



**EPA Vapor Intrusion Workshop**  
***Measurement-Based Methods for Protective &  
Defensible Chlorinated VI Exposure Determinations***

Wheeler and SEND Buildings In Indianapolis – Radon and Differential  
Pressure Data in VOC Site Management  
IECC Climate Zone 5A

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# Site History

- An industrial facility from 1911 until 1995.
- Since SEND purchased the property in 1998 they have completed renovations, converting first and second floors into 36 live-work lofts for low-income artists, galleries, office space and a theater.
- Various environmental assessments as well as the removal of six petroleum product USTs between 1998 and 2006.
- Primary contaminants TCE and PCE
- TCE concentrations in groundwater Dec. 2005, depths typically between 25-30 ft (bls):
  - 10.2  $\mu\text{g/L}$  directly upgradient (north) of Zone A
  - 24.1  $\mu\text{g/L}$  along the west edge of Zone A
  - $< 5 \mu\text{g/L}$  in four wells in Zone C and along the east edge of the building
  - Between 34 and 200  $\mu\text{g/L}$  in a group of ten wells located downgradient (south) from Zone C.



# Building Background – Wheeler Arts Building

- 100,000 sq ft
- Mix of slab-on-grade and basement construction, build in stages
- Contains more than 40 separate heating, ventilation and air conditioning (HVAC) zones and at least three major areas with different building envelopes.
- The Wheeler Arts Building has three main basement zones for this analysis:
  - A Northern, essentially unoccupied basement (17,250 sq ft) with two overlying occupied stories
  - B Central, essentially unoccupied basement (9,180 sq ft) with two overlying occupied stories
  - C Southern, slab-on-grade single story, used primarily for storage (7,790 sq ft).



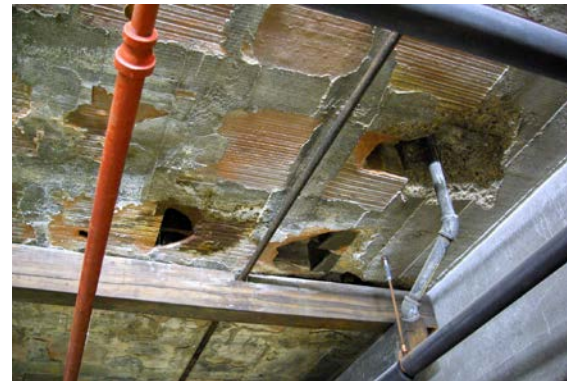
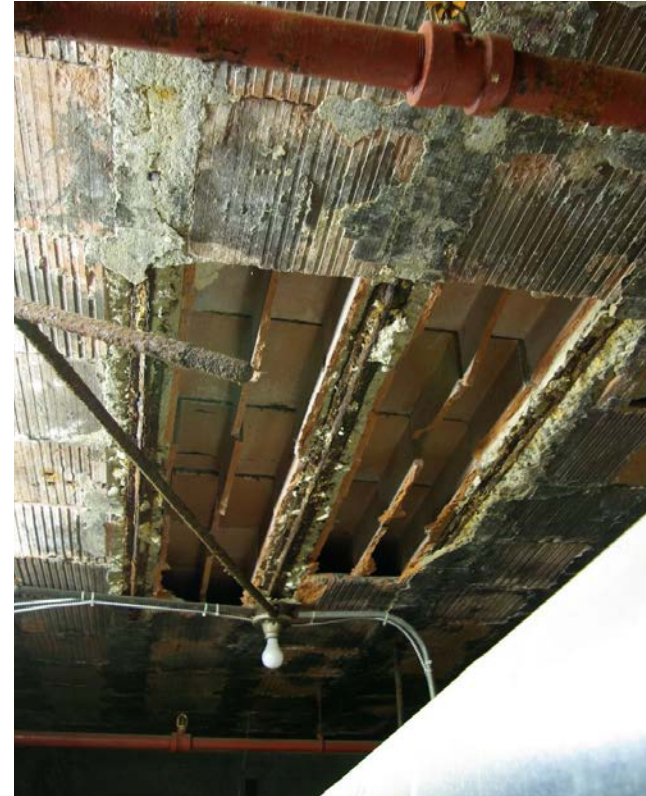
Wheeler Building Exterior



Wheeler Renovated  
First Floor Common  
Area



Hollow Tile  
Construction in  
Wheeler  
Basement Ceiling  
Provides Complex  
Flow Paths



