Gas Migration Field Investigations at a Leaking Petroleum Well

PTAC's Water Innovation Planning Committee Meeting

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M. Cathy Ryan, Professor
Tiago A. Morais, PostDoc (formerly PhD)
Rafael Terada, Post Doc
Neil A. Fleming, former MSc student
Bernhard Mayer, Professor

Ulrich Mayer, Professor, UBC
Beth L. Parker, Professor, University of Guelph
Steve Chapman , University of Guelph

May 9th, 2024

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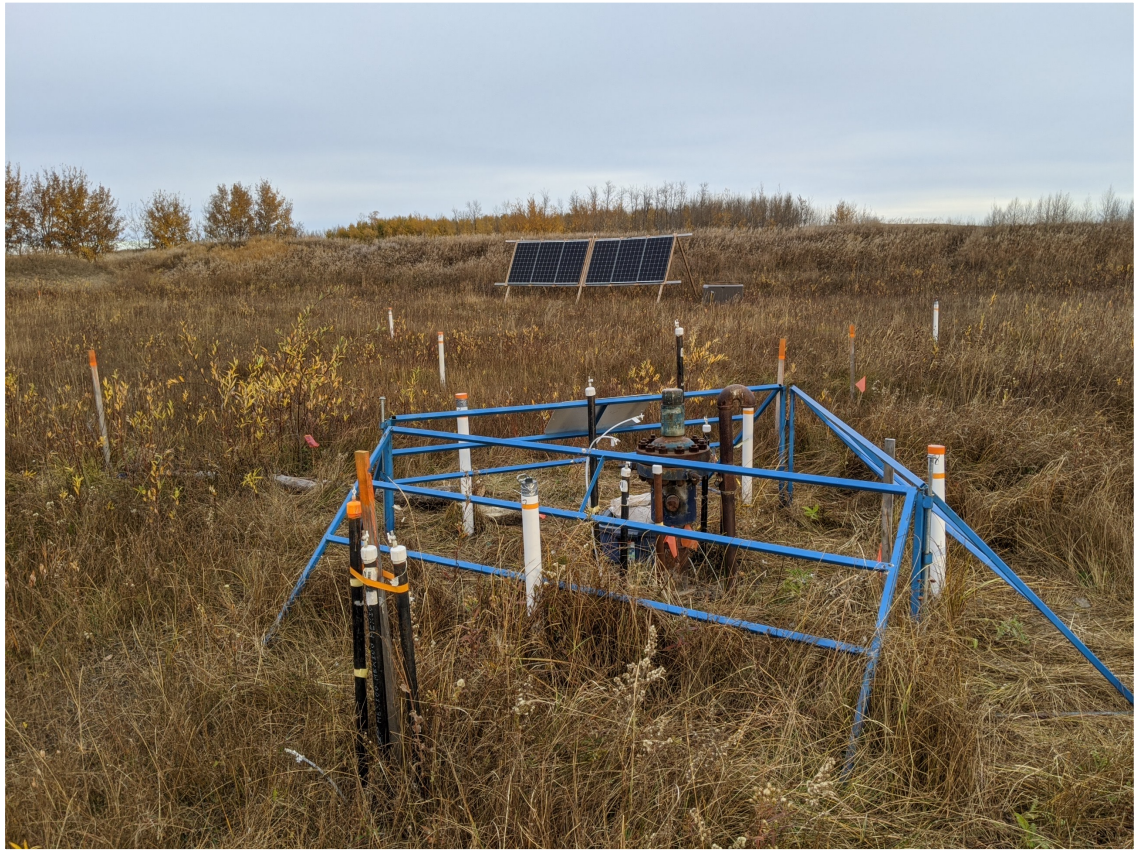
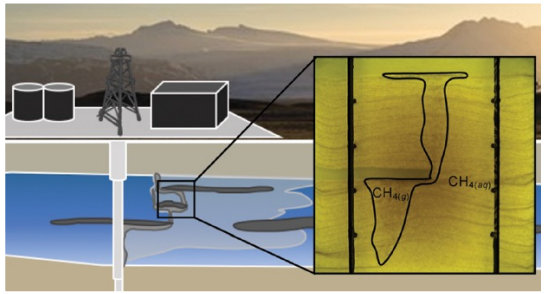
Motivation

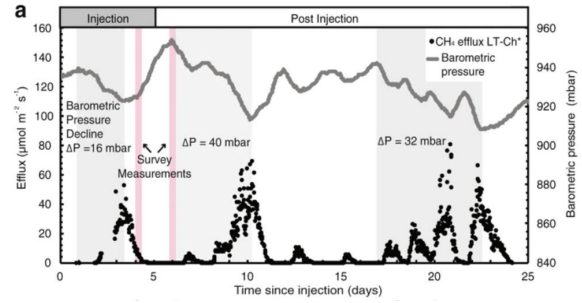
- Greenhouse gas emissions
- Groundwater impacts
  - Dissolved CH_4
  - Chemical and microbiological shifts due to CH_4 invasion
- Land Use
  - Safety concerns
- Inactive/suspended wells
  - Anecdotally ~$150K+ per well repair attempt
  - ‘Low-leaker’ repairs are notoriously unsuccessful

Characterize GM and determine if findings from previous studies are observed around industry wells





Van de Ven & Mumford, 2020



Forde et al, 2019

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Project Timeline

- Industry Partners ✓
- GM surveys ✓
- Preliminary fieldwork ✓

PHASE 1 ✓

Comparison of GM testing across multiple industry wells

- Fieldwork ✓
- First manuscript ✓
- Second manuscript ✓

PHASE 2 ✓

Identification and selection of a suitable well for further investigation

Detailed characterization of emissions and concentrations characteristics of the study well

