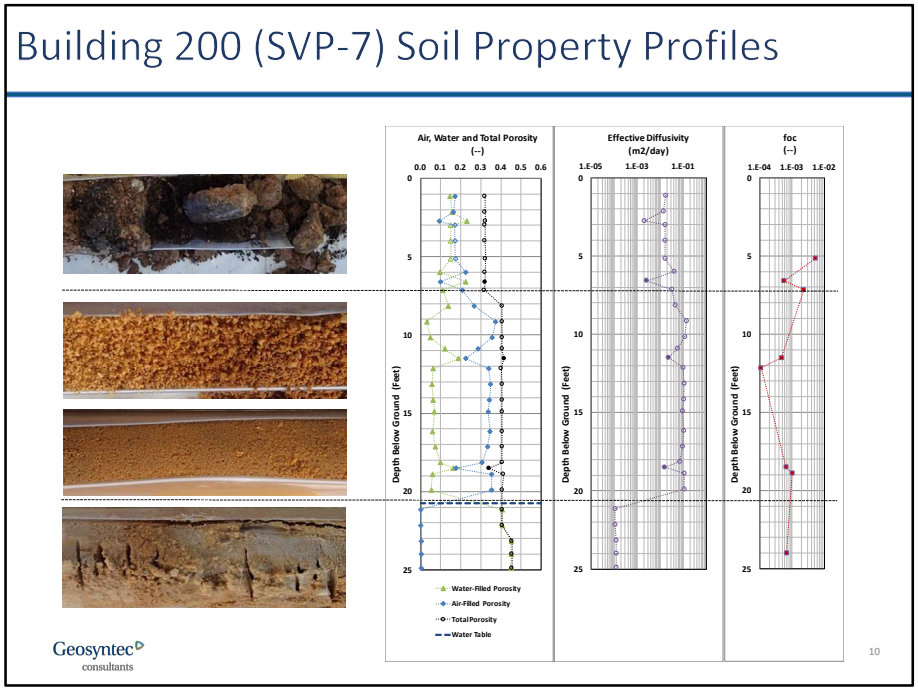
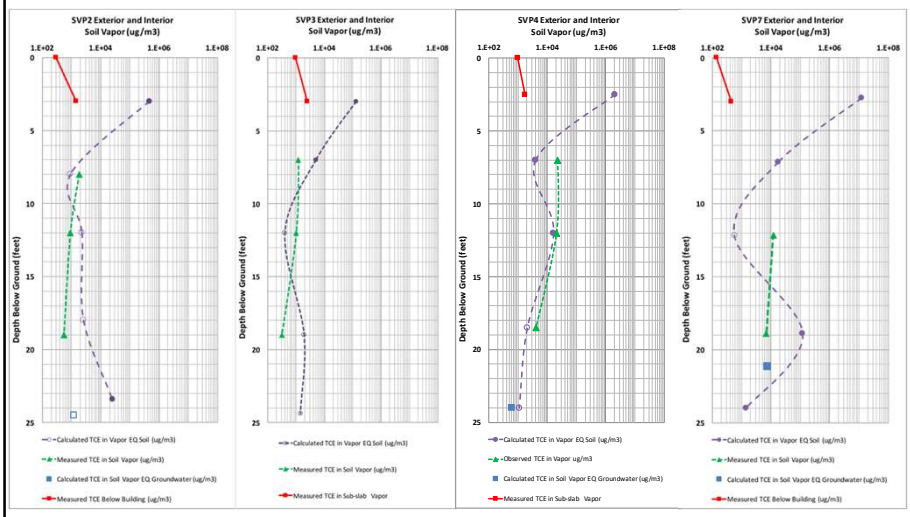


Collected soil samples for
VOC, moisture content, specific gravity, TOC analyses at 5 stratigraphic intervals in each of the 4 new SVP locations

Soil gas sampling at 4 exterior and 4 interior locations

Raritan Building 200 Soil TCE Profiles



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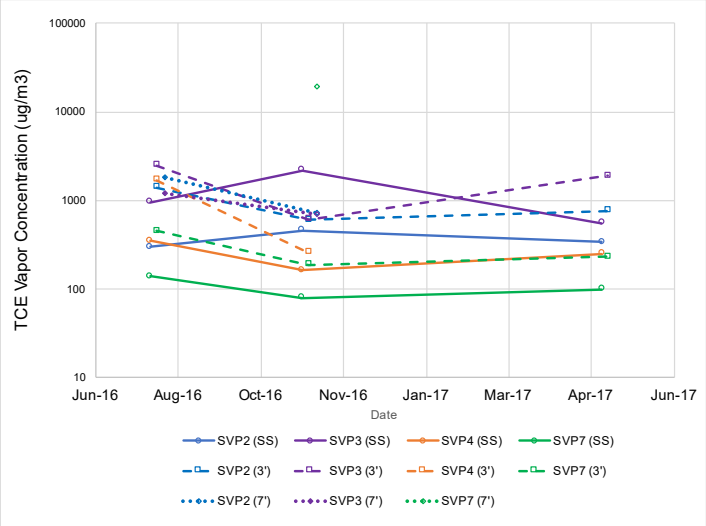
ML_{Vadose} TCE Vapor Concentrations Over Time



