TCE in sanitary sewers: characterizing spatial and temporal variability, extent, and risk assessment strategies

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Outline

- Evaluating the Sewer Pathway
  - How prevalent is sewer contamination?
  - How stable are sewer concentrations?
  - How to screen for the Sewer pathway?
  - Possible impacts from Sewer pathway
- Introduction to the AROMA analyzer
  - Analyzer mode of operation
  - Analyzer Performance

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Prevalence of Sewer Contamination

- Multiple studies across the US and internationally have identified cVOCs in sewer systems that intersect groundwater plumes, NAPL, or are in the vadose zone of groundwater contamination
- Ongoing effort to evaluate sewers to determine extent of contamination

Prevalence of Sewer Contamination

- ESTCP Study (Tom McHugh/ Lila Beckley @ GSI)
  - Five sites evaluated for TCE/PCE in sewer (ASU house, Indiana EPA house, Moffett,
    Houston Dry cleaners, Austin Dry cleaners)
  - In all all areas concentrations of > 10x screening were found in >40% of man holes
- ET Study
  - 6 Bay area sites evaluated
    - TCE detected at 5 of 6 sites
    - TCE > 10x screening at 4 of 6 sites
- Kelly Pennell and EPA
  - Extensive characterization of MEW superfund site
- Elevated TCE/PCE concentrations have been found at a majority of sites.
- Most tested Sites have sewer @ or near water table.
  - Indiana Site has sewer in vadose zone

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MEW Superfund

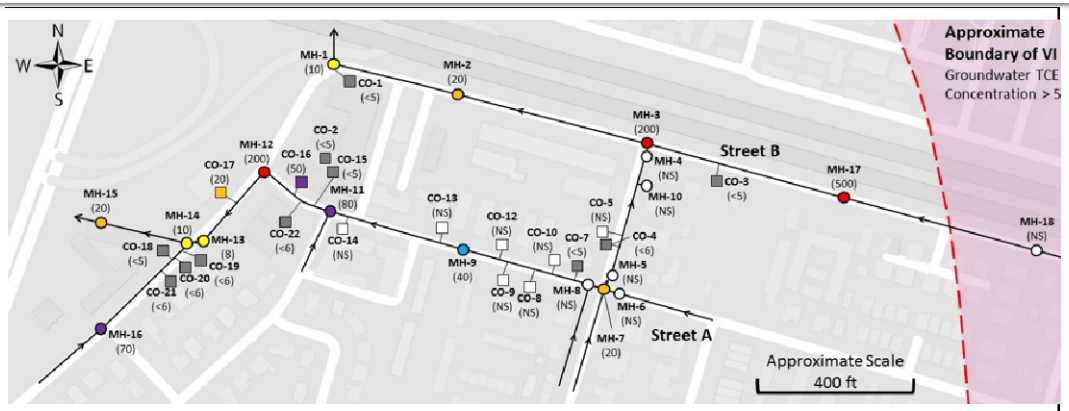

Fig. 5a. Sewer Gas TCE Concentrations measured by TO-15 (August 11, 2015)

Fig. 5b. Sewer Gas TCE Concentrations measured by TO-17 (August 11-18, 2015)

TCE Concentrations Detected in Sewer Gas (µg/m³)	
NS	> 10 – 20
ND	> 20 – 40
> ND – 10	> 40 – 150
	> 150

Legend	
MH-17	Manhole
CO-13	Clean out
←	Sewer flow
NS	Not Sampled
ND	Not Detected
(20)	TCE in µg/m³

Note: Sewer lateral locations were approximated. The connection for CO-2 could not be confirmed. Sewer flow directions were estimated. Not all manholes and cleanouts are included.

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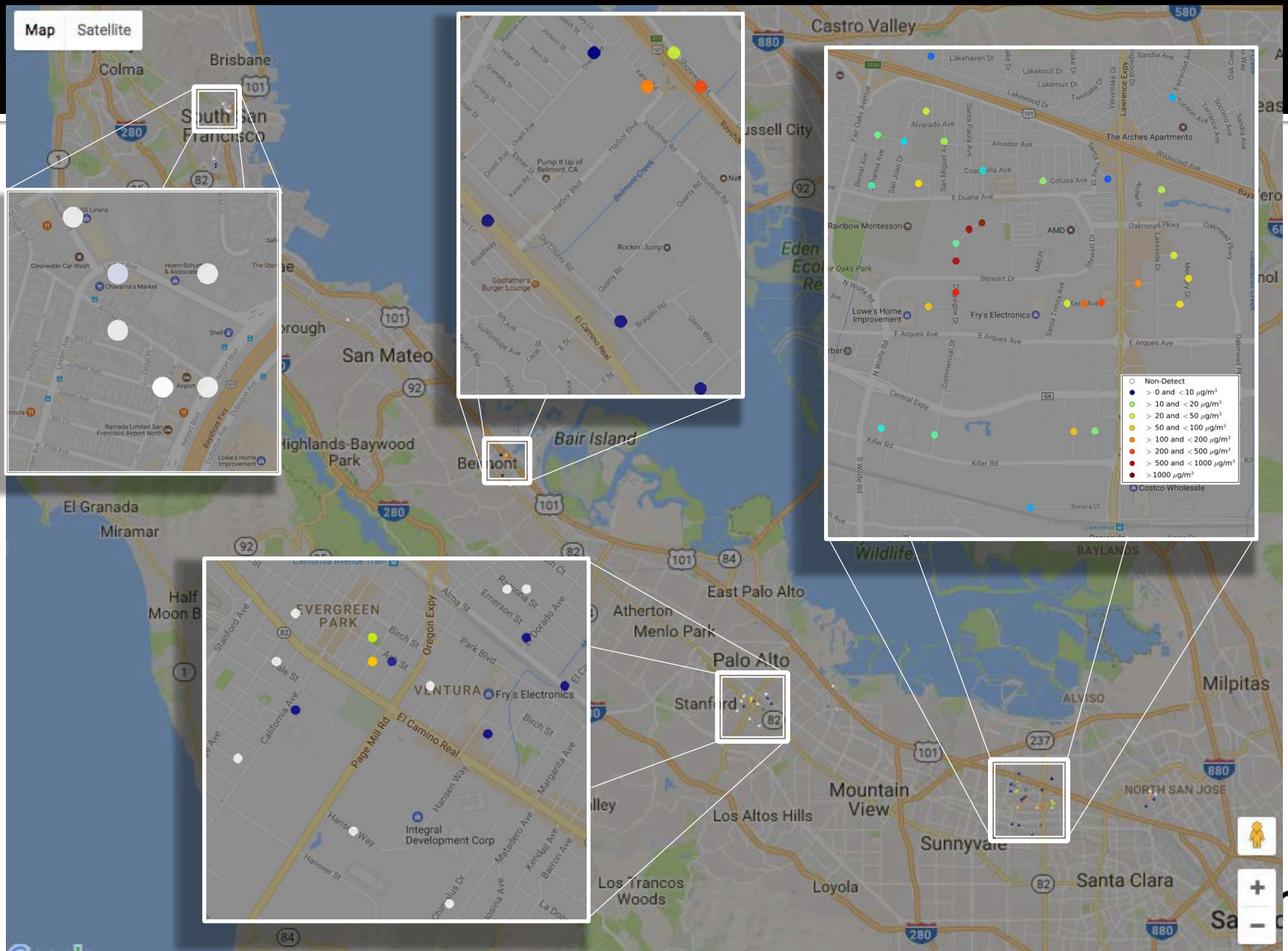
Sewer Measurement Overview



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Sewer Pathway Risk

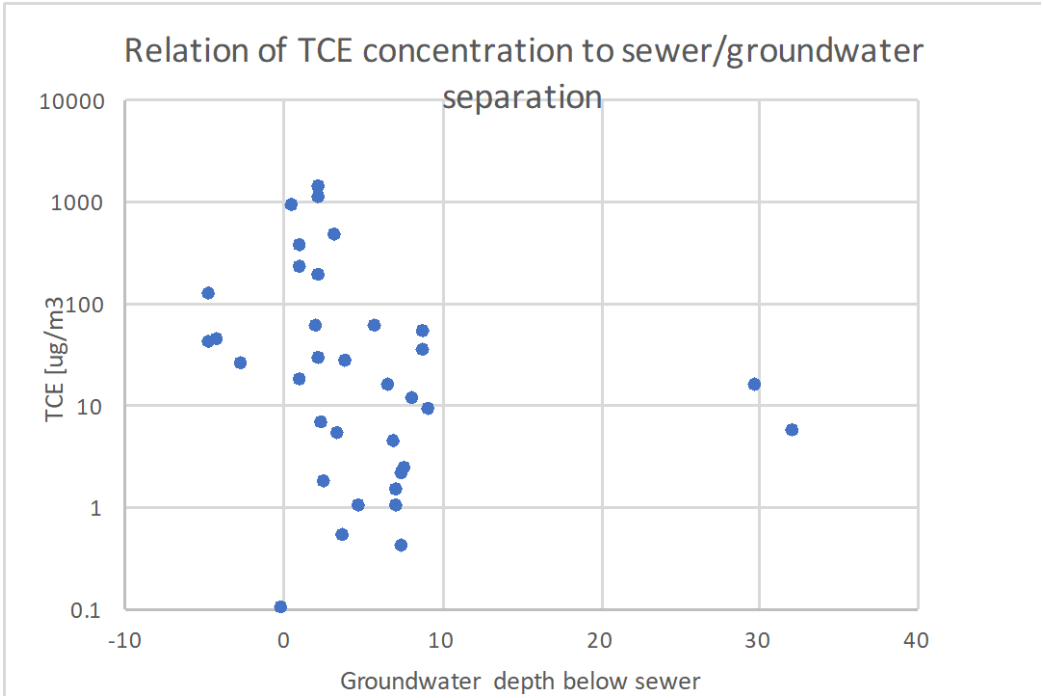
- Significant cVOC concentration in sanitary sewers is *common*
- Elevated cVOC concentrations frequently extend well beyond plume boundaries
- Sewers with bulk discharge may lead to secondary source areas with "traditional" VI risk

Screening the Sewer Pathway

- Mechanical factors
  - Sewer age
  - Sewer and groundwater depth
  - Extent and concentration of groundwater/vadose zone contamination
- Sampling strategies and challenges
  - Sampling variability
  - Sampling duration
  - Sampling methodology

Relationship of TCE concentration to groundwater/sewer separation

- Highest TCE concentrations observed when first groundwater and sewer are at same depth
- Groundwater depth from extracted monitoring well data.
- Only a limited subset of all data has sewer depth and groundwater



