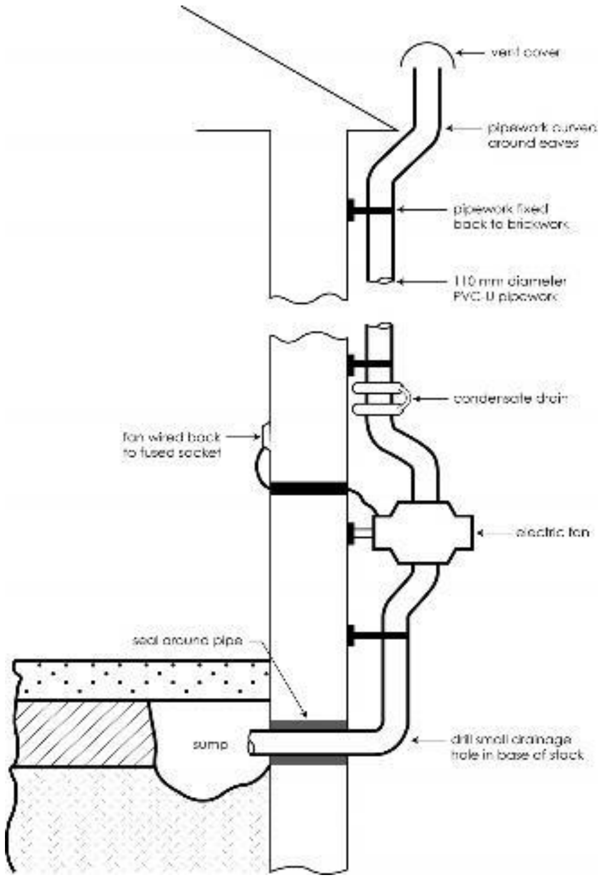
New Tools for Evaluating Sub-Slab Depressurization Systems and Identification of Alternative Vapor Pathways

Darius Mali, P.Eng, W. Wertz, P. Nicholson and T. McAlary
Geosyntec Consultants, Inc.
dmali@Geosyntec.com

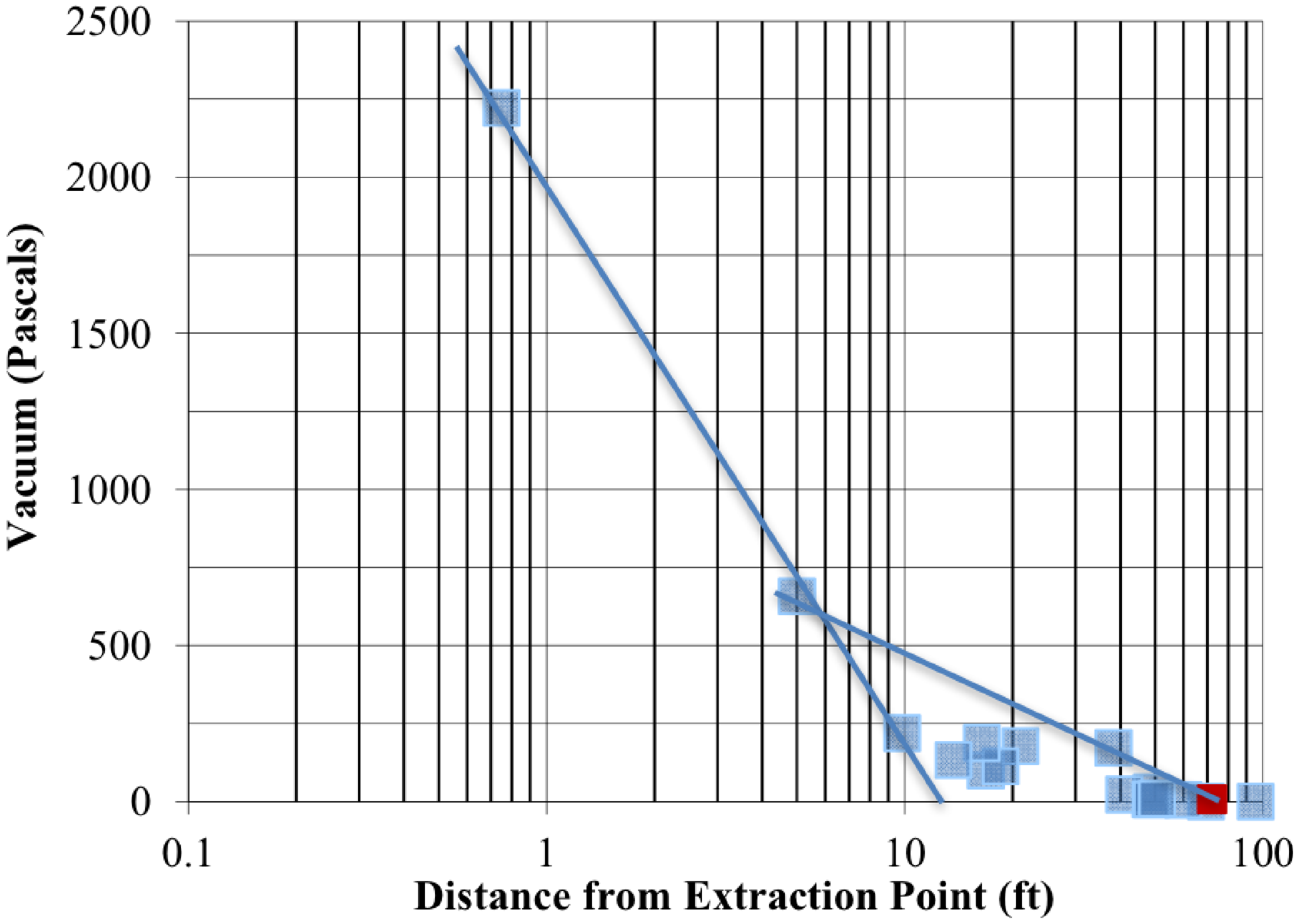
Overview

- Goals: Optimize Sub-Slab Depressurization Systems (SSD) and Identify Preferential Pathways
- The Problem: 30+ year old design and monitoring specifications
- Site Description: “Sun Devil Manor” in Layton, Utah
- Methods: pneumatic testing, tracer testing, mathematic modelling and mass flux monitoring, all with land drain open and closed
- Results: New Tools to Assess & Optimize Depressurization Systems and Identify Preferential Pathways

Sub-Slab Depressurization (SSD) Systems



Current Standard Practice for SSD Design



Tool: Measure steady-state vacuum vs radial distance, plot on a semi-log plot, extrapolate to target vacuum of 6 to 9 pascals (ASTM E-2121)

or maybe 1 Pa is enough? (AARST, 2017)