Gaps in Wheeler  
Basement Ceiling

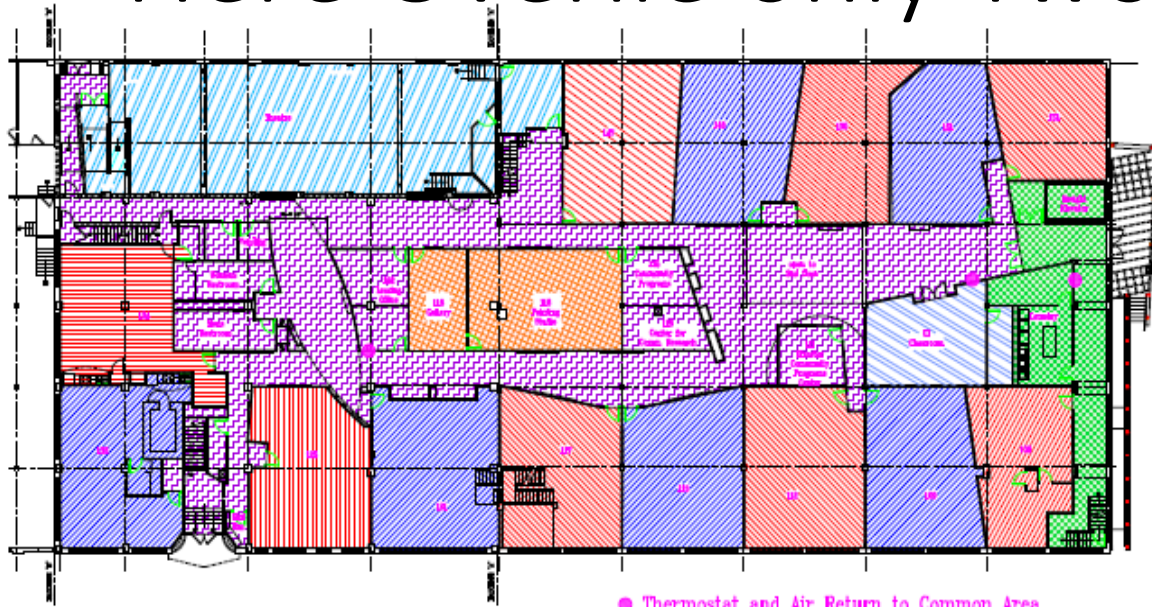


Send Office Building Exterior





# Complex HVAC Zones – Upper Floors Shown Here Overlie only Two Basement Zones

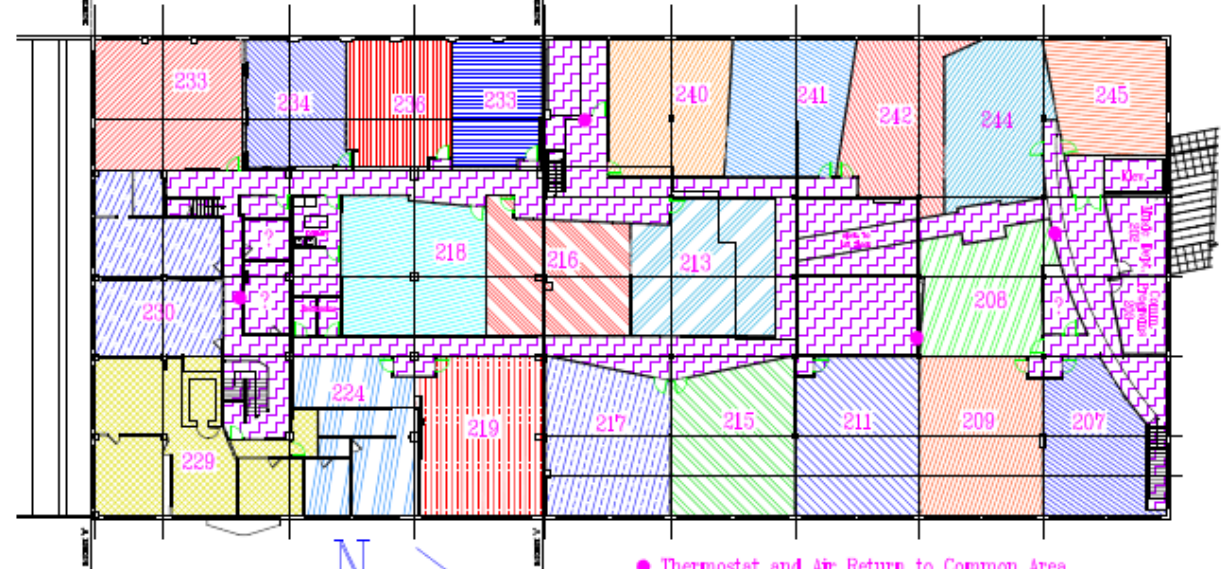


● Thermostat and Air Return to Common Area



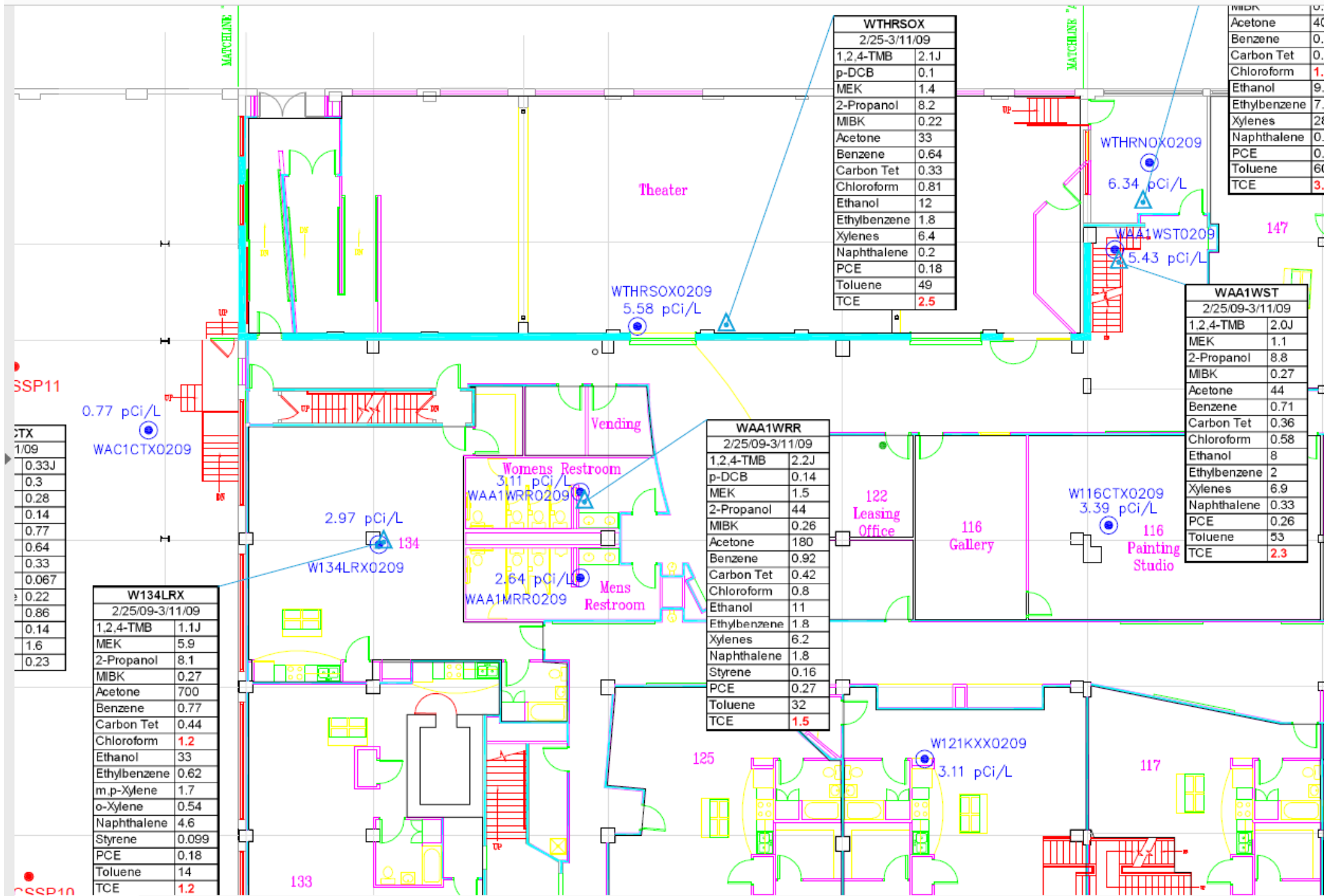
19 First Floor HVAC Zones

25 Second Floor HVAC Zones



● Thermostat and Air Return to Common Area





Radon Used to Spatially Map Soil Gas Influence in Complex Buildings

- Zoomed in Portion of First Floor Shown

- 50 total electret radon screening locations (2 day)

- Two week VOCs sampled at 8 basement, 11 first and 2 second floor locations in Wheeler

