Streamlining Vapor Intrusion Assessments with High Volume Sampling (HVS) at Large Industrial Facilities

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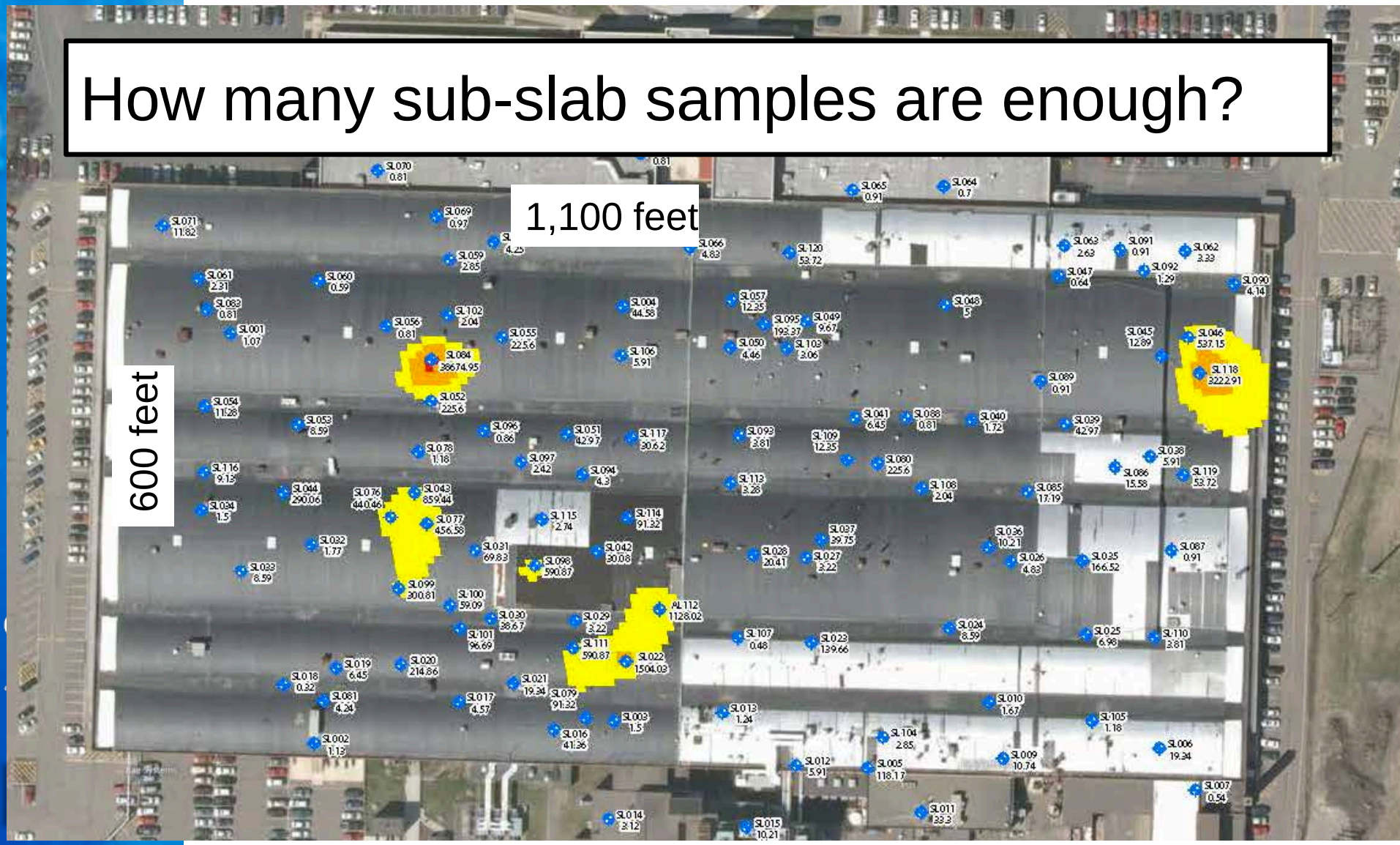
Agenda

- Introduction: Collaborative VI Demonstrations (Abigail Hendershott)
- Problem: Spatial Variability
- Solution: High Volume Sampling
- The HVS Approach
- Example Case Study

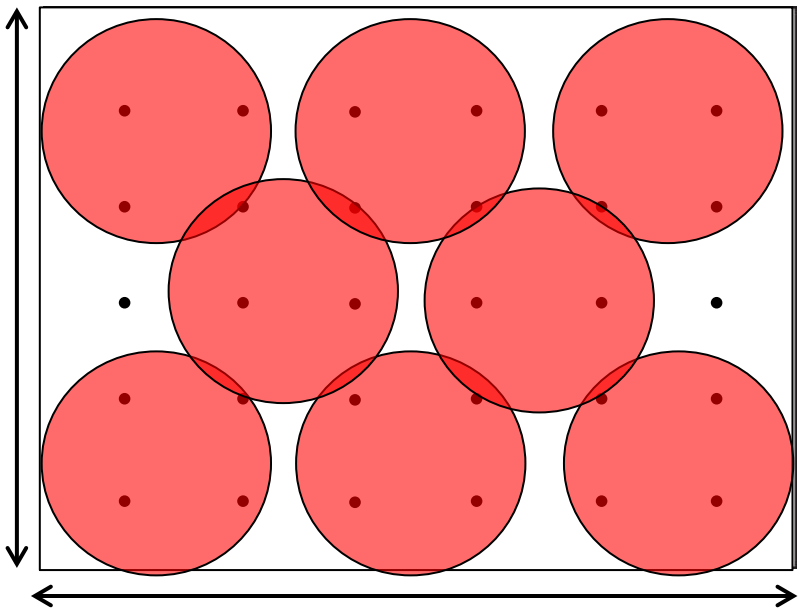
Spatial Variability

How many sub-slab samples are enough?



HVP vs. Conventional SSPs

HVP locations



105,000 ft^2

- 10 x less locations
- Lower analytical costs
- Shorter time period, less disruption

Benefits of HVS

- Conventional sub-slab sampling methods have generated data that show substantial spatial and temporal variability, which often makes interpretation difficult.
- High Volume Sampling integrates a sample over a large volume of extracted soil gas to obtain a spatially-averaged soil gas concentration for an area under the sub-slab.
- Field screening of total VOC concentrations during the High Volume Sampling provides insight into the spatial distribution of vapors at progressive distances away from the sampling point, generally to a radius of up to 50 feet.

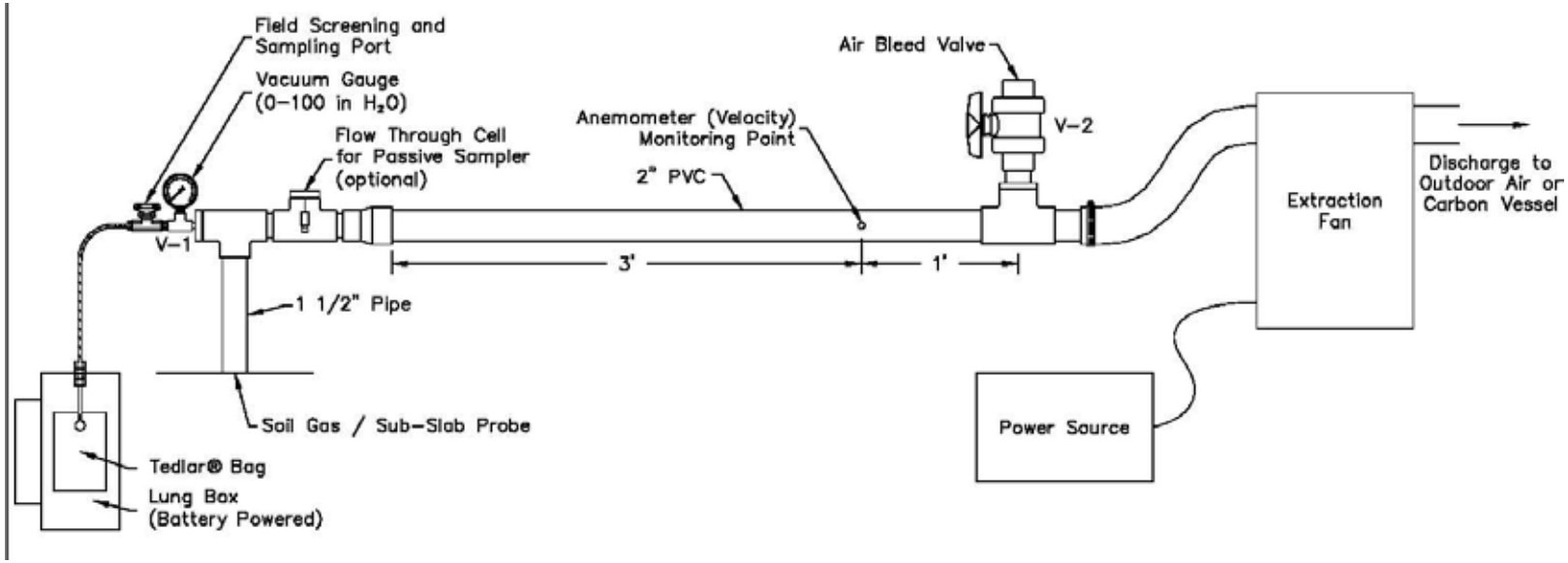
Benefits of HVS

- Conventional sub-slab sampling methods may fail to identify areas of elevated vapor concentrations between discrete sample locations, while High Volume Sampling minimizes this risk.
- Provides soil gas information for large buildings while requiring fewer holes drilled through the floor.
- The extraction flow rate and transient vacuum response is also monitored, supporting the optimal design of any sub-slab venting system that may be needed.