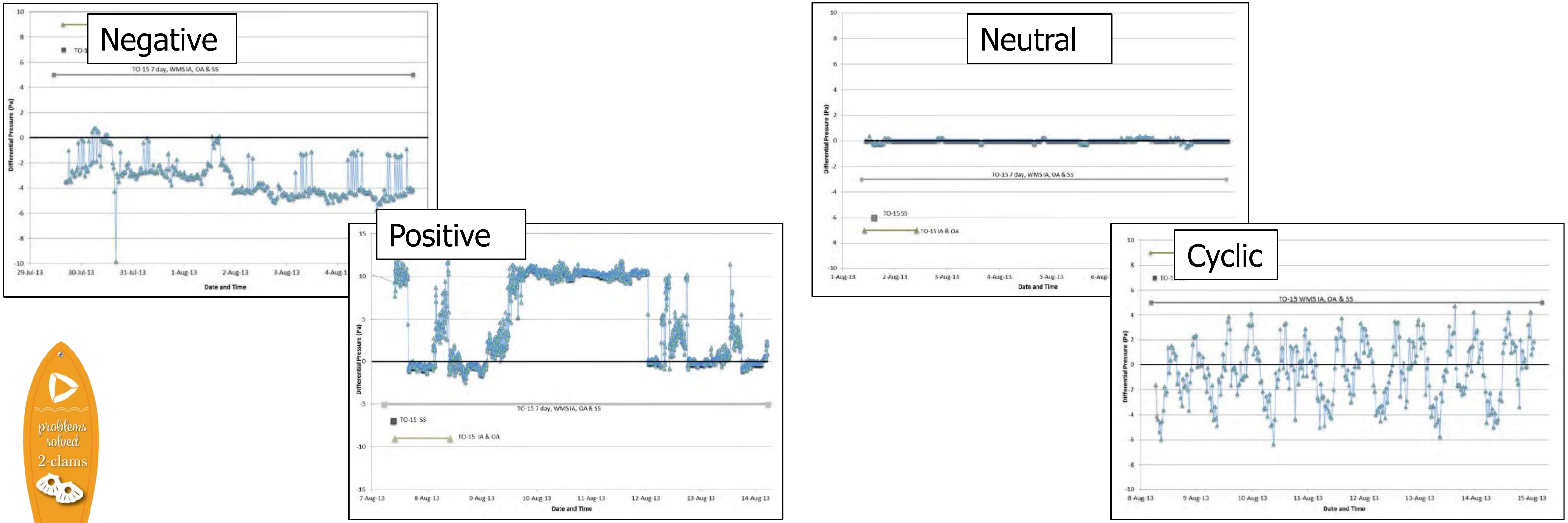
How much variability is there in the cross-slab vacuum?

How sensitive is your radius of influence to this variability?

For the plot at left, 12ft < ROI < 70 ft

Problems with Vacuum as a Solo Metric

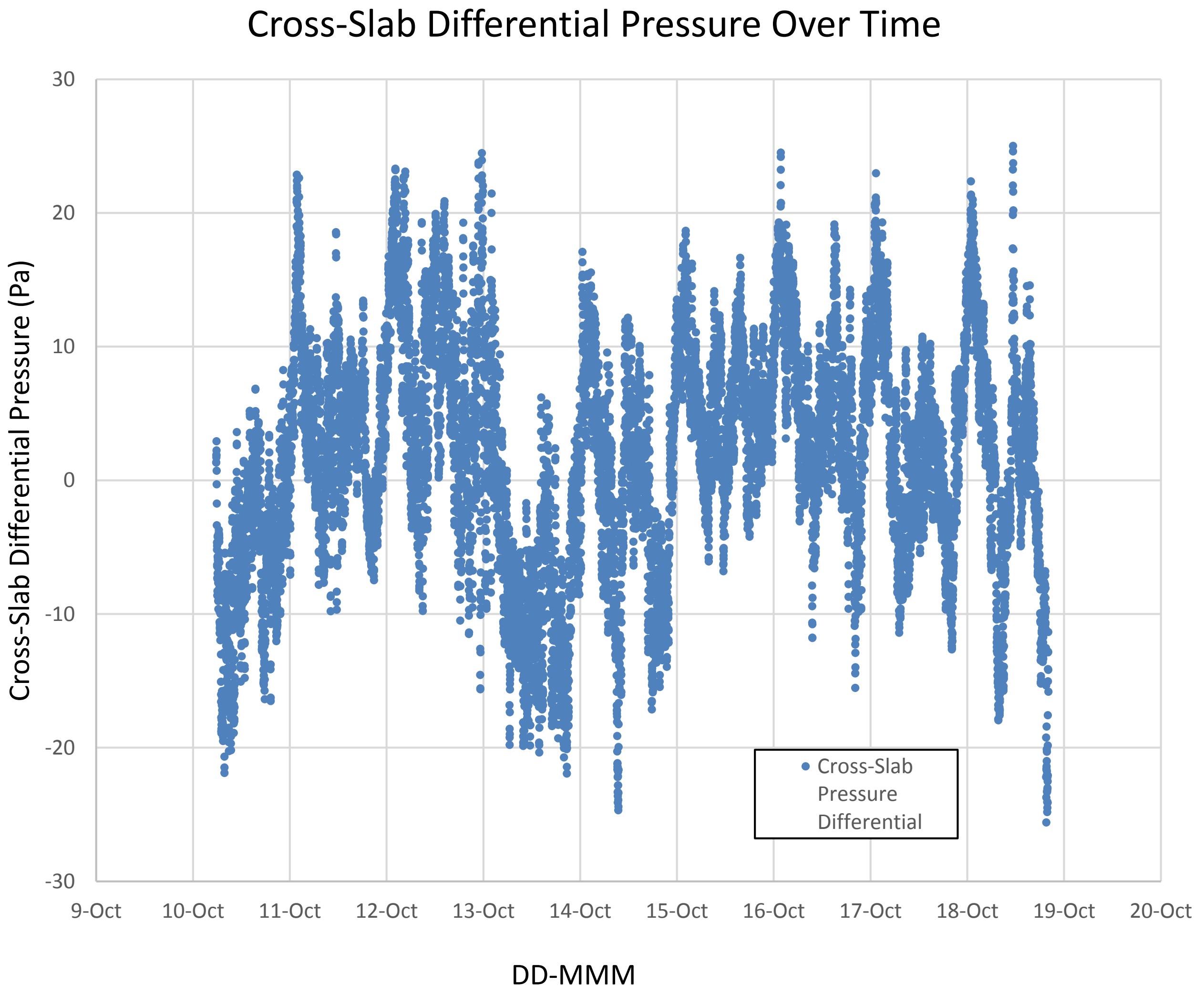
Not all buildings have the same ambient pressure – depends on inflow and outflows
Pressure varies over time
Pressure varies between air zones



problems solved 2-clams

Signal: Noise Ratio

How do you measure 1 Pa of applied vacuum if you have a 40 Pa range of fluctuations?

