

Assessment of toluene biodegradation activity in groundwater from a shallow bedrock aquifer with phytoremediation

Andrea Roebuck (aroebuck@uoguelph.ca), Kamini Khosla, Kari Dunfield
(University of Guelph, Guelph, ON, Canada)

Jeremy Fernandes, Beth Parker, Steve Chapman (G360 Group, University
of Guelph, Guelph, ON, Canada)

Ramon Aravena (University of Waterloo, Waterloo, ON, Canada)

Elizabeth Haack (Advisian)



Site Introduction-Recap

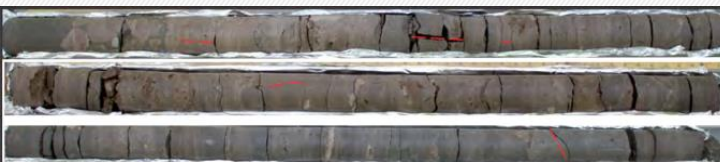
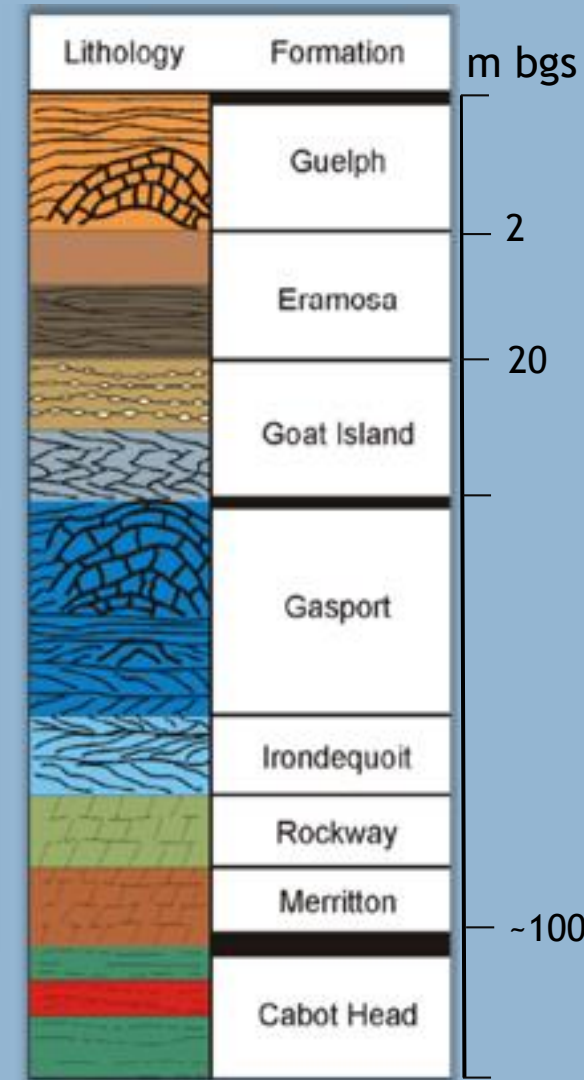
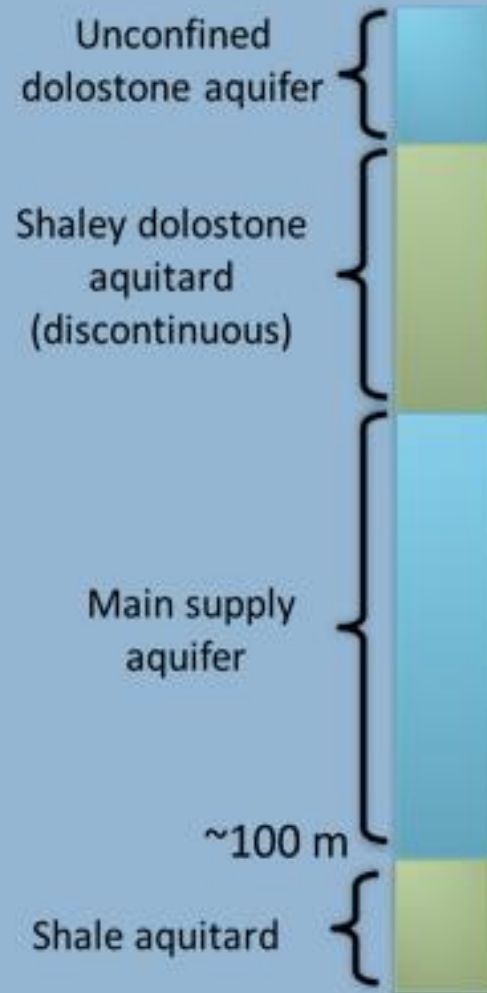
Collaboration with BP, G³⁶⁰, and the University of Waterloo



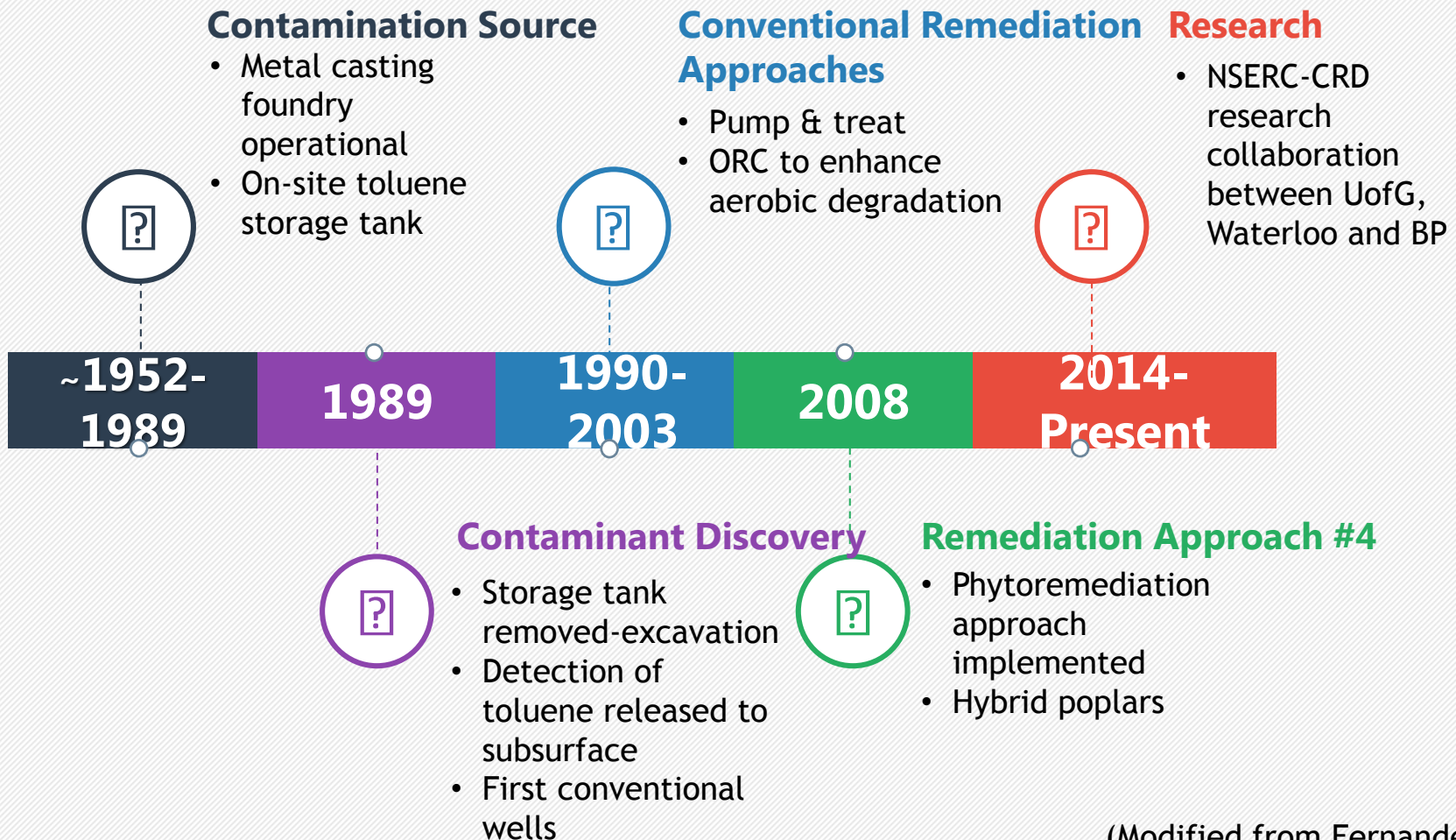
- Toluene contaminated brownfield in Southwestern Ontario