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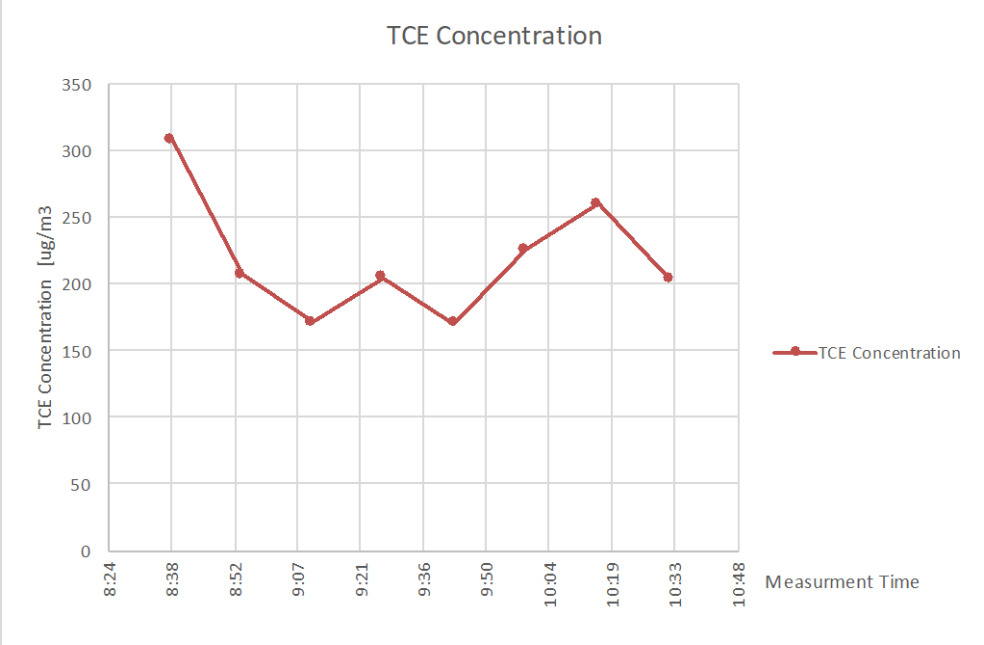
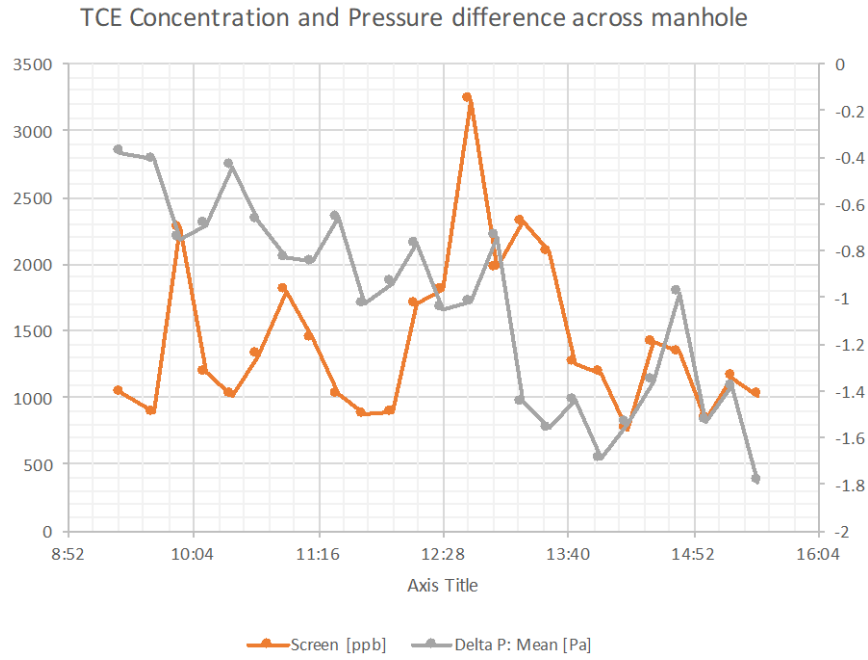
Short Term Temporal Variability



Near MEW



Moffett Field

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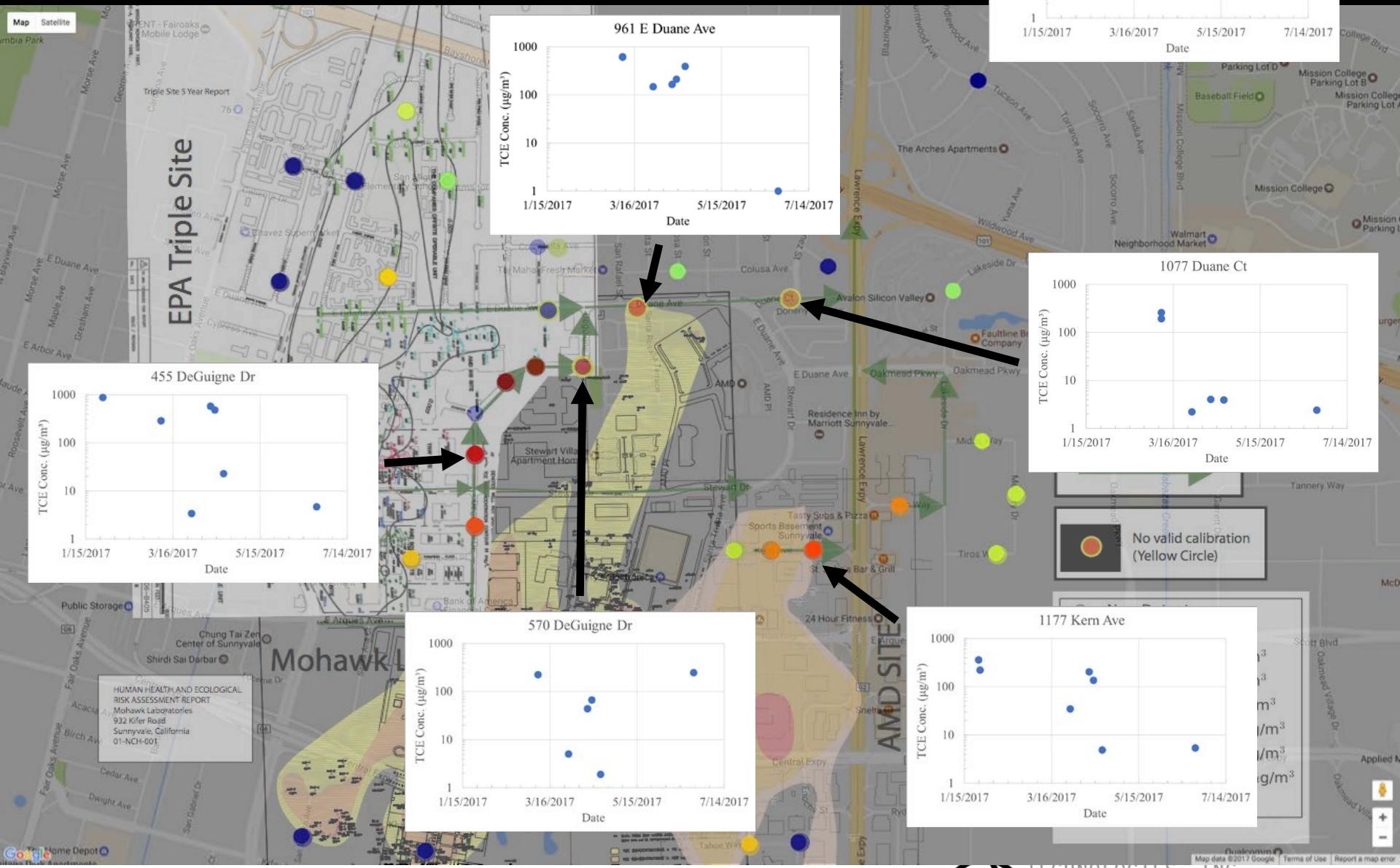
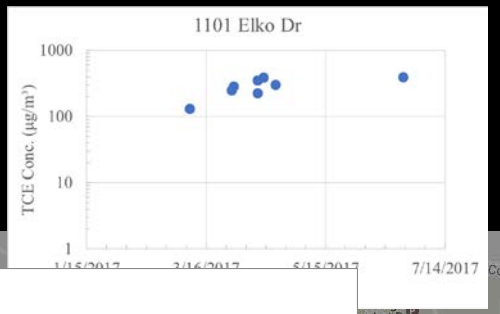
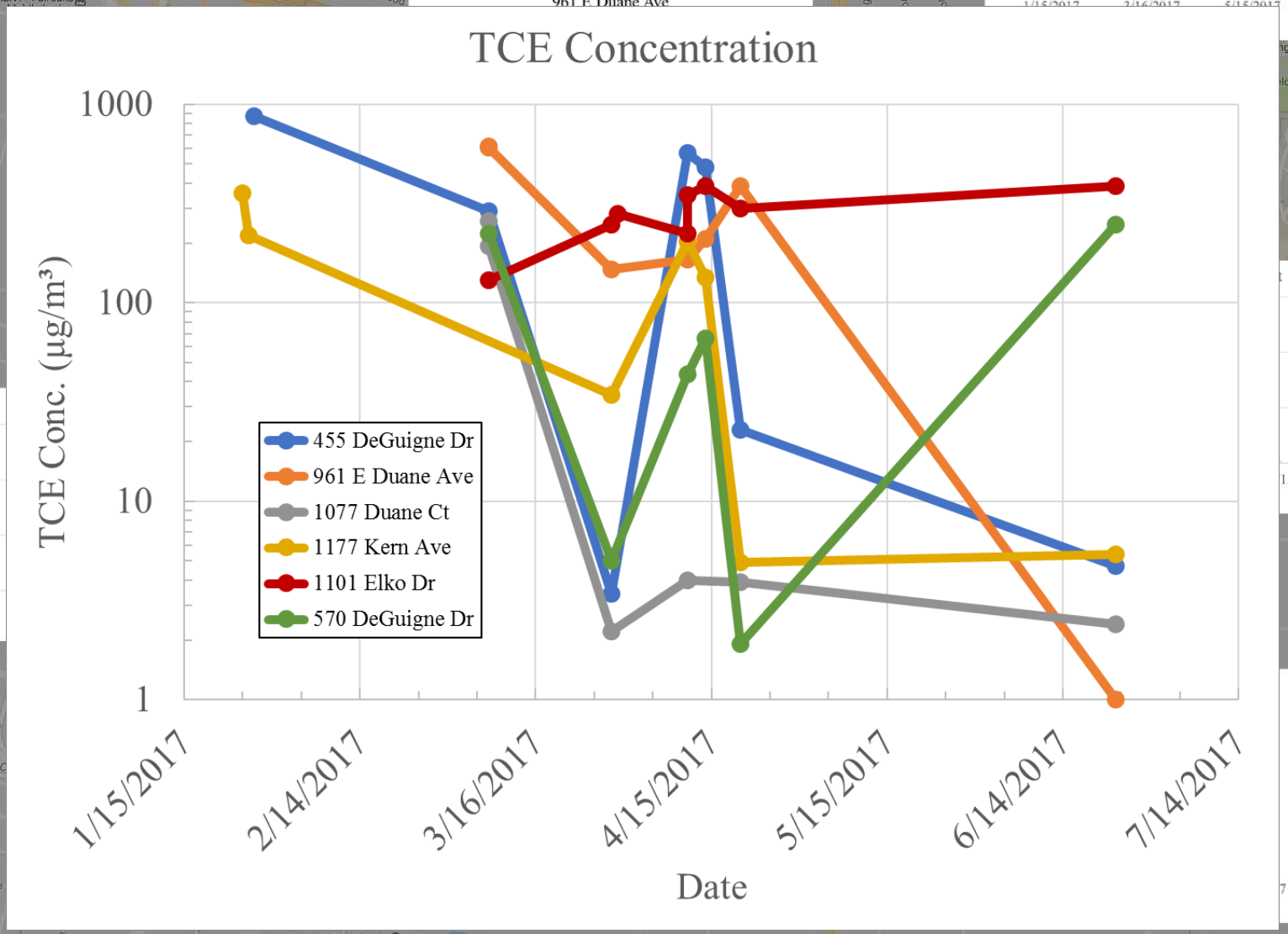
Sewer Variability