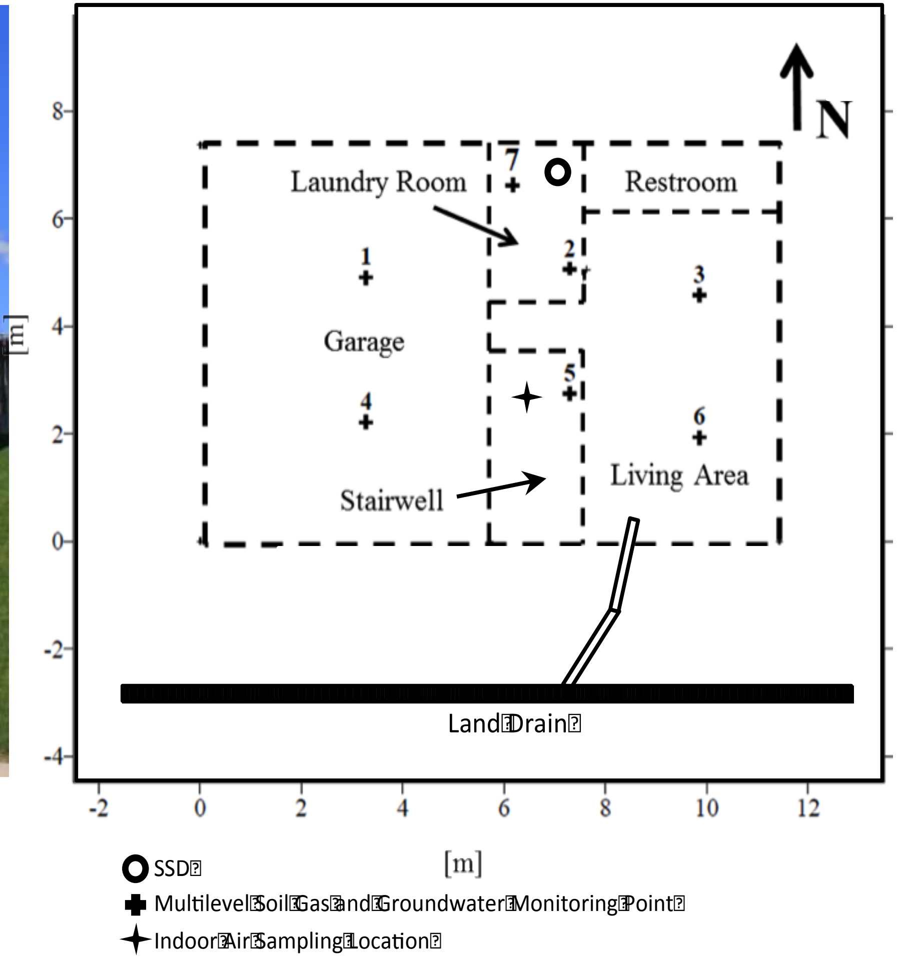


Sun Devil Manor

Residence in Layton Utah purchased by ASU for SERDP research

Extensively monitored for several years

Preferential pathway (land drain) now has a valve that can be opened or closed



Toolbox of Methods

Transient and steady-state pneumatic tests (vacuum vs time and distance)

Helium tracer tests (inter-well and flood)

Cross-Slab SF_6 tracer test

Mathematical Modeling

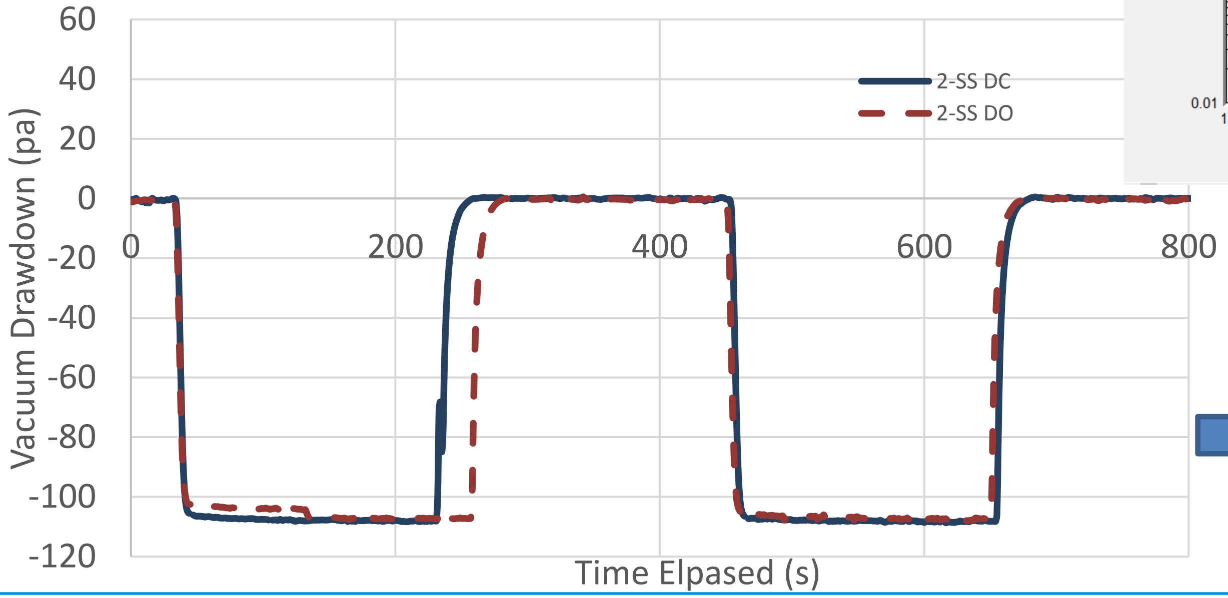
Step-tests (mass removal vs flow rate)

problems solved
2-clams

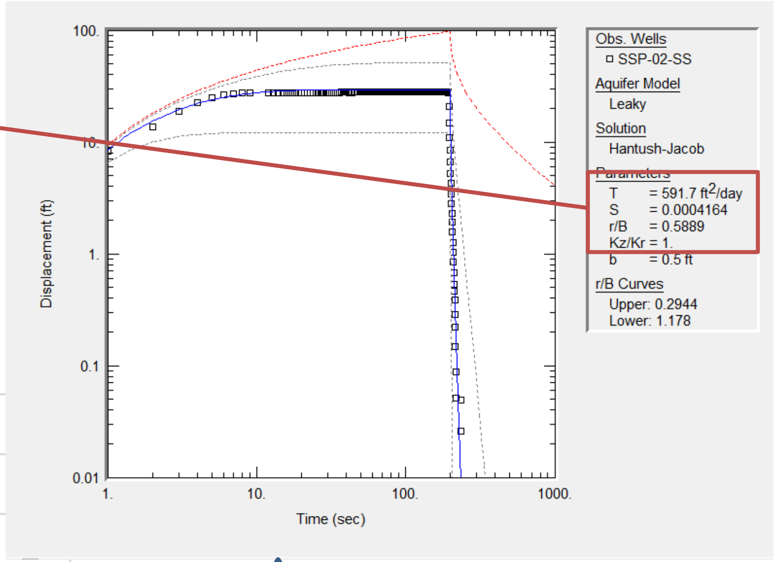
Geosyntec consultants

Transient pneumatic testing (vacuum vs time)