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August 2016 – ML_{Soil} Estimates of TCE

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Application to VI Risk Management

- Calculate RME indoor air concentration from mass loading:

$$IA_{RME} = ML_{1,\ 2,\ or\ 3} / (V_{bldg}\ AER)$$

- Calculate mass loading threshold from target indoor air concentration:

$$ML_{threshold} = IA_{target}\ V_{bldg}\ AER$$

IA	=	indoor air concentration
$MF_{1,\ 2,\ or\ 3}$	=	mass loading characterized by Methods 1, 2, or 3
AER	=	air exchange rate
RME	=	reasonable maximum exposure

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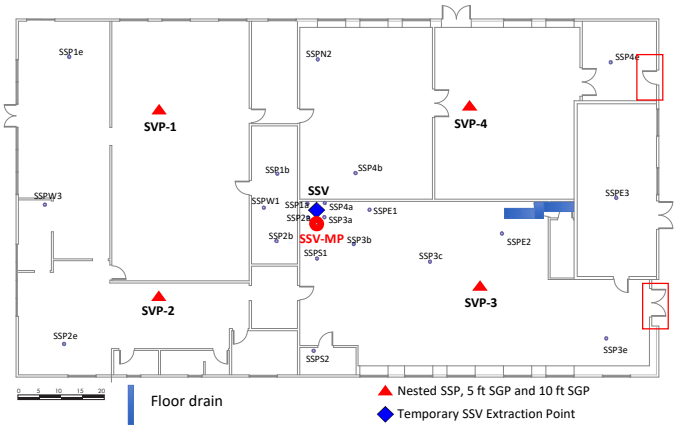
Mass Loading Layout Building 11193



Floor drain

Sub-slab probes (SSPs) will be installed at radial distances of 3, 12 and 45 feet to measure vacuum in several compass directions to assess anisotropy

- Nested SSP, 5 ft SGP and 10 ft SGP
- Temporary SSV Extraction Point
- Communication Test Point SSP
- SSV Nested Monitoring Probe (SS, 5 ft, 10 ft)
- Blower Door Location

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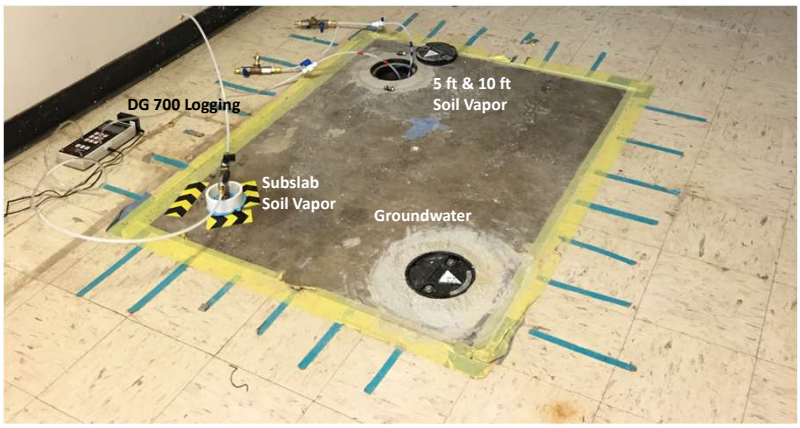
Monitoring Point Configuration



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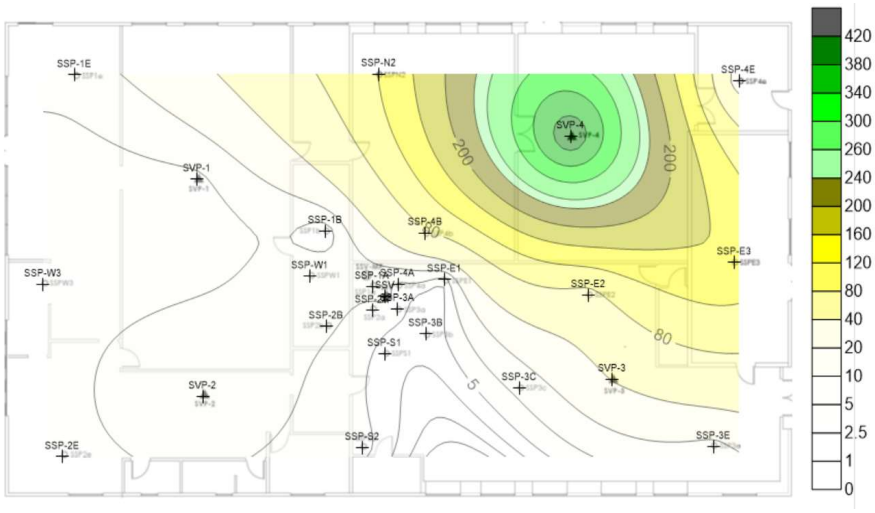
Contour Map of Subslab PID Readings



PID Reading (PPM)