Site Geology and Physical Context

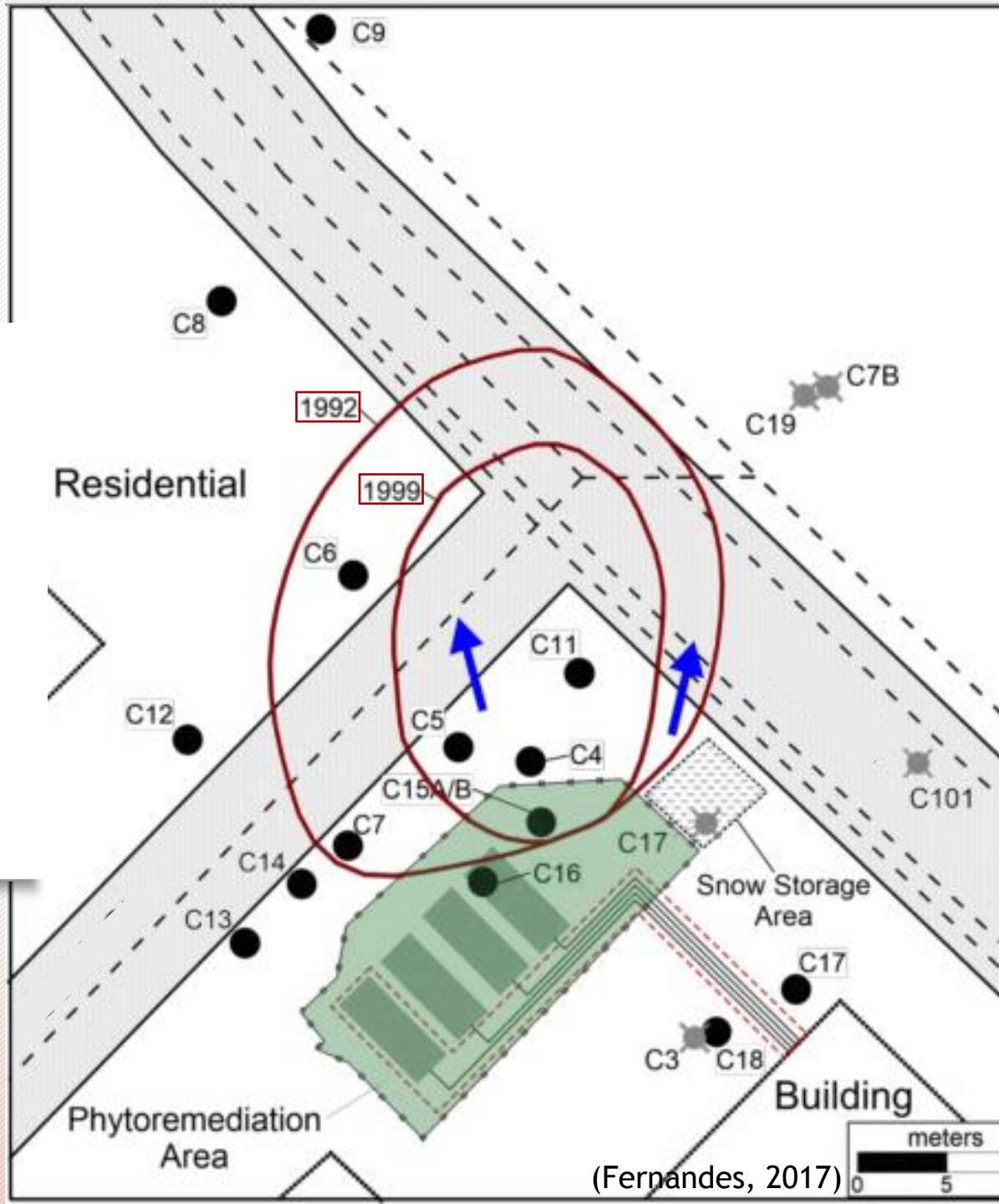
- Fractured (Silurian era dolostone) bedrock aquifer
- Porous rock matrix
- Gasport is main water supply for 500 000 residents



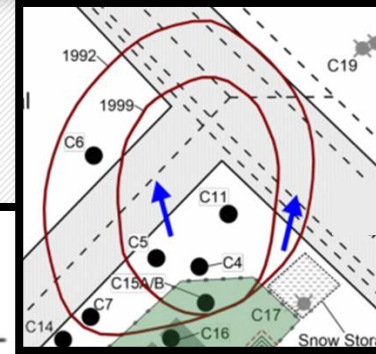
Site History



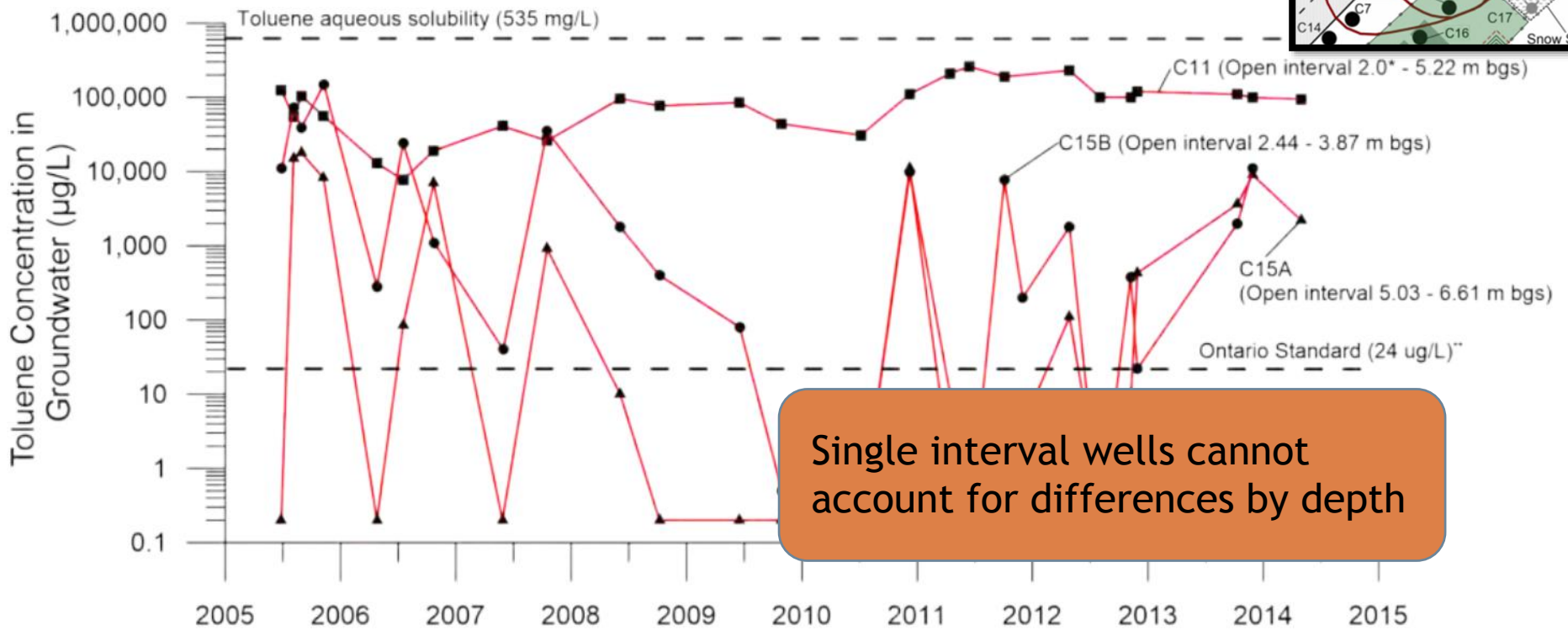
Historical Data



Historical Data



a. Toluene concentrations



Single interval wells cannot account for differences by depth

The Discrete Fracture Network (DFN) Approach

Drill New Coreholes

1. Rock Core

VOCs

Core Logging

2. Borehole

Geophysics and hydrophysics

Hydraulic transmissivity

Multilevel system:

Hydraulic head

Contaminant concentration

Hydrochemistry

Microbial Sampling

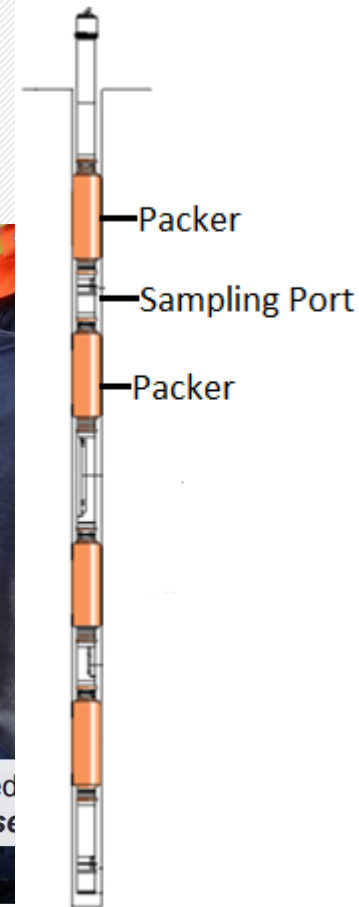


Figure 1.
Multilevel System



The Discrete Fracture Network (DFN) Approach

Drill New Coreholes

1. Rock Core

VOCs

Core Logging

2. Borehole

Geophysics and hydrophysics

Hydraulic transmissivity

Multilevel system:

Hydraulic head

Contaminant concentration

Hydrochemistry

Microbial Sampling

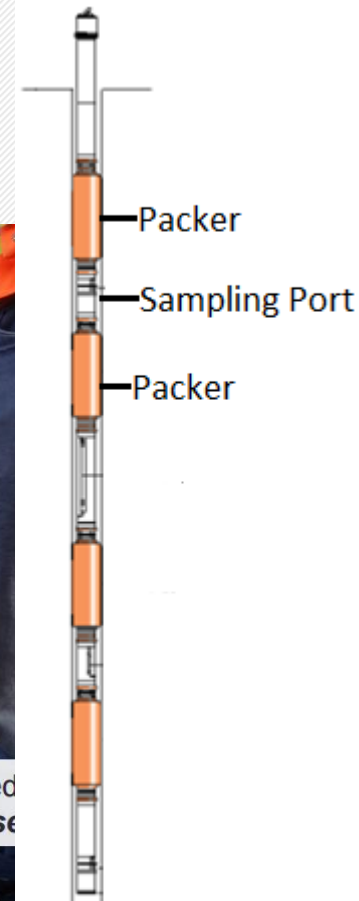
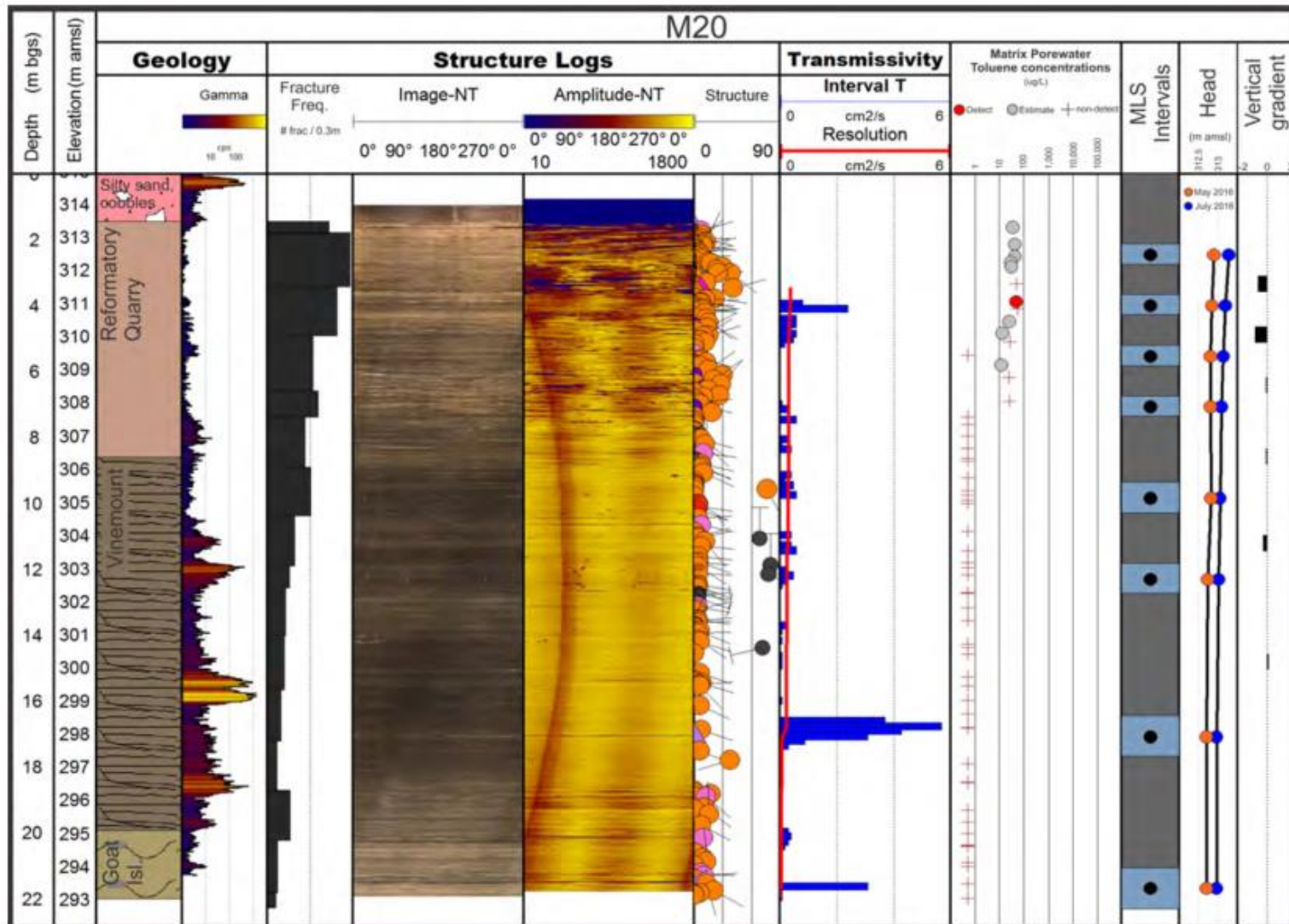


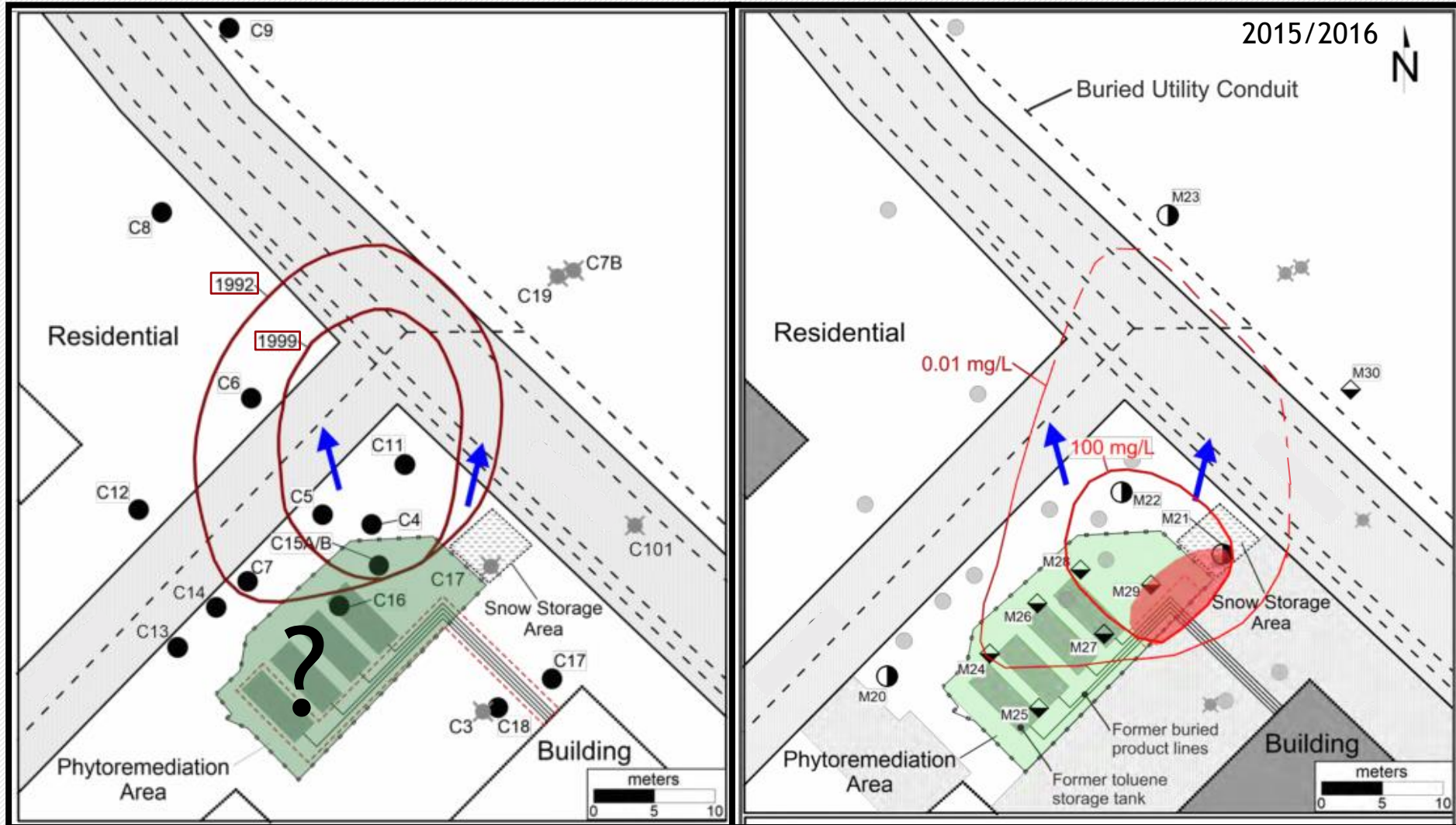
Figure 1.
Multilevel System

- High resolution plume delineation
- Fracture network characterization
- Depth discrete data collection