The HVS Approach

- Take a larger sample (1,000 to 100,000 L)
  - Characterize sub-slab by integrating over volume
  - Use to delineate & reduce # of samples, but provide better characterization of sub-slab conditions
- Monitor flow and vacuum
  - Limit vacuum not flow (sub-slab gravel can yield high flows)
  - Can aid in the design of a mitigation system if needed
  - Measure floor slab leakance
  - Calculate ROI

HVS Testing Apparatus



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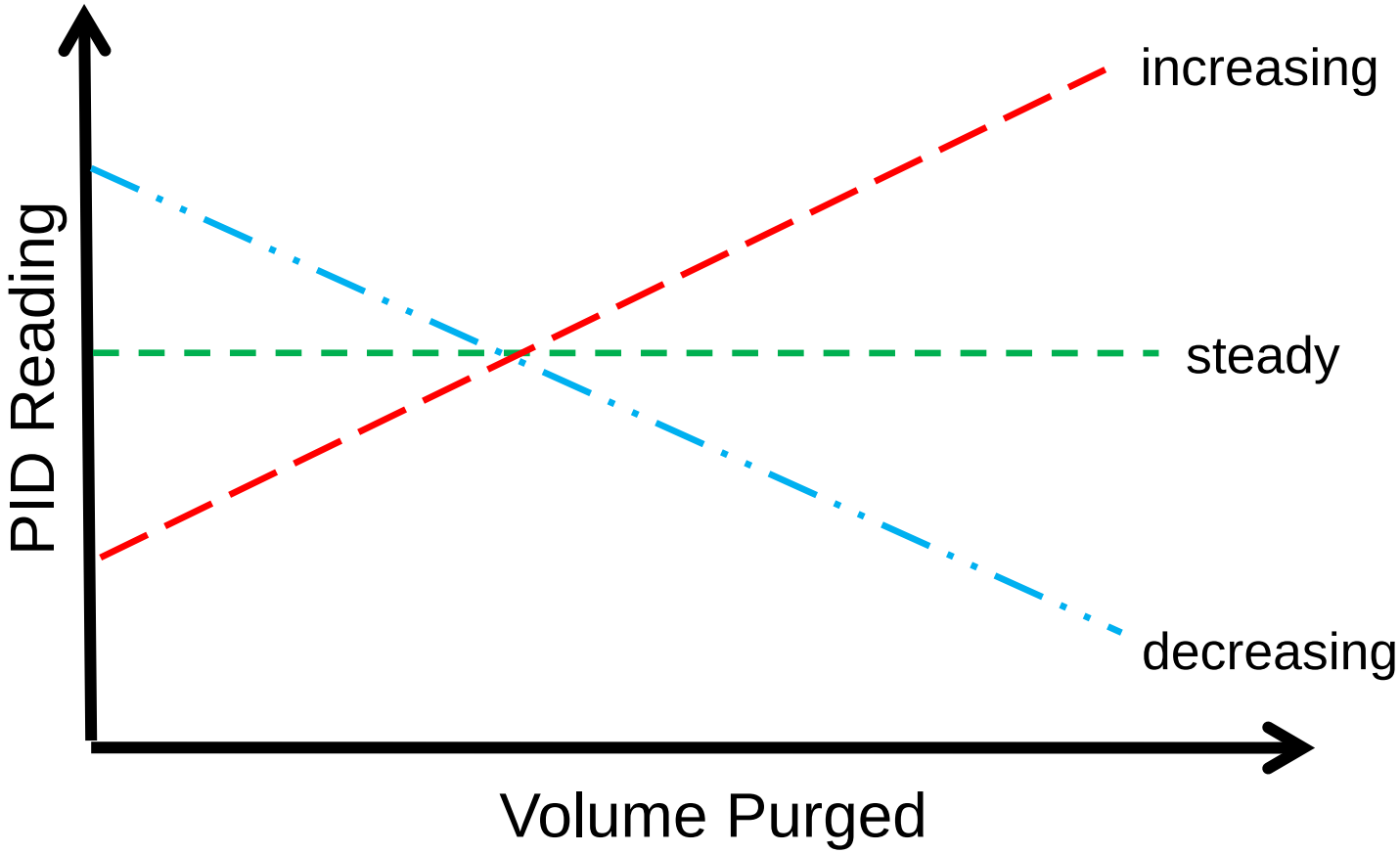
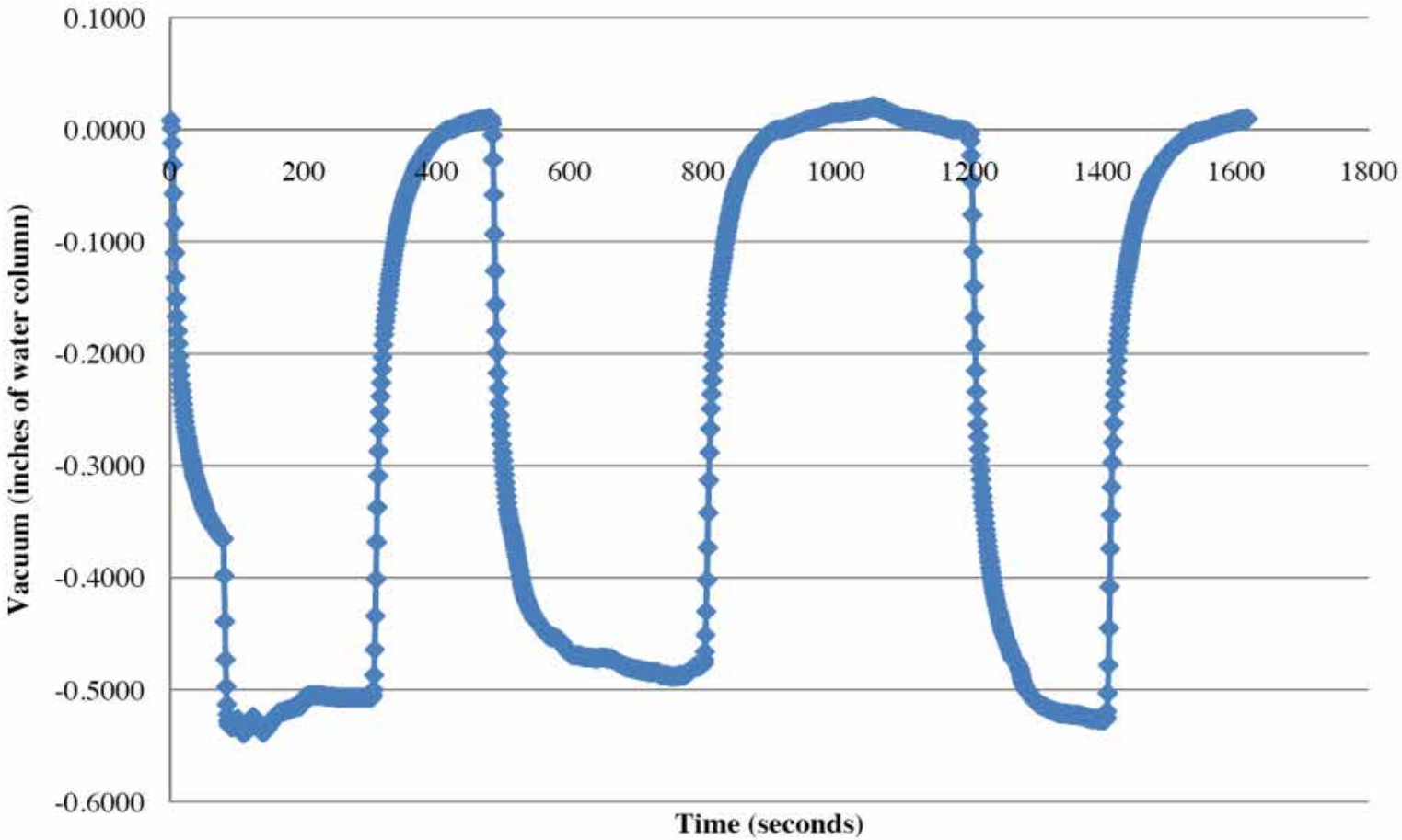
HVS Testing Apparatus