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Temporary SSV Setup

Roof vents sealed with plastic

Window sealed with plastic

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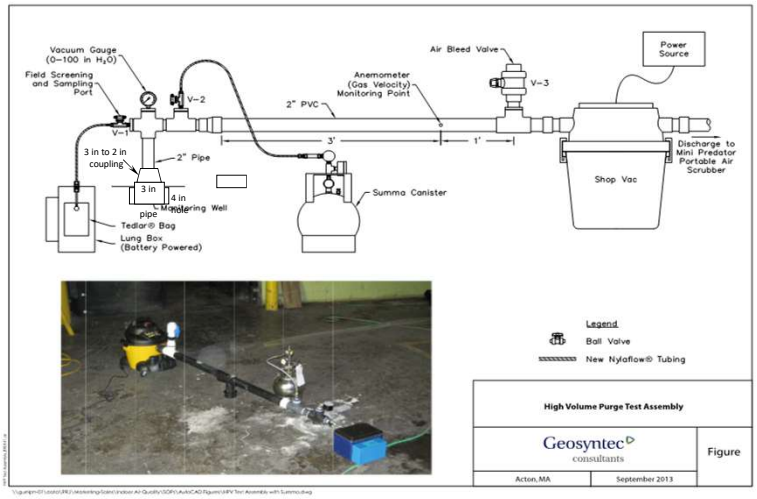
Suction point was located near the middle of the building, plumbed to an Obar fan.
Typically achieved about 60 scfm at about 20 inches of water column vacuum in the pipe.
Tall stack was used to minimize potential for re-entrainment of vented gas to indoor air.

Temporary SSV Setup



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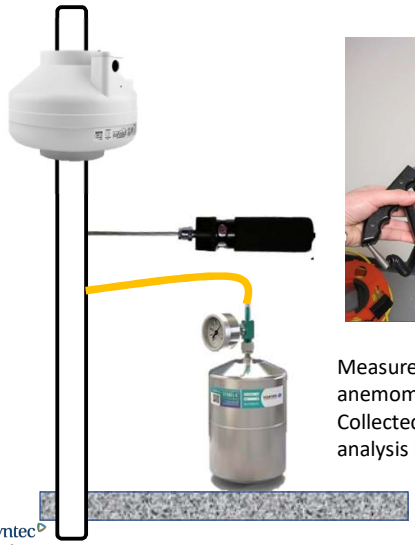
SSV Measurements



Measured flow in vent pipes with a thermal anemometer
Collected vapors from vent pipe via Summa for analysis by EPA TO-15

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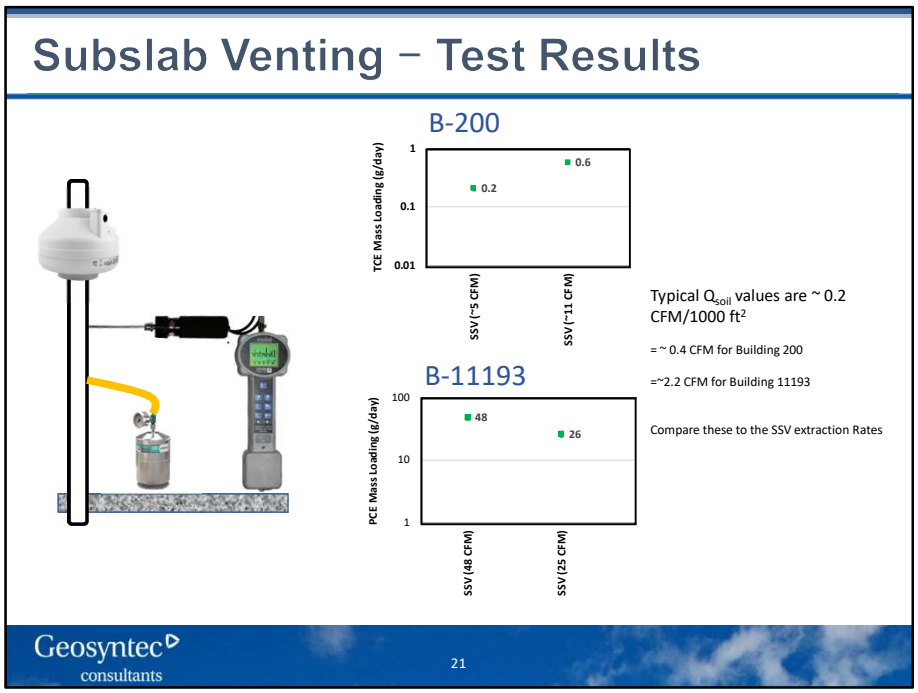
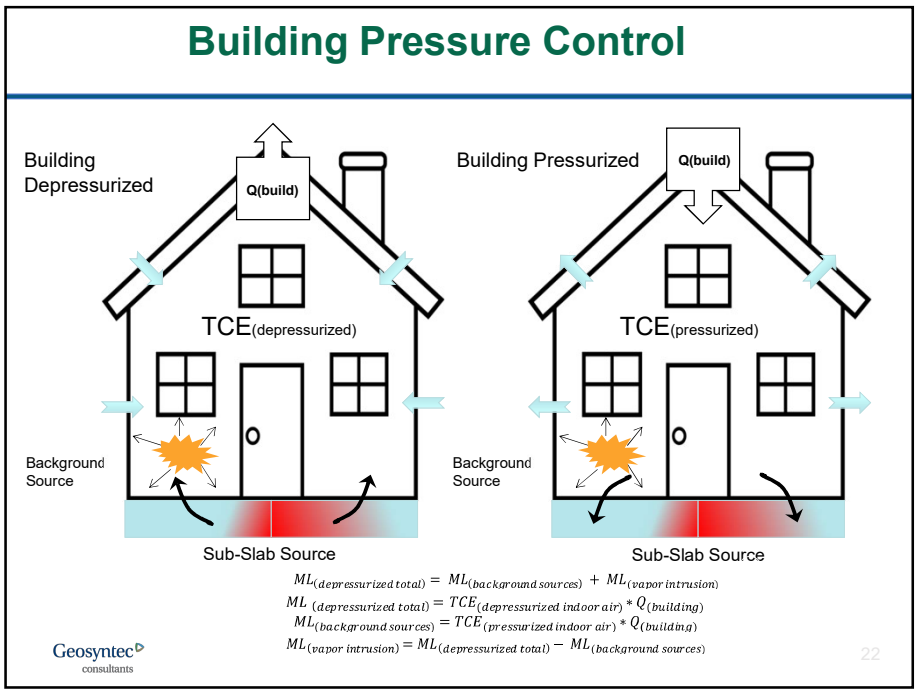