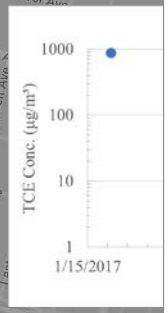


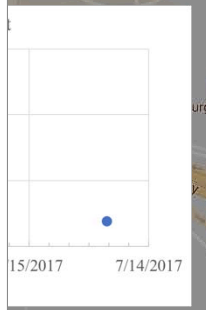
Sewer Variability

~1 mile









Sampling Recommendations

- Sample within 12" of manhole bottom (avoid vertical concentration gradient)
- Sample Mid-day for grab (tentative conclusion), >24h for passive
- **Multiple, widely spaced sampling events required**
- Driving factors for sewer concentration not yet determined

Sewer Vapor Impact

- Water/Soil gas plume extents may not capture a significant VI risk.
- Combination of direct detection and tracer measurement indicate a **0.02 (50x)** attenuation factor is conservative (for risk protection)

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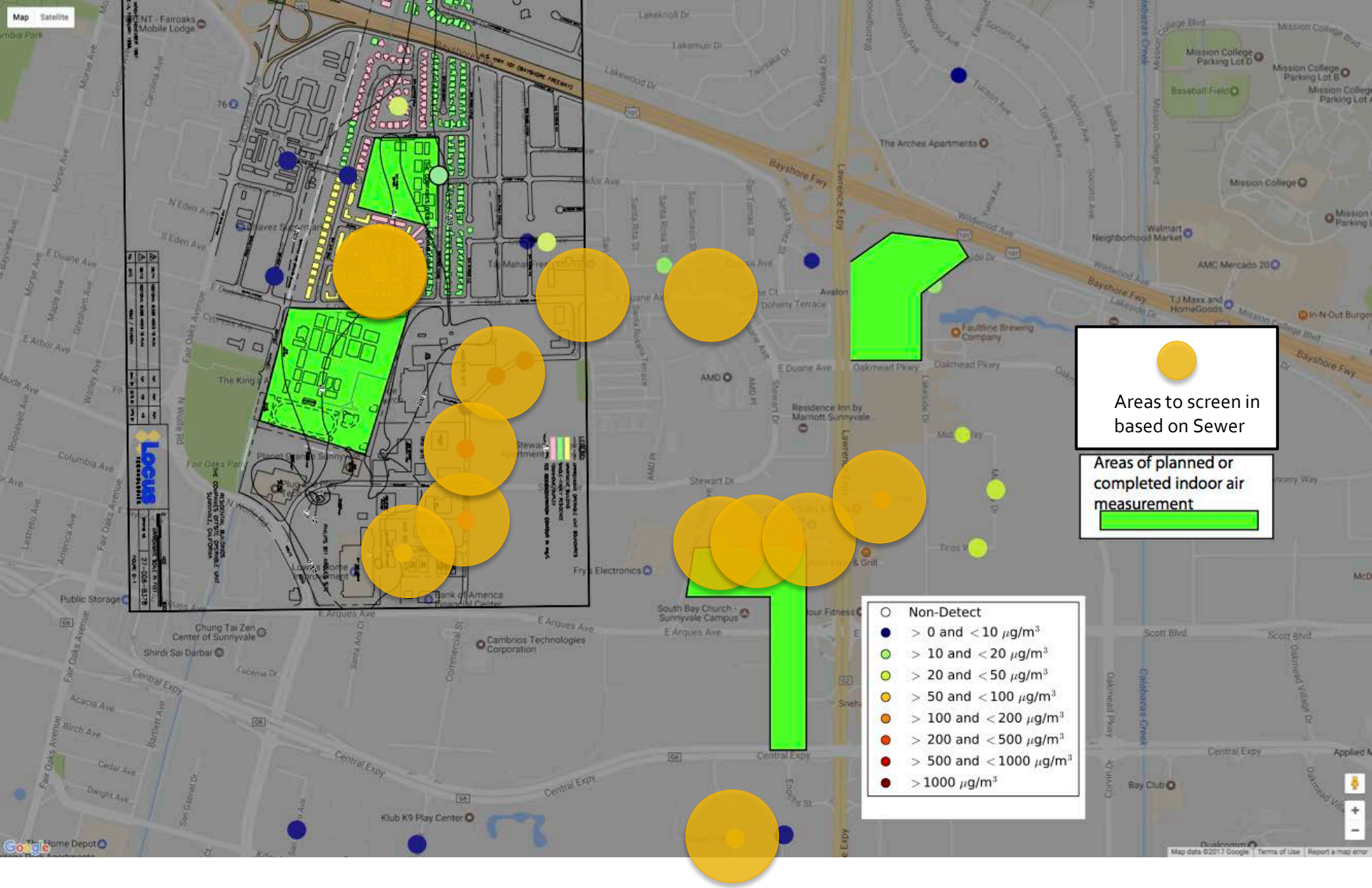

Planned indoor air studies track plumes, areas potentially impacted by sewer pathway are not considered in screening criteria

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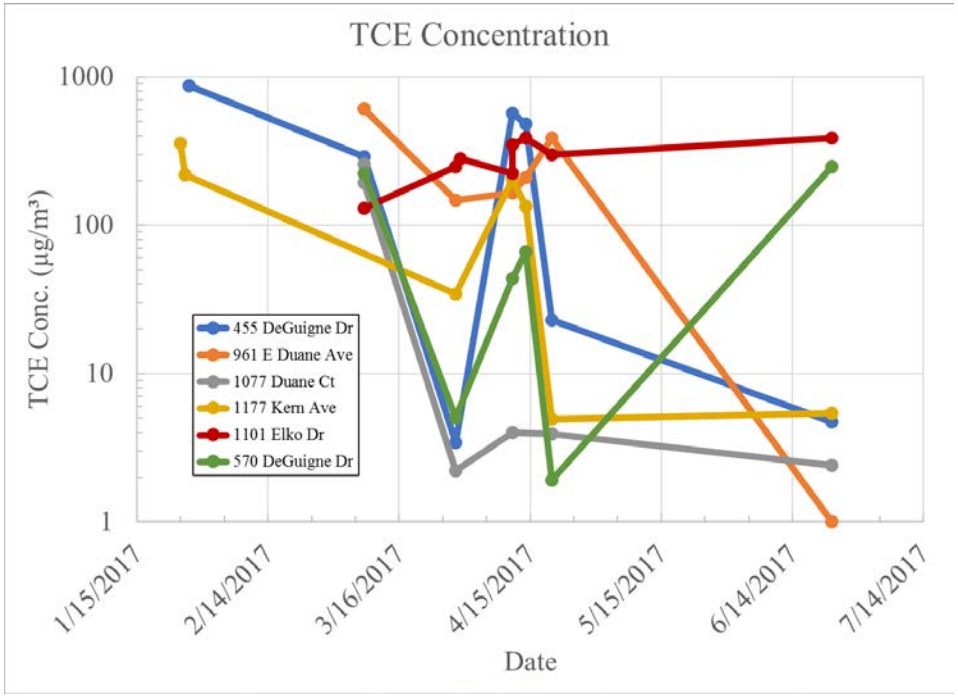
Challenges of Indoor Air Screening

Variability complicates the picture

Source Variability



- Source (sewer main) may be highly variable

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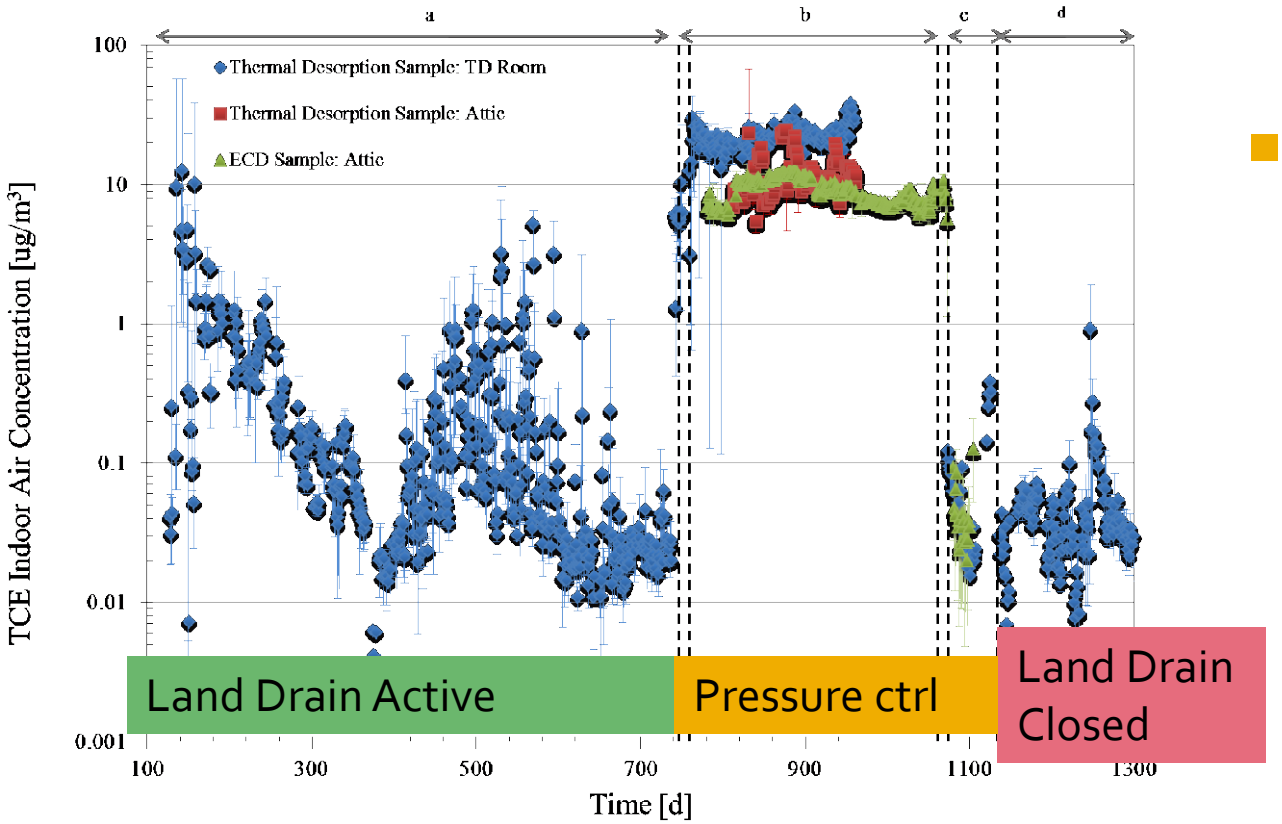
"Pathway" variability



- Active sewer (land drain) pathway drove high variability.

