Estimating Sub-slab Constituent Concentrations Using Riser Monitoring Data

Jessica Schaettle, PE
Project Engineer

Krystal Kyain

Sigrida Reinis, Ph.D., P.E.

- 2022 SF RWQCB updated Vapor Intrusion Mitigation Guidance
- Relies heavily on sub-slab soil gas monitoring
  - Long-term monitoring
  - Termination monitoring
- Systems without sub-slab probes?

California Water Boards

Vapor Intrusion Mitigation Guidance

Technical Resource Document

San Francisco Bay
Regional Water Quality Control Board

Table 5 – Monitoring for Ventilation VIMS (SSV, CSV Systems)

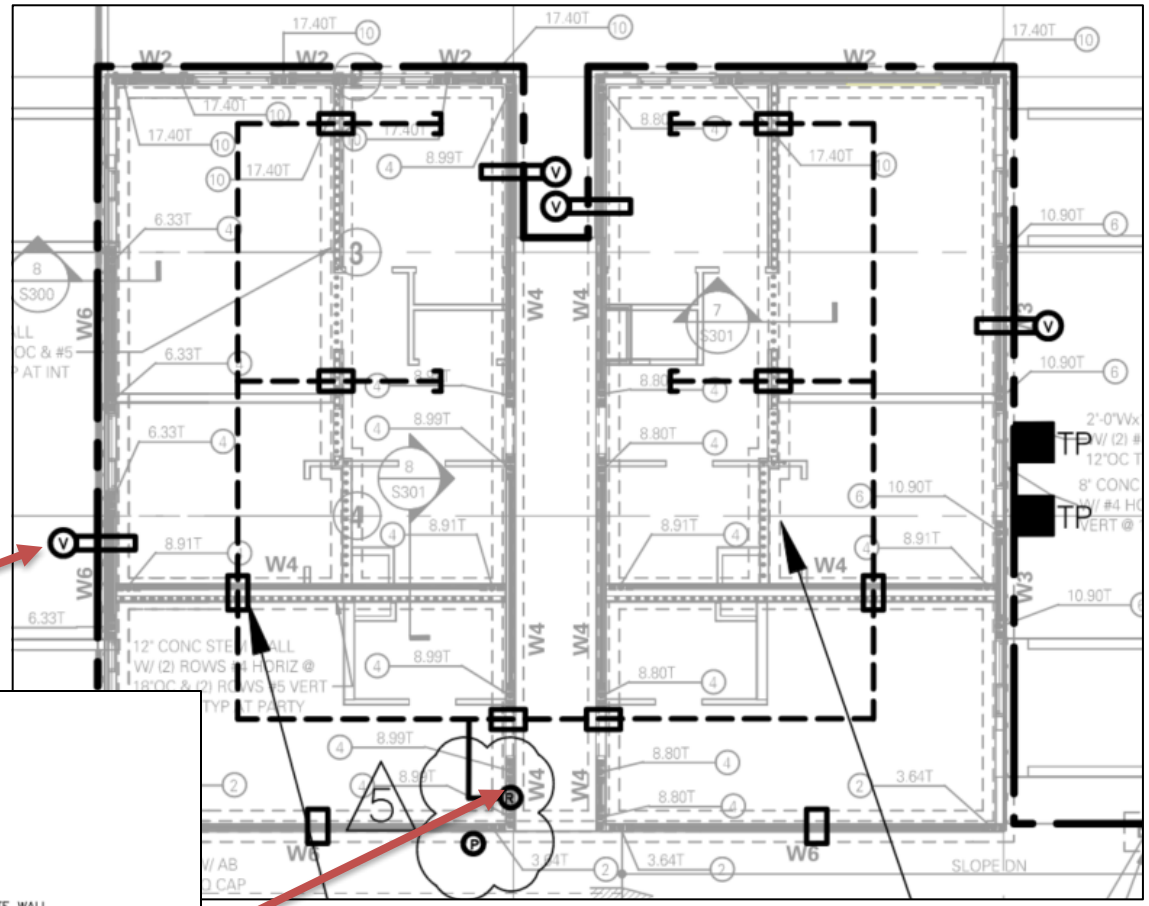
	Baseline: Year 1 Q1, Vents Capped	**Startup:** Year 1 Q1, VIMS Operational	**LTM:** Year 1 Q2	**LTM:** Year 1 Q3	**LTM:** Year 1 Q4	**LTM:** Years 2 - X, Annual WCS	**LTM:** 5 Year Reviews WCS	**Shut-Down or Decom:** Year X, Initial Season	**Shut-Down or Decom:** Year X, Opposite Season
Inspections	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pressure Differential (Subslab to Indoor Air)	◈	◈					◈	◈	◈
Outdoor Air*	✓	✓	◈	◈	◈	◈	◈	◈	◈
Vent Riser Air*	✓	✓					◈	◈	◈
Indoor Air*	✓	✓					◈	◈	◈
Subslab Soil Gas or Crawl Space Air*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Near-Source Soil Gas*	✓		○	✓	○	○	○	○	○
First Groundwater*	✓		○	✓	○	○	○	○	○