PID READING VS. VOLUME PURGED



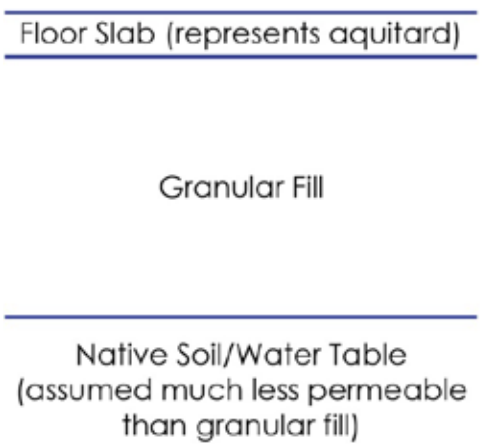
Drawdown and Recovery



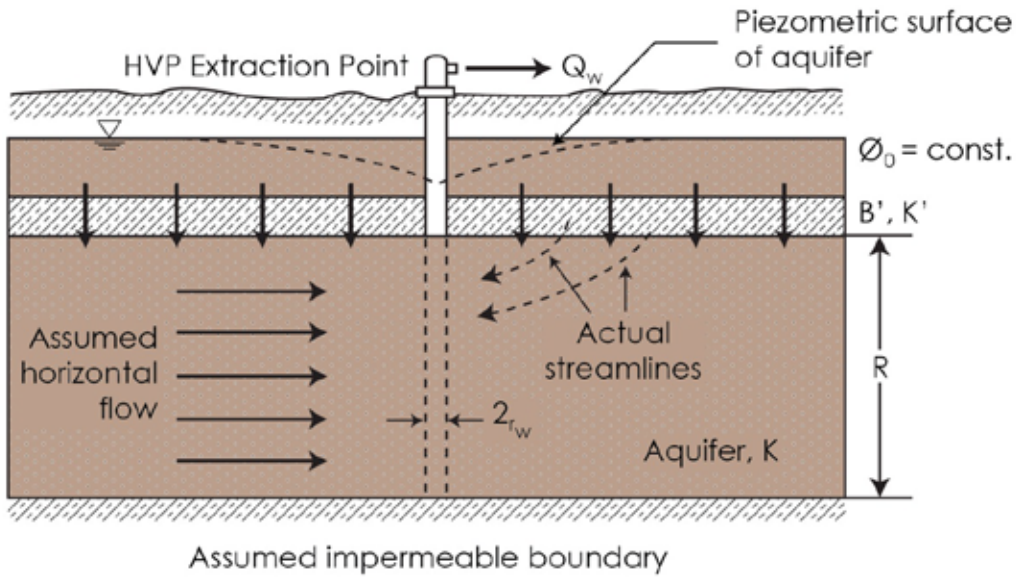
Hantush Leaky Aquifer Model

Hantush & Jacob, 1955

HVP Test Conceptual Model



Hantush Jacob Conceptual Model



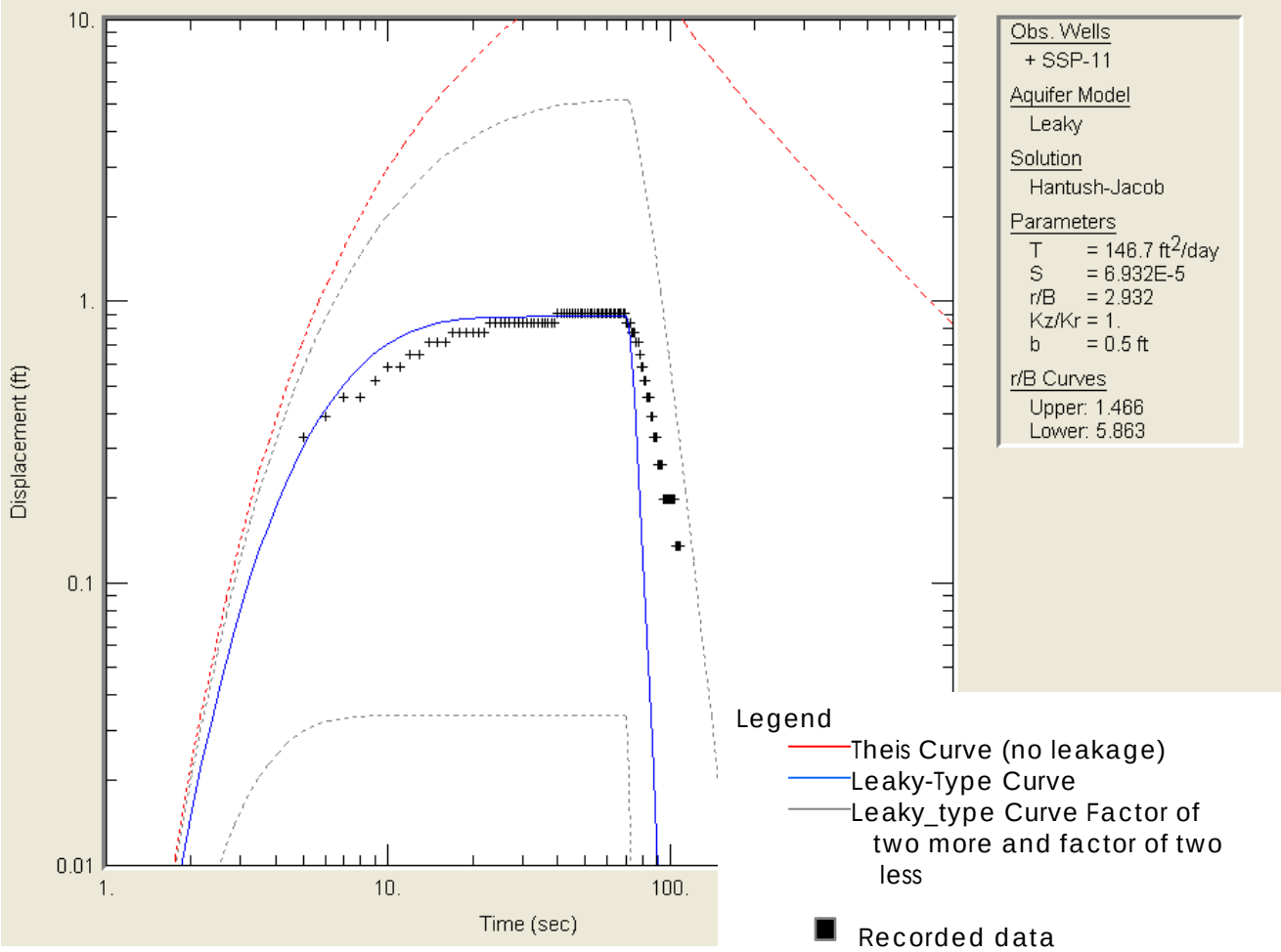
Thrupp, G.A., Gallinatti, J.D., Johnson, K.A., 1996, "Tools to Improve Models for Design and Assessment of Soil Vapor Extraction Systems", in Subsurface Fluid-flow (Groundwater and Vadose Zone) Modeling, ASTM STP 1288, Joseph D. Ritchey and James O. Rambaugh, Eds., American Society for Testing and Materials, Philadelphia. pp 268-2

Massman, J. W., 1989, "Applying Groundwater Flow Models to Vapor Extraction System Design," J. of Environmental Engineering, Vol. 115, No. 1, pp. 129-149.

Type-Curve Analysis

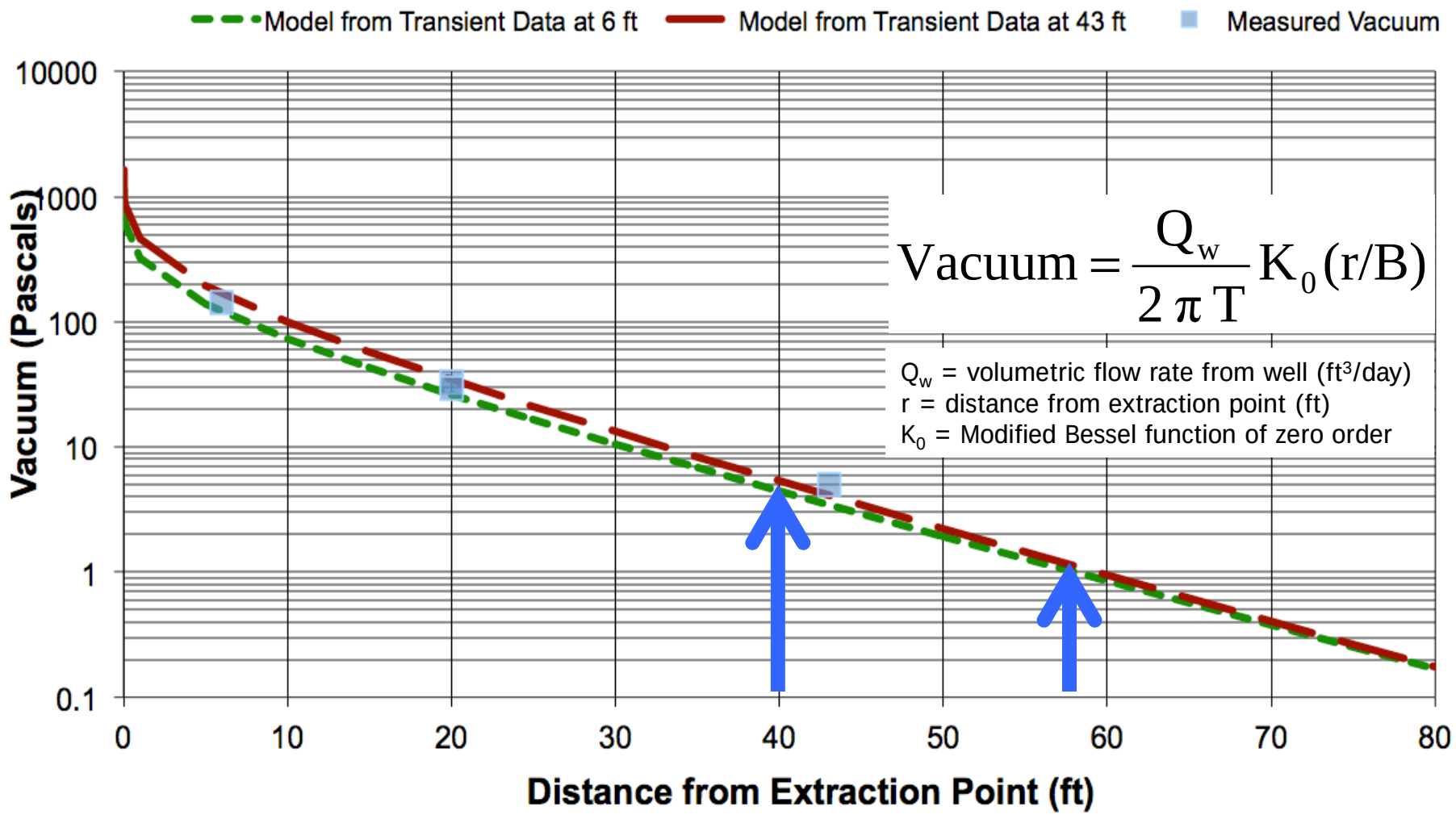
Almost perfect fit to model.