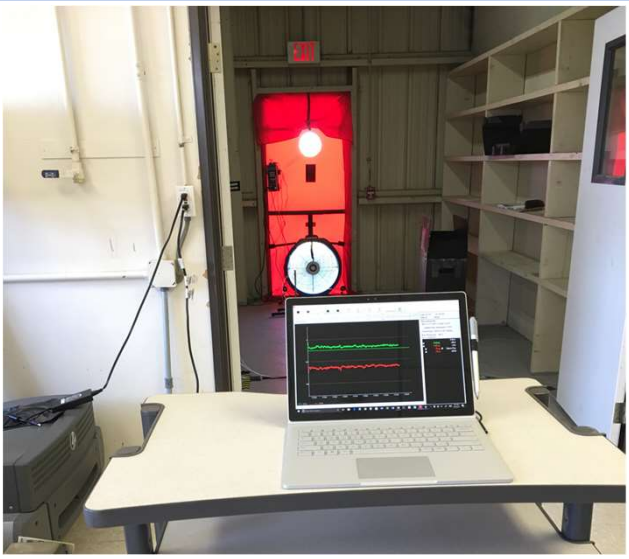
SSV vapor flow rate is >10X the estimated vapor flow rate (Qsoil) across the slab for both buildings.

Calculate Qsoil: MLssv = CssvQssv; MLbpc = Mlslab = CssQsoil; Qsoil = MLbpc/Cssv:



TCE concentrations in indoor air due to VI will be enhanced when the building is depressurized and diminished when the building is pressurized. TCE concentrations due to background sources will not change substantially between pressurization and depressurization.

Blower Door Setup



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Differential Pressure Across Door

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Pressurized and Depressurized

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Note the pressure line
What is the pressurization (positive or negative) in each photo?

PID Readings During Building Depressurization

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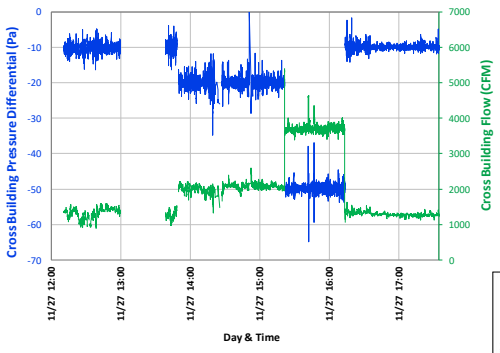
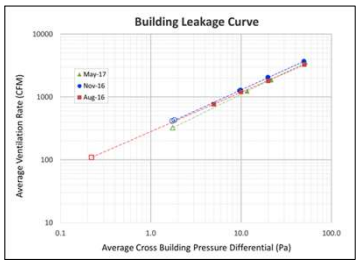
Building 200 Cross-Building Pressure and Flow Rate





Pressure Step	Average Cross-Building Pressure Differential (Pa)	Average Blower Door Flow Rate (CFM)
Negative 10	-9.6	1258
Negative 20	-20	2047
Negative 50	-50	3695
Negative 10 (2)	-9.9	1286