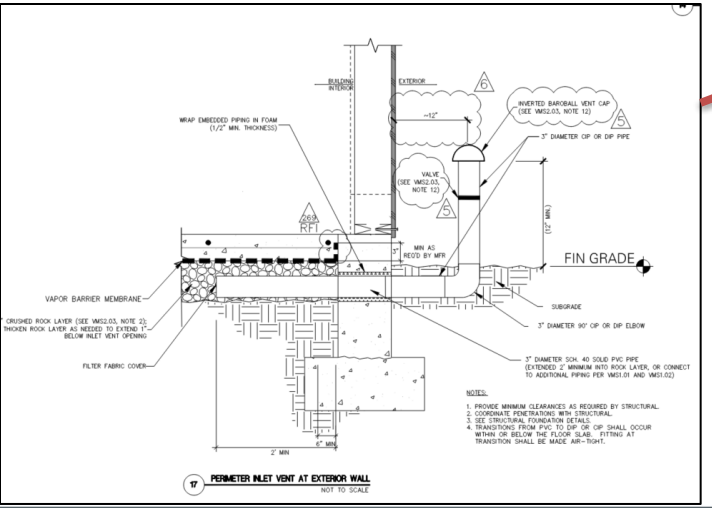
✓ = Include in monitoring plan

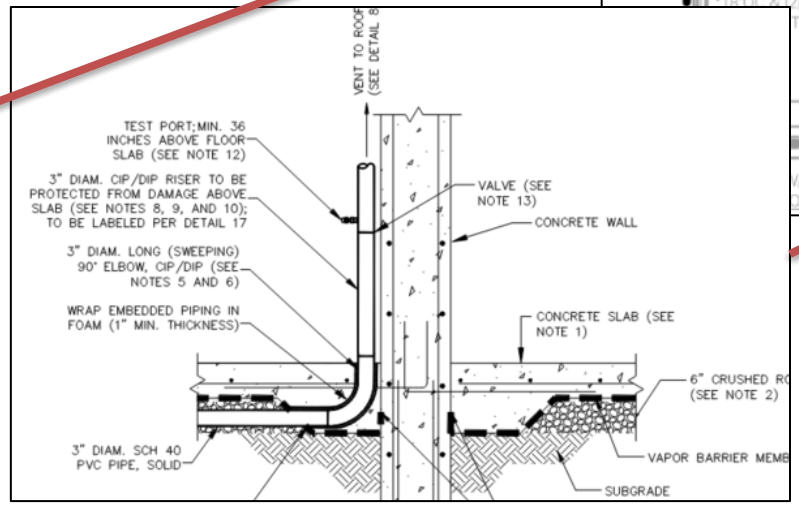
Question

- How can we terminate long-term monitoring without sub-slab ports?
  - Install through finished slab/membrane = $, time, damage
  - But – have accessible riser test ports
    - Is there a strong correlation?

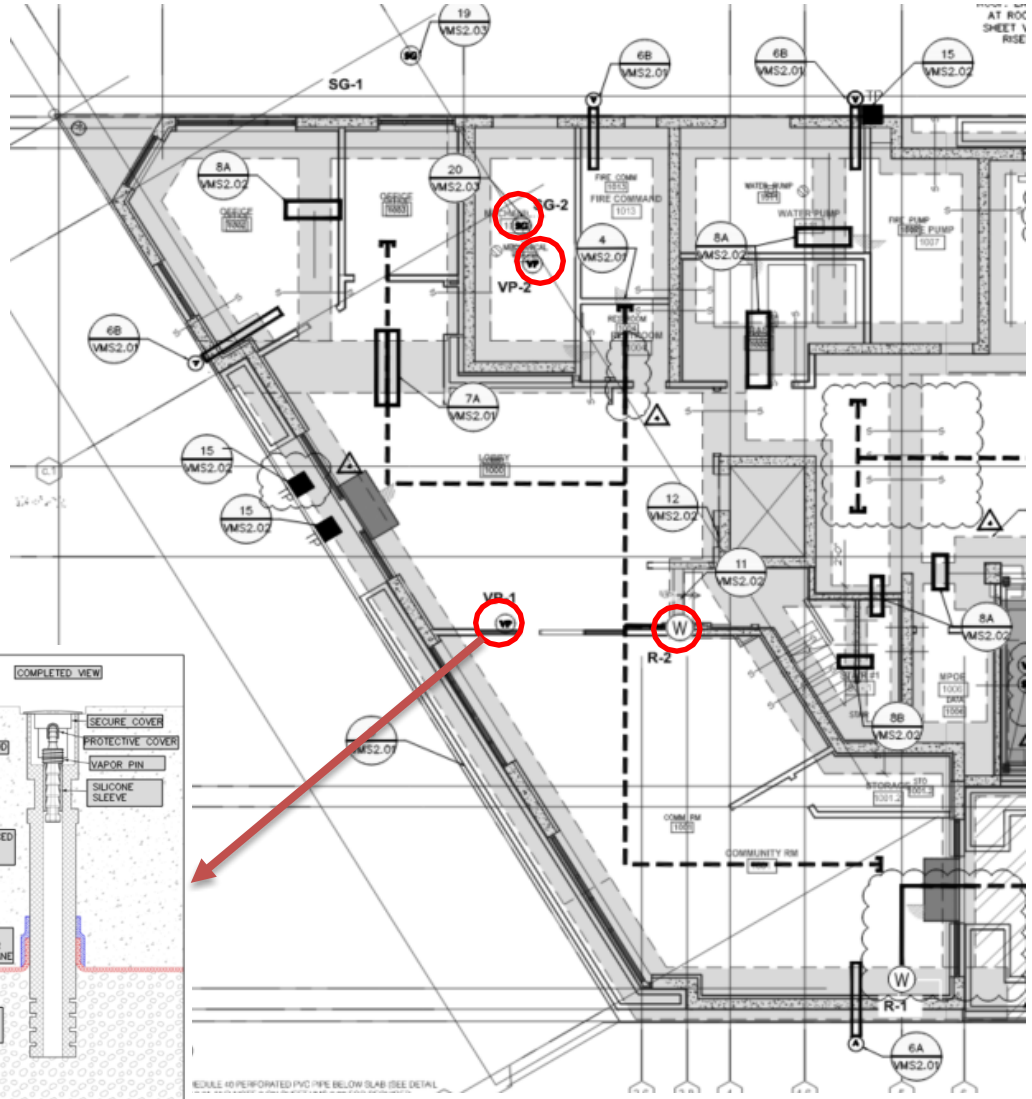
- Typical <u>passive</u> VMS
  - Sub-slab membrane
  - Lateral vent piping
  - Fresh air inlets
  - Exhaust risers with test ports and wind-assisted turbines







- Updated our typical VMS to follow 2022 regulatory guidance
  - Added sub-slab sampling ports as standard
  - Maintained riser test ports
- Continue to include both in monitoring program