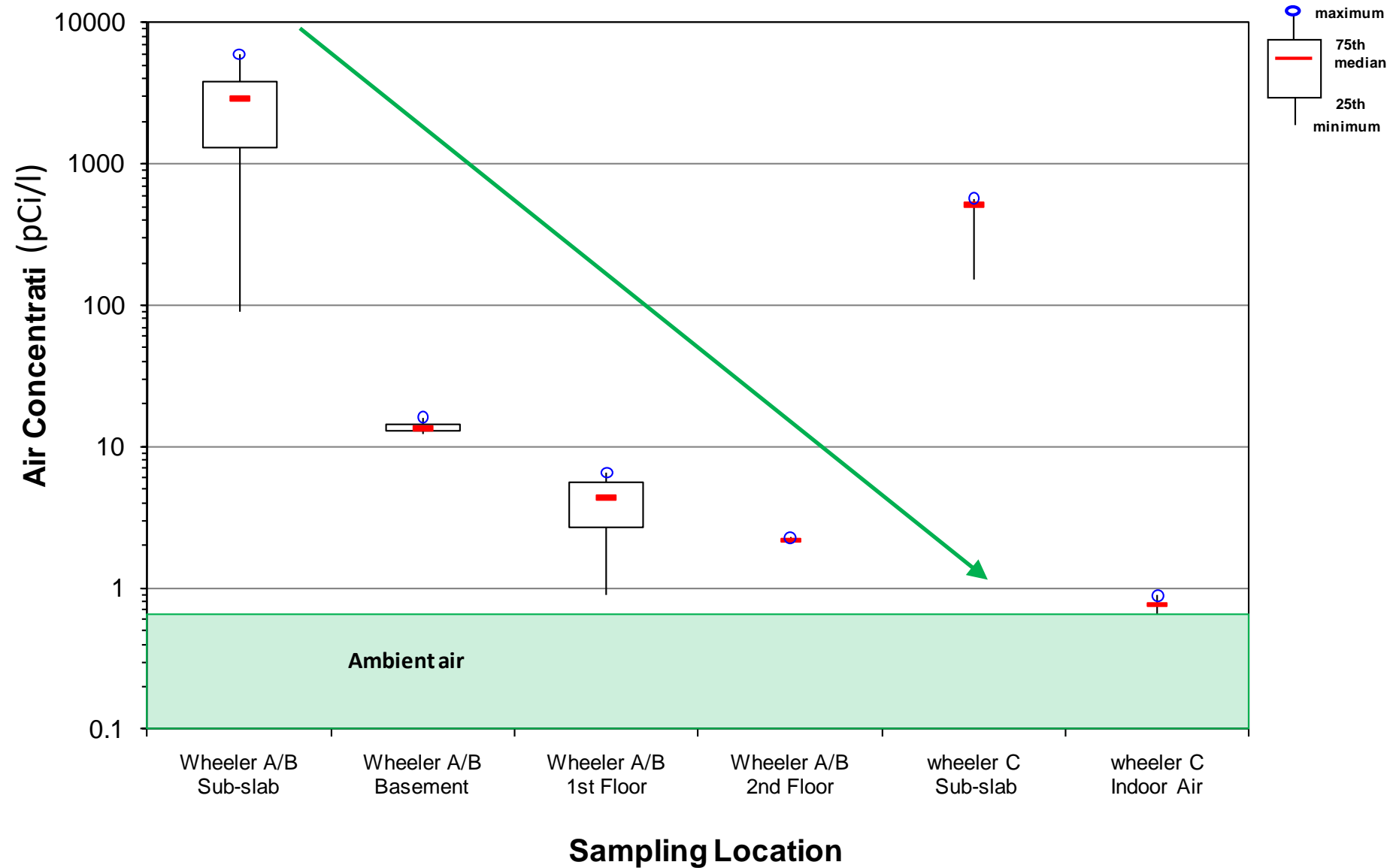


# Building Background – SEND Office Building

- 1,300 square-foot slab-on-grade SEND office building (the former powerhouse for the industrial facility).