Single Borehole Datasets: Profiles



Multilevel Distribution

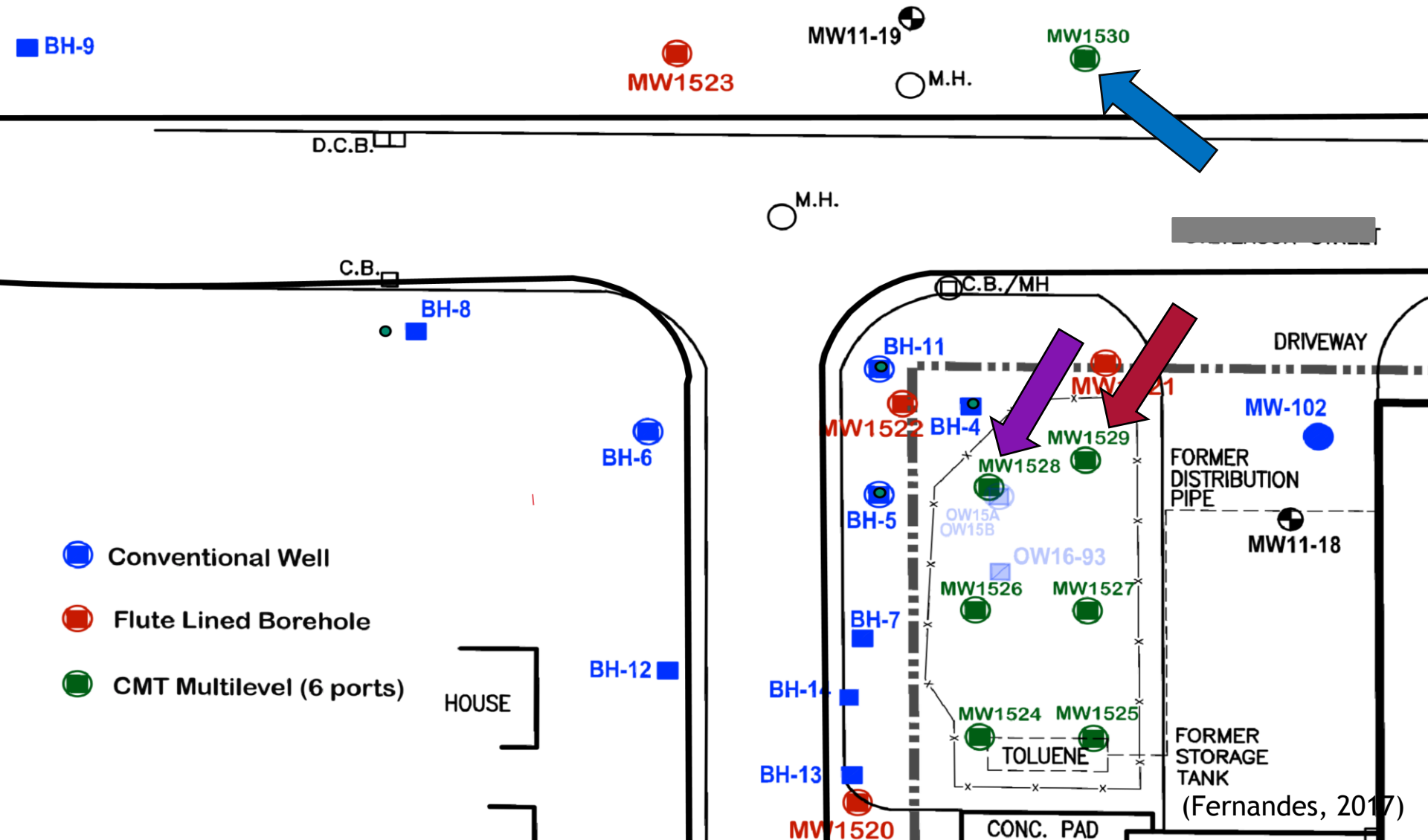


Objectives:

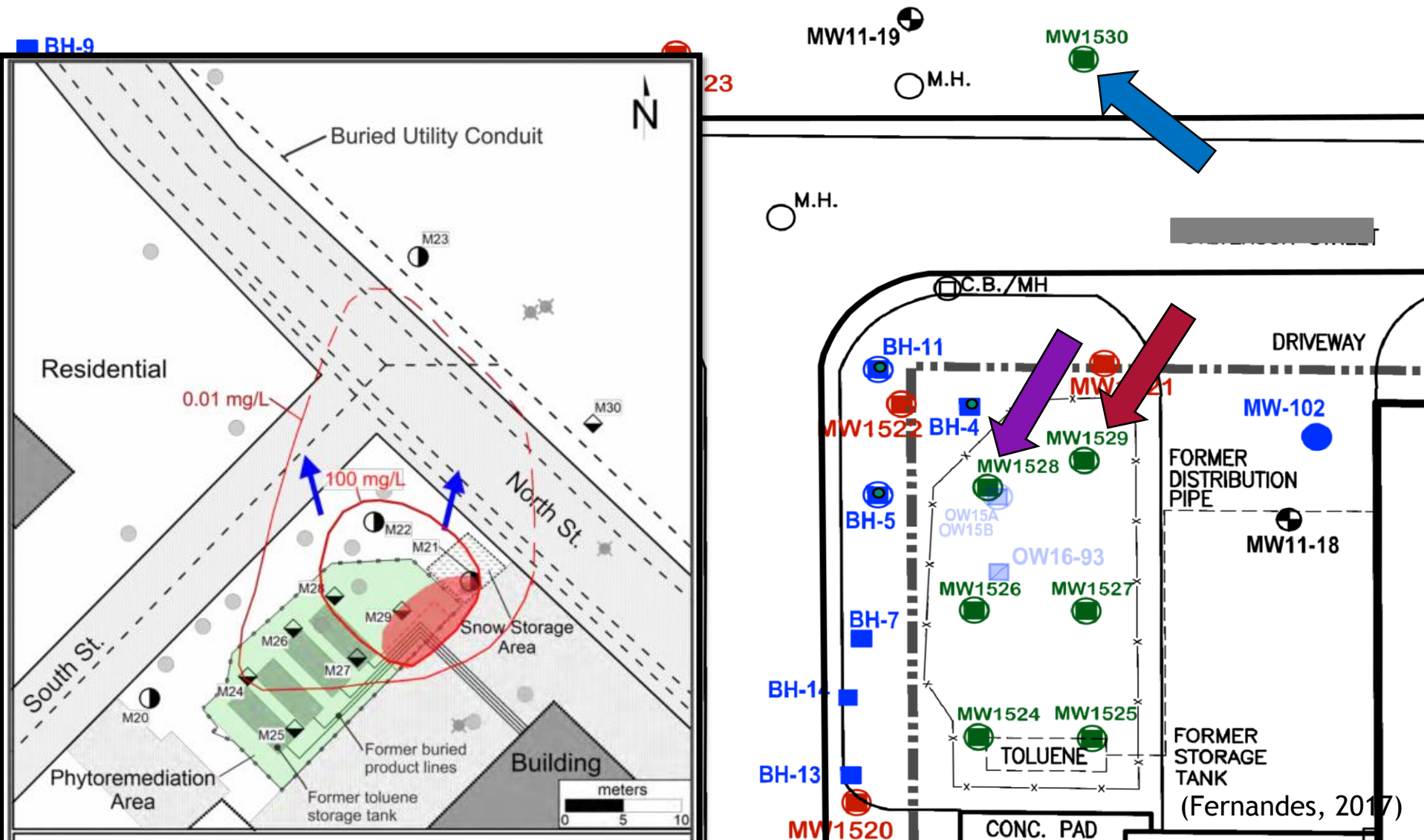
- Quantify abundance and potential degradation activity of anaerobic toluene degraders in **groundwater** using molecular methods