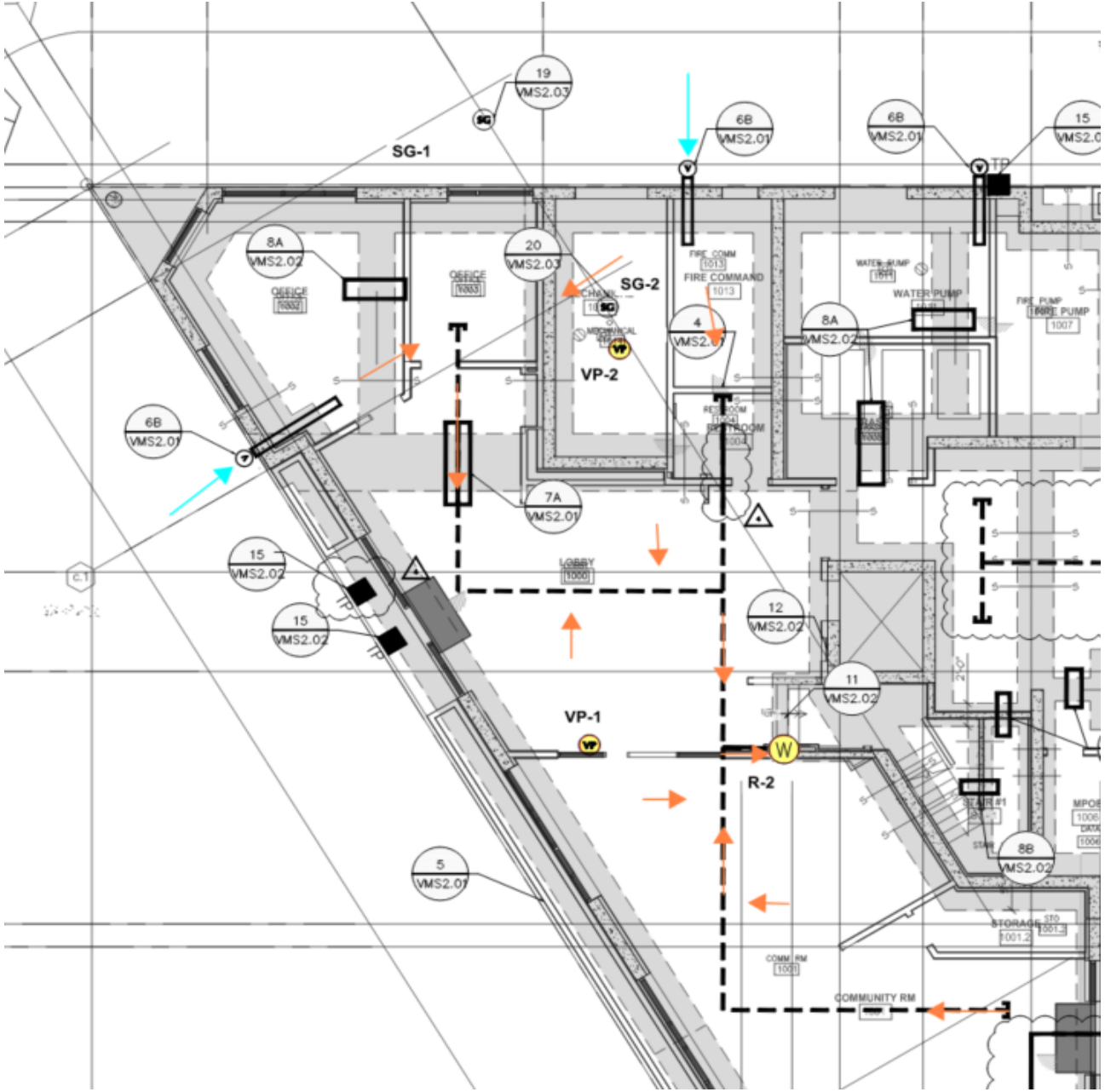


Approach – Data Compilation

- Compile riser and sub-slab data (mini database)
  - Same event and location for paired data
    - 108 paired data points
  - Different systems, different layouts, with and w/out inlet vents
  - Compare average sub-slab and average riser concentrations
  - 8 projects (SF Bay), 17 sampling events
    - Add as available

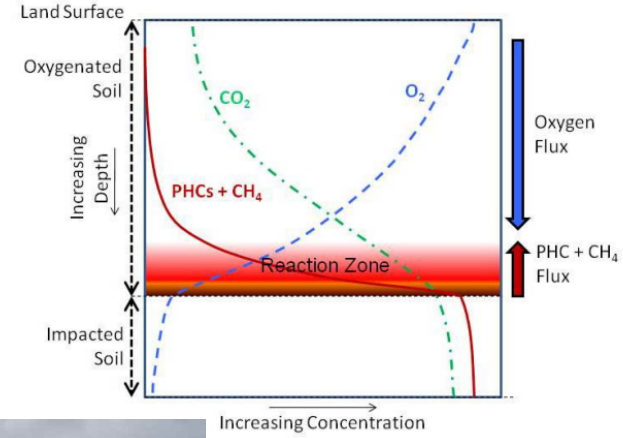
Approach - Goals

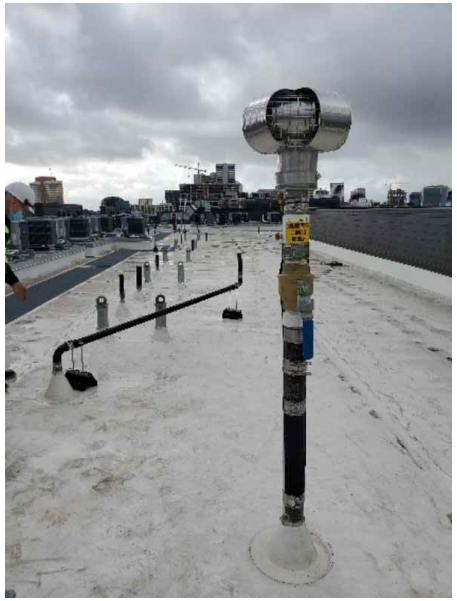
- Determine relationship between sub-slab and riser concentrations
- Driving parameters?
- Can we extrapolate to other sites?