Guo, Y. Vapor Intrusion at a Site with an Alternative Pathway and a Fluctuating Groundwater Table. Ph.D. Thesis, University of Arizona, 2015.

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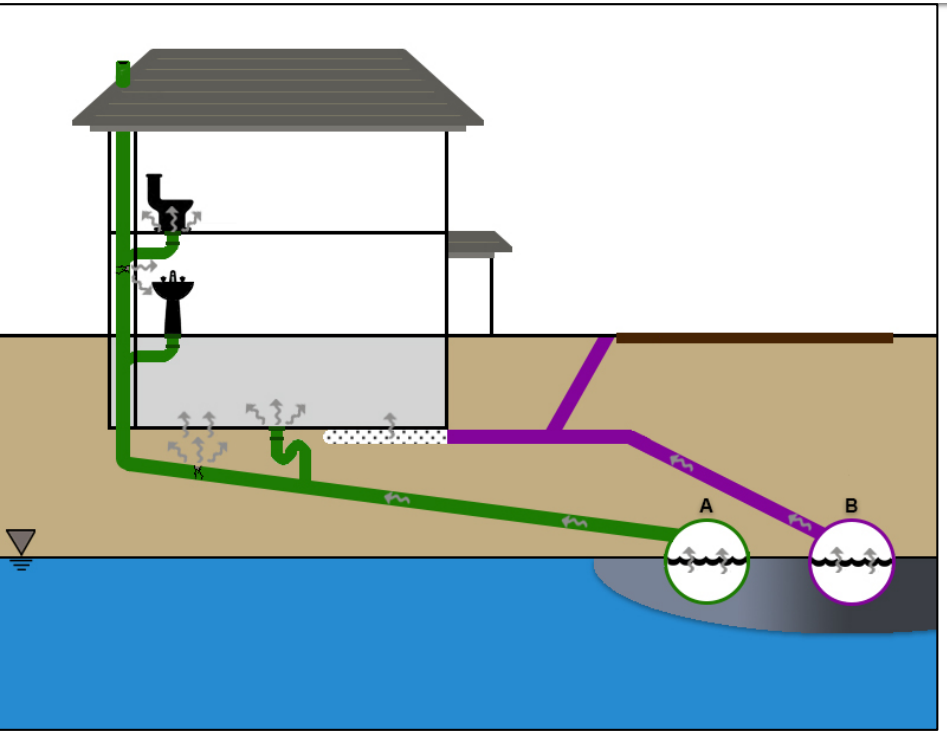
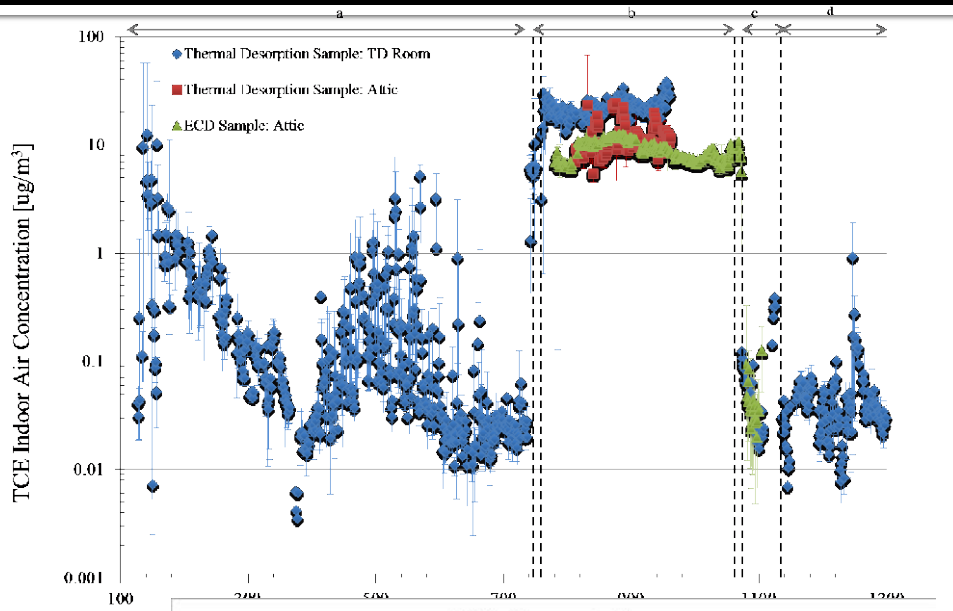
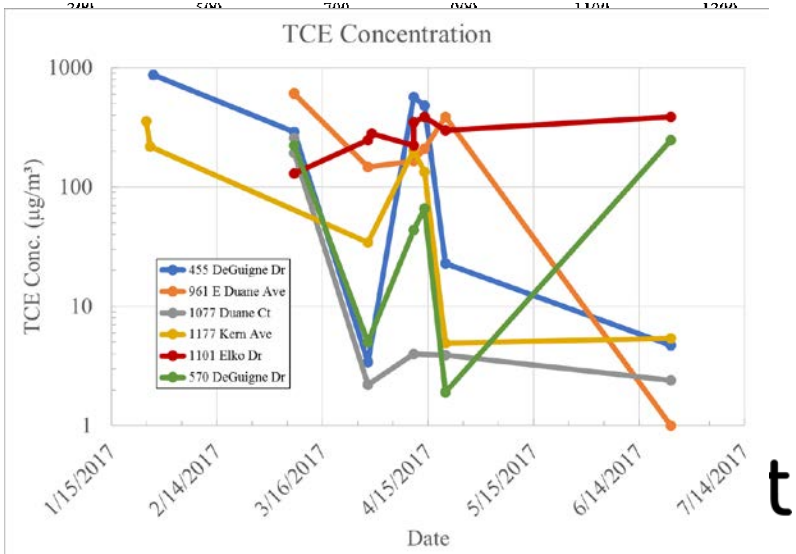
Screening with Source and Pathway Variability







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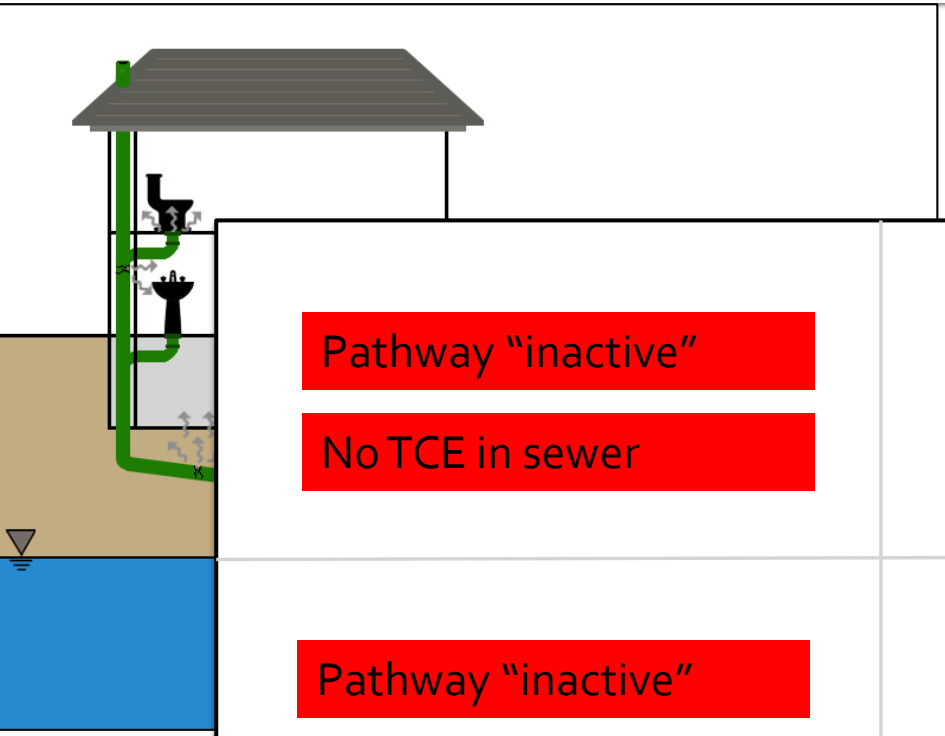
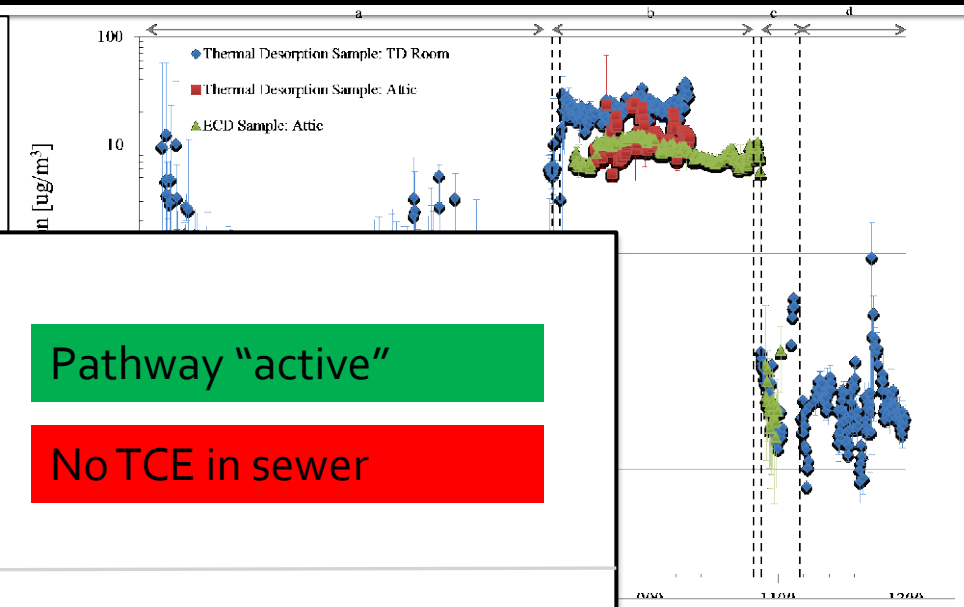
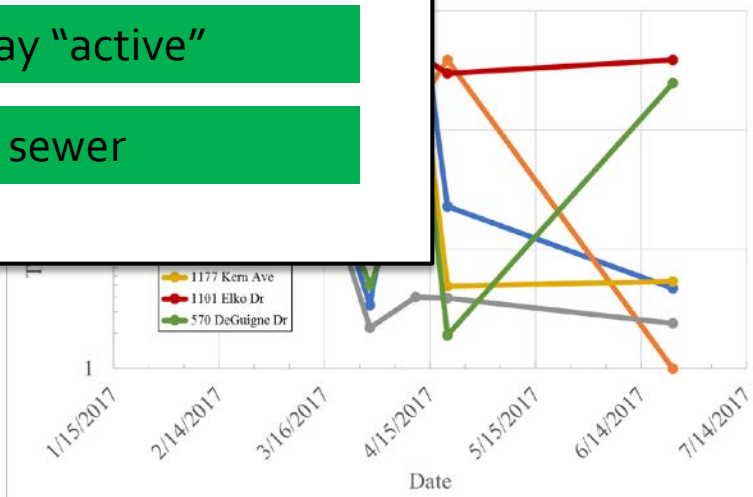
Screening with Source and Pathway Variability