Sampling Groundwater

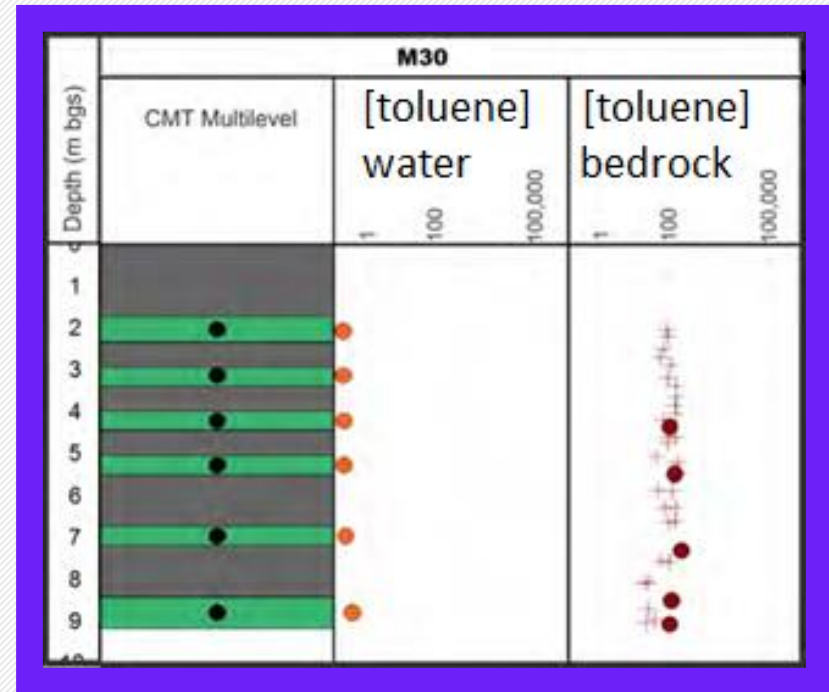


Sampling Groundwater



Rock Core and Groundwater Data

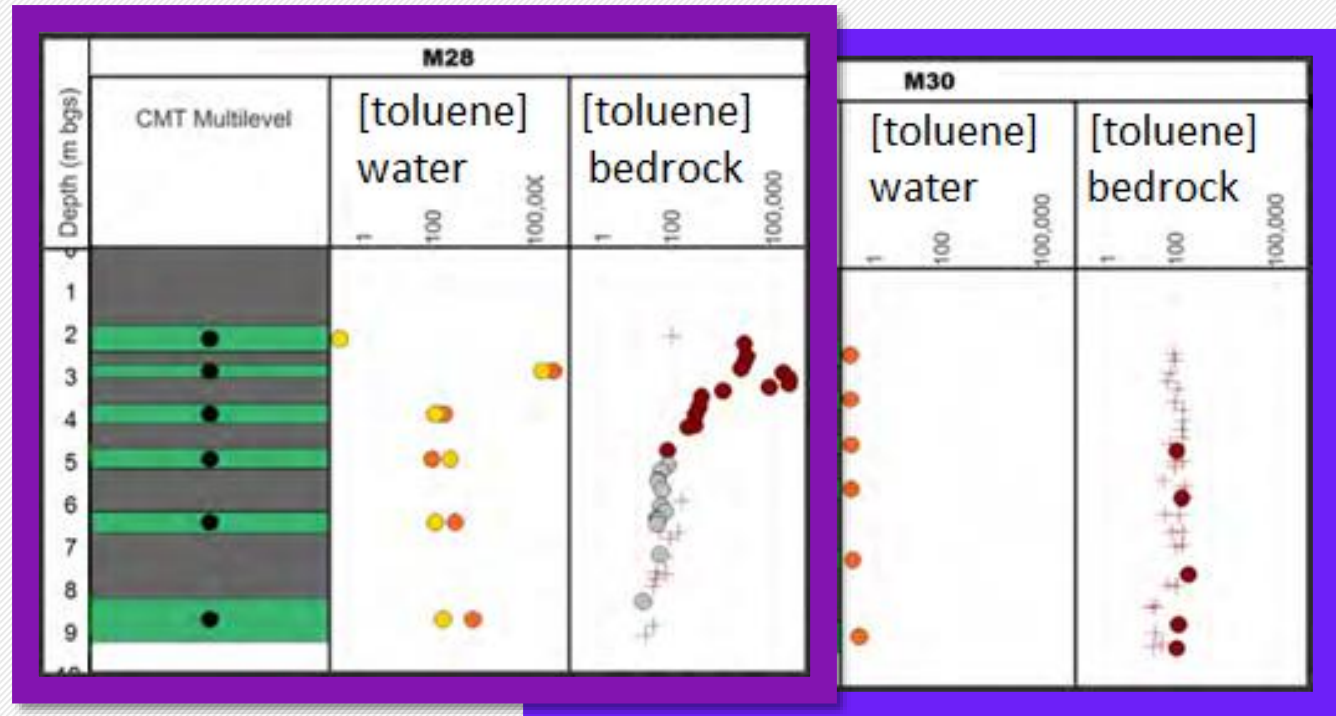
Off Site



Rock Core and Groundwater Data

Down Gradient

Off Site

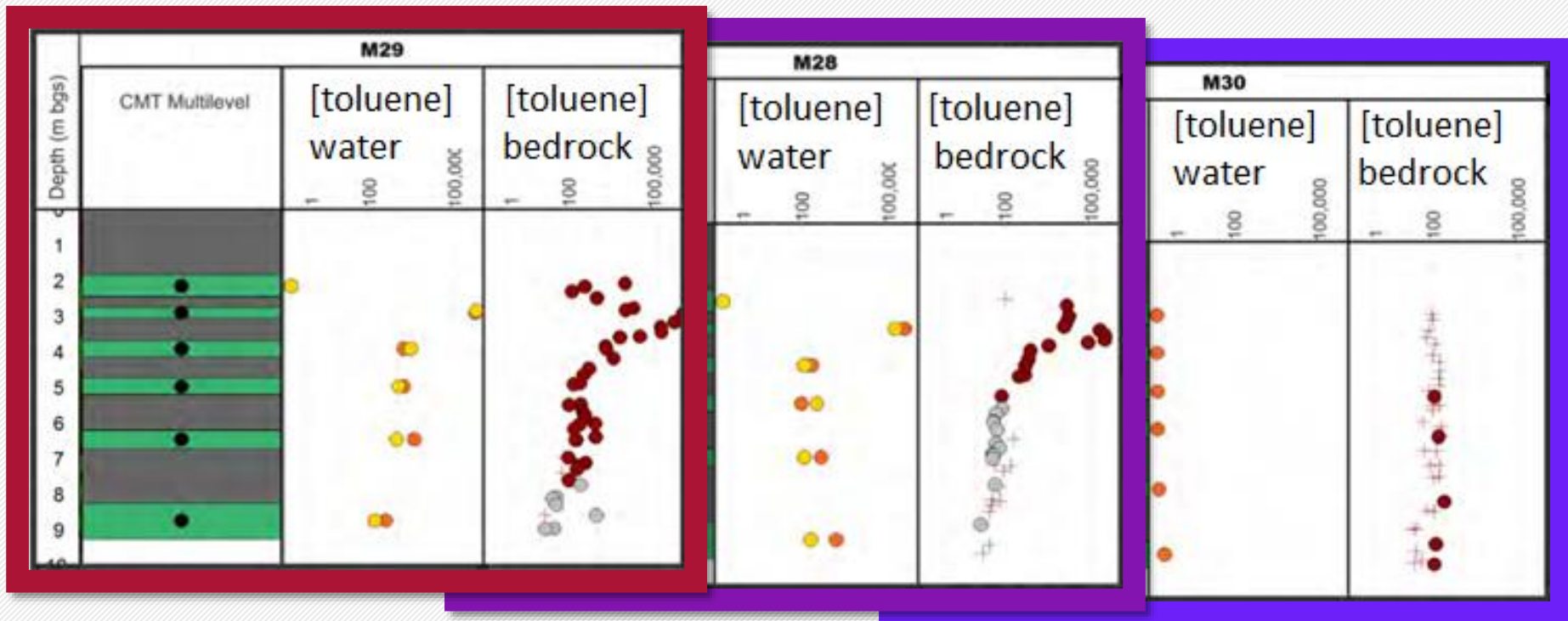


Rock Core and Groundwater Data

Source Zone

Down Gradient

Off Site



- ~95% of toluene mass located mainly in first 2m of bedrock matrix

- Diffusion
- Sorption
- Biodegradation

Sample Collection

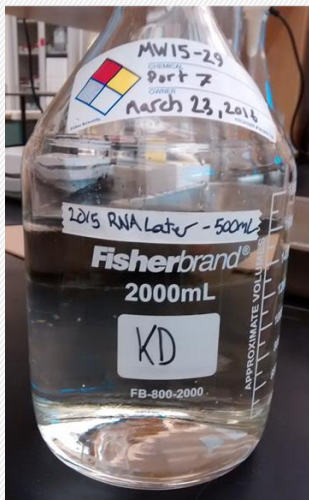
Sampling Events:

November 2015

March 2016

June 2016

November 2016

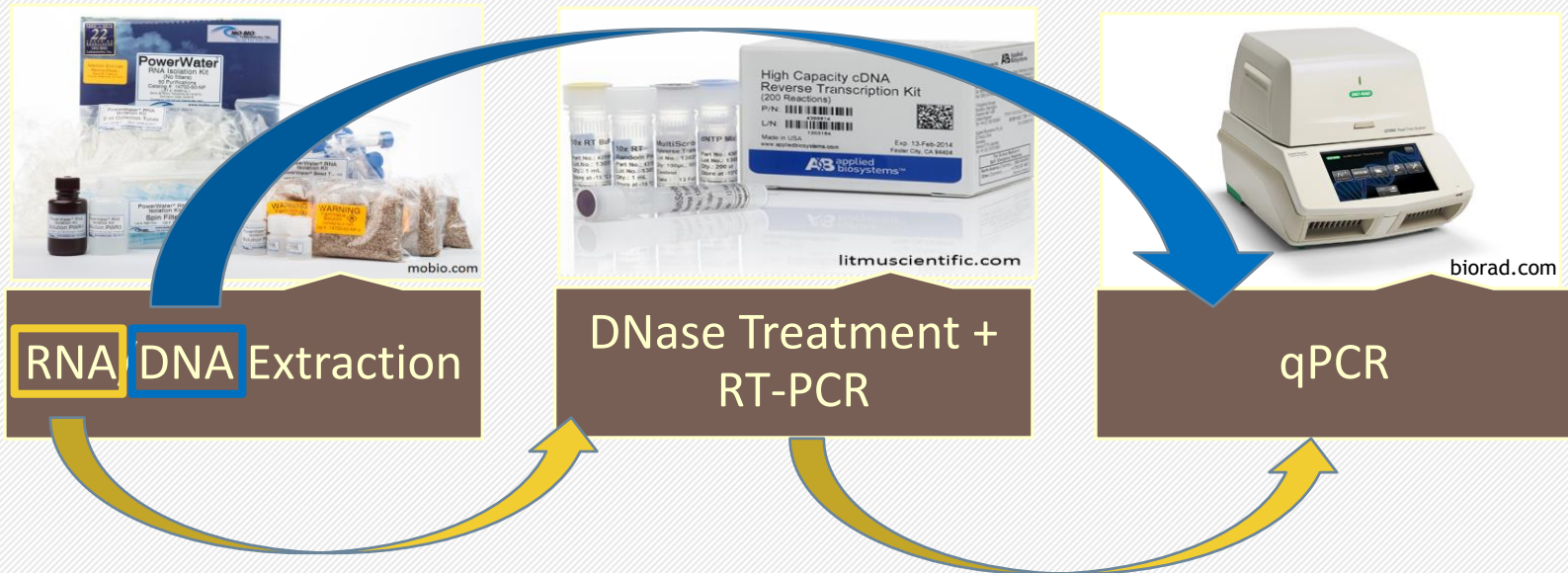




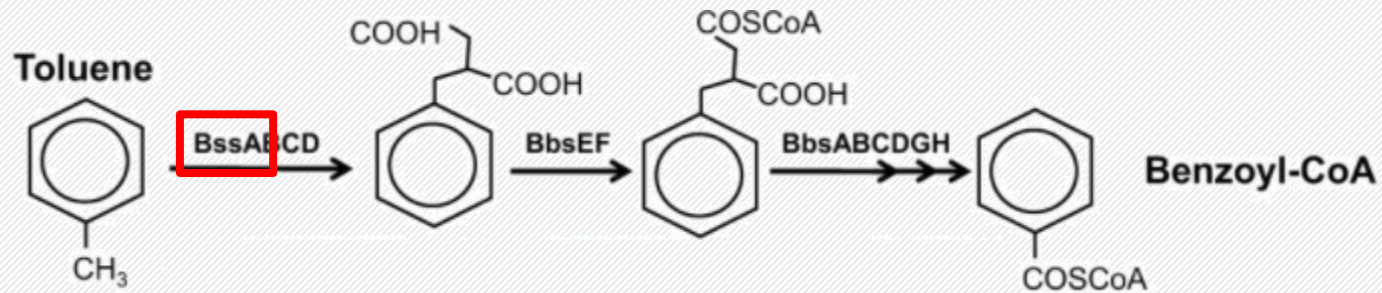
Sample Processing- Filtration

Microbial communities are captured by vacuum membrane filtration using a 0.22 μ m pore membrane.

Sample Processing Molecular Process



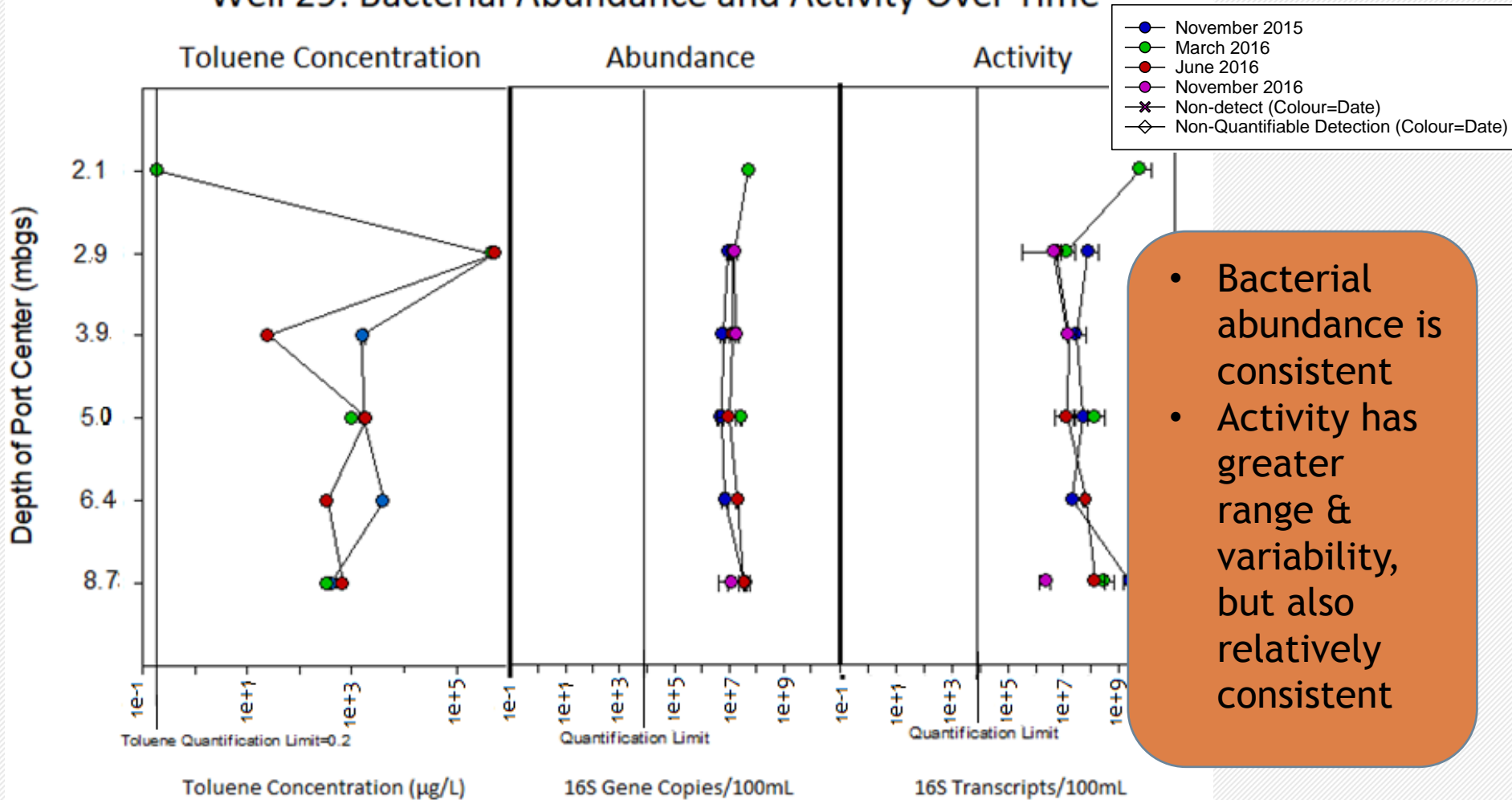
Bacterial abundance & activity:
16S rDNA and rRNA



(Modified from Zhang *et al.*, 2013)