Not bad for 2 minutes of data collection



Flow = 15 cfm
Distance to extraction point = 30 ft
Leakance (B) = 10 ft

Measured versus Modeled Vacuum

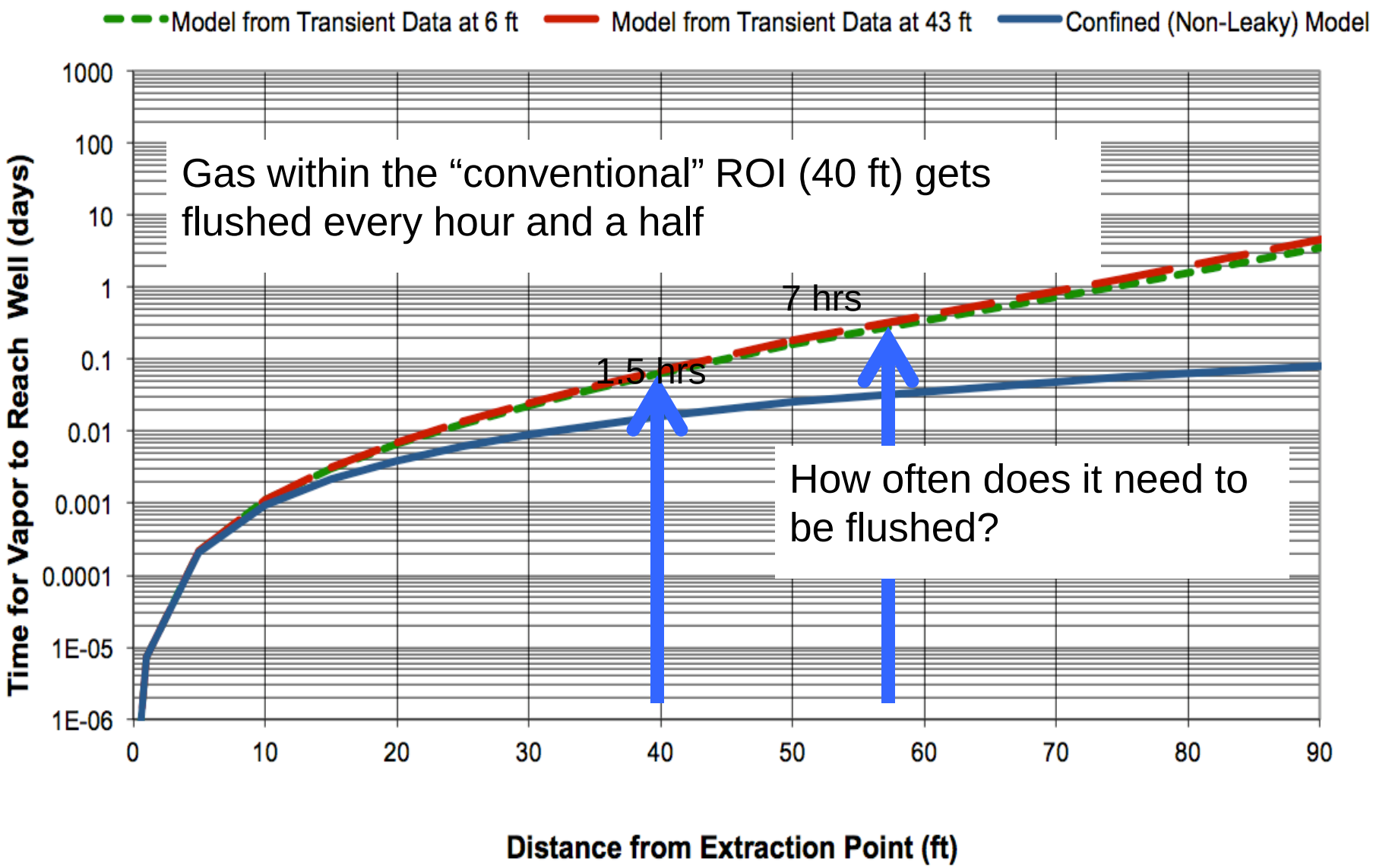


$$\text{Vacuum} = \frac{Q_w}{2\pi T} K_0(r/B)$$

Q_w = volumetric flow rate from well (ft^3/day)
r = distance from extraction point (ft)
K_0 = Modified Bessel function of zero order

(1 inch of water column ~ 250 Pa

Purge Time vs. Distance



Case Study – Plymouth MI

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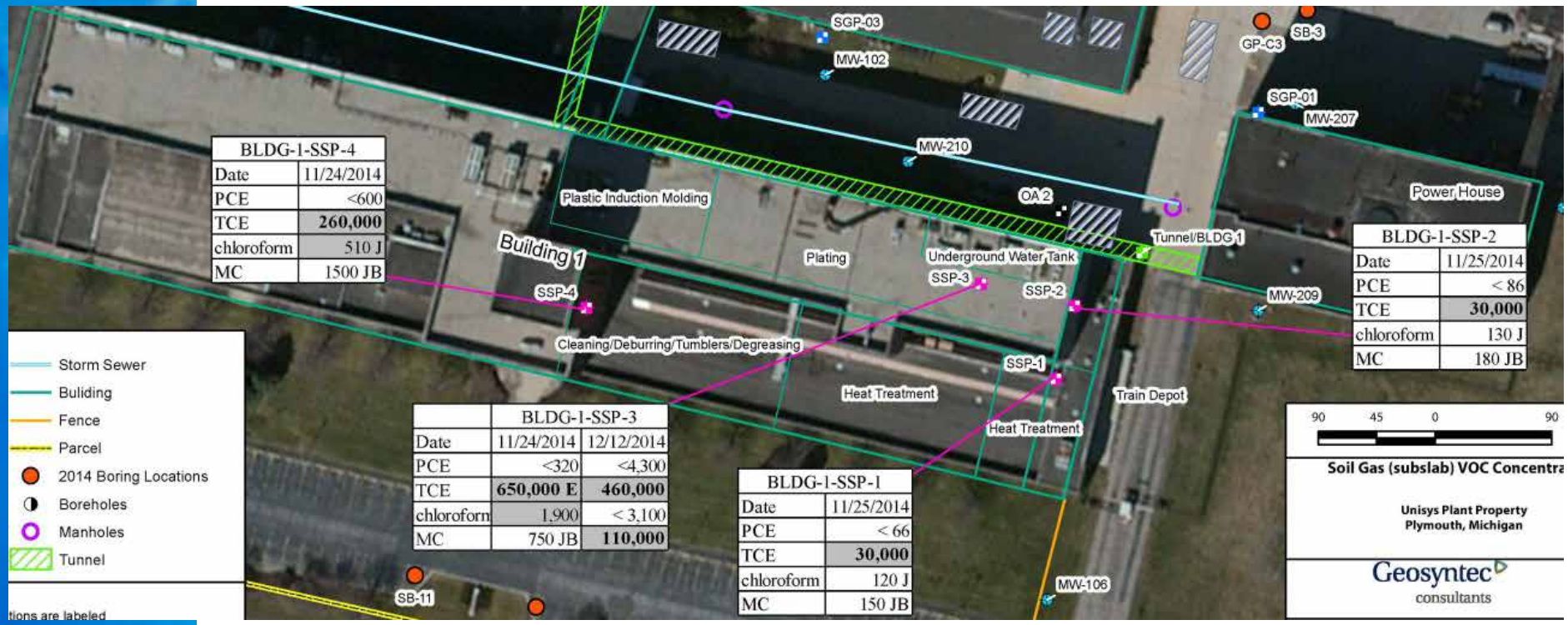
Site Background