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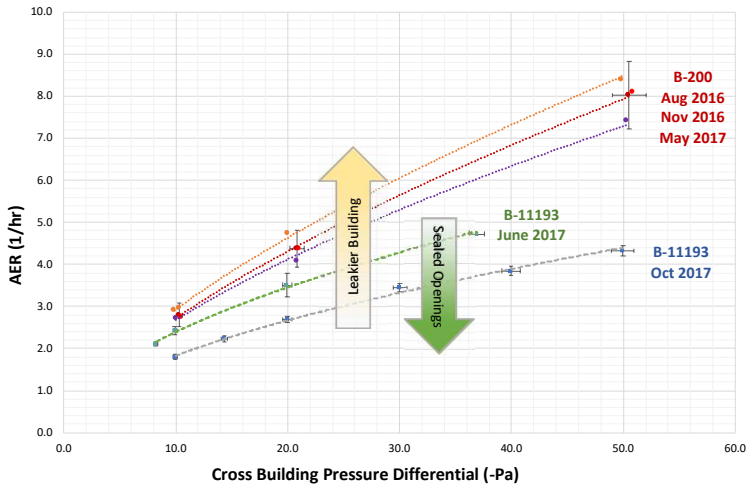
The blower door and associated software is designed to allow the user to set a cross-building pressure differential and the fan flow rate will automatically adjust to maintain that pressure differential.

Upper left graph shows cross-building pressure differentials and blower door fan flow rates as a function of time. Cross building pressures tested in Nov 2016 field event included, in order, -10 Pa, -20 Pa, -50 Pa and -10 Pa again. The afternoon of the day of the test was very windy, and that is reflected in the greater variability in the data during that period.

Average values of the pressure differentials and flow rates were calculated and are shown in the table. Following standard procedures used in the energy audit industry, the data were plotted on a log-log plot and a power curve was fitted to the data to derive a site-specific building leakage curve (bottom right graph). The fitted equation shown on the plot can be used to estimate building ventilation rates for cross-building pressure differentials not specifically tested.

Building Pressure Control – Test Results

- Building leakage curves developed from fan flow rates and building pressure differentials characterize building envelope leakiness.



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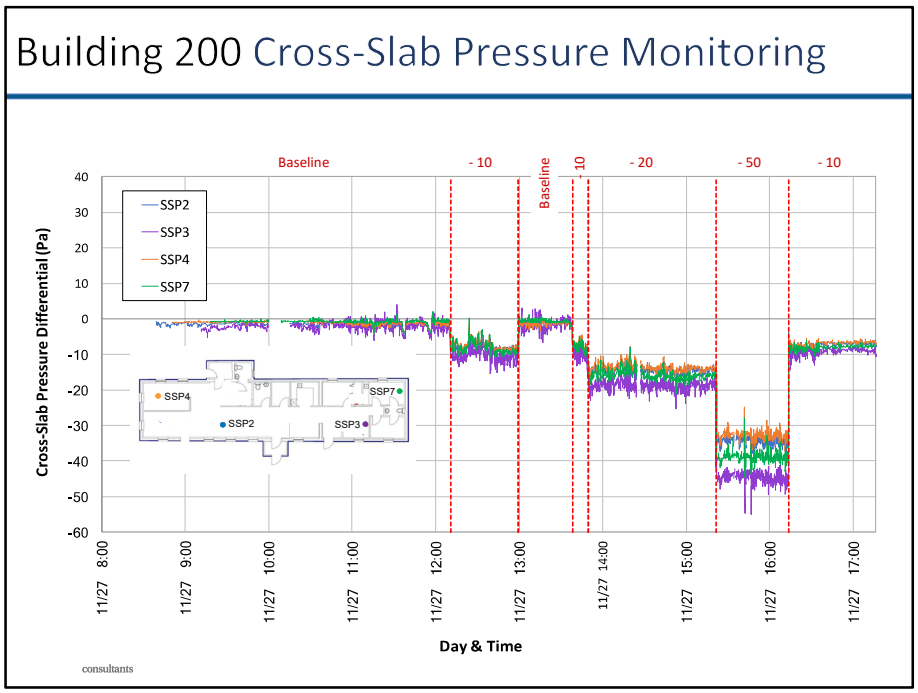
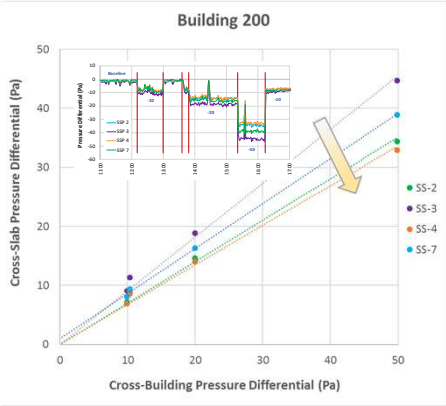


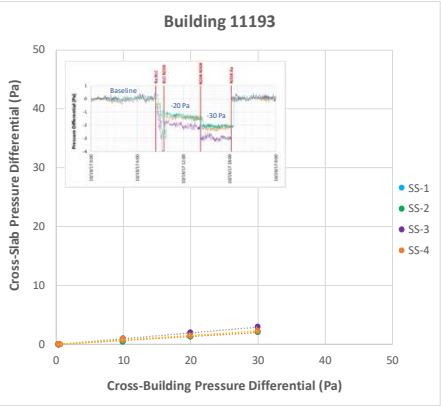
The measured cross-slab pressure differentials at the four sub-slab probe locations shown on the inset floor plan are plotted as a function of time. The vertical red lines show the points at which the cross-building pressure differential was changed. Baseline pressure differentials were measured prior to the beginning of the depressurization tests and again partway through first -10 Pa testing period.