Pathway "inactive" No TCE in sewer	Pathway "active" No TCE in sewer
Pathway "inactive" TCE in sewer	Pathway "active" TCE in sewer





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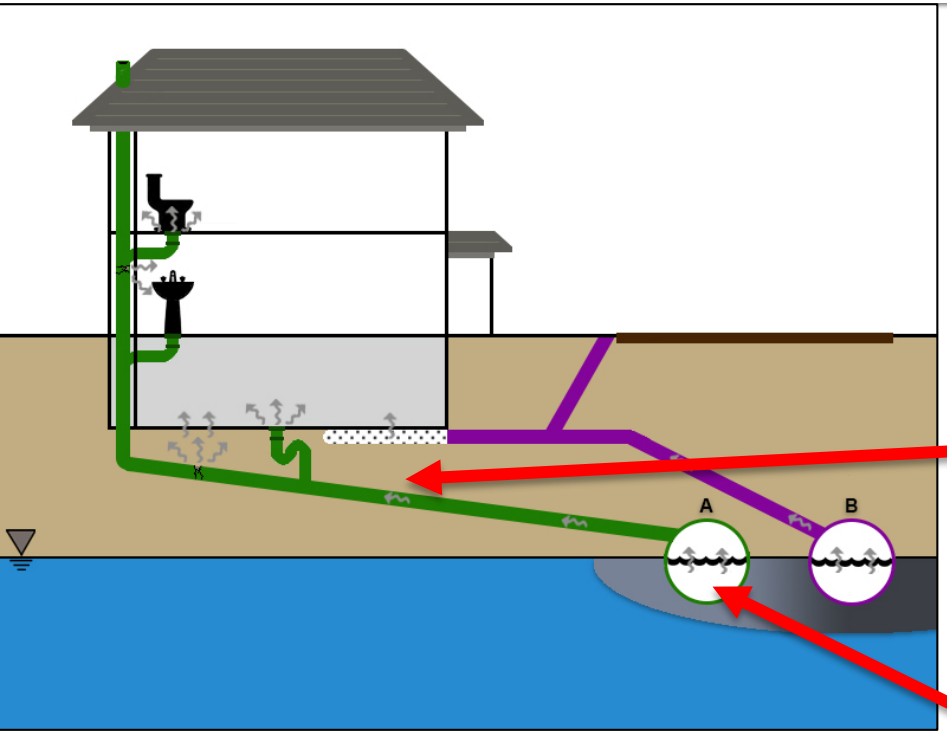
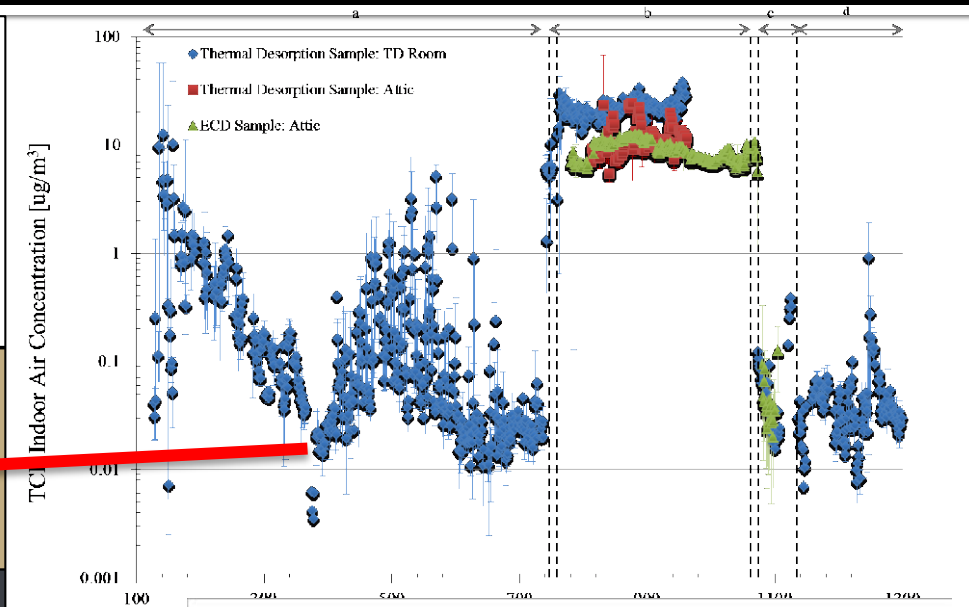
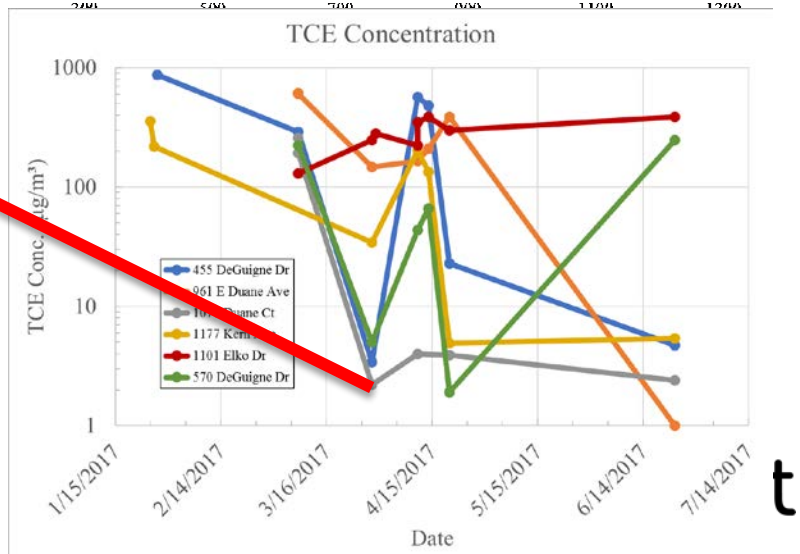
Screening with multiple variables







Pathway "inactive"