- 56 acre site, with 7 buildings
- Built 1940's-50's
- Building 1 – historical operations included: heat treatment, degreasing, plating, plastic moulding
- Depth to GW ~11 ft
- TCE primary COC – vadose zone source

Initial Sub-slab Samples



BLDG-1-SSP-4	
Date	11/24/2014
PCE	<600
TCE	**260,000**
chloroform	510 J
MC	1500 JB

BLDG-1-SSP-2	
Date	11/25/2014
PCE	< 86
TCE	**30,000**
chloroform	130 J
MC	180 JB

	BLDG-1-SSP-3	
Date	11/24/2014	12/12/2014
PCE	<320	<4,300
TCE	**650,000 E**	**460,000**
chloroform	1,900	< 3,100
MC	750 JB	**110,000**

BLDG-1-SSP-1	
Date	11/25/2014
PCE	< 66
TCE	**30,000**
chloroform	120 J
MC	150 JB

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HVS Scope of Work

- 6 HVS locations
- 6 IA and 1 OA sample
- PID, Landfill gas for O2, CO2, CH4
- Transient data collection

Sample Locations

Focused on historical chemical handling areas/coverage of building

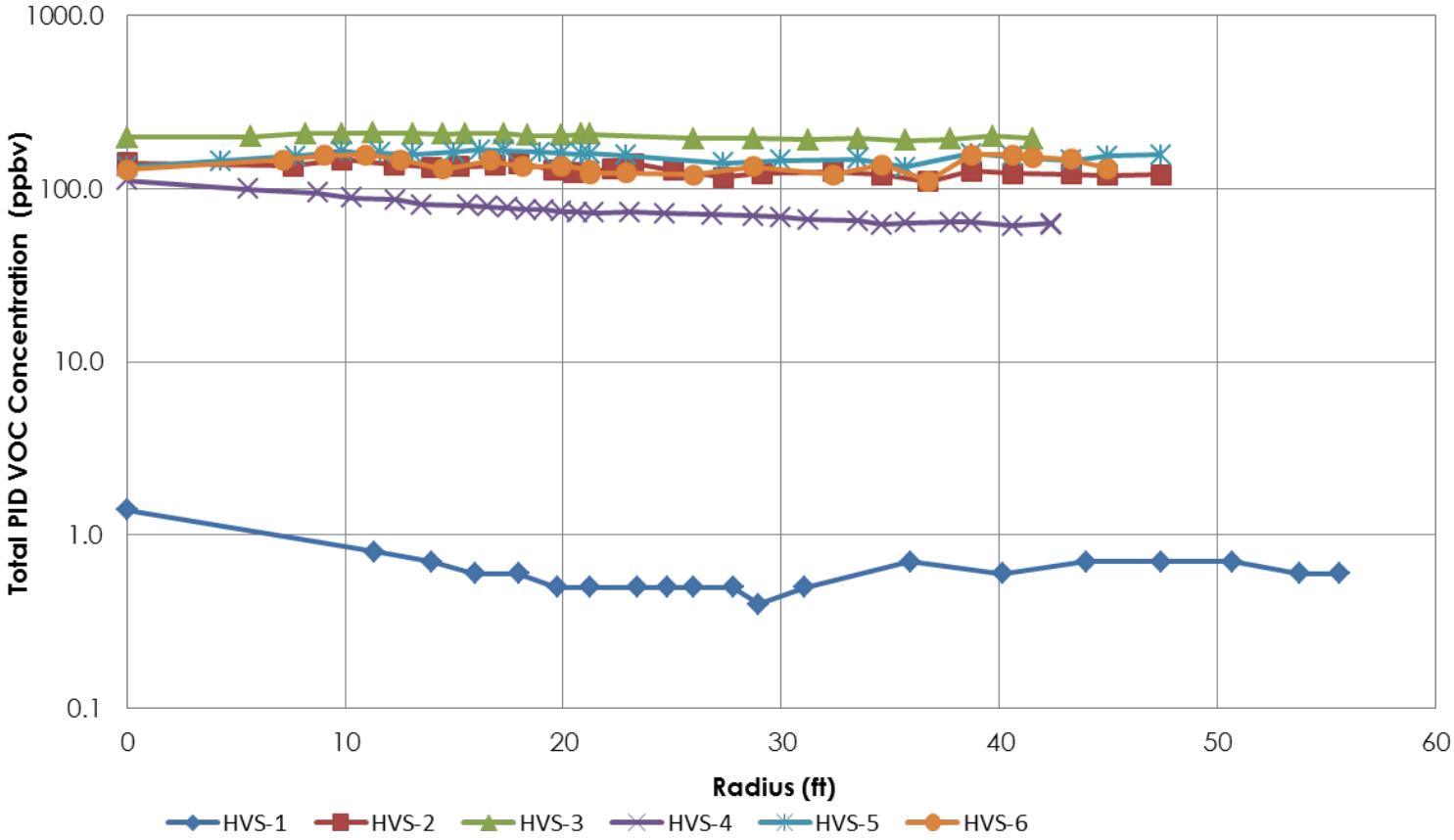
High Volume Sampling Demonstration

Sample train from the shop-vac hose to the High Volume Sampling fittings.

High Volume Sampling Demonstration

The sample train connects to a tedlar bag (in the blue lung box) for PID screening total VOC concentrations during purging under the sub-slab. A sample is routed to the Summa canister at the beginning and end of the purging for laboratory analysis.

PID vs. Radius



Notes:
Measurements collected with a 10.6 eV lamp PID
PID - photoionization detector
eV - electron volt
ppbv - parts per billion by volume
L - liters