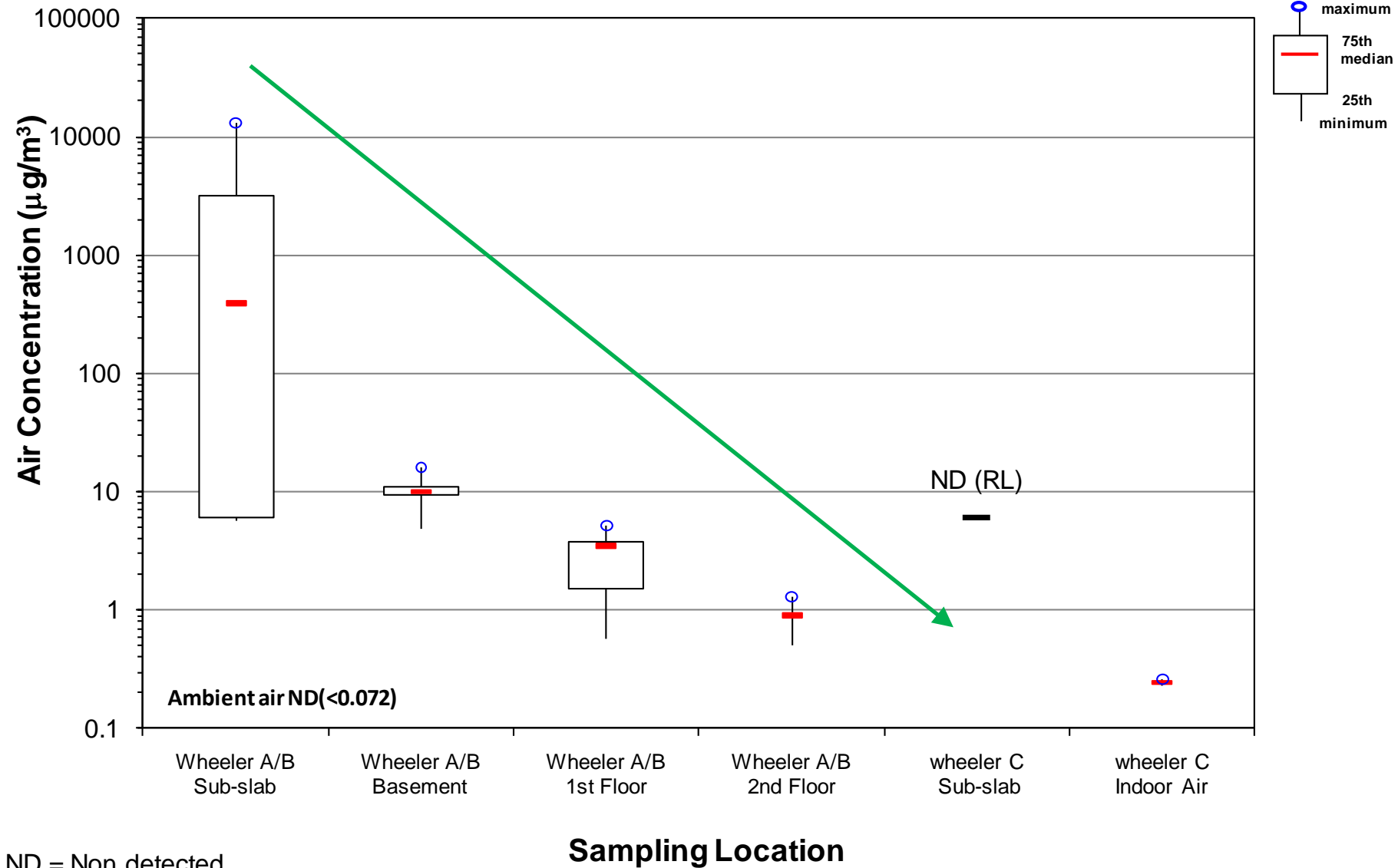


# Radon Distribution Among Floors – Suggests VI



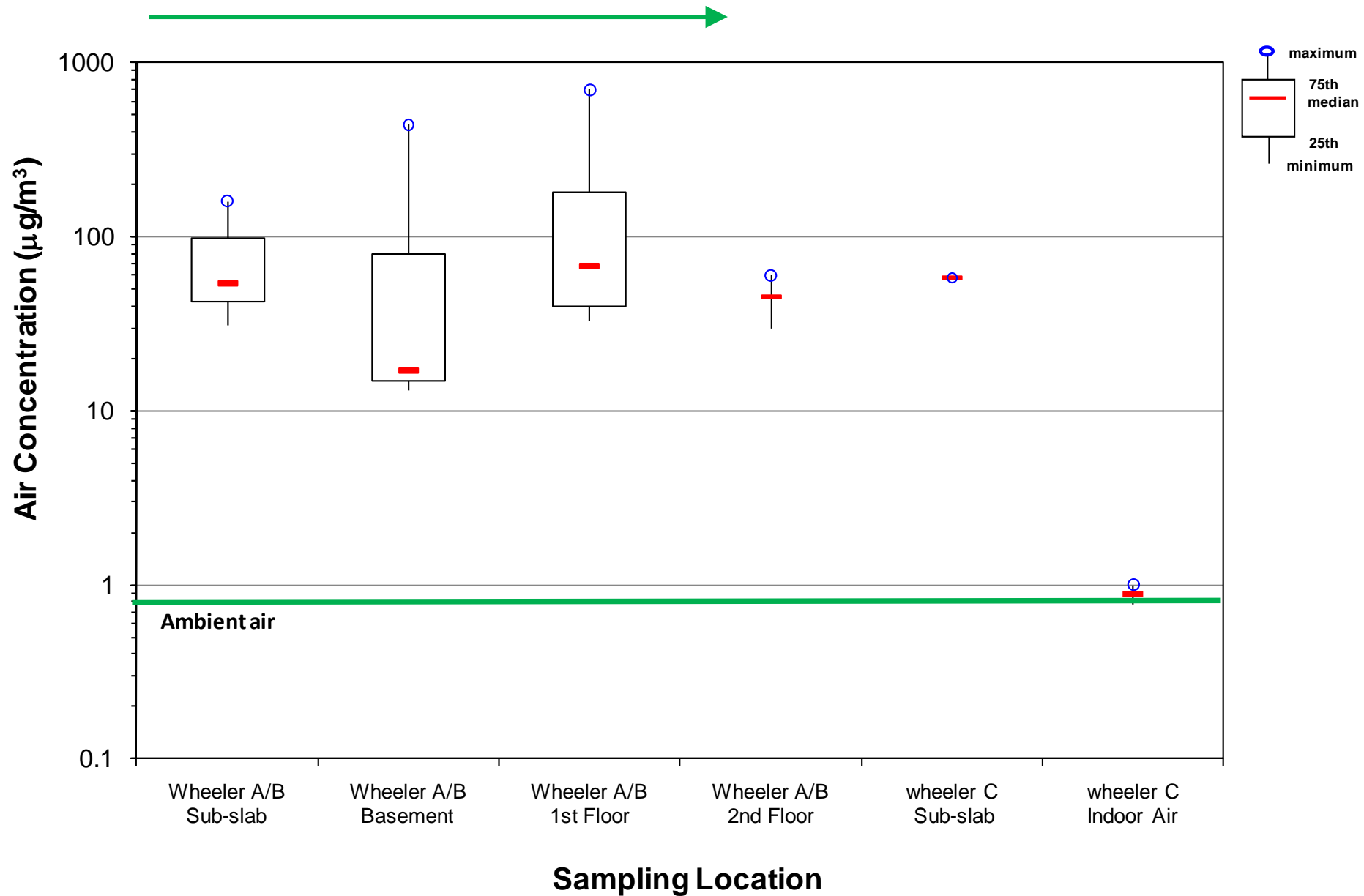


# TCE Concentration Among Floors – Suggests VI

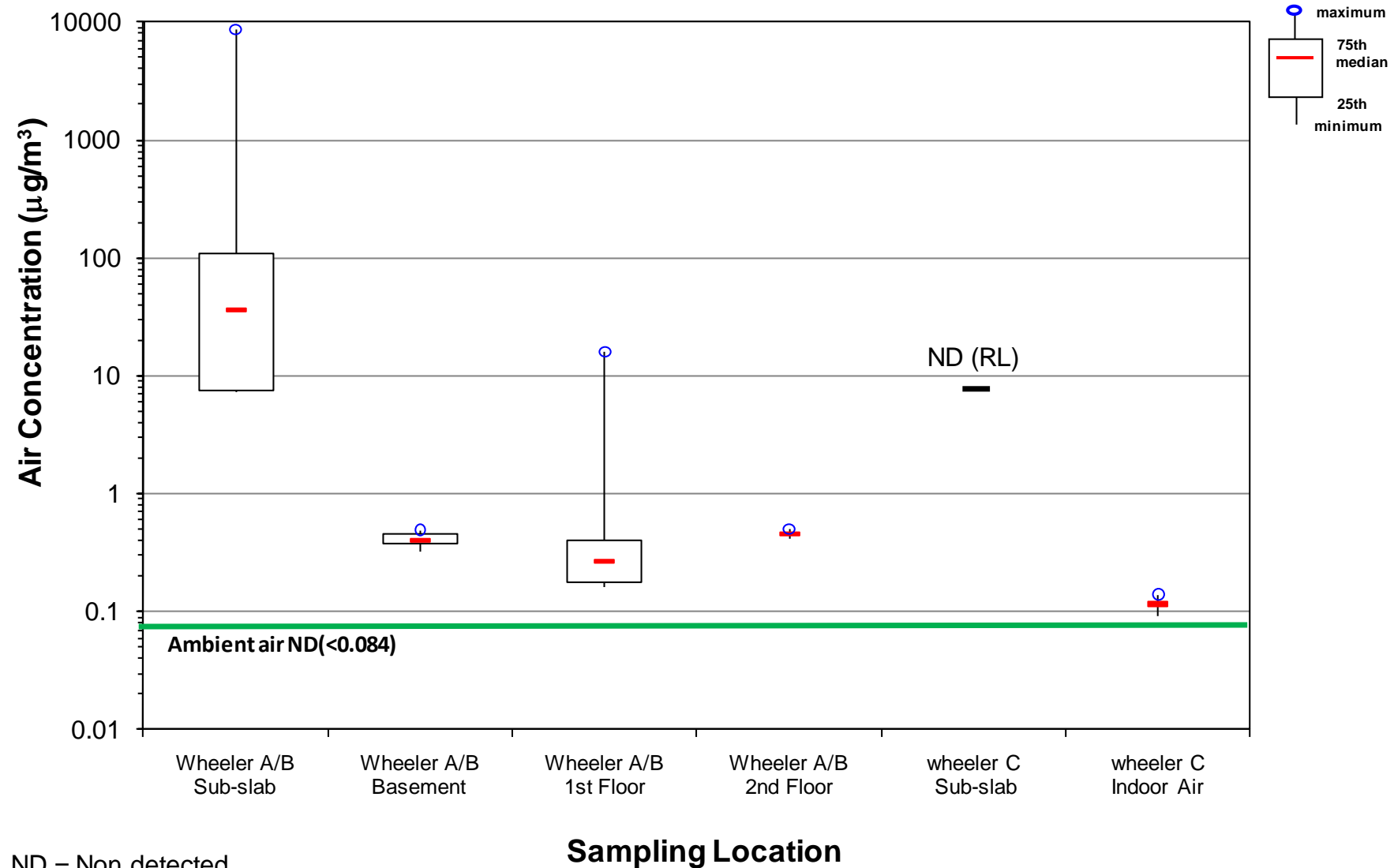


ND = Non detected  
RL = Reporting limit

# Acetone Distribution Among Floors – Suggests Indoor Source



# PCE Distribution Among Floors – Suggests VI Plus Indoor Source

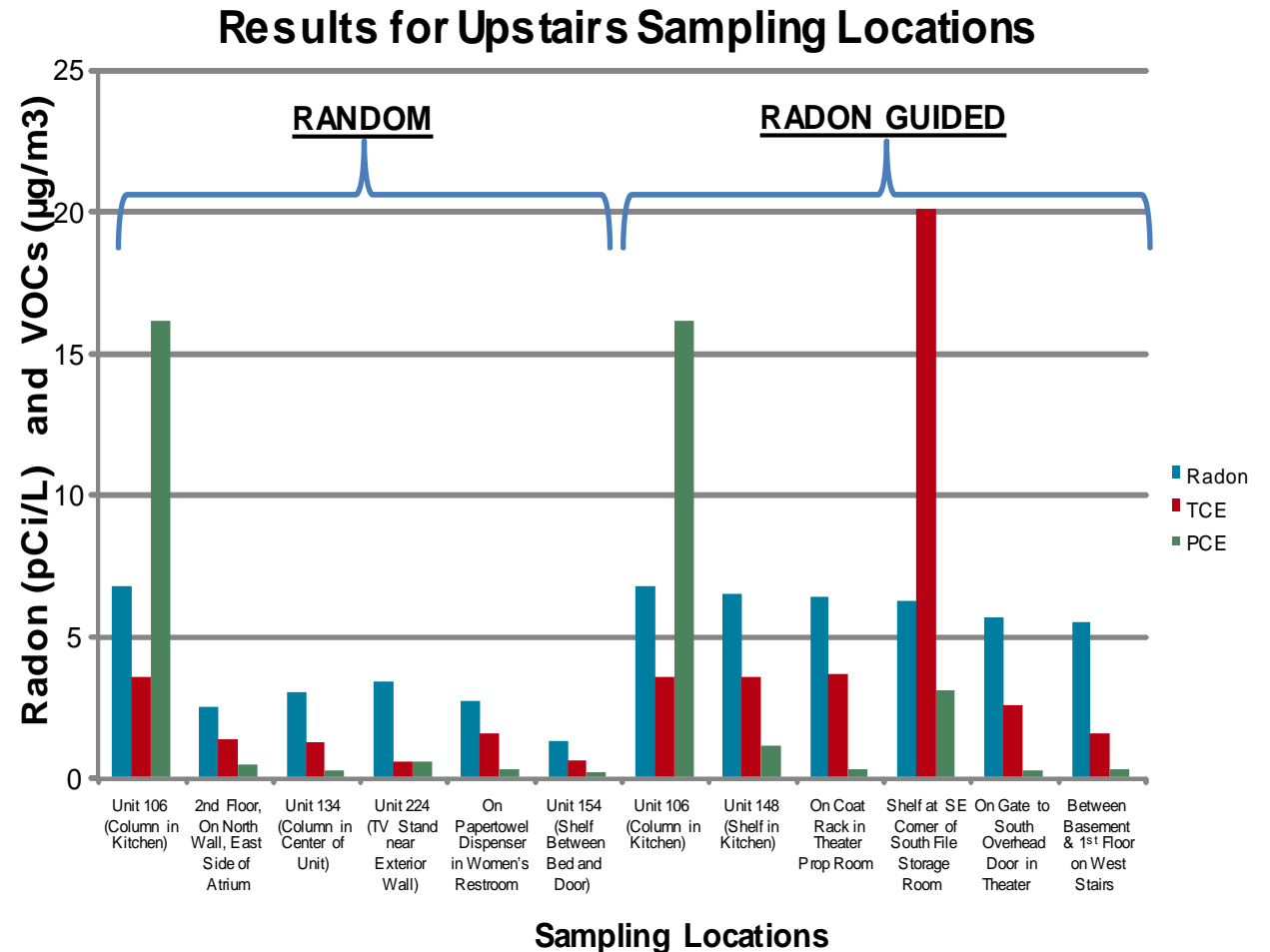


ND = Non detected  
RL = Reporting limit

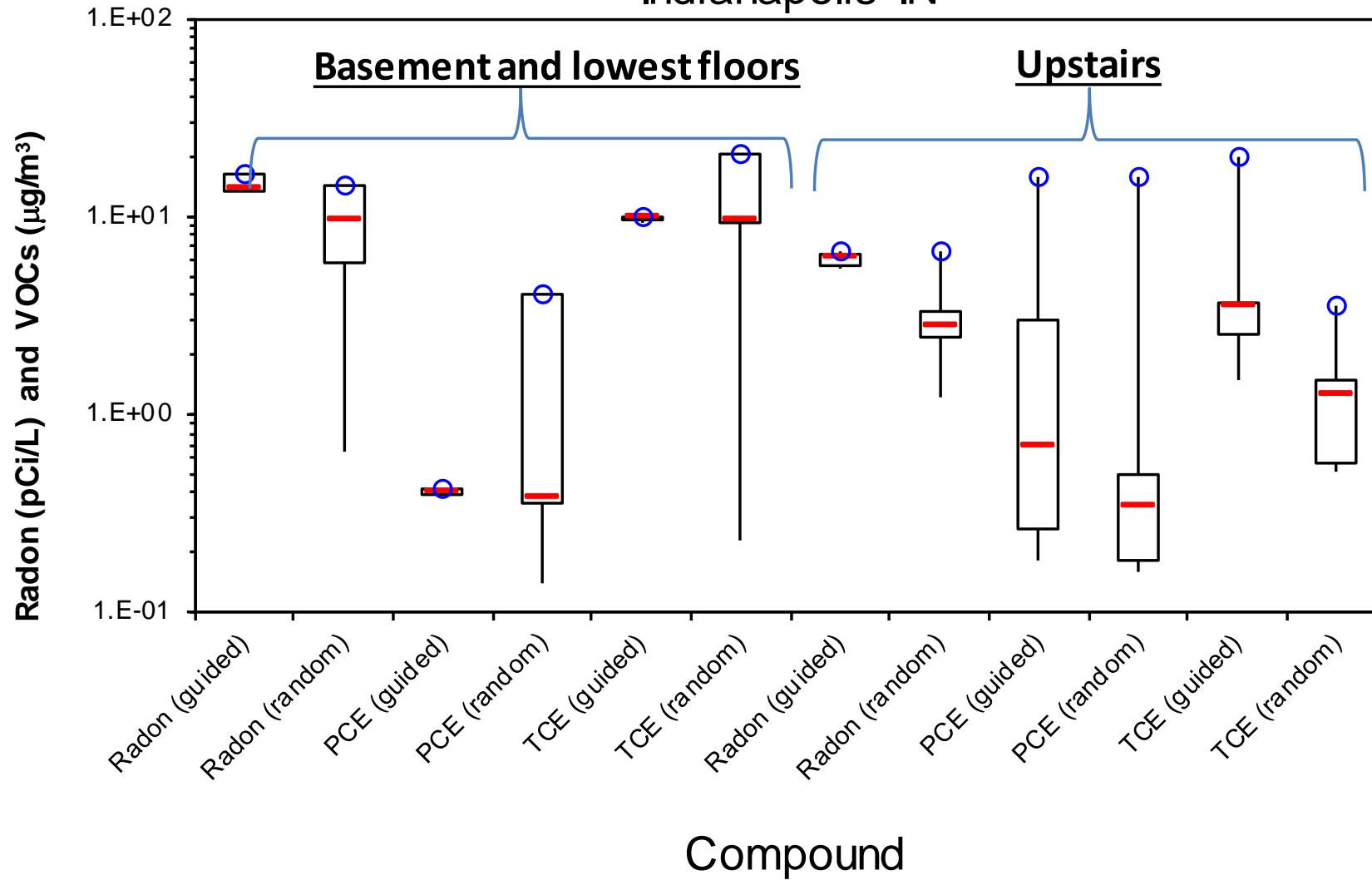


# Example: Randomized Trial of Radon Tracer for Spatial Sampling Application

- Fifty locations within the Wheeler complex were screened for radon
- Then two subsets of these sample locations were selected for passive VOC sampling, one randomly and the other based on the radon.
- The upstairs radon guided samples were significantly higher in trichloroethene (TCE) than the randomly selected locations
- t-test shows that the two mean concentration values for the guided and randomly collected data are statistically different for the data collected at the 95 percent confidence level.