The graph shows that all the sub-slab locations respond to changes in the cross building pressure differential, though to varying degrees. Sub-slab locations where the sub-slab differentials are less than the cross-building differentials indicate more communication across the slab than areas where the sub-slab differentials are approximately the same as the cross building differentials. On average the cross-slab differentials are approximately 75% of the cross building differentials.

Building Pressure Control – Test Results, Cont'd

- Cross slab vs. cross building pressure differential relationships characterize slab/subslab susceptibility to vapor transport.





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Higher Susceptibility to Cross-Slab Vapor Transport

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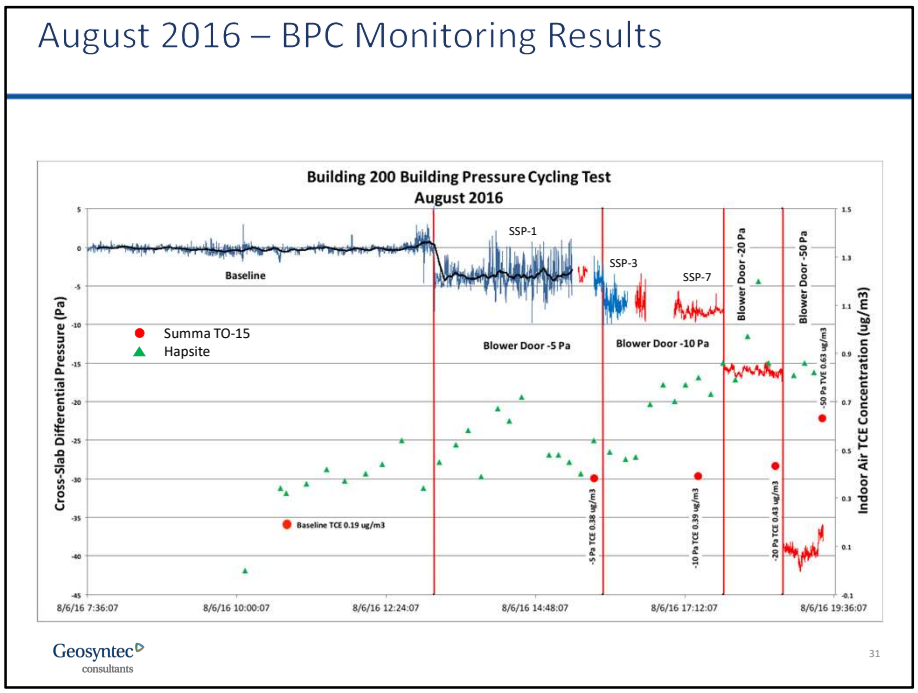
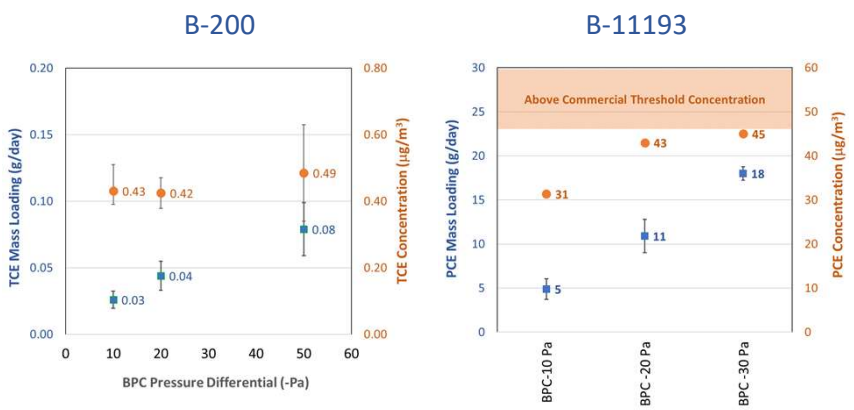


HAPSITE samples collected periodically from 10:08 to 19:28 (40 samples)

Indoor air Summa grab samples collected at a location in front of blower door during each pressure step. Outdoor Summa grab samples collected at the beginning and end of the BPC test

Building Pressure Control – Test Results, Cont'd

- Calculate mass discharge through the building from indoor air concentrations measured when the building is depressurized.