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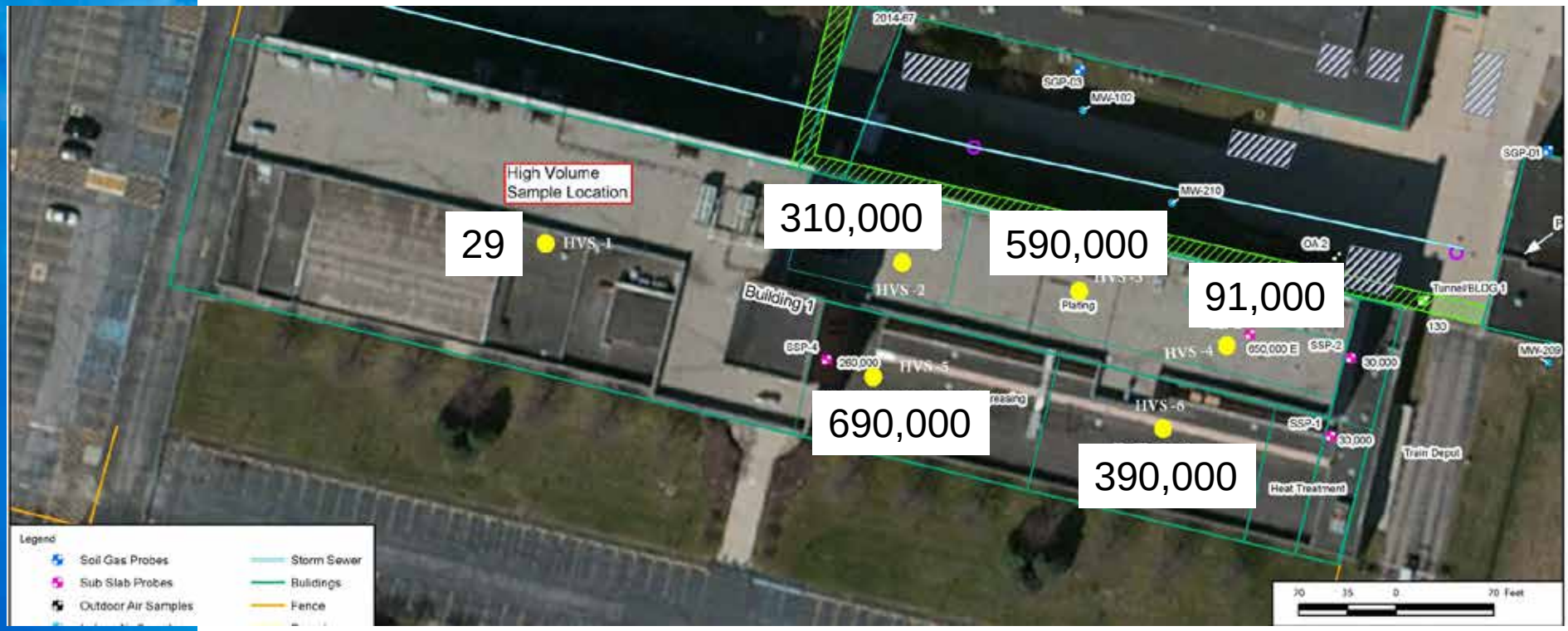
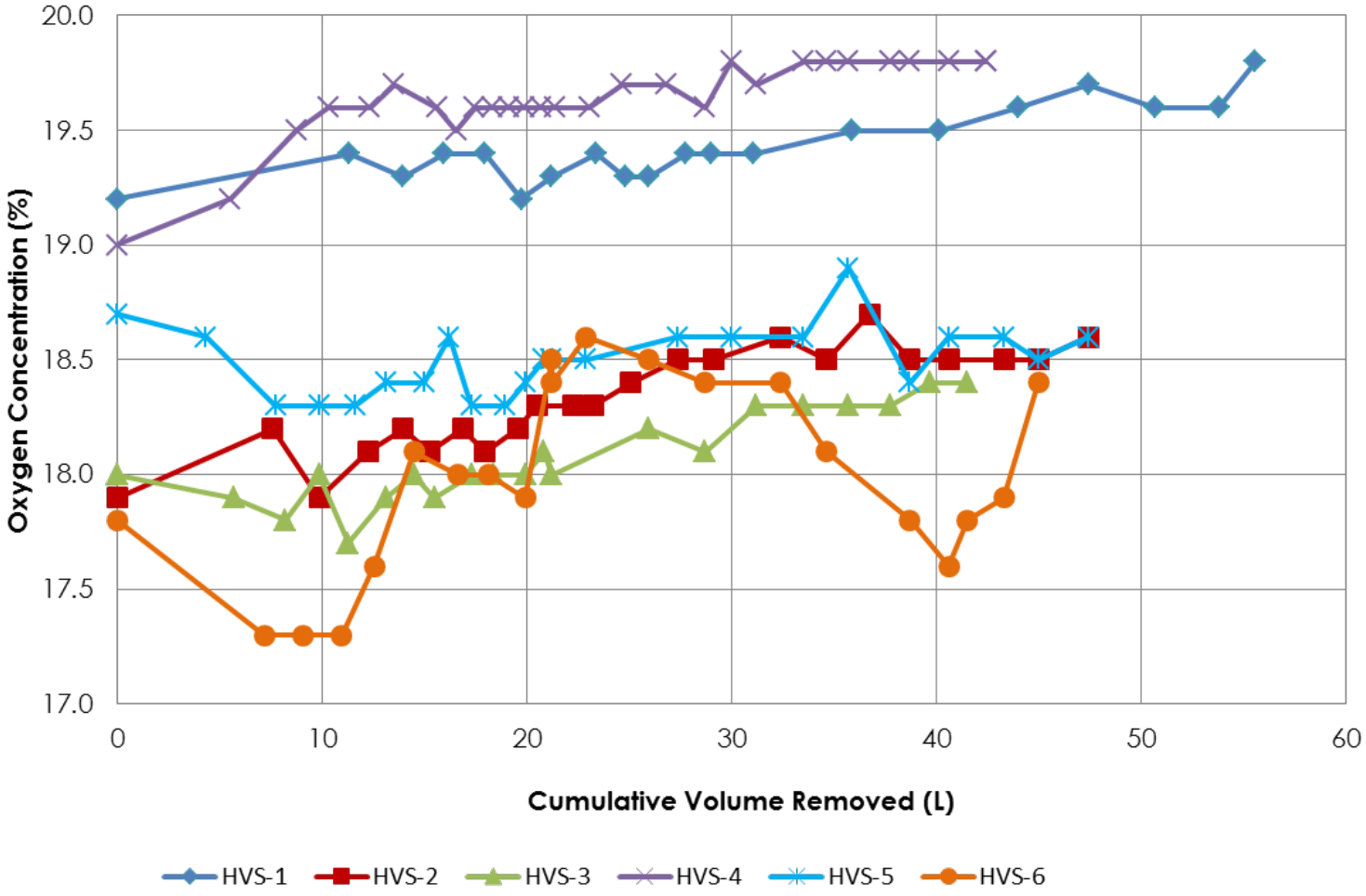
HVS TCE Analytical



Units µg/m³

O_2 vs. Radius



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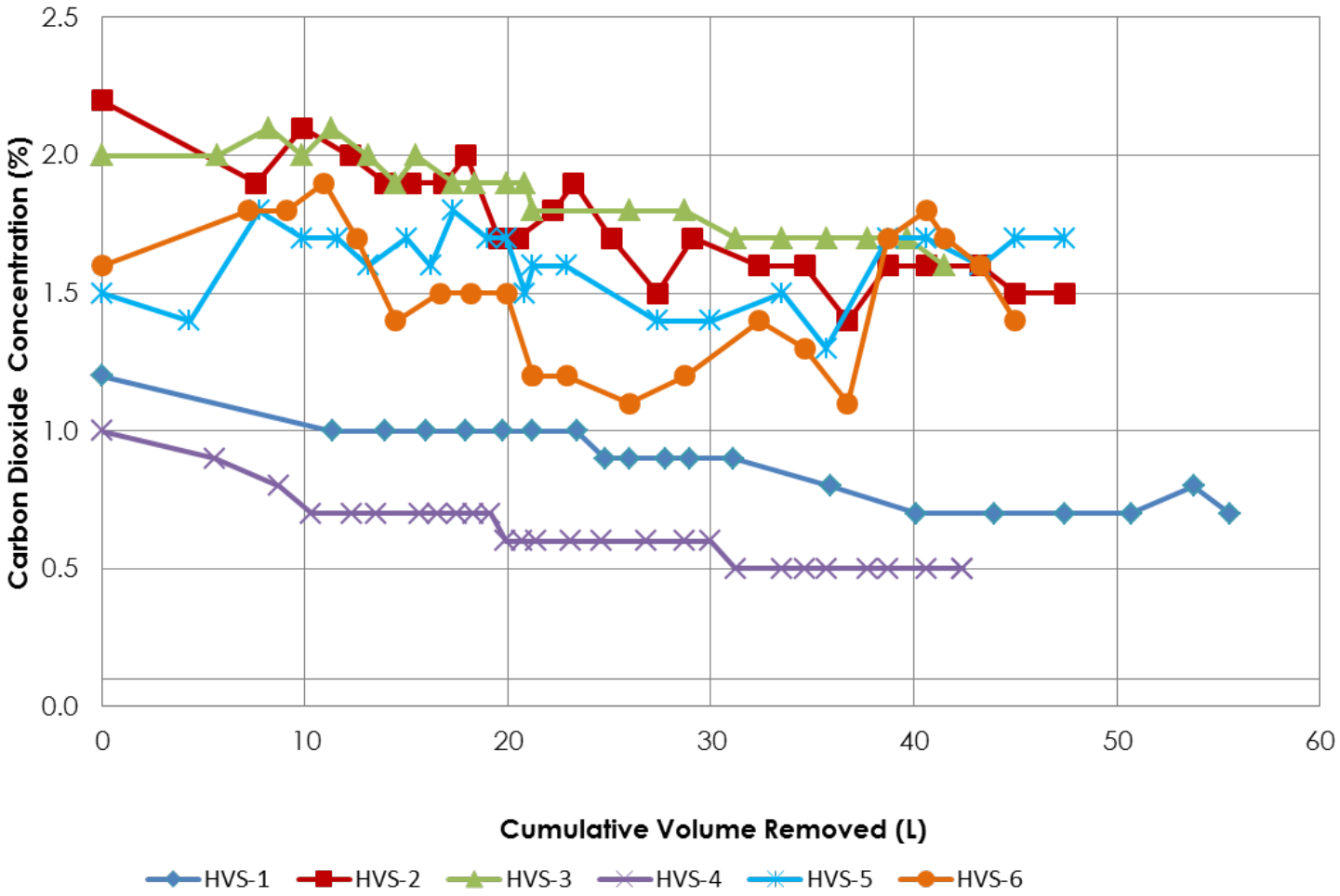
CO_2 vs. Radius