Measure vacuum every second using a pressure transducer and datalogger



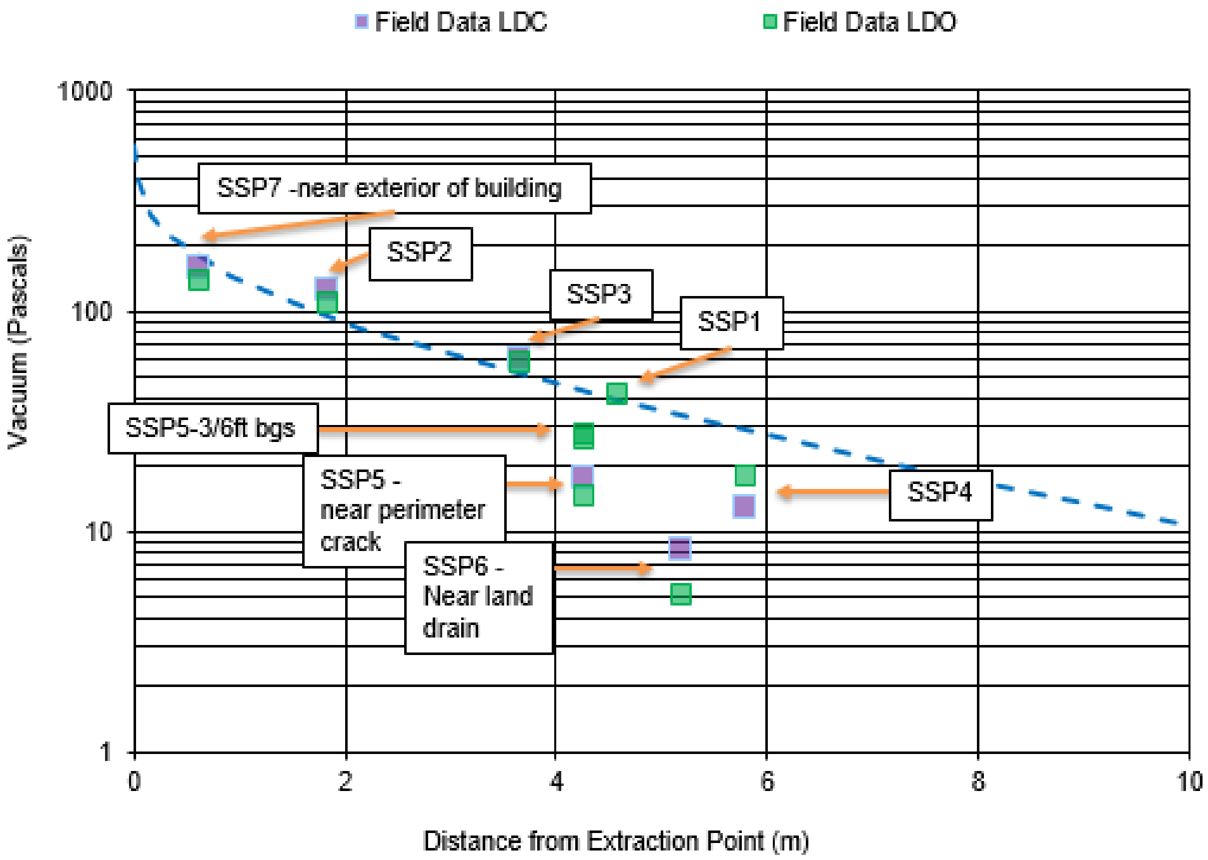
Parameters
T = Transmissivity
B = Leakance



Import to AQTESOLV and fit the trend using the Hantush-Jacob Leaky Aquifer Model (1955)

problems solved 2-clams

Steady-State Pneumatic Testing (vacuum vs distance)



Measure steady-state vacuum at different radial distances from the suction point

Compare to trend expected from Hantush-Jacob Model

$$\text{Vacuum} = \frac{Q_w}{2\,\pi\,T} K_0(r/B)$$

Locations with less vacuum than expected provide clues

SSP-5 is near an obvious gap between the floor and wall, sub-slab probe showed much less vacuum than 3 and 6 ft probes

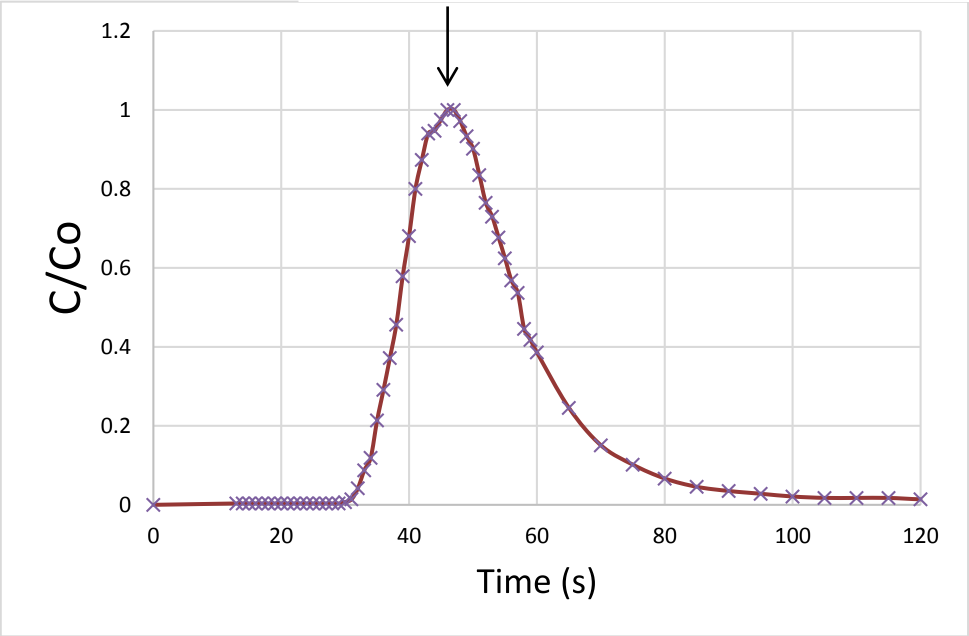
SSP-6 is closest to the land drain, also shows greatest difference LDO/LDC

Helium Inter-well tracer test (travel time vs flow and distance)