# Statistics for Guided and Random VOC Sampling Results Indianapolis IN



# Radon Source Strength; Spatial and Temporal Variability

- Indianapolis is in Marion county which is EPA zone 1 (high radon susceptibility)
- SSP12 is a wall port – shows substantially lower radon
- But the others exhibit two OOM variability over space and time

	Date/Time	Concentration (pCi/L)	Temp (C°)	RH (%)	Range (pCi/L)
SSP01	12/30/09 10:20	6054.05	16	34	5837.84 - 6270.27
	1/5/10 13:17	6054.05	9	31	5837.84 - 6270.27
	1/6/10 15:30	5351.35	12	33	5135.14 - 5567.57
SSP02	12/30/09 11:00	3081	16	34	2946 - 3216
	1/5/10 14:27	559	12	43	517 - 602
	1/6/10 16:46	3730	13	41	3568 - 3892
SSP03	12/30/09 11:20	3676	15	53	3486 - 3865
	1/5/10 14:49	4027	12	52	3838 - 4216
	1/6/10 17:06	3892	13	47	3703 - 4081
SSP04	12/30/09 12:20	3811	15	36	3622 - 4000
	1/5/10 15:47	4081	12	44	3892 - 4270
	1/6/10 18:06	3838	12	51	3649 - 4027
SSP05	12/30/09 12:00	3973	16	53	3784 - 4162
	1/5/10 15:26	4054	13	35	3865 - 4243
	1/6/10 17:46	3946	13	48	3757 - 4135
SSP06	12/30/09 11:40	630	16	36	561 - 698
	1/5/10 15:07	646	13	48	584 - 708
	1/6/10 17:06	768	14	54	697 - 838
SSP07	12/30/09 10:40	59	16	34	19 - 98
	1/5/10 13:46	305	11	41	266 - 344
	1/6/10 16:06	551	12	60	507 - 596
SSP08	12/30/09 12:40	5054	15	38	4811 - 5297
	1/5/10 16:06	5703	10	31	5432 - 5973
	1/6/10 18:26	5351	12	36	5081 - 5622
SSP12	12/30/09 14:25	84	16	56	65 - 104
	1/5/10 14:07	< 22.78	12	41	< 22.78
	1/6/10 16:27	< 22.51			< 22.51



# Applications of Radon As Mitigation Tracer - Monitoring in Breathing Zone

*Mitigation - subslab depressurization in June 2009*

Indoor Air Radon Results Before and After Mitigation, SEND Office, Indianapolis, IN

Location	Pre-Mitigation System Radon Concentration (pCi/L)	Post-Mitigation System Radon Concentration (pCi/L)
NE Portion of Office	5.89	0.9
North Side of Break Room	5.64	0.7
Second Floor File Storage Room	5.69	0.5

SEND Office Building, Indianapolis, IN - VOC's Before and After Mitigation in Indoor Air

Location	Stage	Sampling Period	Method <sup>1</sup>	VOC's	
				PCE	TCE
North Side of Break Room	Pre-Mitigation	2/25-3/11/09	RadTO-17	4.1	21
		2/25-3/11/09	RadTO-17	3.9	20
		2/25-3/11/09	RadTO-17	3.5	18
		2/26-27/09	CanTO-15	4.2	19
		3/4-5/09	CanTO-15	5.5	24
	3/9-10/09	CanTO-15	3.6	16	
	Post-Mitigation	6/12-16/09	RadTO-17	0.37	0.79
South Storage Room 2nd Level	Pre-Mitigation	2/25-3/11/09	RadTO-17	3	20
	Post-Mitigation	6/12-16/09	RadTO-17	0.35	0.62



# AlphaGuard Radon Monitor Entry Point Measurements

## SEND Office Building Entry Routes Before and After Mitigation

Location	Stage	Date	Concentration (pCi/L)	Range (pCi/L)
<b>SEND Office Sources</b>				
Crack in Breakroom Floor	Pre-Mitigation	4/21/2009	20.41	16.97-23.84
	Post-Mitigation	6/26/2009	0.92	0.11-1.73
Joint between Floor and West Wall	Pre-Mitigation	4/21/2009	131.08	120.76-141.41
	Post-Mitigation	6/26/2009	0.97	0.16-1.78
Ambient (Parking Lot NE of SEND Bldg)		6/26/2009	< 0.81	< 0.81

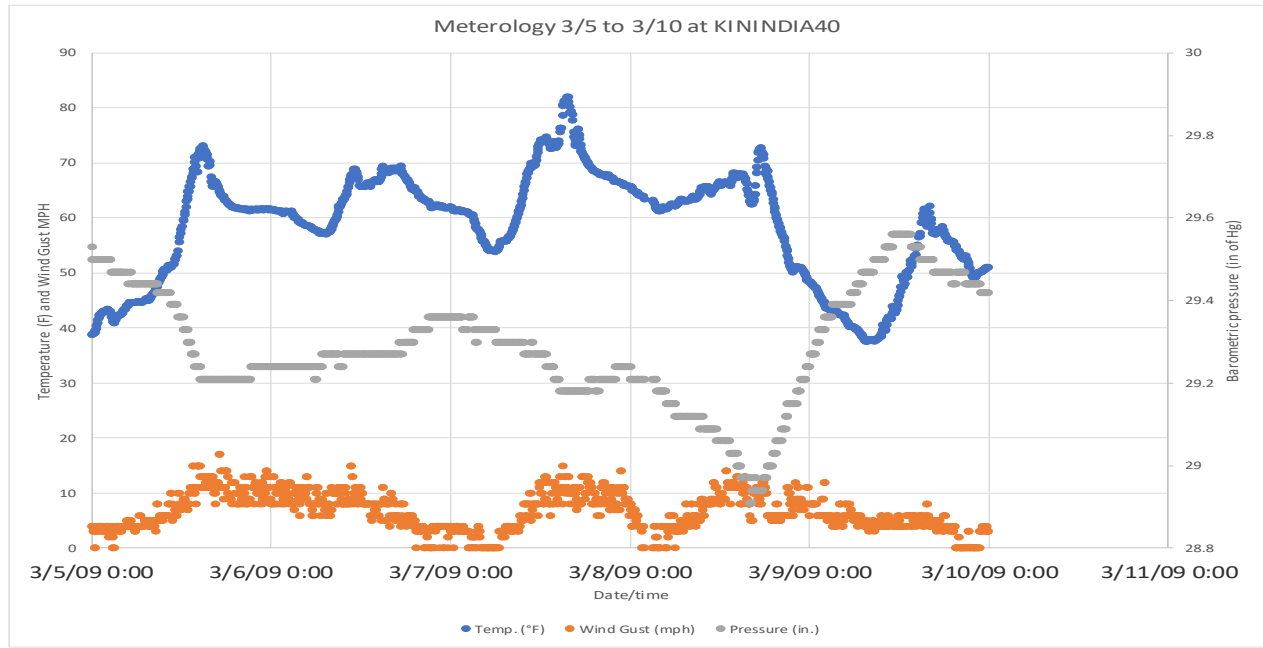
Bq/m<sup>3</sup>: Becquerels per cubic meter