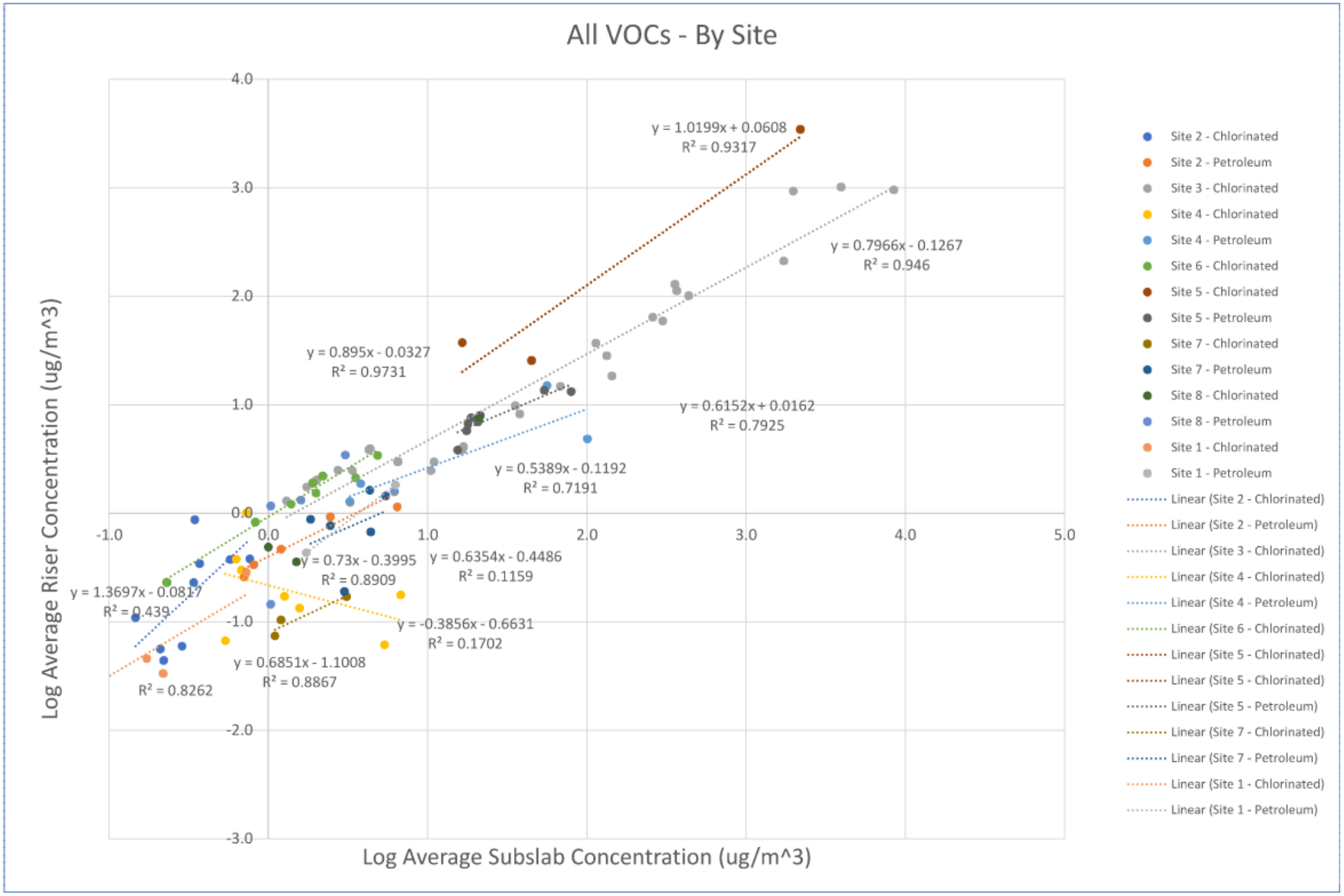
Parameters Evaluated

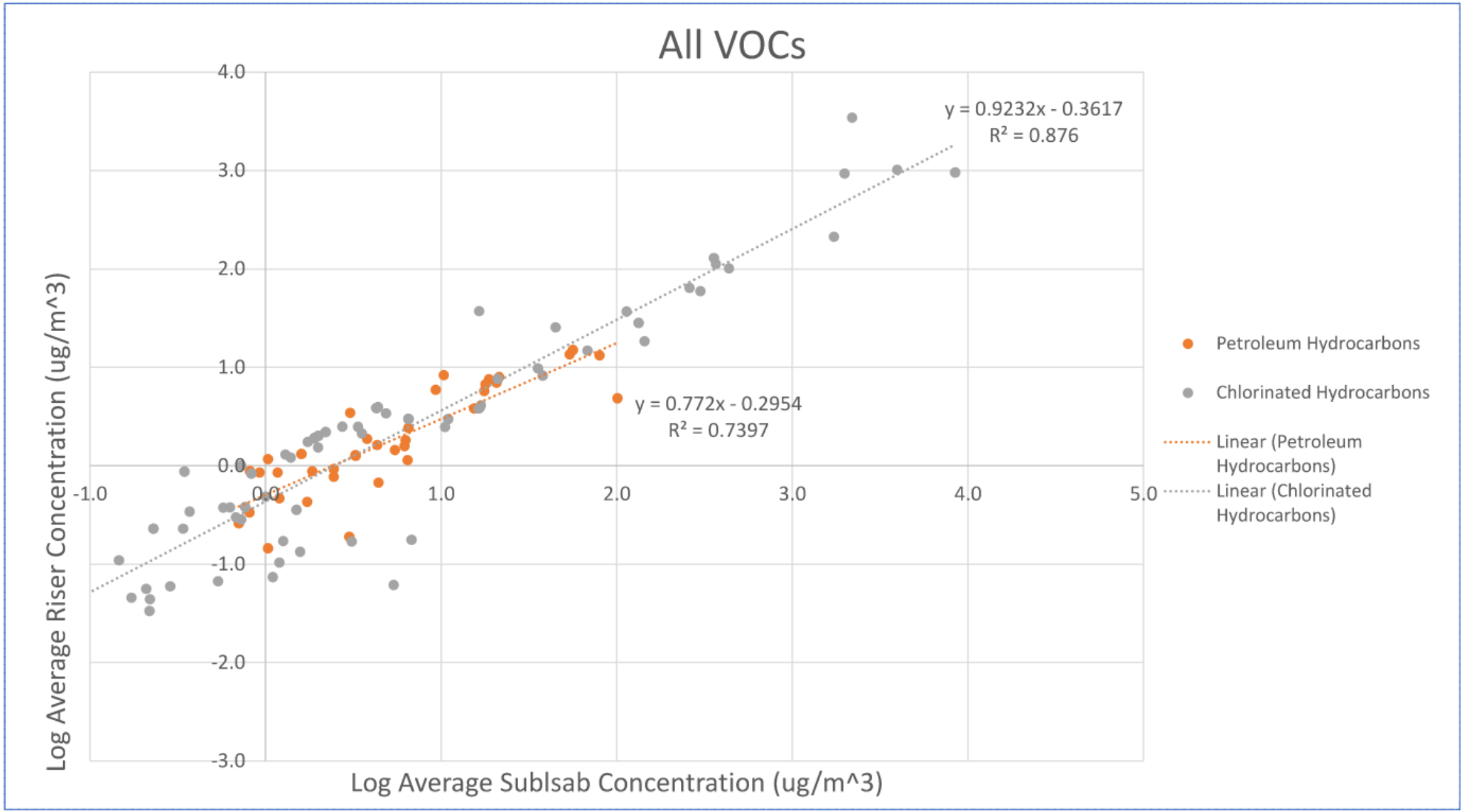
- Chlorinated hydrocarbons vs. petroleum hydrocarbons
- Passive air flow / # of air exchanges
- Location of riser test ports
- # of perimeter inlet vents per riser
- Length of piping / area vented