Inject helium into a sub-slab probe near an operating vent-pipe

Monitor Helium in the vent-pipe to get a breakthrough curve

Travel time = 46 seconds from radius of 12 ft

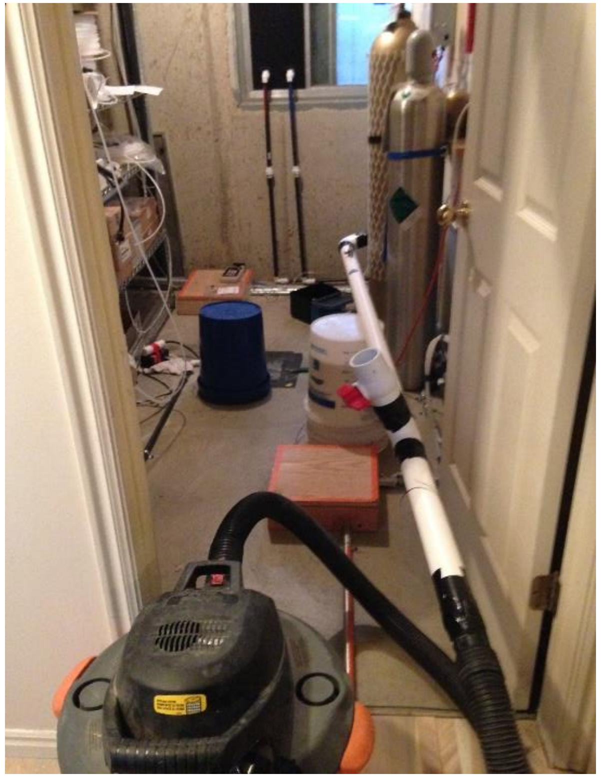


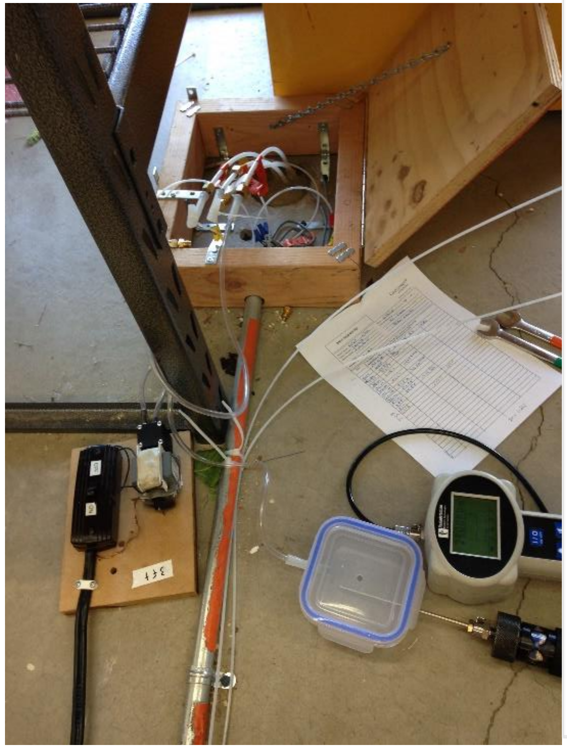
This data took less than 2 minutes to collect

These tests are quick, simple and very informative using low-cost equipment that is easily rented

Helium Flood tracer test

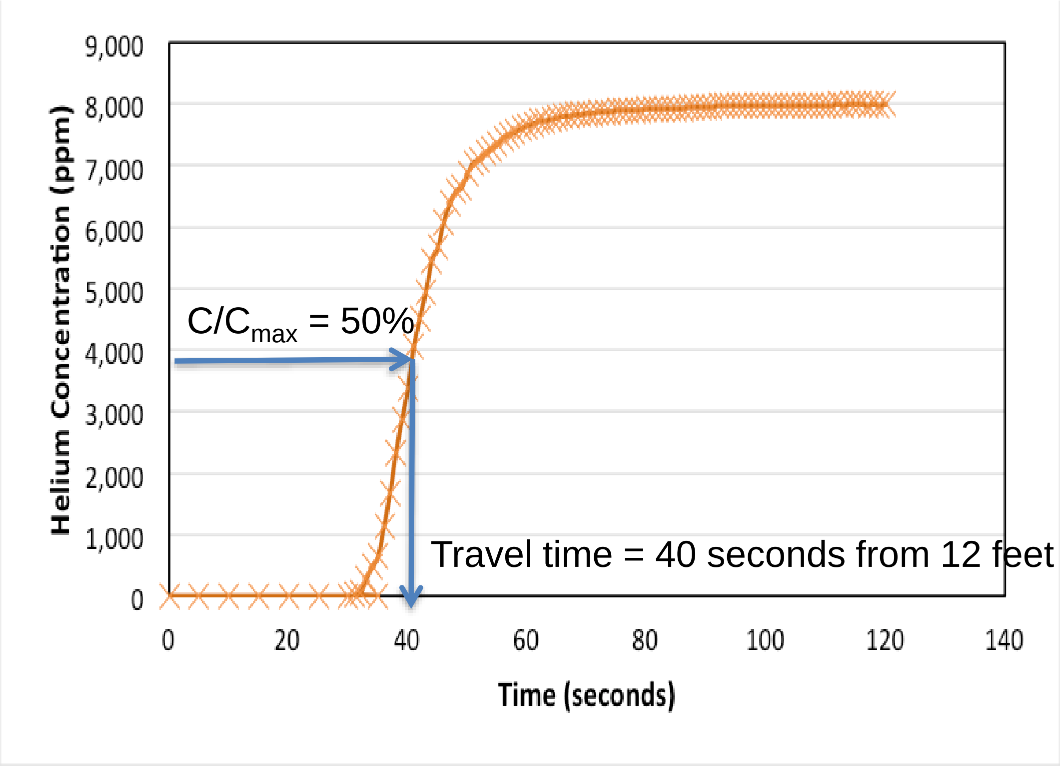
Inject helium at a concentration of ~ 1% v/v