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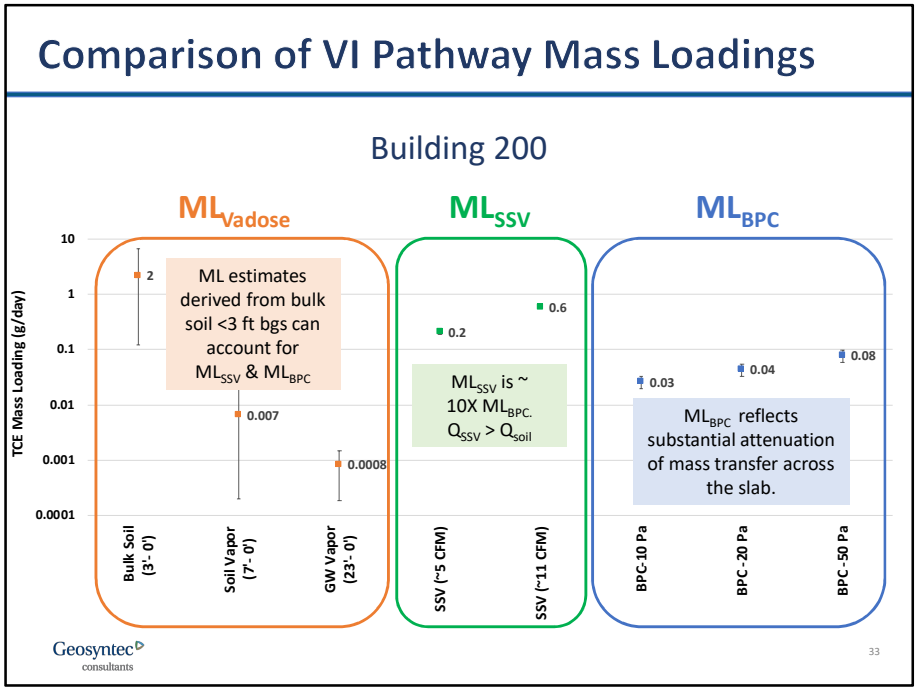
These slides reflect the interplay of source strength, building leakage (Qbldg) and cross slab vapor transport (Qsoil) on indoor air quality.

B200 exhibits a leakier envelope and little pressure communication across the slab so the mass loading and indoor air quality do not change much over the range of differential pressures.

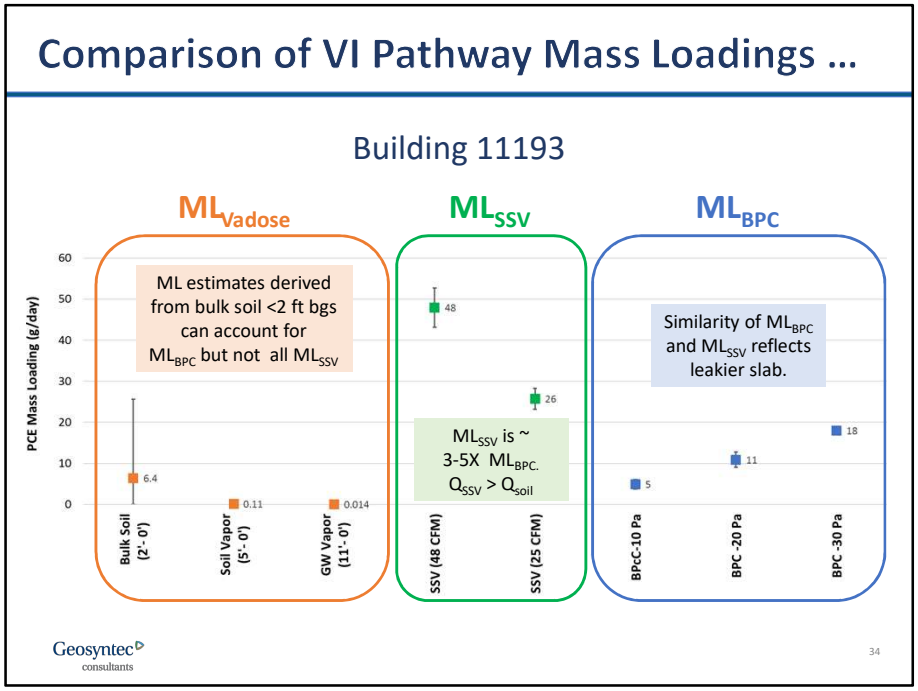
In contrast B-11193 has a tighter building envelope and a leakier slab such that the mass loading through the slab increases at a greater rate than the increasing building air exchange can dilute the concentrations .

IA concentrations measured under depressurized building conditions are an upper estimate of exposure point concentrations. If measured IA concentrations are lower than screening levels, there is unlikely to be significant risk from VI at any time.



Soil concentrations vary by orders of magnitude under the building.

Building 200 has a SSV system that has been operating for a long time (roughly a steady-state condition). ML assessment results suggest system may no longer be needed. The BPC tests were conducted after 3 days of SSV shutdown. Could turn off SSV system for a longer time (30 days) and conduct BPC test again.

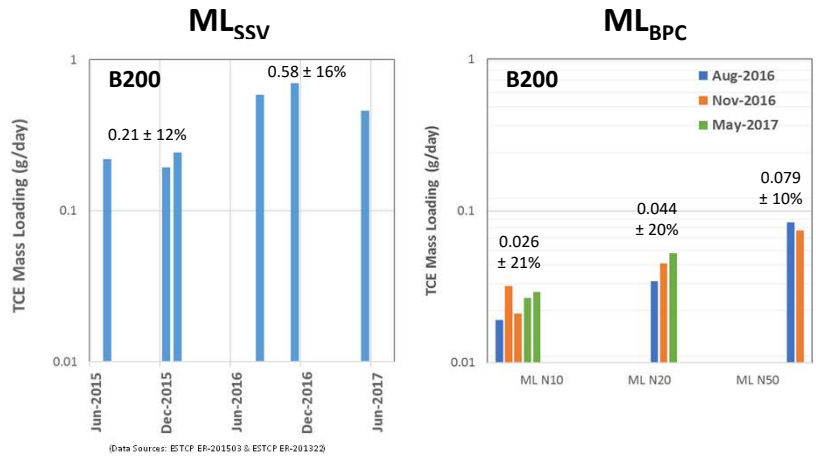


Soil concentrations vary by orders of magnitude under the building. Variability likely not fully defined.