Bacterial Abundance and Activity

Well 29: Bacterial Abundance and Activity Over Time



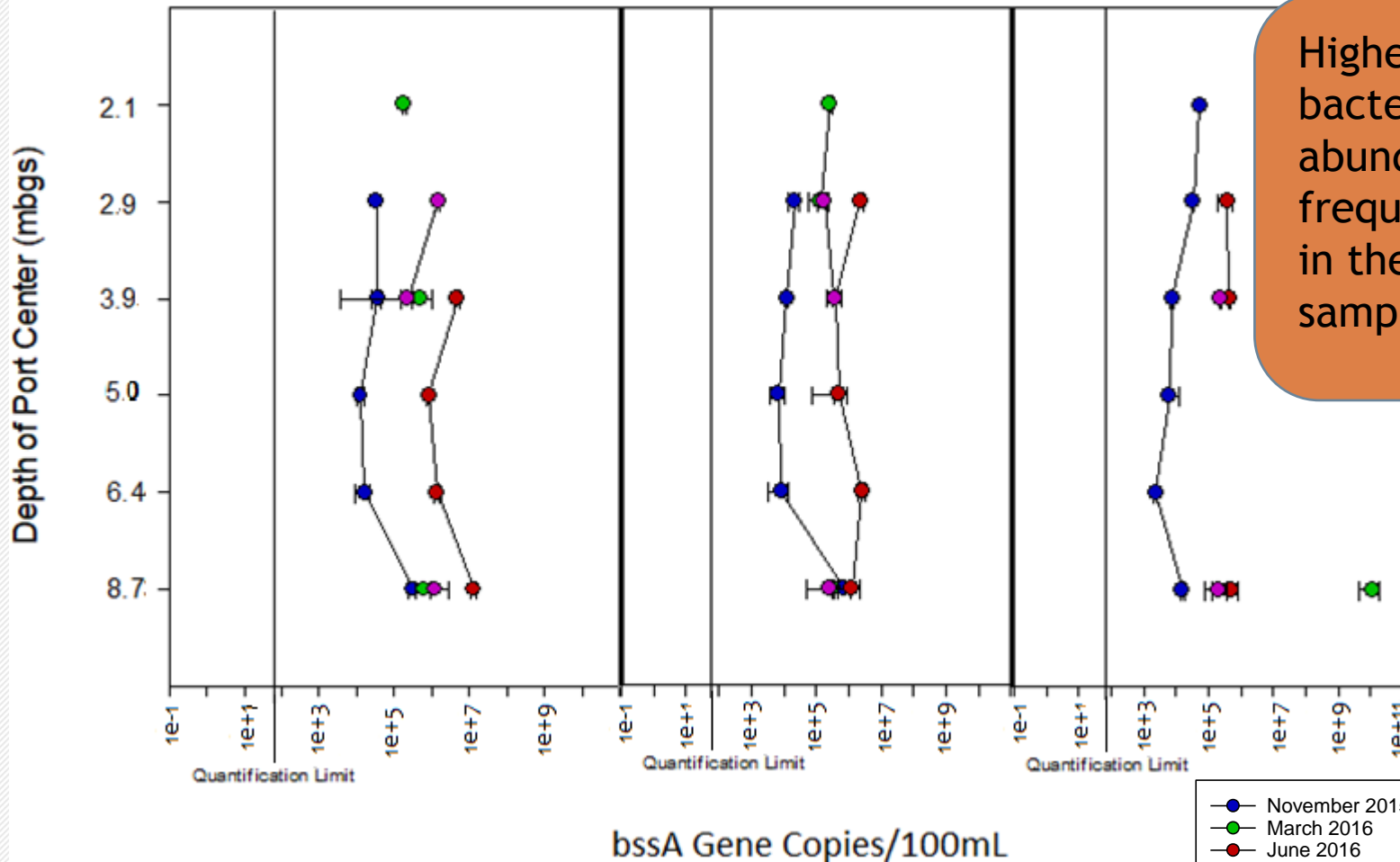
- Bacterial abundance is consistent
- Activity has greater range & variability, but also relatively consistent

Seasonal Trends In Potential Anaerobic Degradader Abundance

Well 28-Downgradient

Well 29-Source Zone

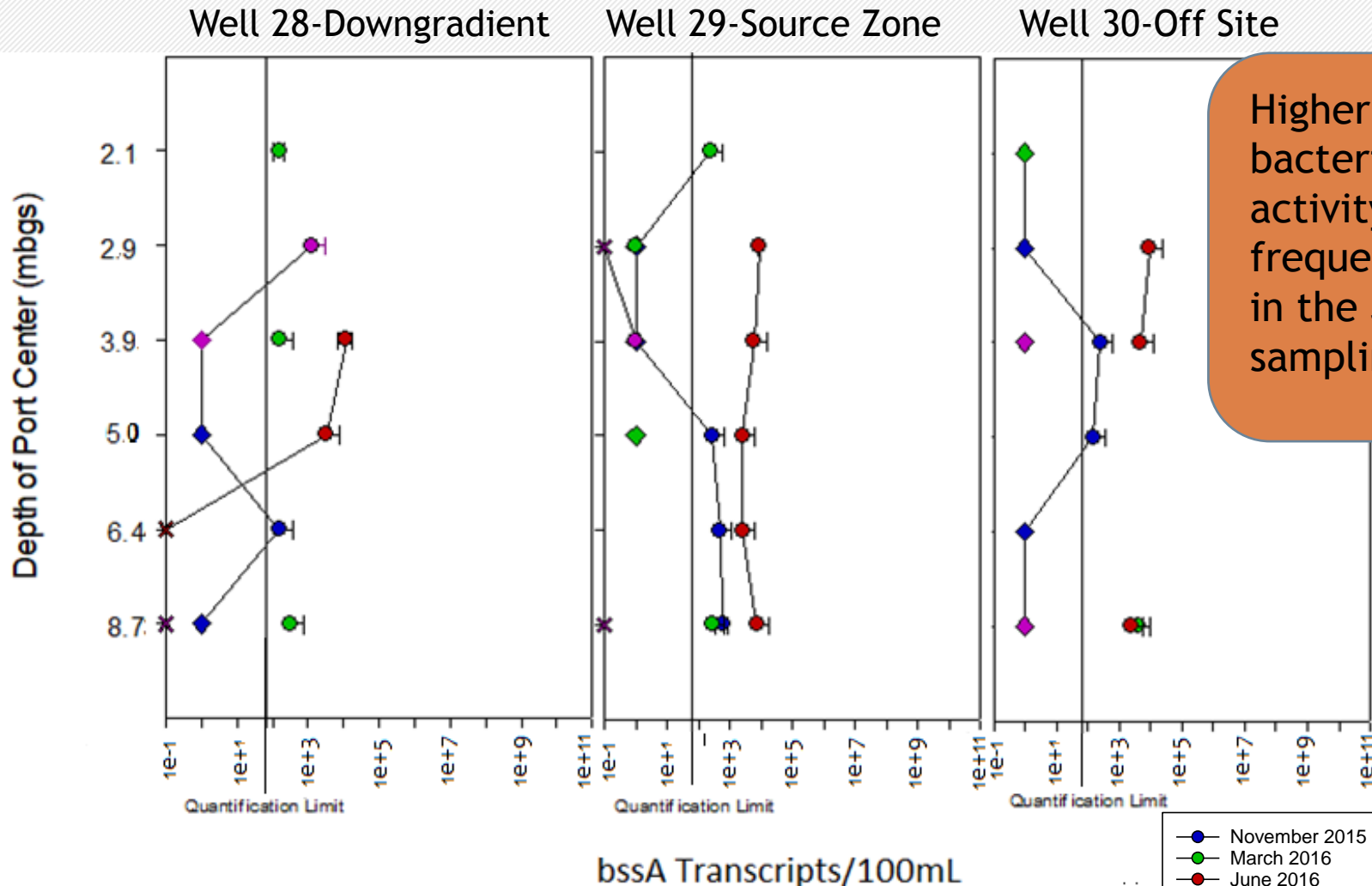
Well 30-Off Site



Higher bacterial abundance frequently seen in the June sampling event

- November 2015
- March 2016
- June 2016
- November 2016
- ✕ Non-detect (Colour=Date)
- ◇ Non-Quantifiable Detection (Colour=Date)