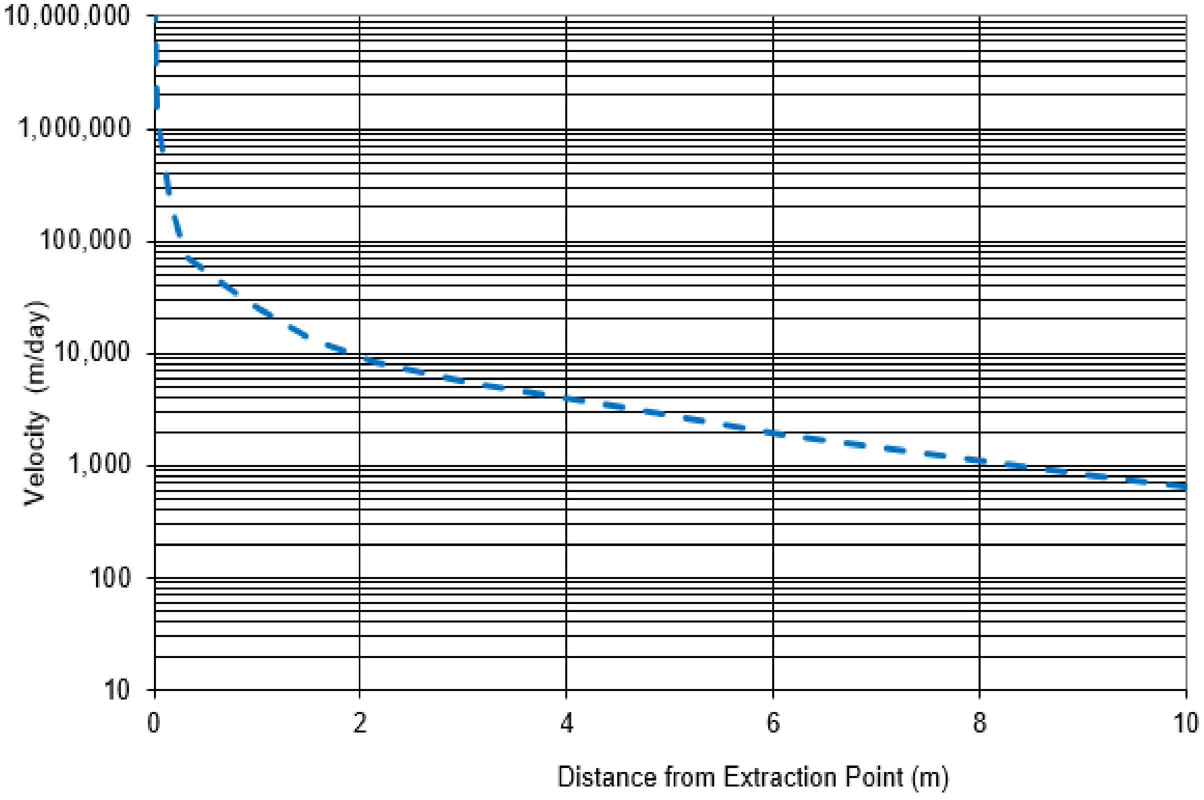
Monitor helium arrival at probe

Travel time is time to reach C/Cmax of 50%

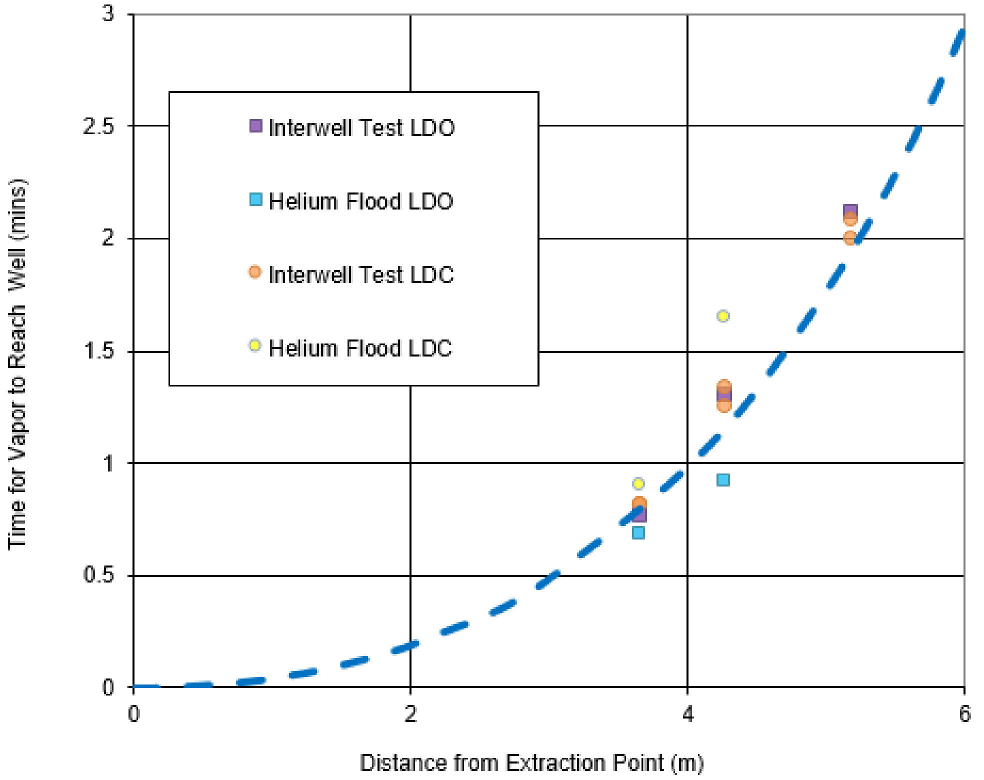


Mathematical Model Verification

Velocity vs radial distance $Velocity = \frac{Q_w}{2\,\pi\,b\,n}\frac{1}{B}K_1(r/B)$

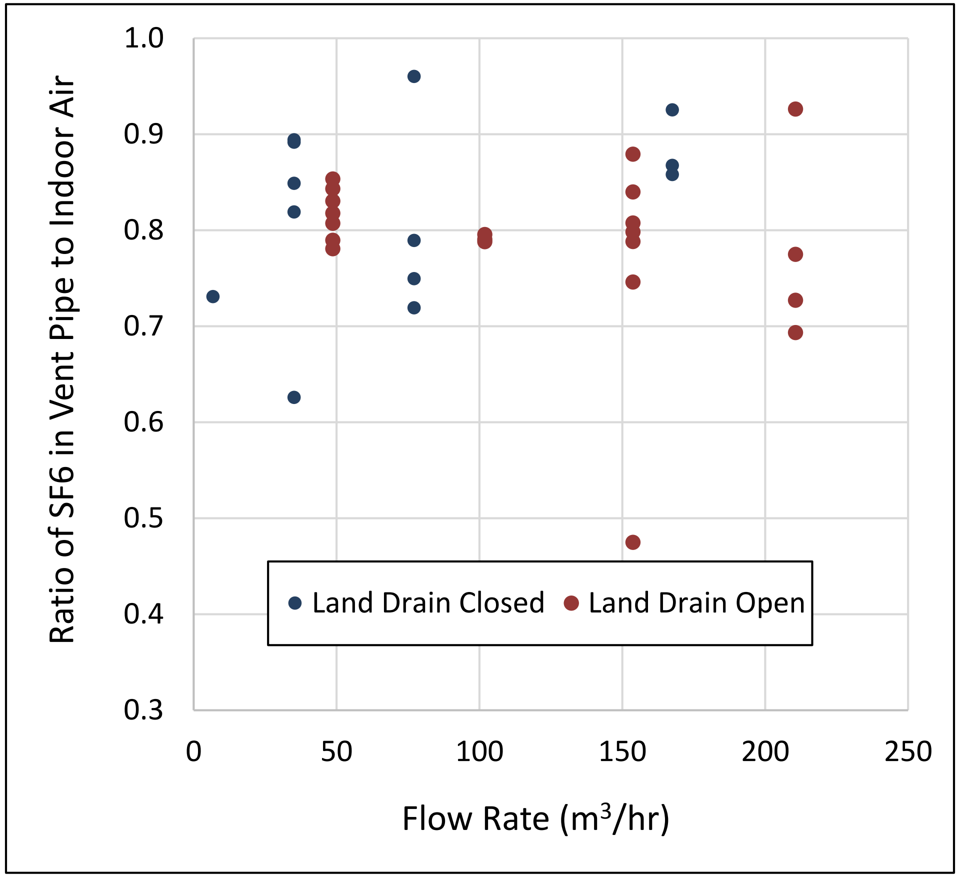


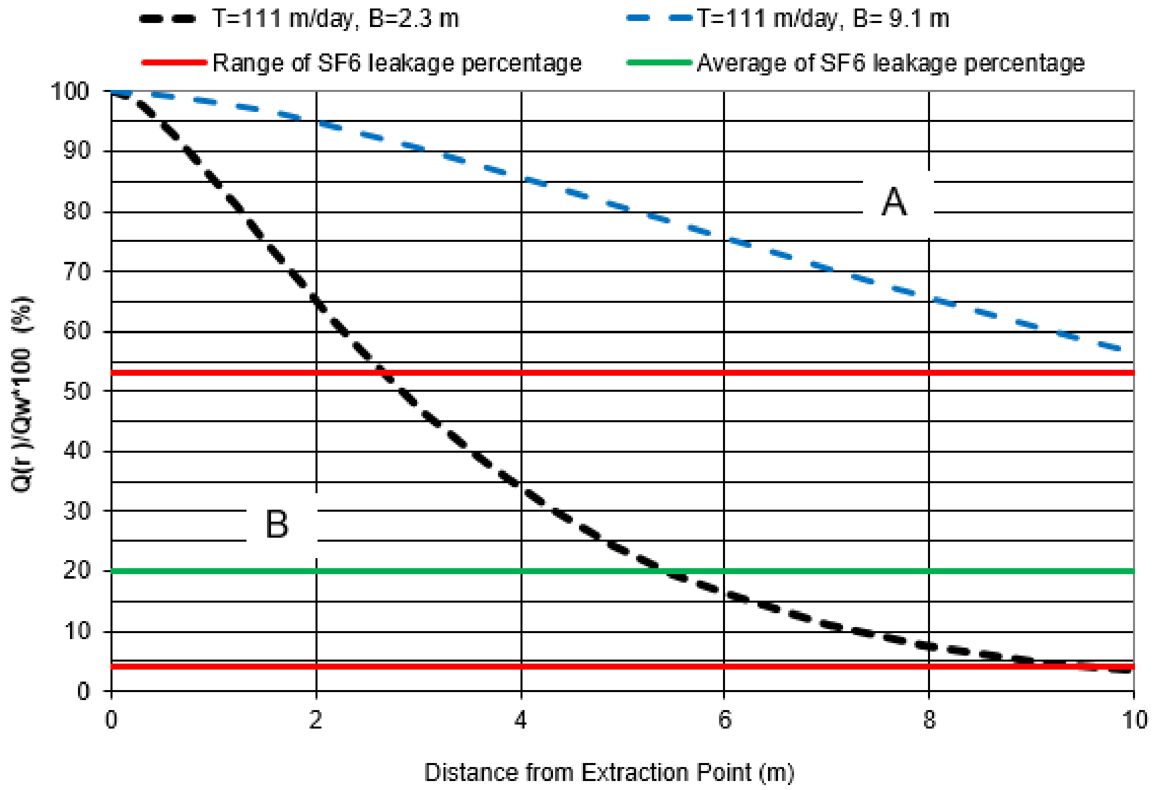
Travel time vs radial distance $t_{travel} = \int \frac{\partial r}{v(r)}$