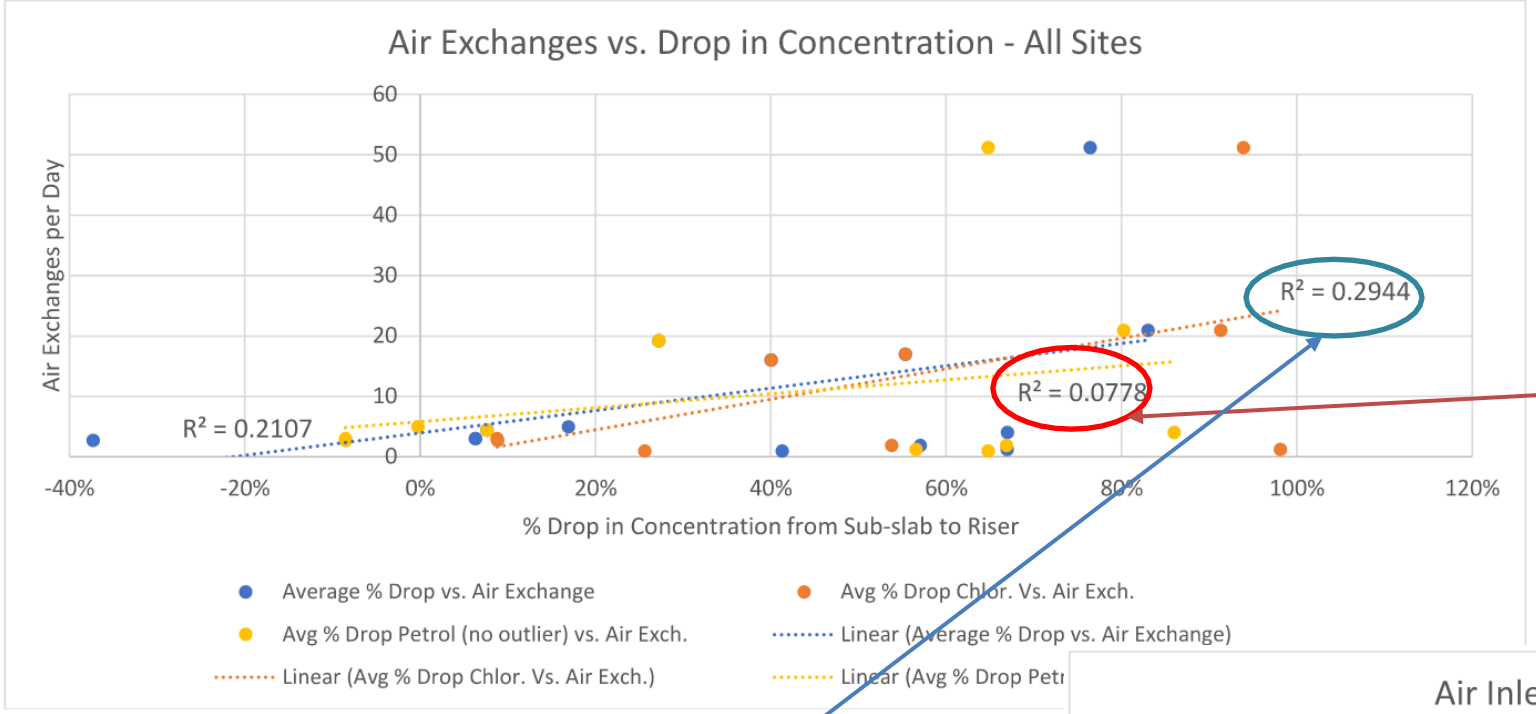




Site	Date	Average % Drop	Average % Drop - CHC	Average % Drop - PHC	Air Exchanges per Day	# Air Inlets per Riser	Pipe Length	Area per Riser
1	3/5/2024	66%	64%	73%	--	2.00	206	8667
2	1/7/2021	41%	26%	65%	0.92	2.50	104	7600
3	7/1/2014	55%	55%	--	17	0.89	47	1789
3	3/1/2017	40%	40%	--	16	0.89	47	1789
3	2/1/2022	46%	46%	--	--	0.89	47	1789
3	7/1/2022	79%	79%	--	--	0.89	47	1789
4	12/20/2020	67%	98%	57%	1.2	3.50	75	4350
4	1/20/2021	57%	54%	67%	1.84	3.50	75	4350
5	8/10/2023	37%	-47%	69%	4.96	0.00	113	6700
6	7/3/2023	6%	9%	-9%	2.96	1.67	276	8900
6	7/6/2023	-37%	9%	-9%	2.67	1.67	276	8900
7	6/20/2023	76%	94%	65%	51.2	3.50	126	3500
7	7/11/2023	83%	91%	80%	20.9	3.50	126	3500
7	4/25/2024	27%	--	27%	19.2	3.50	126	3500
8	5/24/2023	67%	57%	86%	4.02	4.00	166	6000
8	4/26/2023	17%	76%	0%	4.94	4.00	166	6000
8	4/25/2024	8%	--	8%	4.39	4.00	166	6000
	Average	43%	50%	45%				