pCi/L: picoCuries per liter

1 pCi/L = 37 Bq/m<sup>3</sup>

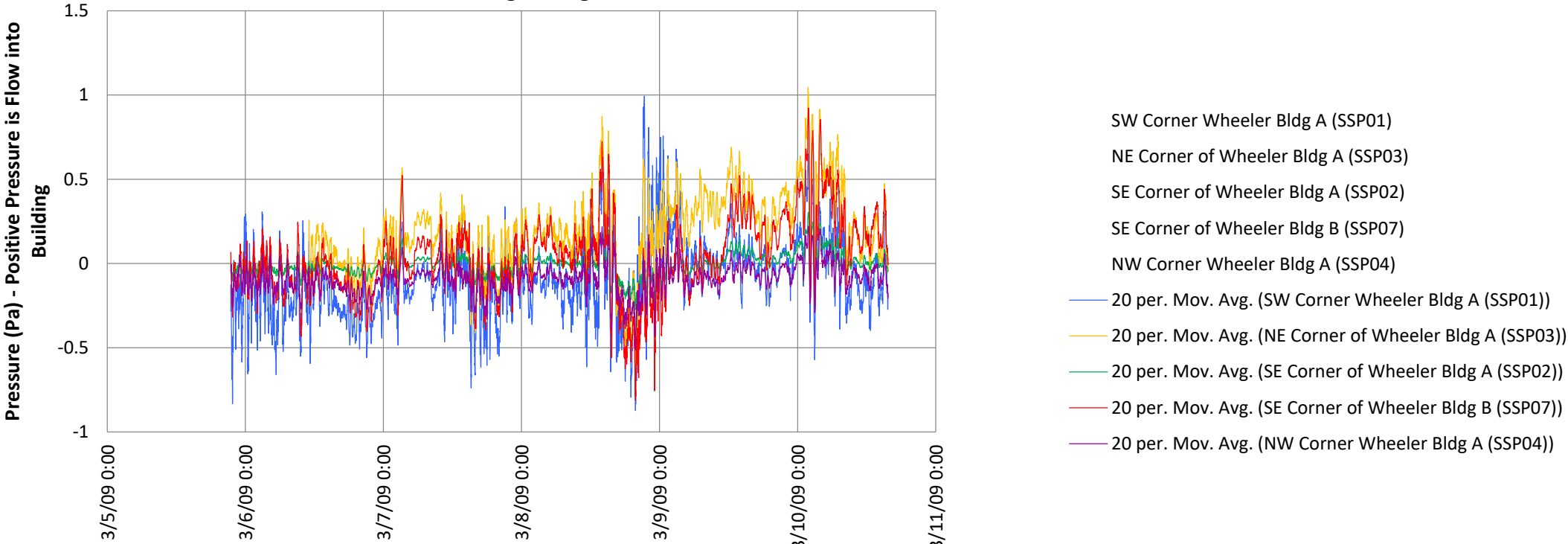
RH: Relative Humidity





Falling barometer produces flow into the building at some but not all locations.

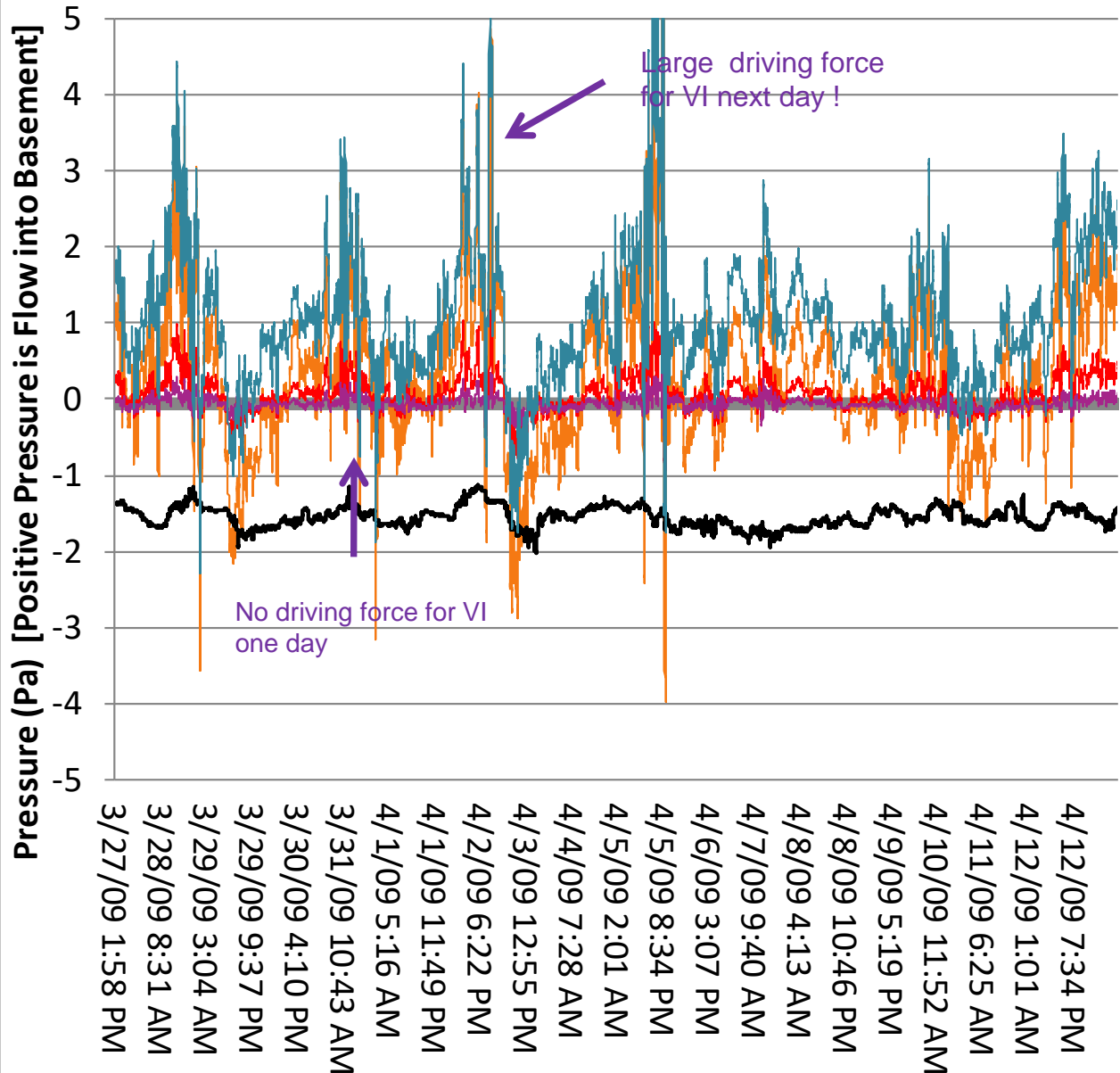
Moving Averages for Sub-slab Pressure Differentials for 3/5 - 3/10



- SW Corner Wheeler Bldg A (SSP01)
- NE Corner of Wheeler Bldg A (SSP03)
- SE Corner of Wheeler Bldg A (SSP02)
- SE Corner of Wheeler Bldg B (SSP07)
- NW Corner Wheeler Bldg A (SSP04)
- 20 per. Mov. Avg. (SW Corner Wheeler Bldg A (SSP01))
- 20 per. Mov. Avg. (NE Corner of Wheeler Bldg A (SSP03))
- 20 per. Mov. Avg. (SE Corner of Wheeler Bldg A (SSP02))
- 20 per. Mov. Avg. (SE Corner of Wheeler Bldg B (SSP07))
- 20 per. Mov. Avg. (NW Corner Wheeler Bldg A (SSP04))