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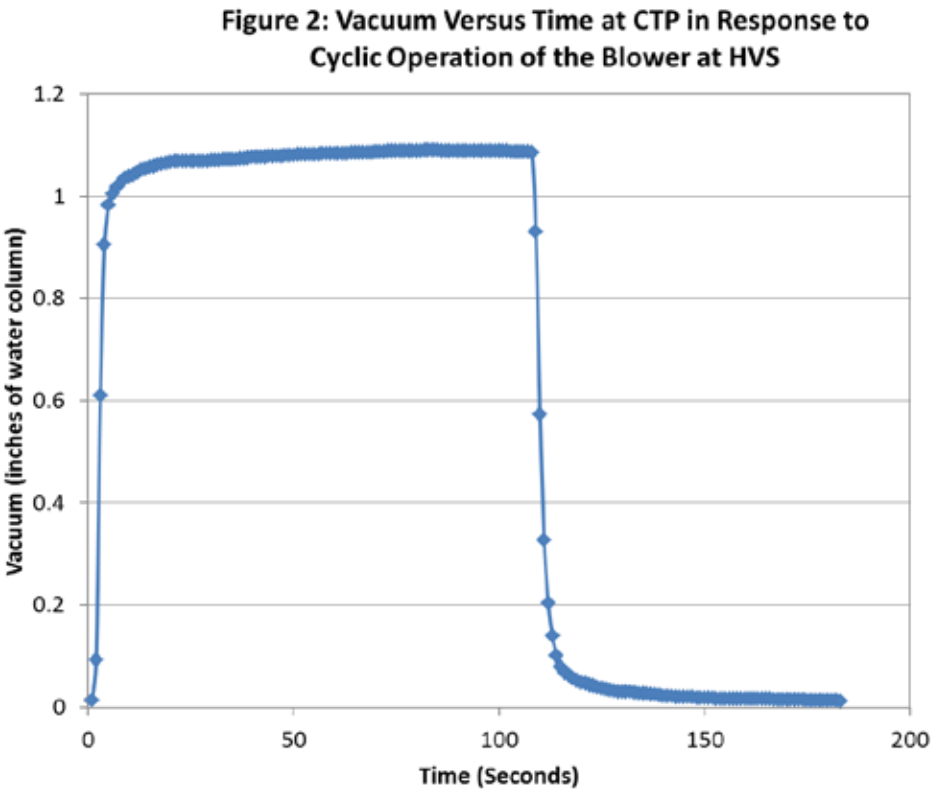
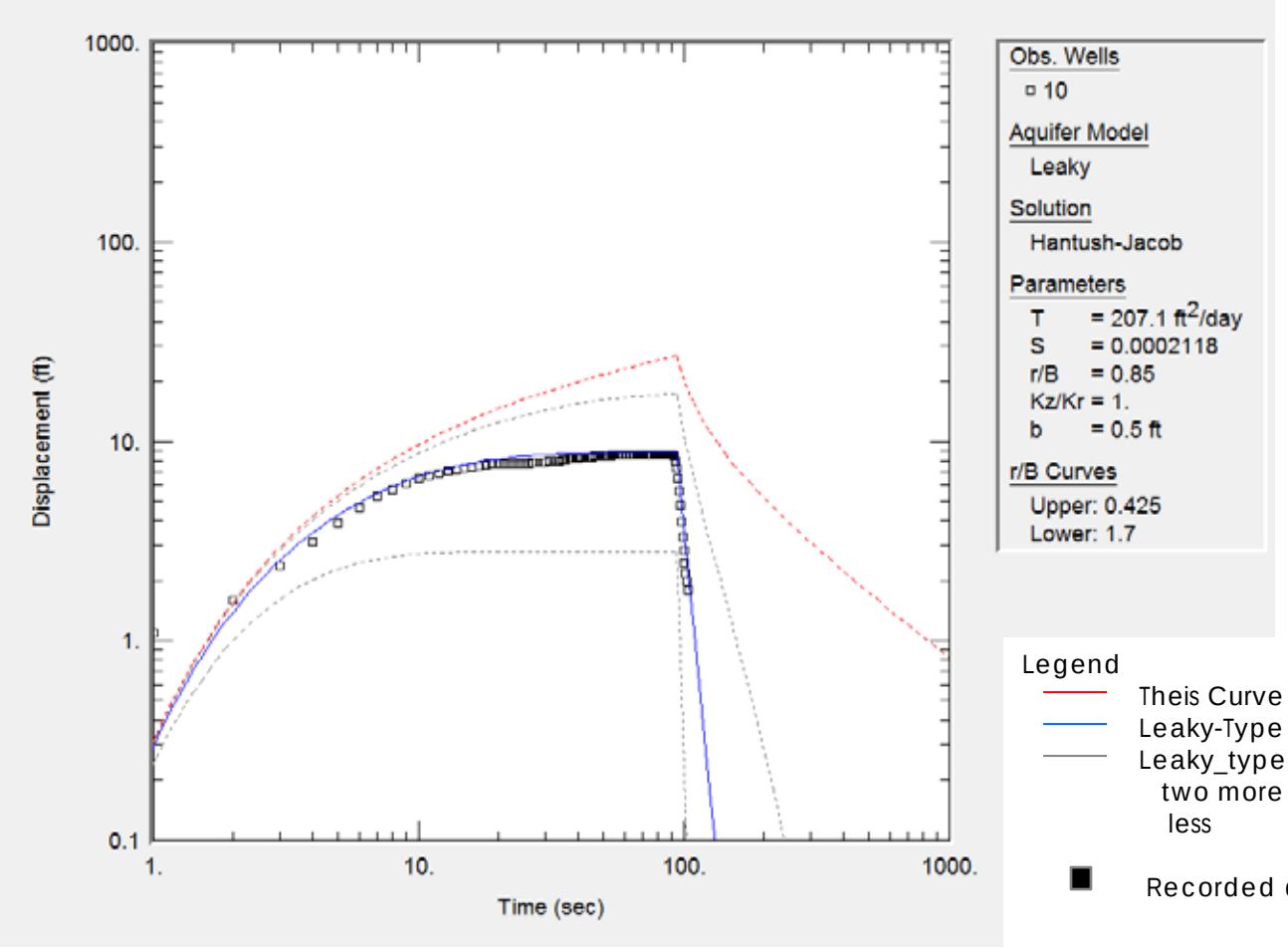
High Volume Sampling Demonstration

Communication test points are located 3, 10, and 30 feet away from the extraction point. The 10-foot location is circled in red.