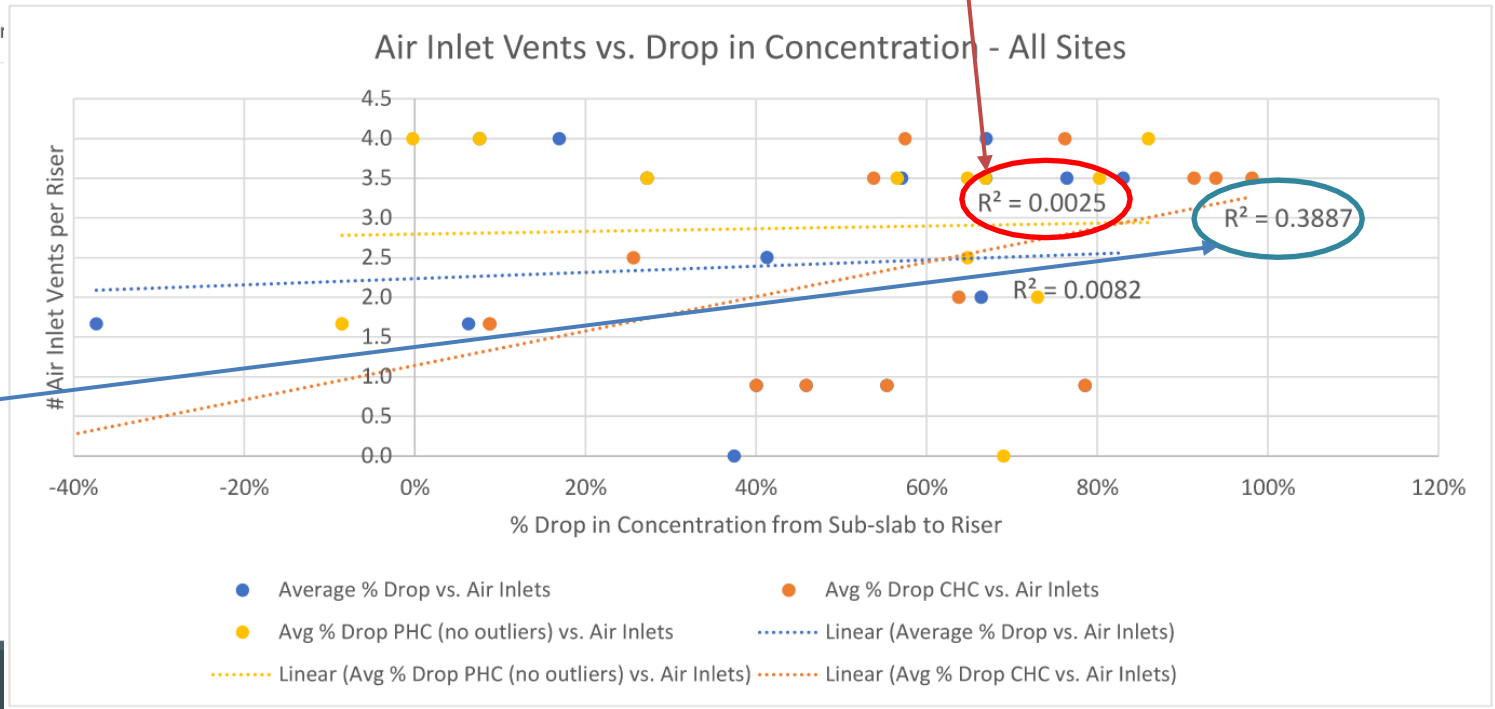

All VOCs - By Site
Log Average Riser Concentration (ug/m^3)
Log Average Subslab Concentration (ug/m^3)
y = 1.0199x + 0.0608
R² = 0.9317
y = 0.7966x - 0.1267
R² = 0.946
y = 0.895x - 0.0327
R² = 0.9731
y = 0.6152x + 0.0162
R² = 0.7925
y = 0.5389x - 0.1192
R² = 0.7191
y = 0.73x - 0.3995
R² = 0.8909
y = 0.6354x - 0.4486
R² = 0.1159
y = 1.3697x - 0.0817
R² = 0.439
y = -0.3856x - 0.6631
R² = 0.1702
y = 0.6851x - 1.1008
R² = 0.8867
R² = 0.8262
Site 2 - Chlorinated
Site 2 - Petroleum
Site 3 - Chlorinated
Site 4 - Chlorinated
Site 4 - Petroleum
Site 6 - Chlorinated
Site 5 - Chlorinated
Site 5 - Petroleum
Site 7 - Chlorinated
Site 7 - Petroleum
Site 8 - Chlorinated
Site 8 - Petroleum
Site 1 - Chlorinated
Site 1 - Petroleum
Linear (Site 2 - Chlorinated)
Linear (Site 2 - Petroleum)
Linear (Site 3 - Chlorinated)
Linear (Site 4 - Chlorinated)
Linear (Site 4 - Petroleum)
Linear (Site 6 - Chlorinated)
Linear (Site 5 - Chlorinated)
Linear (Site 5 - Chlorinated)
Linear (Site 5 - Petroleum)
Linear (Site 7 - Chlorinated)
Linear (Site 7 - Petroleum)
Linear (Site 1 - Chlorinated)
Linear (Site 1 - Petroleum)


All VOCs
y = 0.9232x - 0.3617
R² = 0.876
y = 0.772x - 0.2954
R² = 0.7397
Petroleum Hydrocarbons
Chlorinated Hydrocarbons
Linear (Petroleum Hydrocarbons)
Linear (Chlorinated Hydrocarbons)
Log Average Riser Concentration (ug/m^3)
Log Average Sublsab Concentration (ug/m^3)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