No TCE in sewer

NO VI Detected

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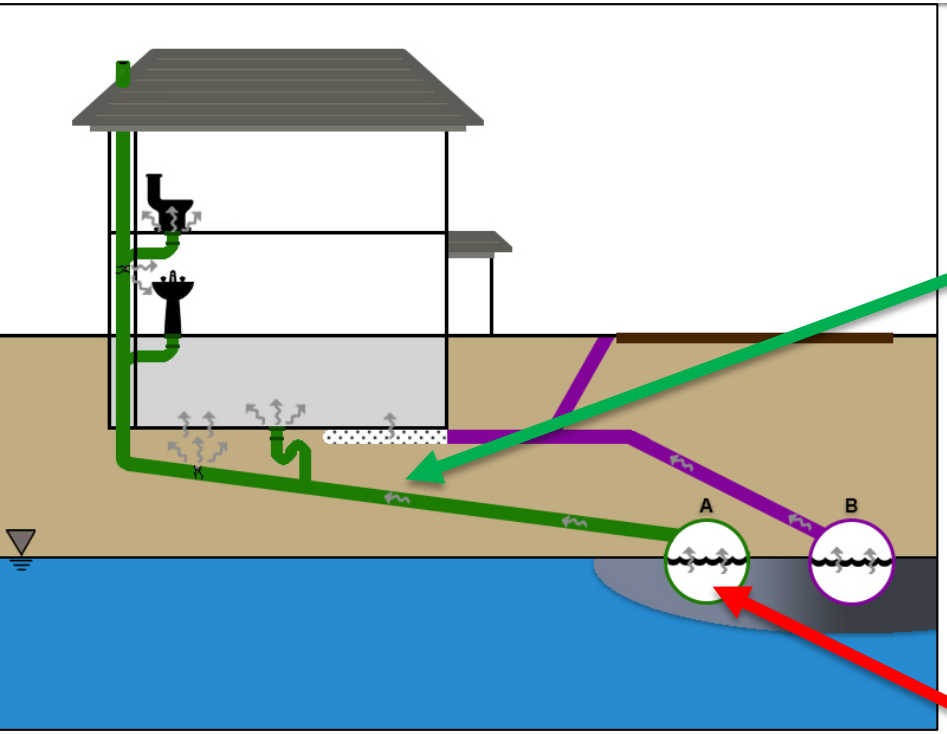
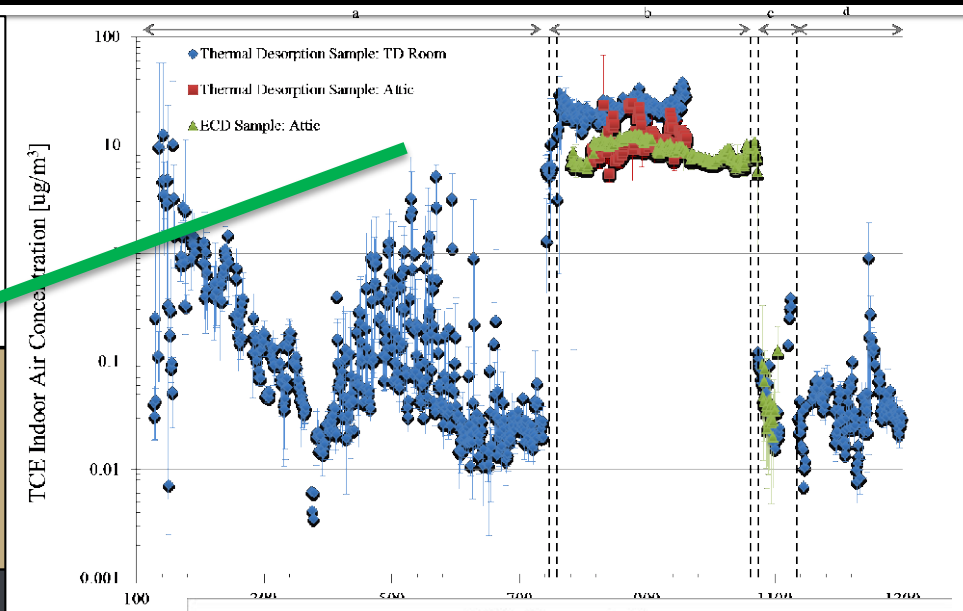
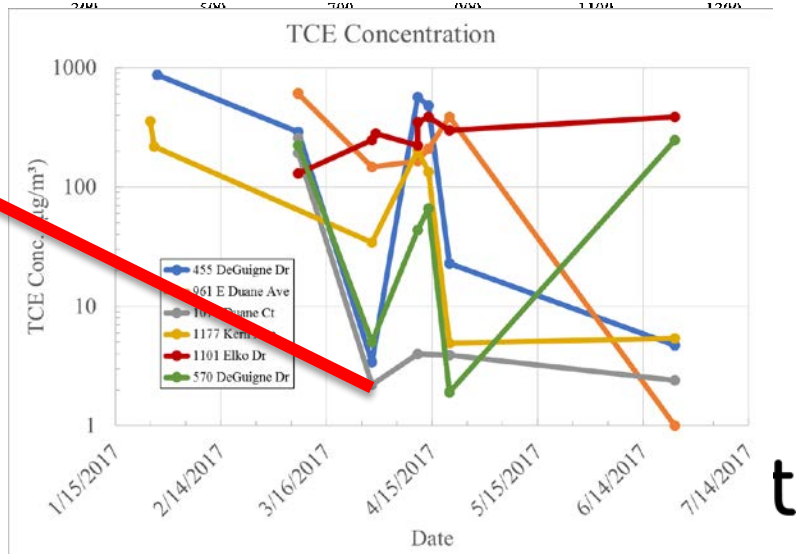
Screening with multiple variables







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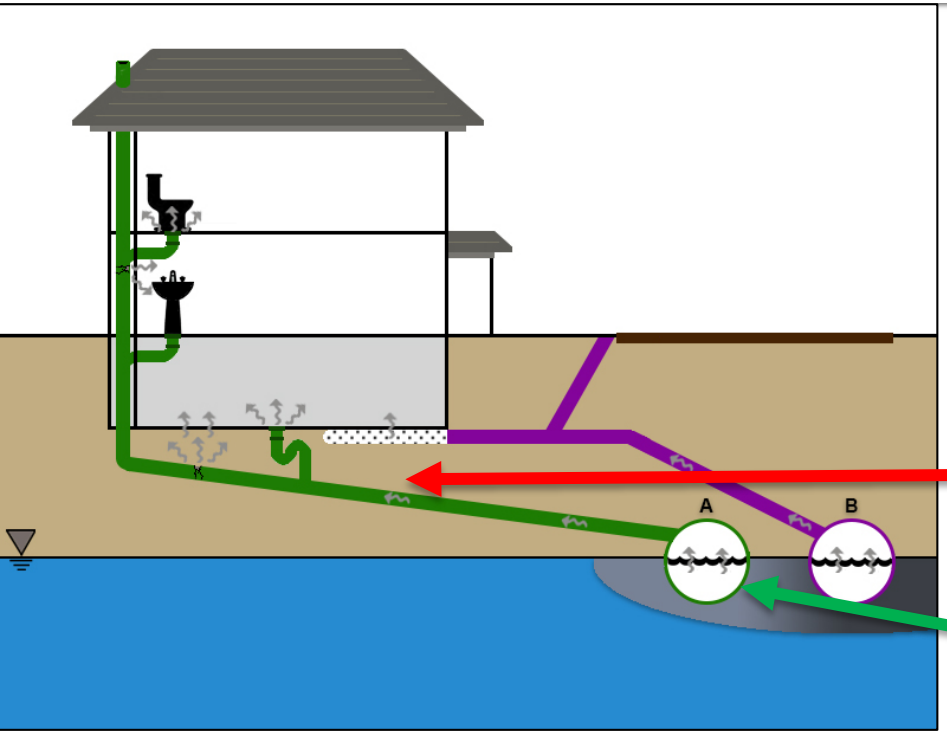

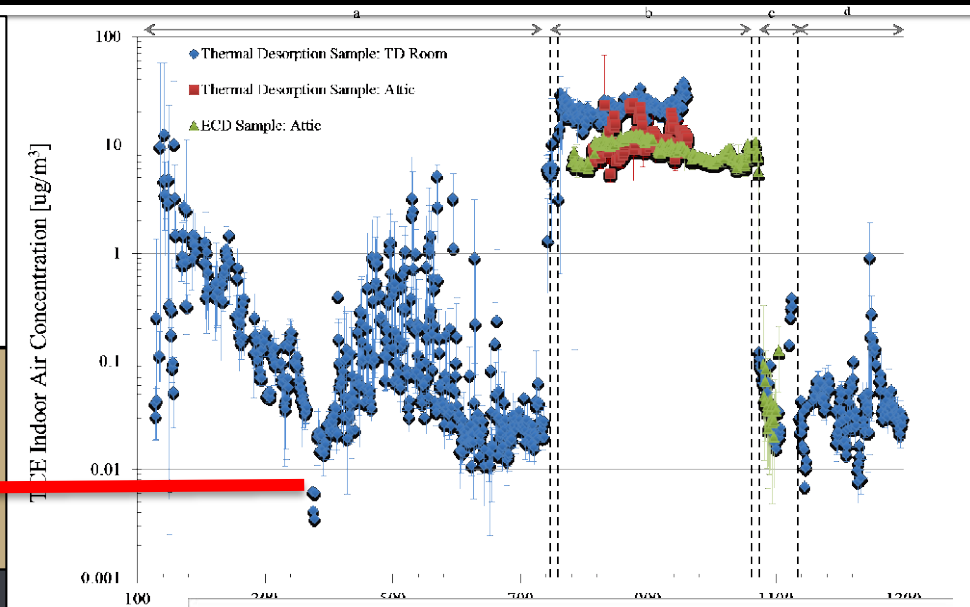

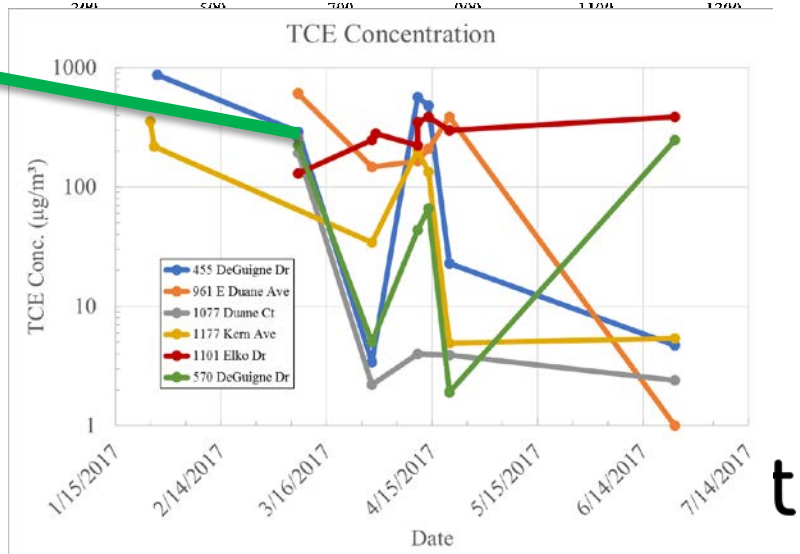

Pathway "inactive"