Cross-Slab SF_6 Tracer Test

$$Q(r)/Q_w = \frac{r}{B} K_1(r/B)$$



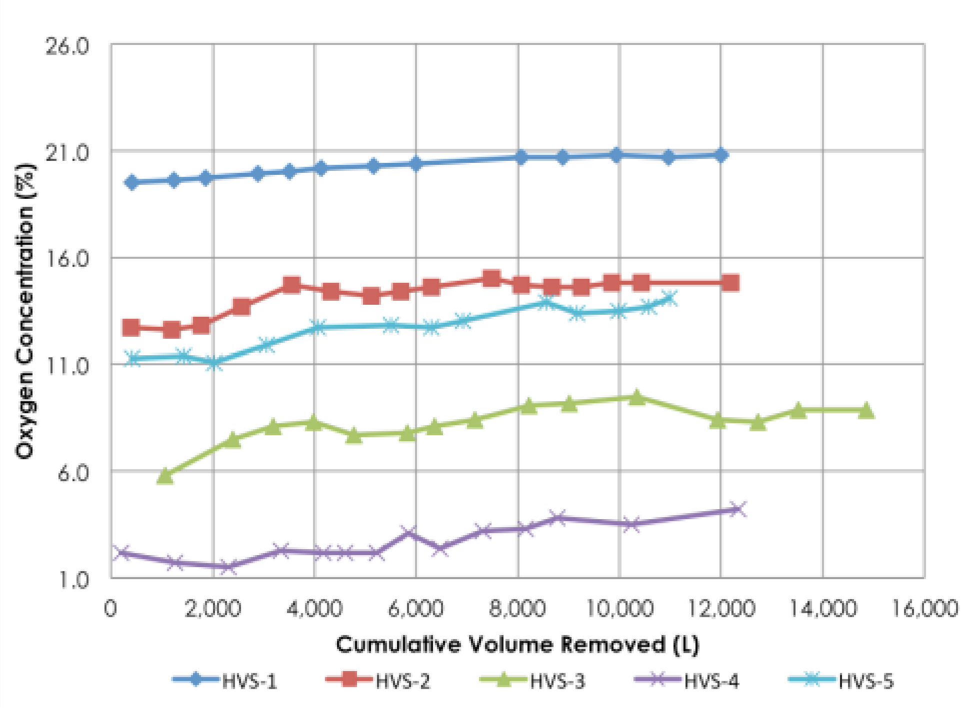


A - Area above the curve represents leakage during sample collection interval
B - Area below the curve represents soil gas extracted from subslab region during the sample collection interval

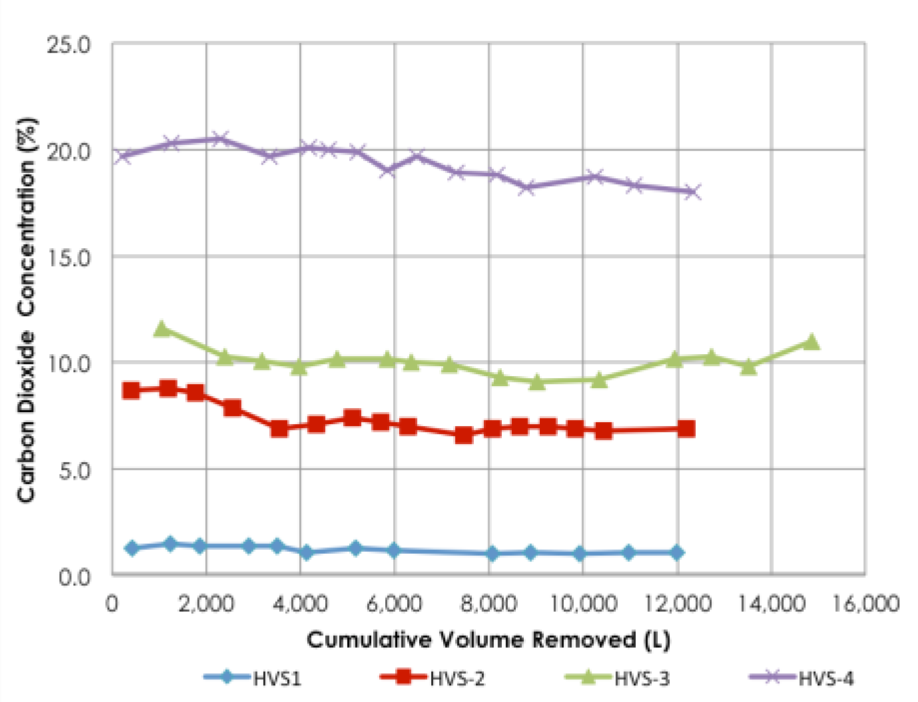
Cross-slab leakage measured via SF6 tracer test matches range calculated using model

Cross-Slab Tracer Test Alternative

O_2



CO_2

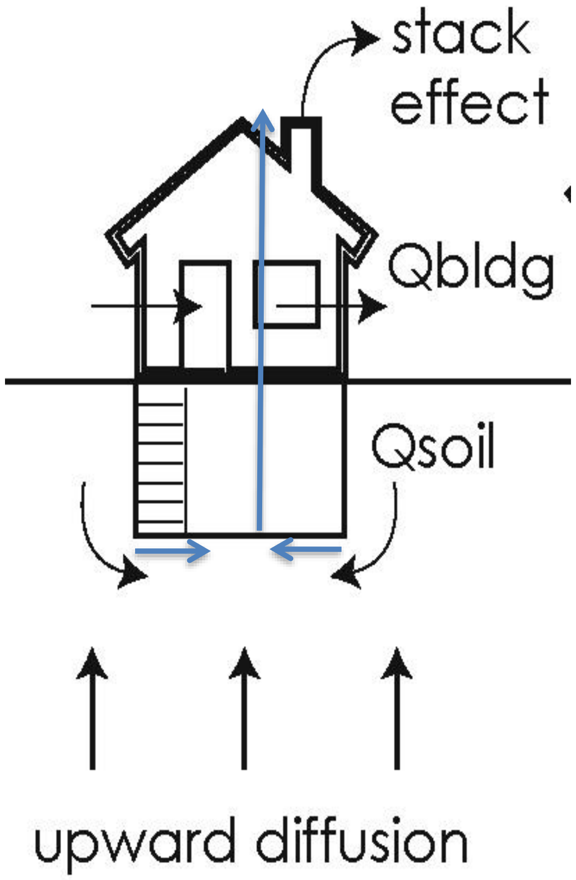


Slight increase in O_2 with volume purged

Slight decrease in CO_2 with volume purged

Both trends are consistent with minimal leakage of air through the floor slab

Step Tests (mass removal vs flow rate)