Transient Data



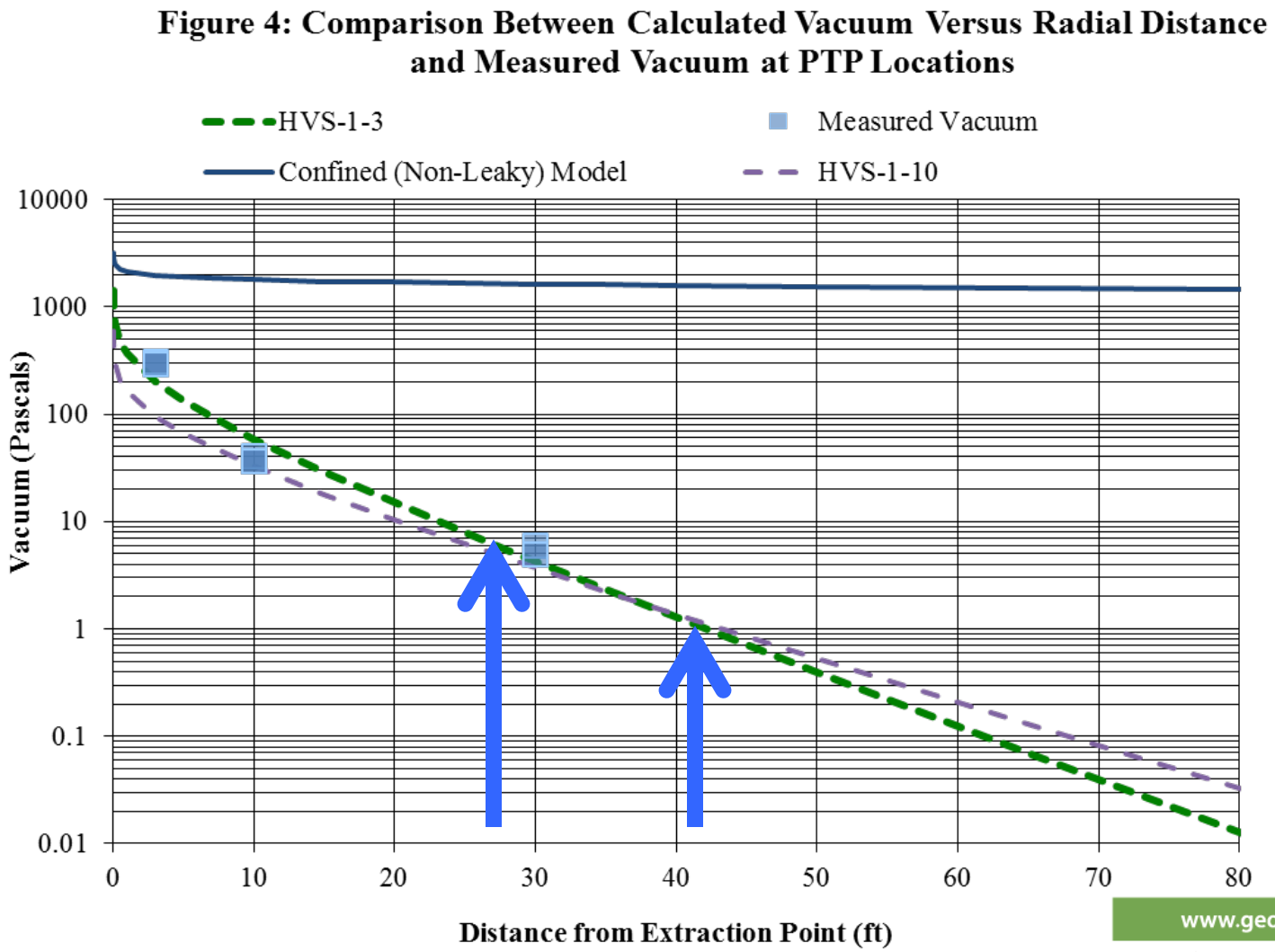
Hantush & Jacob Curve Fitting



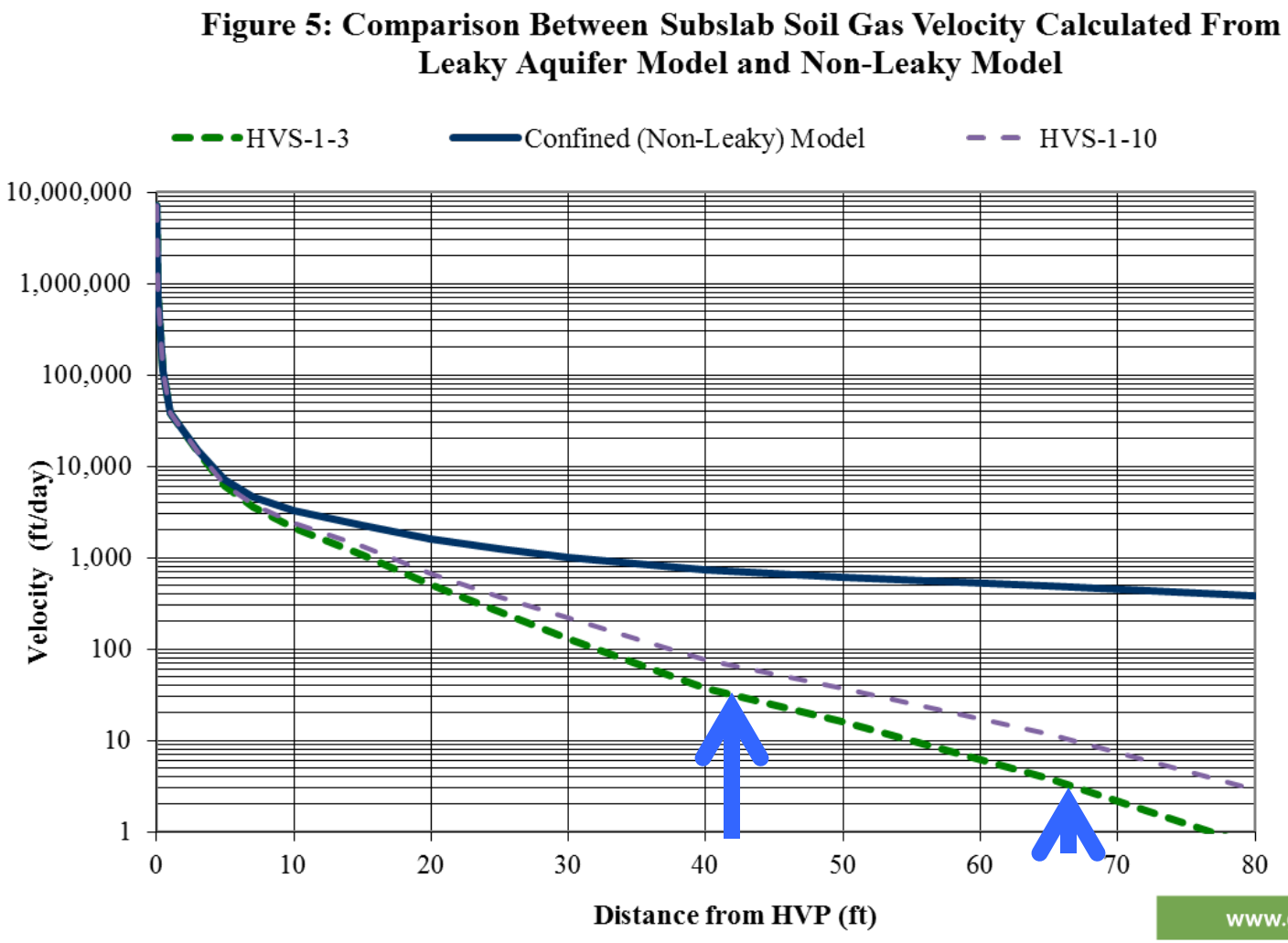
Legend

- Theis Curve (no leakage)
- Leaky-Type Curve
- Leaky_type Curve Factor of two more and factor of two less
- Recorded data

Vacuum vs. Distance

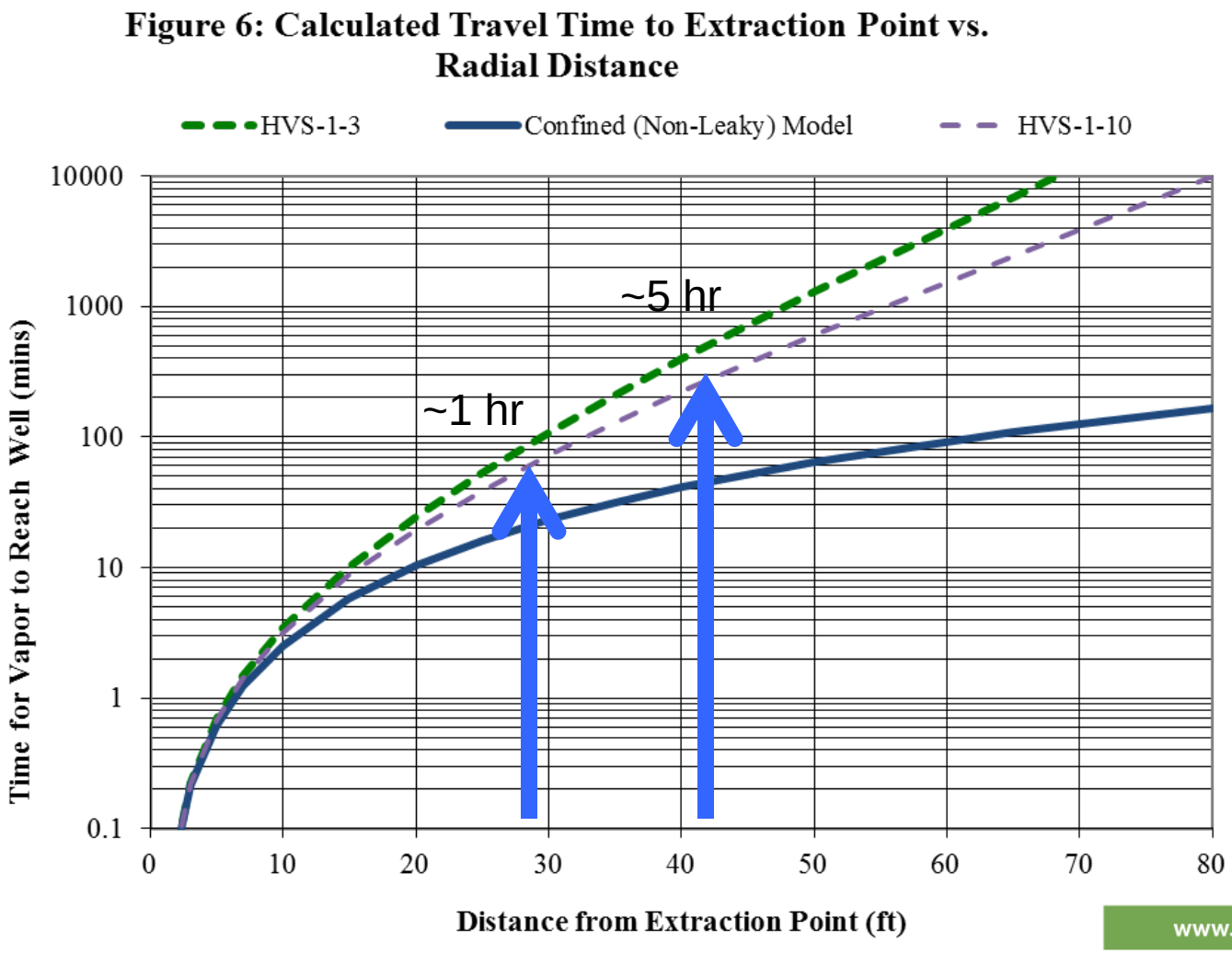


Velocity vs. Distance



Minimum effective soil gas velocity for remediation 3-30ft/d, USACOE, 2002

Travel Time vs. Radius



Transient Data Summary

- Slab has moderate leakage
- Considerable attenuation of TCE concentrations (0.003-0.0001)
- Only a portion of the building targeted
- Estimated ROI ~35 to 50 ft.
- SVE recommended for remediation

Concept of ROI

- Vacuum isn't zero just because we can't measure it.
- ROI based on Vacuum, velocity or travel time
- Consider flow-based design approach:
  - Q_{soil} is ~0.1 to 10 L/min for 100 m^2 building
  - Average radon fan draws ~3,000 L/min (overdesigned)
  - Overdesign no big deal for single family home, but costly for larger buildings

Summary

Volume-integrated samples via HVS:

- § Rapid assessment for large buildings
- § Better characterization and understanding
- § Design data for mitigation systems if needed
- § Less disruption to building occupants

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