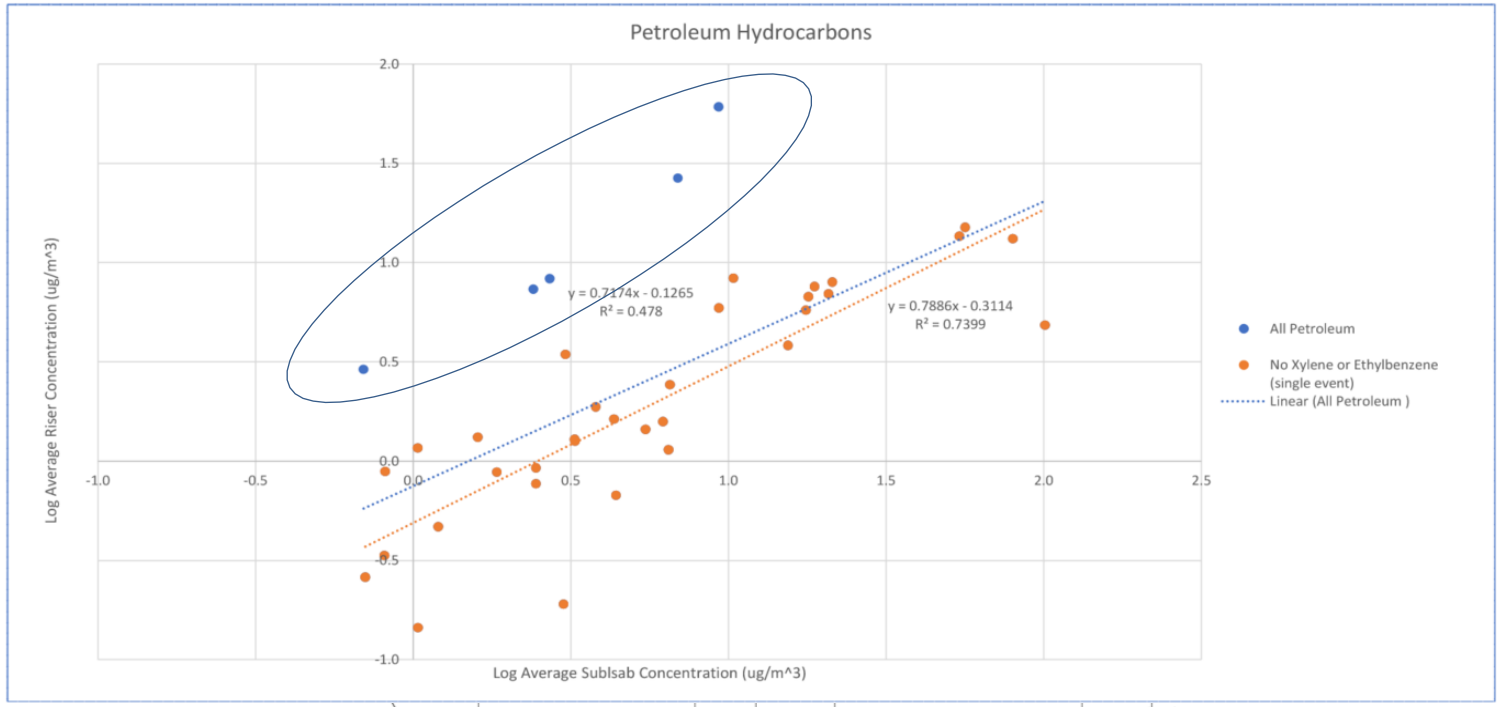


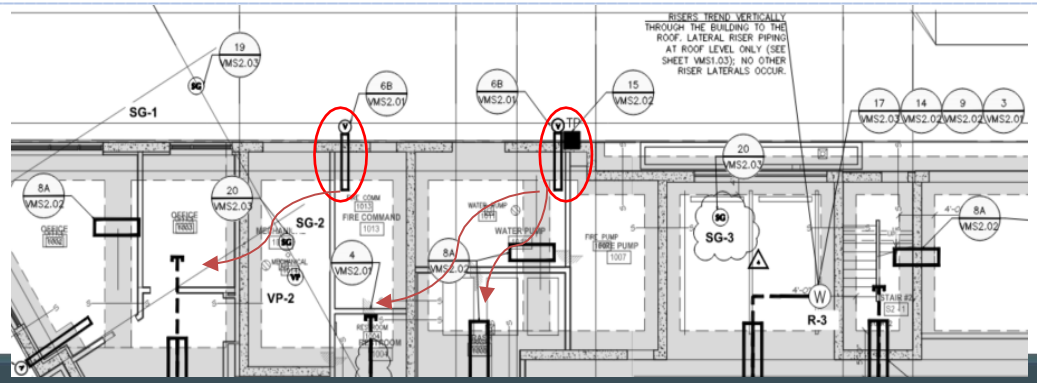
PHCs – no correlation

CHCs – possibly low correlation

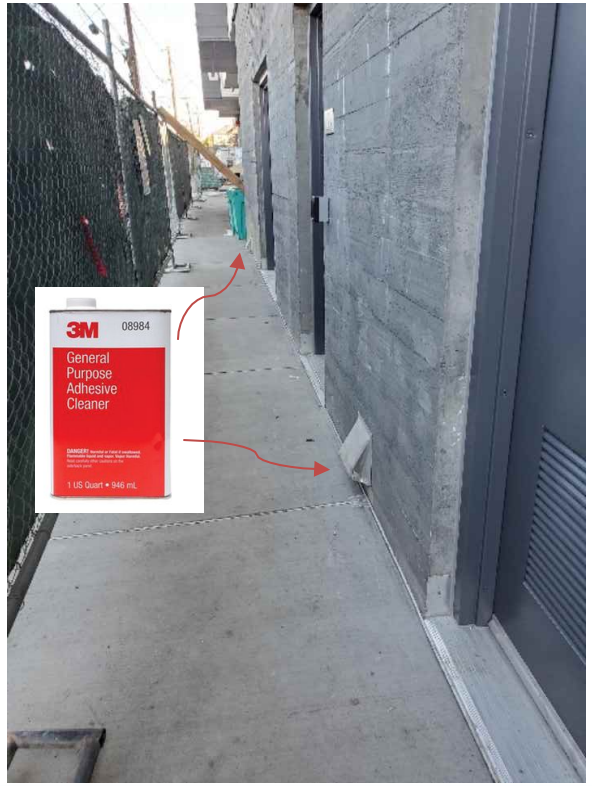


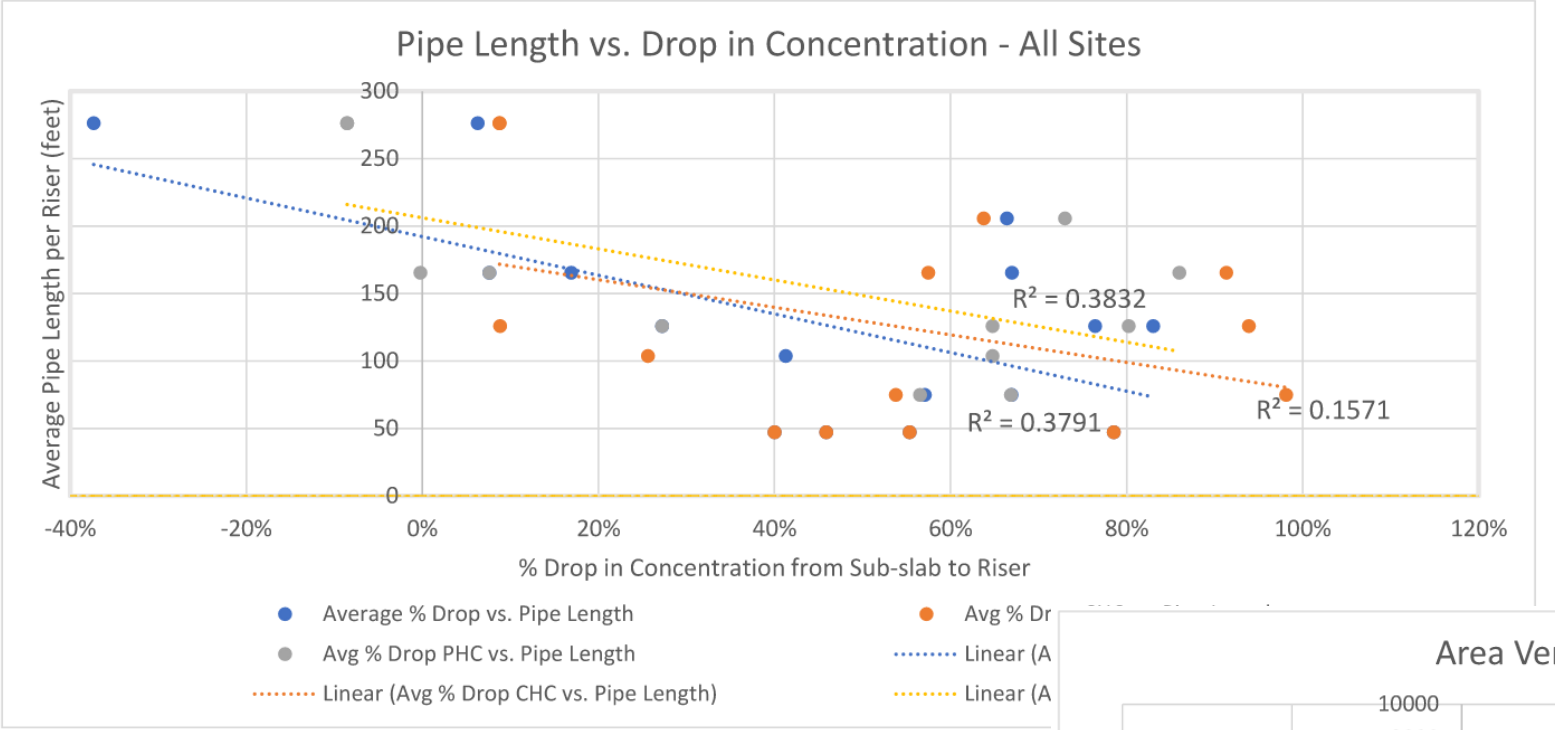
Sidebar – Ambient Air





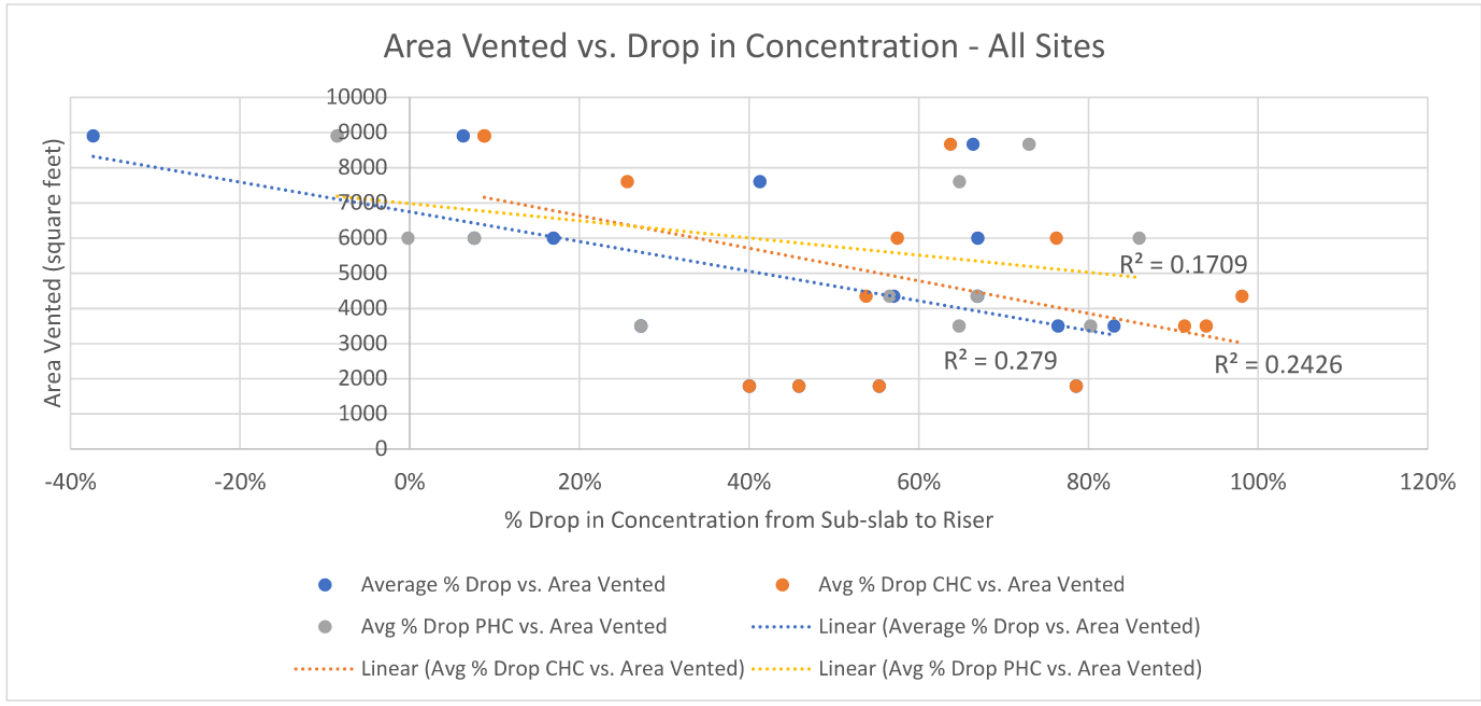
- Outliers during a single sampling event driving down correlation
  - What happened?





- As pipe length decreases, % drop increases

- As area vented decreases, % drop increases
- Result of increased mixing, fewer potential “dead zones”



Results – Empirical Equation

- Used multiple variable linear regression to identify significant variables
  - X Variable 1 = log (riser concentration)
  - X Variable 2 = air inlet vents per riser
  - X Variable 3 = area vented per riser

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.955052242
R Square	0.912124786
Adjusted R Square	0.908247938
Standard Error	0.358712745
Observations	72

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.473730893	0.136880526	3.460907907	0.000934642
X Variable 1	0.963101003	0.054976049	17.51855619	6.58218E-27
X Variable 2	0.187483969	0.05332107	3.516132905	0.000784628
X Variable 3	-7.90234E-05	1.75922E-05	-4.491954039	2.809E-05

Results - Estimation

- Use multiple linear regression equation to estimate sub-slab concentrations from riser data

$$\log(sub\text{-}slab) = \beta_0 + \beta_1 * \log(riser\ concentration) + \beta_2 * (air\ inlets\ per\ riser) + \beta_3 * (ar$$

- Current equations slightly overestimate on average => conservative

# of overestimates	Avg. RPD
65	62%
# underestimates	Avg RPD
51	55%

Future Questions

- Do equations hold for larger range of concentrations?
  - Current range 0.15 µg/m^3 to 8500 µg/m^3
- Do relationships hold for “atypical” VI compounds?
  - SVOCs, mercury vapor, etc.
- Does distance from sub-slab sampling point to risers (or vent piping) affect results?
- Data set is continually expanding, so we hope to provide future updates!

Questions

Jessica Schaettle, PE

Project Engineer

jschaettle@langan.com