TCE in sewer

NO VI Detected

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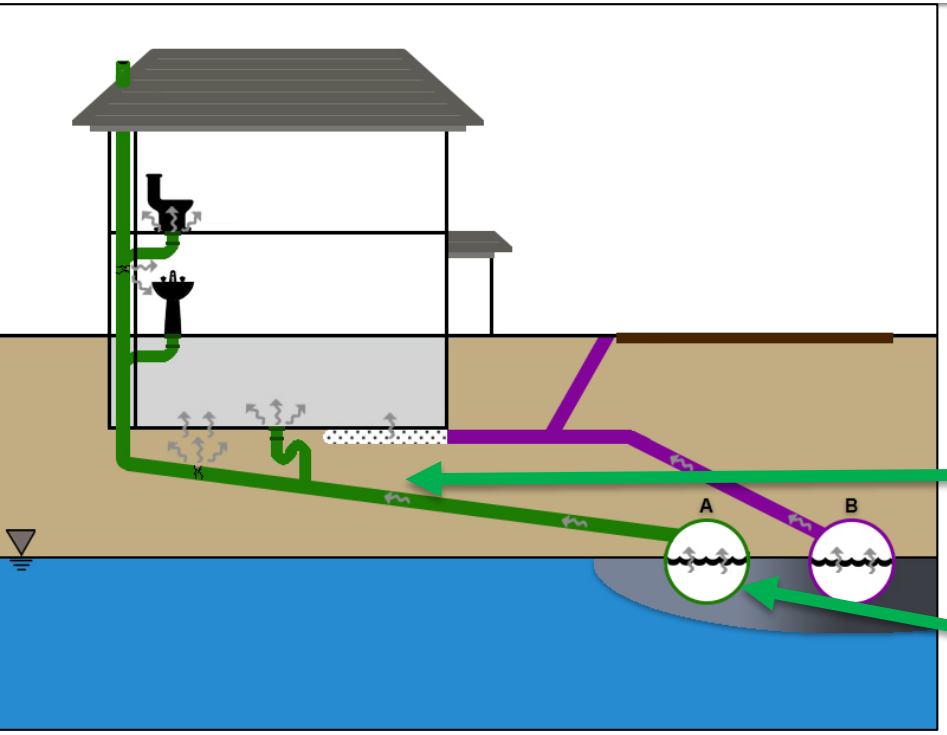
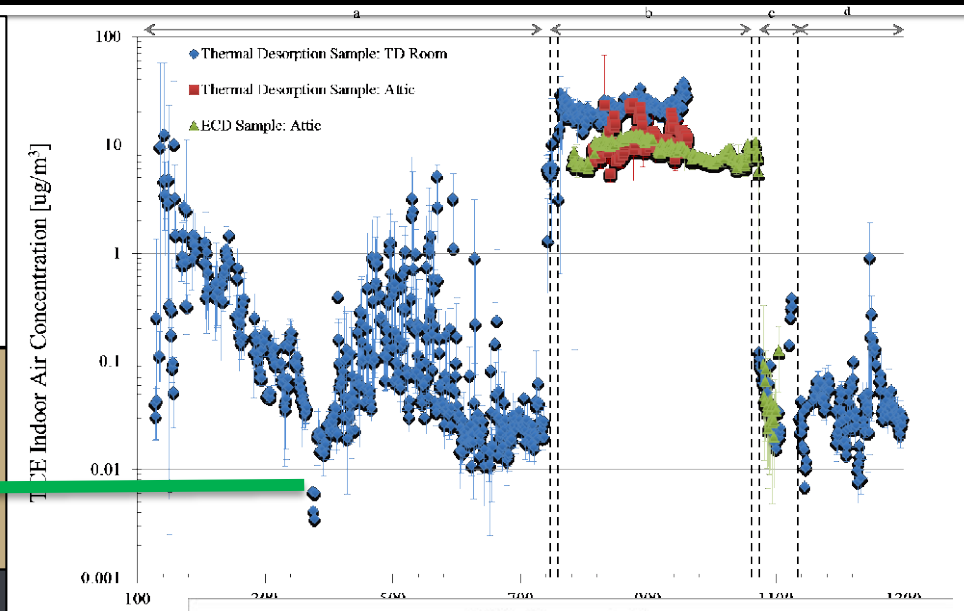
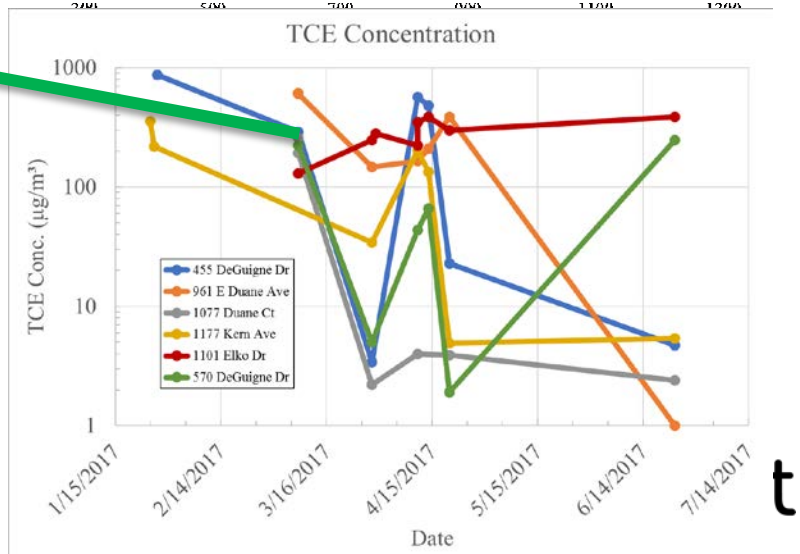
Screening with multiple variables







Pathway "active"

TCE in sewer

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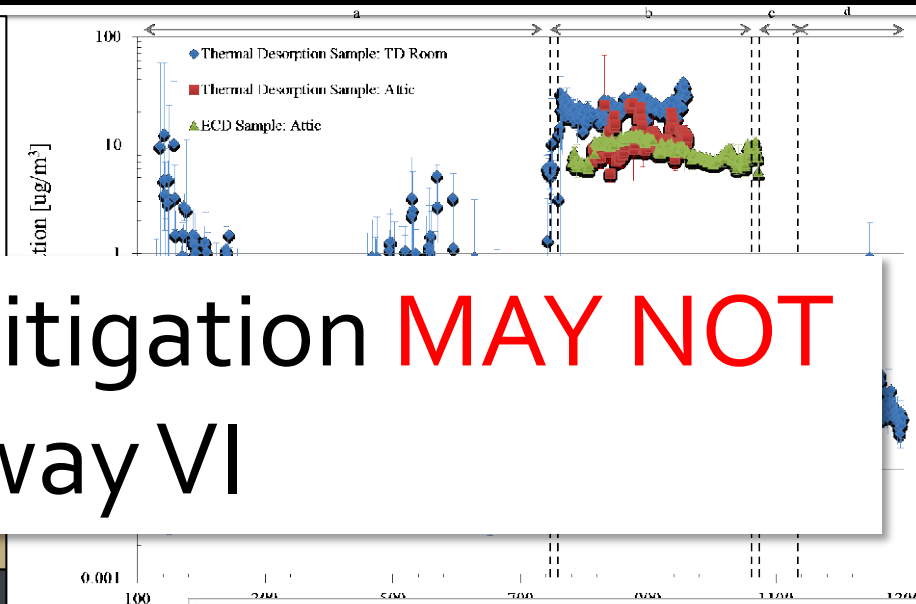
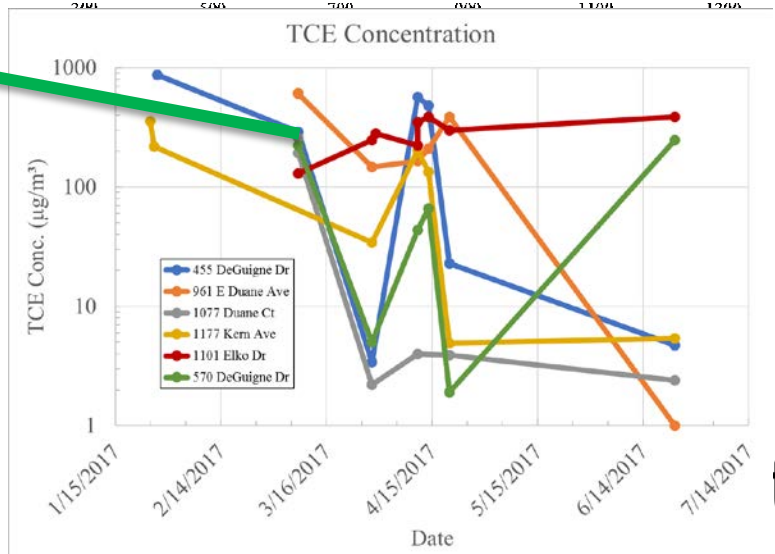
Screening with multiple variables



Soil-gas based VI mitigation MAY NOT impact sewer pathway VI



Pathway "active"

TCE in sewer

} VI Detected

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Conclusions

- cVOCs **frequently** migrate into sewer systems, particularly when sewers and groundwater intersect.
- cVOCs in the sewer **often** lead to unacceptable indoor air concentrations (~10%)
- Initial studies show attenuation factors of 0.02 (50x) have been found at multiple sites
- cVOC concentrations in the sewer can be **highly variable** on multiple timescales
- cVOCs in sewer systems pose a threat **that is comparable to direct soil-vapor driven VI**

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AROMA: Autonomous Rugged Optical Multigas Analyzer

TCE/BTEX trace vapor analyzer

- Real-time results
- Mobile, onsite, all-day battery
- Instrument MDL (3-Sigma, non-zero signal):

Species	MDL [µg/m³]	MDL [pptv]
TCE	0.03	6
Benzene	0.03	10
Toluene	0.06	17
Ethylbenzene	0.15	34
Xylene (combined)	0.15	34

1- Month calibration stability < 3%

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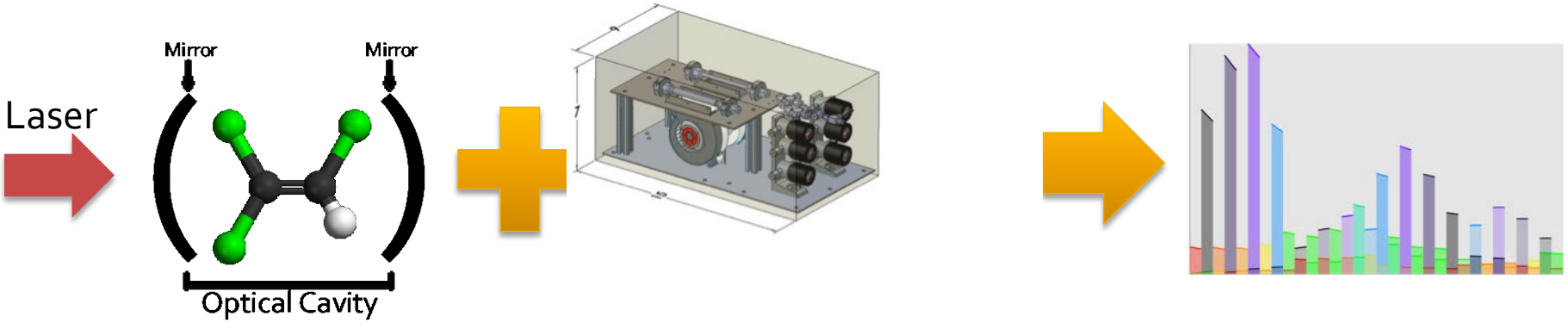
AROMA Approach



Cavity Ring-Down Spectroscopy

- Extremely sensitive optical detection technique
- Fundamental limits: part-per-trillion and better sensitivities
- Robust, compact, rugged
- Fast

Analyte Dispersion

- High performance chemical differentiation
- Selective
- High Dynamic range
- Includes Preconcentration

Chemical Fingerprint

- Dispersion and cavity ring-down spectroscopy yield identifiable chemical fingerprints
- Ultra-trace vapor detection in complex environments