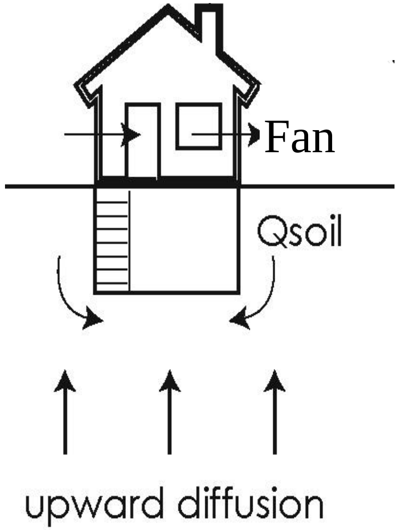
Run the SSD Fan at different flow rates (Q)

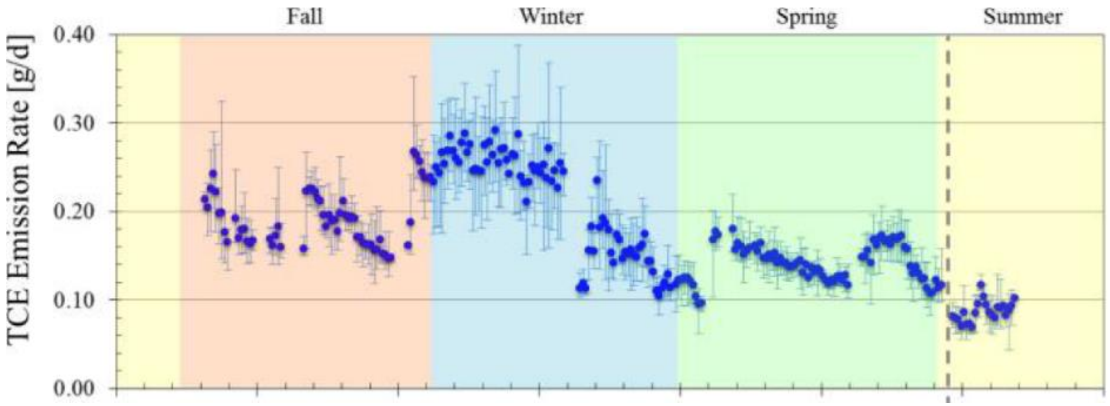
Collect samples from vent pipe for analysis of VOC and/or Radon concentrations (C)

Mass Removal Rate = C x Q

Optimizing the System Flow Rate

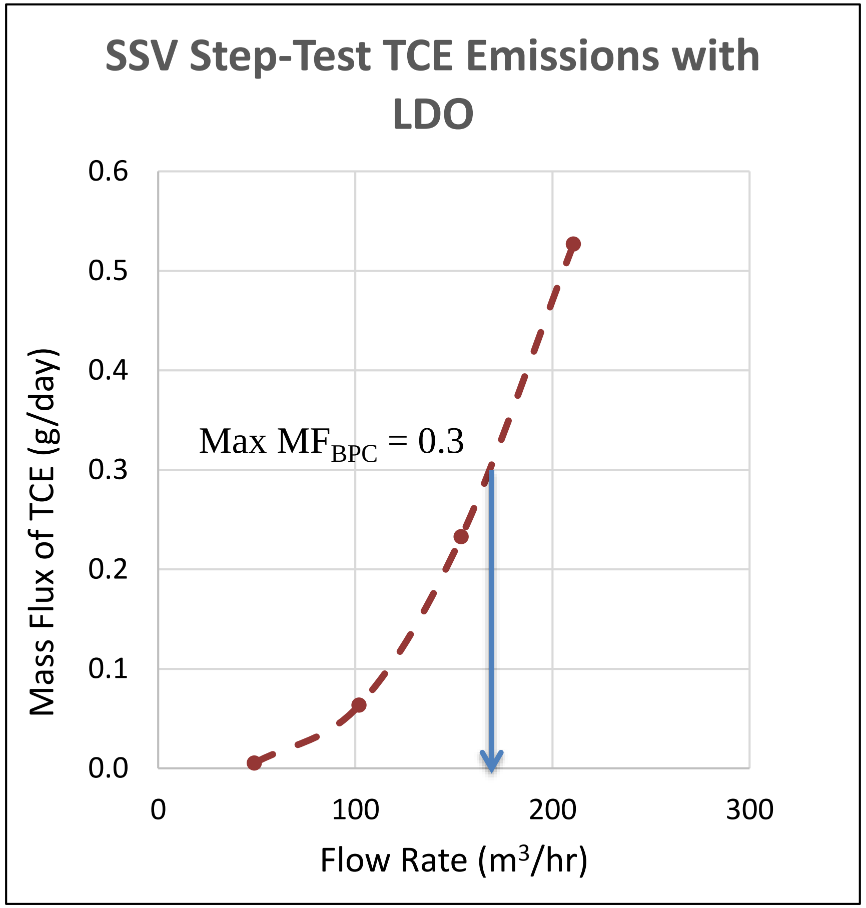
$MF_{BPC} = Q_{build} \times C_{ia}$





Depressurize building and measure flow rate (Qbuild) and concentration (Cia)

MF = 0.1 g/day < TCE < 0.3 g/day
Holton et al., 2015 (SERDP ER-1686)



Performance Criteria

Vacuum:
- 6 to 9 Pascals per ASTM E2121?
- 1 Pascal per AARST 2017?
- Specific to each building based on measured pressure?
- Specific to each season?
- Constantly adjusted through real-time monitoring?

Velocity:
- >3 ft/day per ACOE, 2002?
- > 10x Default Q_{soil} / Area? (5L/min / 1000 ft^2 = 0.3 ft/day)

Mass Flux > Mass flux measured by building depressurization?

problems solved 2-clams

Conclusions

Vacuum is important, but suffers challenges from spatial & temporal variability and signal:noise

It's not difficult or costly to measure flow, permeability, sub-slab velocity or cross-slab leakage, all of which are important as well.

The Hantush-Jacob Model provides a valuable tool for data interpretation – programmable into a spreadsheet.

Vacuum less than predicted by the model indicates preferential flow, and could help to identify preferential pathways.

Some work is needed to demonstrate and validate performance criteria for mass flux, velocity, sub-slab ventilation rates.

QUESTIONS?

Darius Mali, P.Eng, MASc
dmali@Geosyntec.com