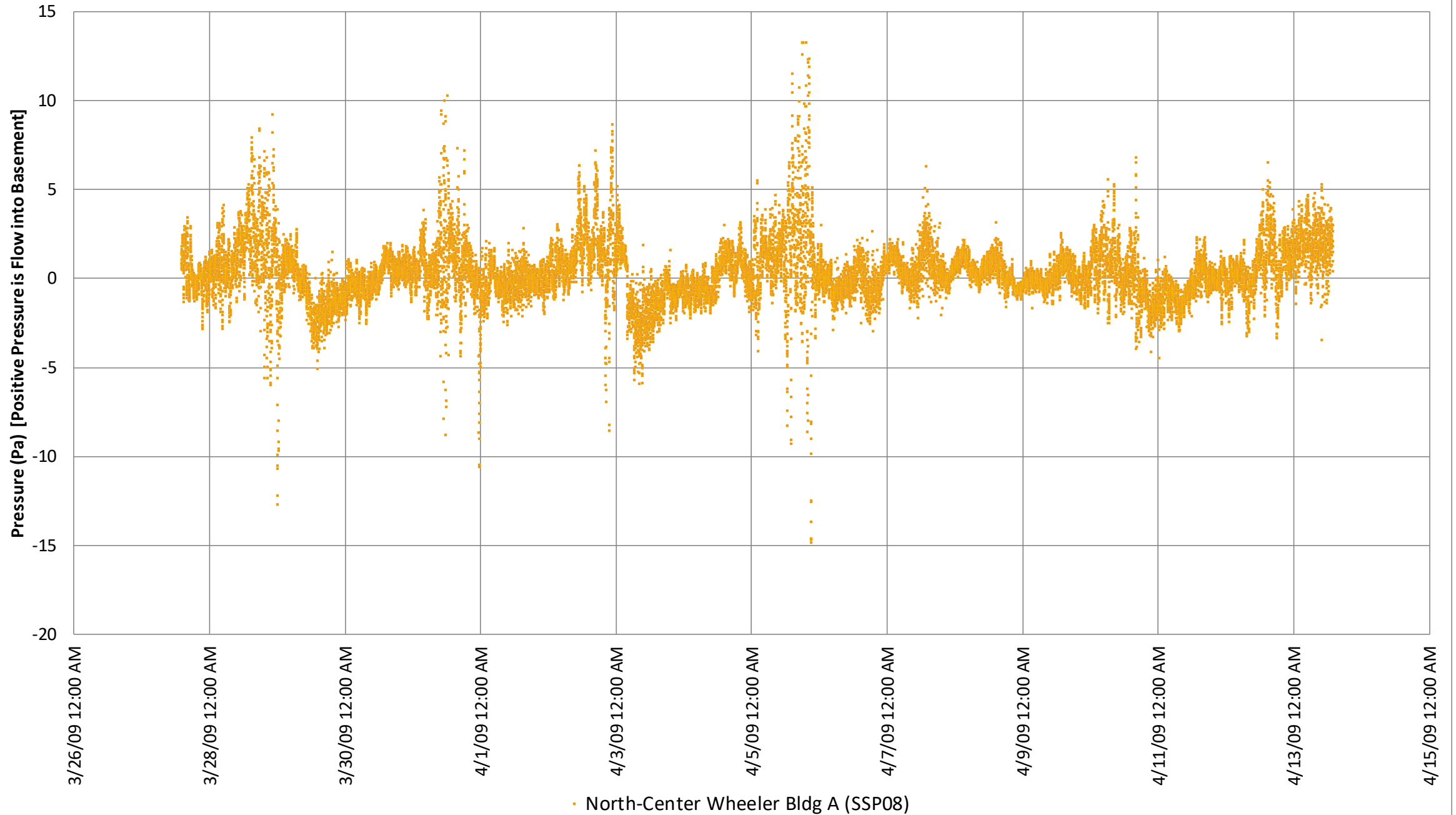
# Moving Average of Pressure Differentials for 3/27/09 - 4/13/09



- South-Center Wheeler Bldg A (SSP05)
- SE Corner Wheeler Bldg B (SSP07)
- NW Corner Wheeler Bldg A (SSP04)
- UPSTAIRS (w/respect to Basement)
- North-Center Wheeler Bldg B (SSP06)
- North-Center Wheeler Bldg A (SSP08)
- 30 per. Mov. Avg. (South-Center Wheeler Bldg A (SSP05))
- 30 per. Mov. Avg. (SE Corner Wheeler Bldg B (SSP07))
- 30 per. Mov. Avg. (NW Corner Wheeler Bldg A (SSP04))
- 30 per. Mov. Avg. (UPSTAIRS (w/respect to Basement))
- 30 per. Mov. Avg. (North-Center Wheeler Bldg B (SSP06))

Subslab-  
interior  
Differential  
Pressures  
(Black is  
basement  
to upstairs)

# Pressure Differentials for March 27 - April 13



# Conclusions

- Radon was a useful tracer to follow soil gas intrusion through a complex multistory multiuse building
- Radon guided sampling of indoor air was shown to be statistically more effective in upstairs locations (space divided into many zones)
- Radon provided useful information on post mitigation performance when used both in the breathing zone and at entry points
- Barometric pressure change appears to be correlated with differential pressure driving force; but differential pressure profiles differ across slab.

# Sources/References

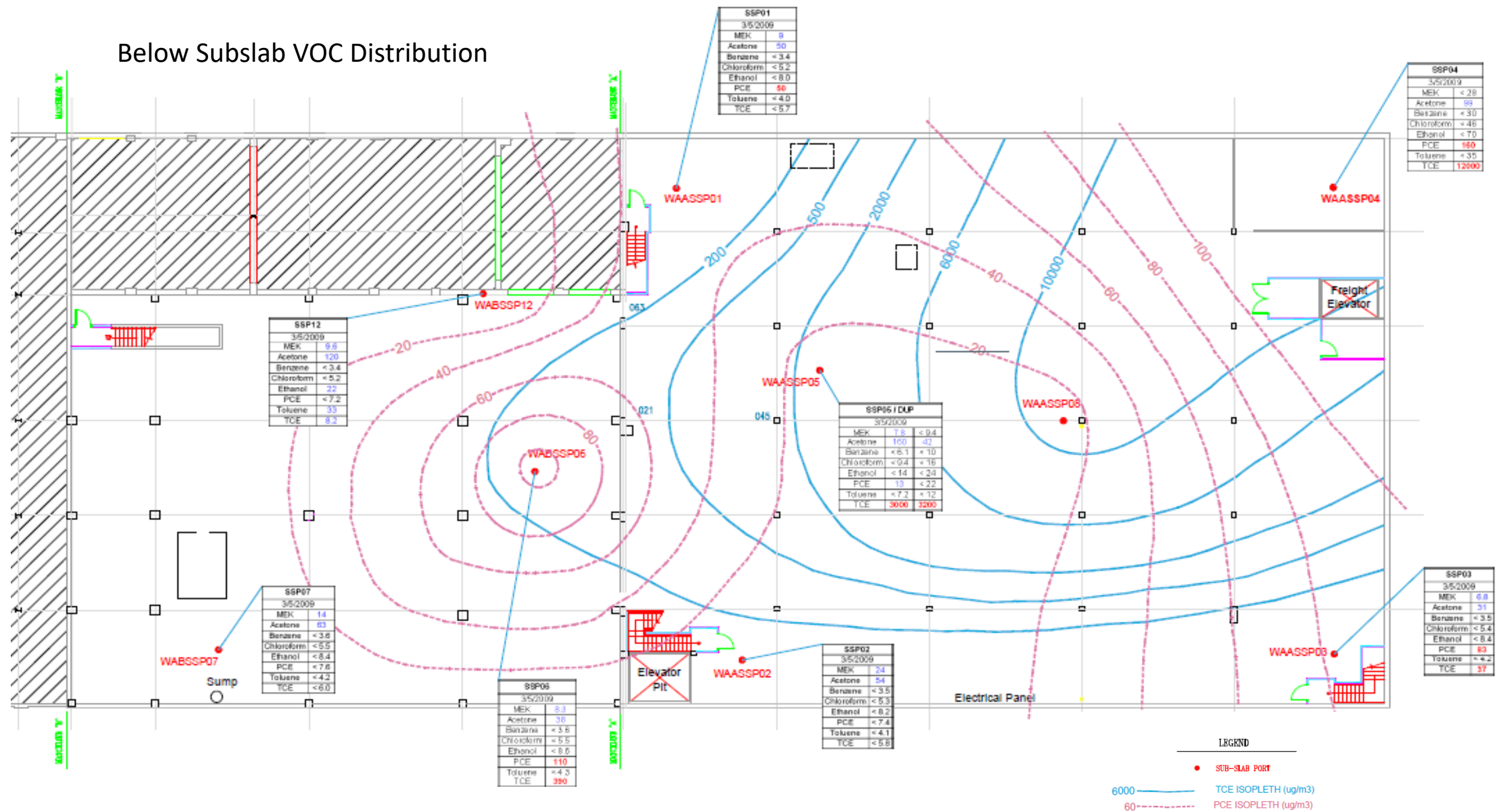
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- Southeast Neighborhood Development
- Rob Uppencamp, ARCADIS
- Ron Mosley (retired) and Dale Greenwell US EPA NRMRL



# Below Subslab VOC Distribution



LEGEND

- SUB-SLAB PORT
- 6000 ——— TCE ISOPLETH (ug/m3)
- 60 - - - - - PCE ISOPLETH (ug/m3)