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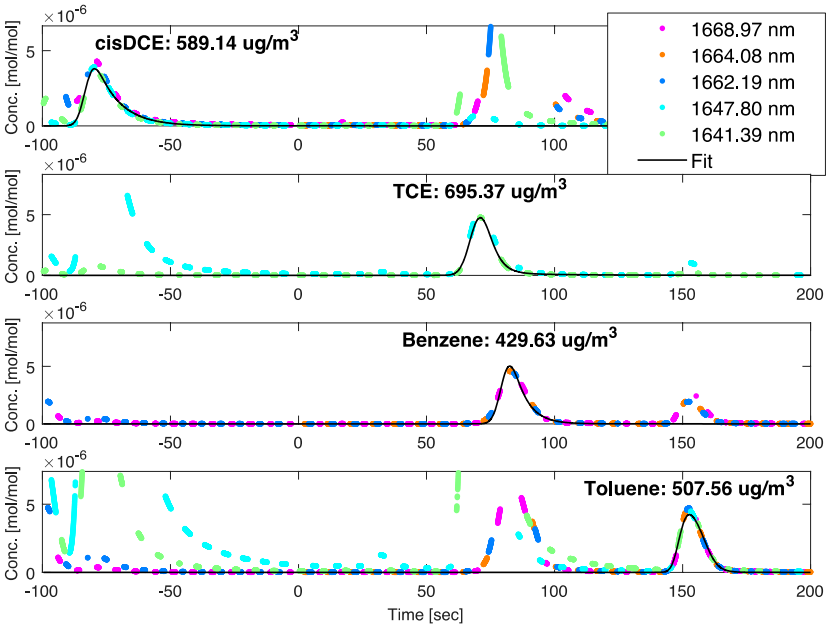
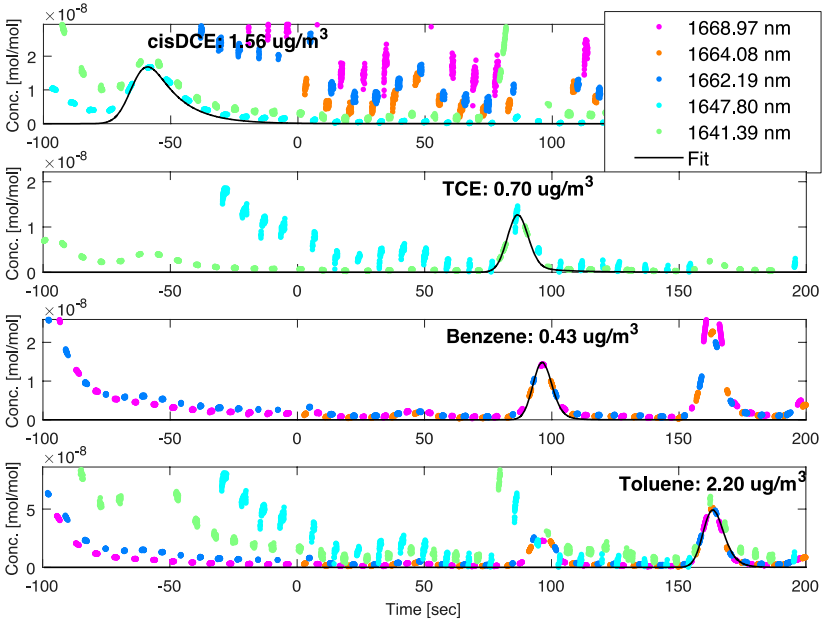
Multispecies detection with hopping



Fast hopping CRDS and analyte dispersion measurements at two concentrations. Automated fitting results (black) shown.



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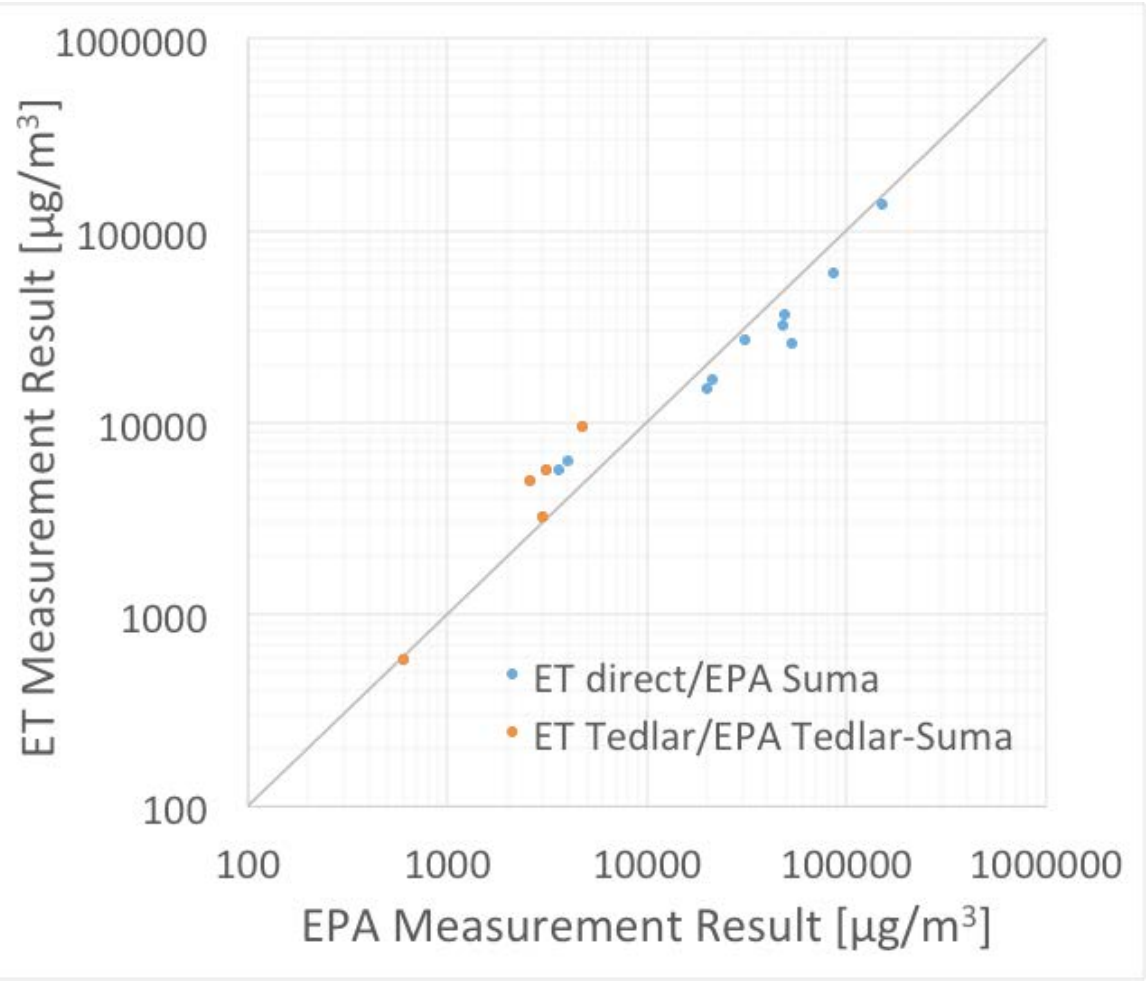
TCE Soil gas side by side



Measurements performed at contaminated site under EPA supervision.
All samples simultaneous TO-15 (analyzed by EPA Region 9 Laboratory) and AROMA.
Blue: Direct samples drawn from soil gas to instrument
Orange: Tedlar intermediated
Excellent agreement over broad dynamic range.
Allows for rapid determination of step-outs

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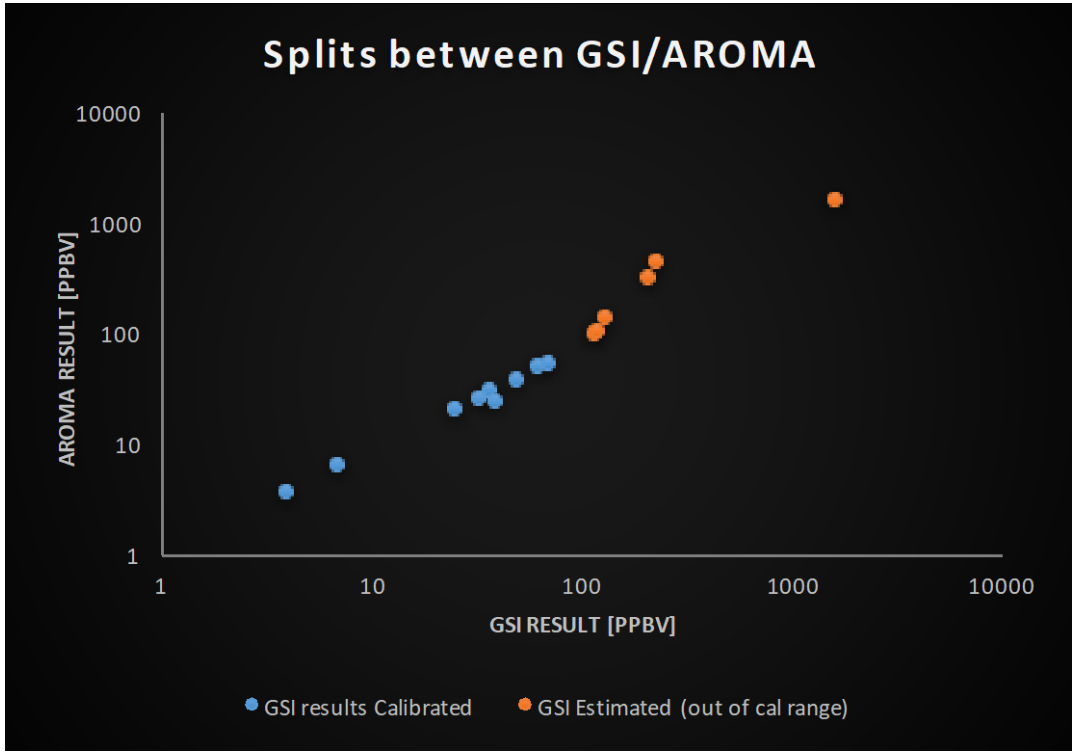
Sewer gas splits with GSI

- Sewer gas splits against Hapsite instrument.
- Thanks to Tom McHugh and GSI (temchugh@gsi-net.com)
- High concentrations out of Hapsite calibration range, estimated results reported. Highest concentration had no reported Hapsite result.



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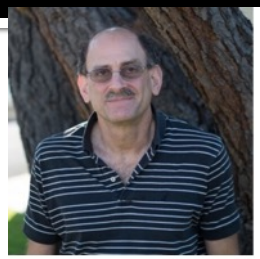
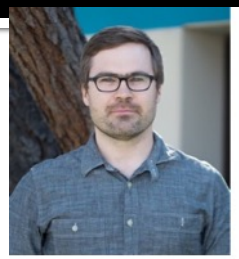
ET science and engineering team


Bruce Richman


Artyom Vitouchkine


Ricardo Viteri


Gunnar Skulason


Anthony Miller

Not Pictured: Mike Armen, Ari Kushner

Special thanks to Kelly G. Pennell, Tom McHugh, Lila Beckley, Yuanming Guo, Blayne Hartman, and Alana Lee for support and advice during this work.

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- Yuanming Guo, Ph.D.
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- EPA Region 9
  - Alana Lee

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