Building 11193 had a temporary SSV system. The rate of mass removal from the SSV at 11193 decreased by about a factor of 30 after a month. Unfortunately didn't have the budget to track it to see if it was asymptotic then or still decreasing.

Comparison of Mass Loading Tests over Time

- …shows BPC and SSV/HVS test results are temporally stable.



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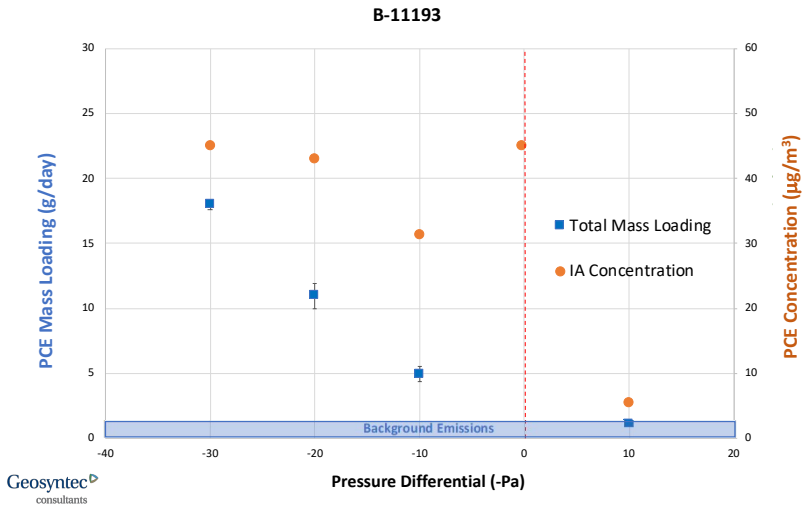
BPC Quantifies Background Contributions

- …to indoor air when the building is pressurized.



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Conclusions

- Mass loading assessment improves understanding of the VI Pathway.
- BPC and SSV/HVS tests evaluate the potential for VI impacts more effectively and efficiently than conventional methods.
- Higher SSV mass loadings relative to BPC mass loadings reflect higher SSV-induced vapor flow rates relative to BPC-induced vapor flow rates through the slab.
- BPC and SSV/HVS test results are consistent (< 2-fold variation) over multiple days and seasons (unless the building structure is modified).
- BPC testing can differentiate background contributions to indoor air from VI-related contributions.
- SSV monitoring offers a means to track remediation performance and assess potential for shutdown of mitigation in lieu of indoor air sampling.

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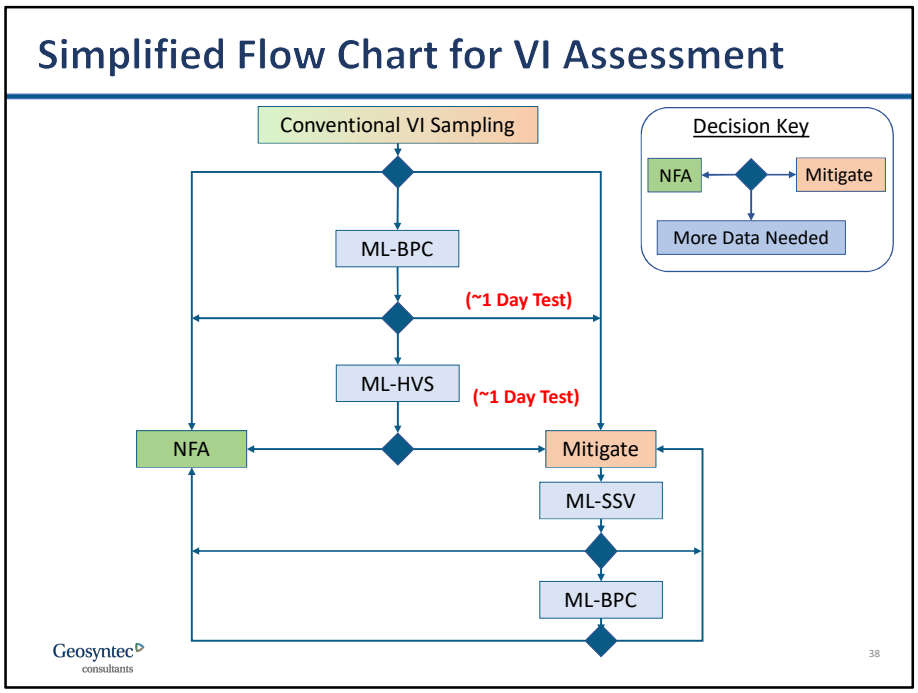

Blue box suggests tests that can be conducted if more data are needed for risk management decisions.