Seasonal Trends In Potential Anaerobic Degradation Activity

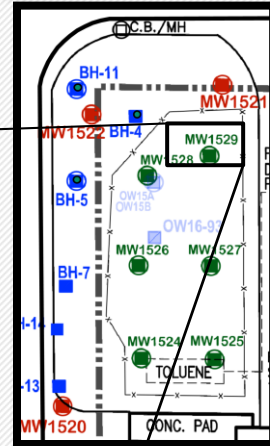
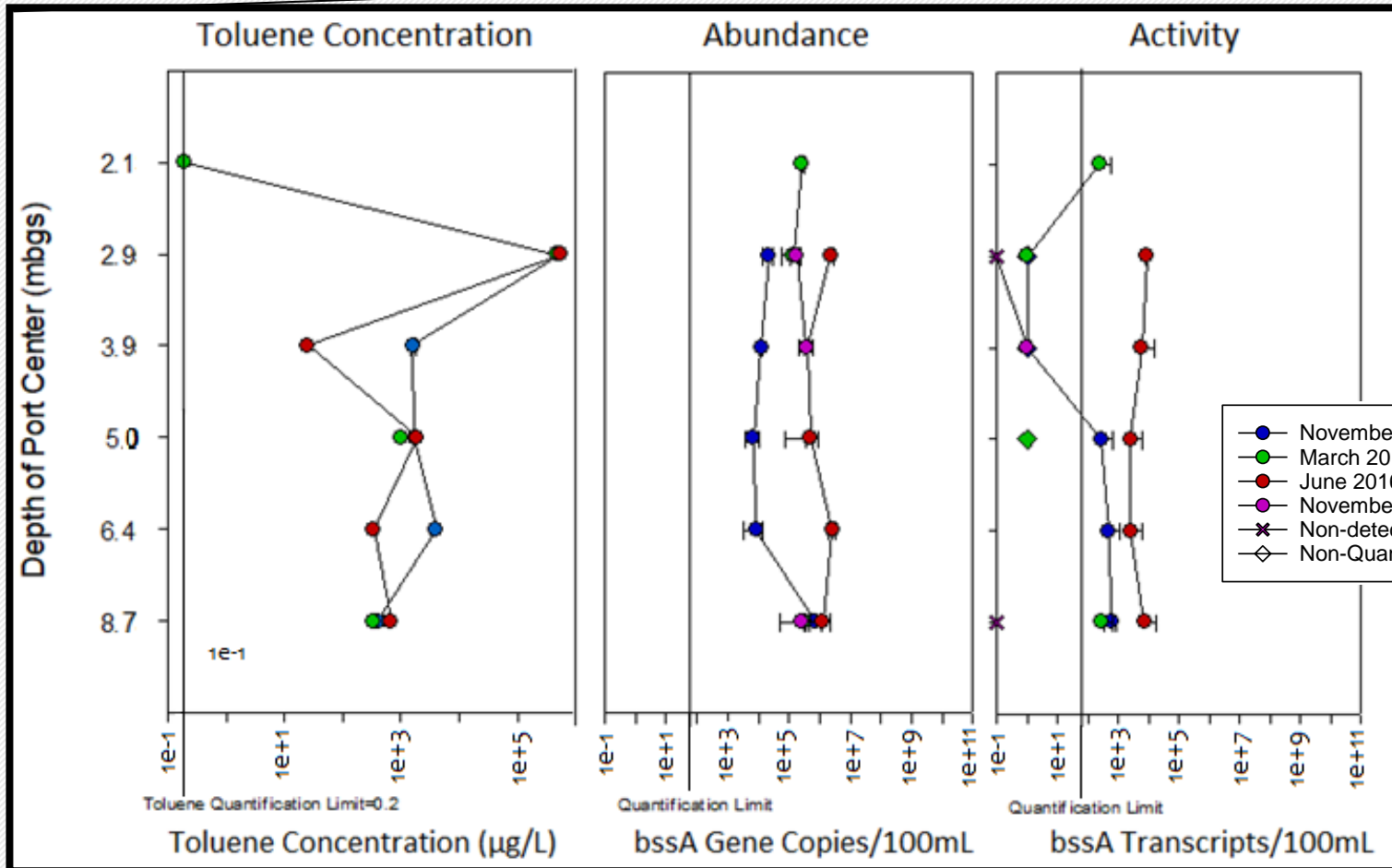


Higher bacterial activity also frequently seen in the June sampling event

- November 2015
- March 2016
- June 2016
- November 2016
- * Non-detect (Colour=Date)
- ◇ Non-Quantifiable Detection (Colour=Date)

Anaerobic Toluene Degradator Abundance and Activity: Overview

Well 29- Source Zone

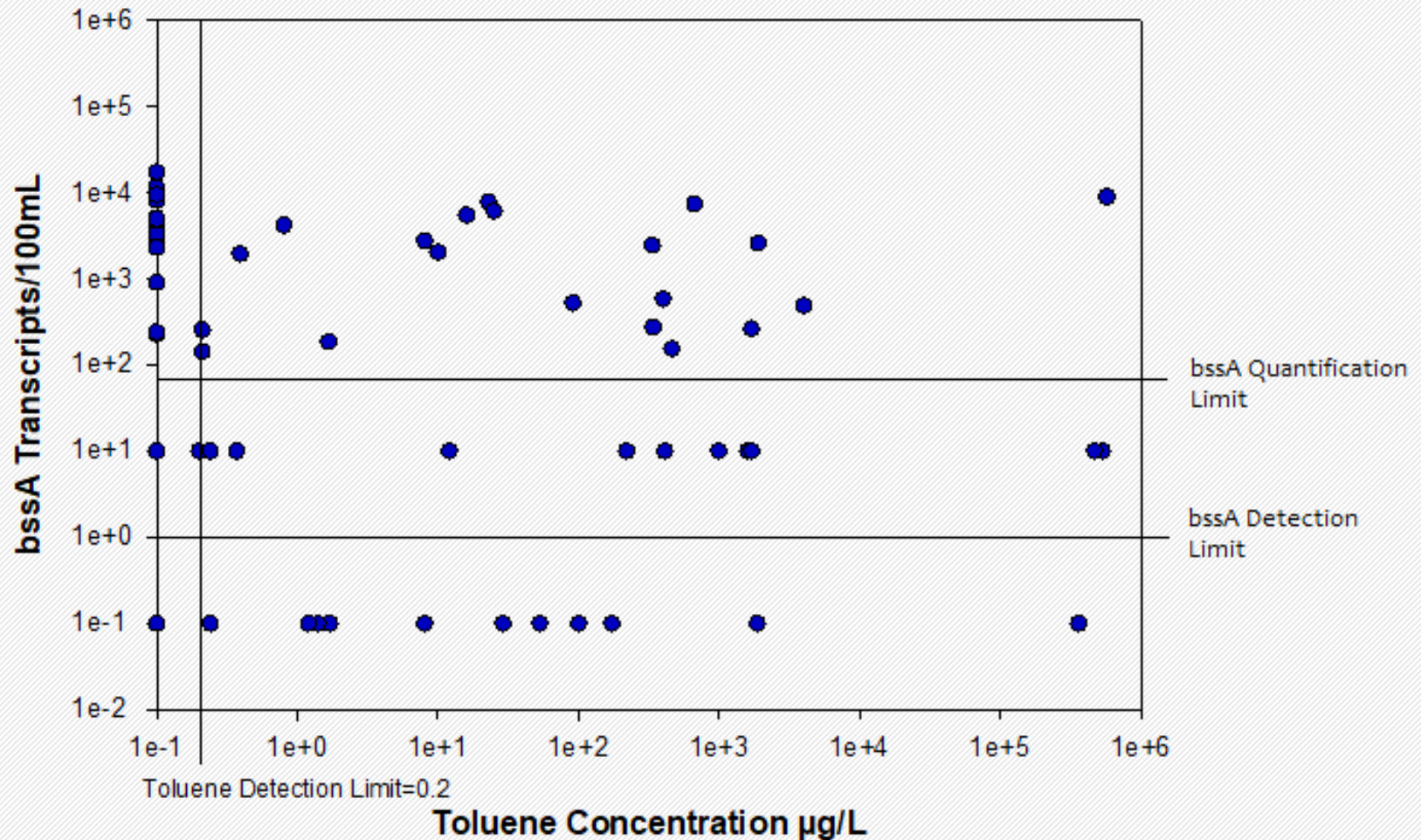


Legend:

- November 2015
- March 2016
- June 2016
- November 2016
- × Non-detect (Colour=Date)
- ◇ Non-Quantifiable Detection (Colour=Date)

Correlation

Toluene Concentration and *bssA* Transcripts



Conclusions & Future Directions

Concluding:

- Consistent bacterial abundance
- Evidence of some seasonal effect
- Active anaerobic degraders detected

Coming up:

- Temporally matching CSIA and microbial sample collection
- Continued seasonal sampling



Acknowledgements



BP Canada Alan Scheibner, Mike Early and Larry Stone

BP Remediation Engineering and Technology David Tsao

G360 Institute for Groundwater Research Beth Parker, Kari Dunfield, Steve Chapman, Jeremy Fernandes, Phillipp Wanner

University of Waterloo Ramon Aravena

Advisian Elizabeth Haack

AECOM Sean Todd, Kelly Ali, Nicholas Frey, Scott Alexander

Additional Thank-you: Kamini Khosla, Michael Ben-Israel, John Drummelsmith, Jonathan Gaiero, Jemaneh Habtewold, Nicola Linton, James Hommersen and many more!

Battelle



References

- Fernandes, J. (2017). *Nature and Extent of Toluene Contamination in a Shallow Dolostone Aquifer using High Resolution Methods for Assessing Natural and Anthropogenic Influences*. MSc. Thesis, School of Engineering. University of Guelph. 98 pp.
- Zhang, T., Tremblay, P., Chaurasia, A. K., Smith, J. A., Bain, T. S., & Lovley, D. R. (2013). Anaerobic Benzene Oxidation via Phenol in *Geobacter metallireducens*, 79(24), 7800-7806.