- Fieldwork ✓
- Third manuscript ✓
- GW instrumentation ✓

PHASE 3 ✓

Preliminary investigation to enable appropriate planning for GW instrumentation

Drilling, coring, and installation of GW monitoring network

- Additional fieldwork
- Fourth publication

PHASE 4

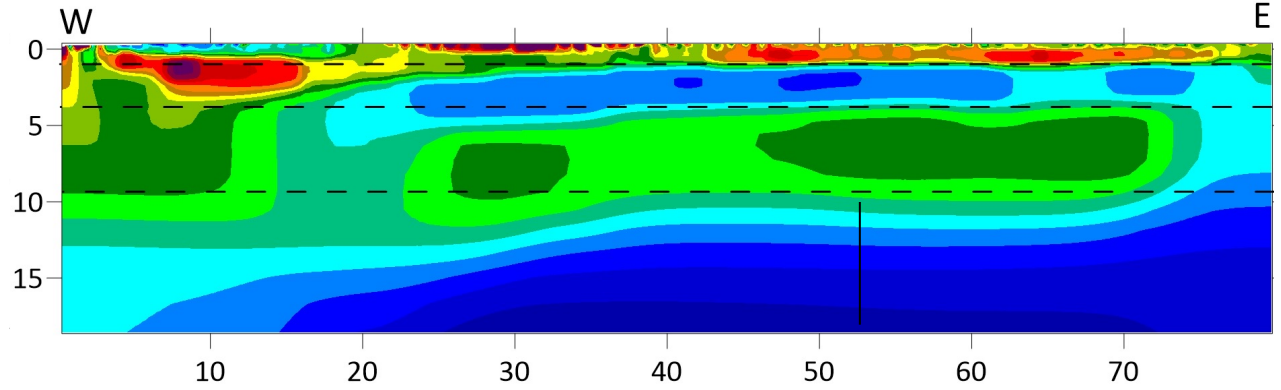
Year-long monitoring supported by mathematical modelling

Phase 1: Site Characterization

- Suspended anonymous petroleum well (AB)
- GM detected for at least 10 years
- Heterogeneous surficial unit
  - 20+ meters of unconsolidated sediments
  - Water table 0.2-1.0 m BGS

Surficial Deposits:
Glacial Till (0-20 m)

Bedrock:
Sandstone (20+ m)



ERT survey (unpublished data)

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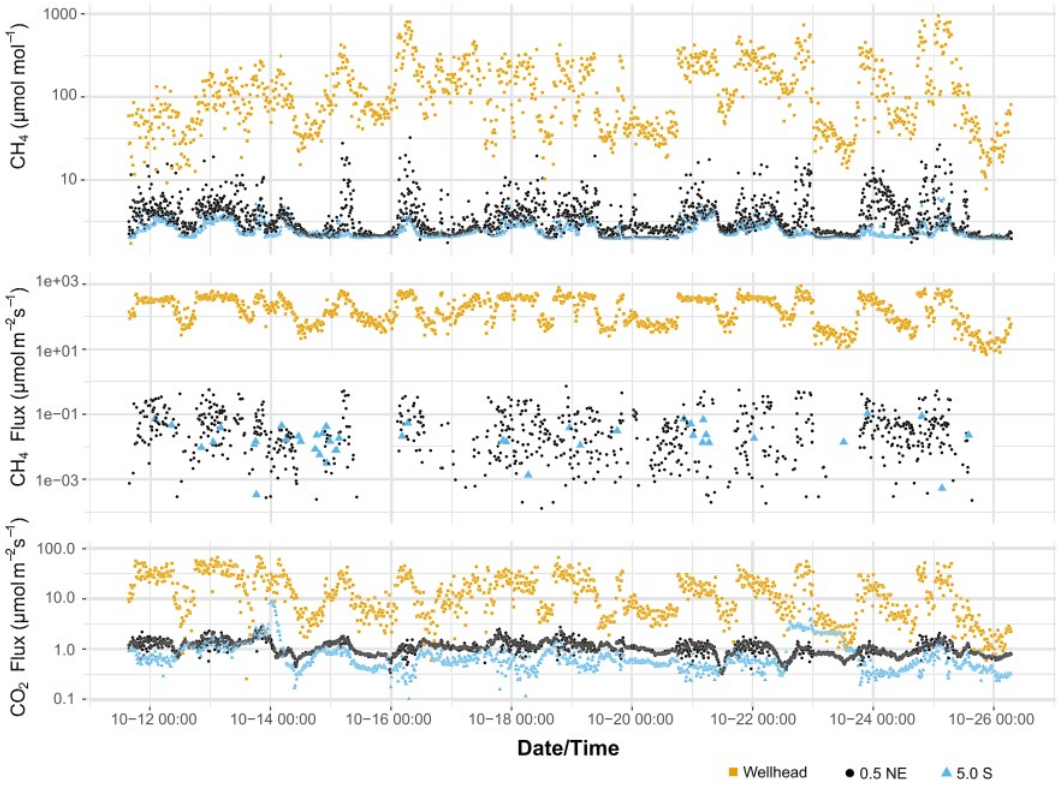
Phase 2: Fugitive Gas Emissions

- Higher CH_4 and CO_2 effluxes around the well head
  - Advective displacement + Diffusion-dominated transport
  - Occasionally detectable more than a few meters away
- Significant temporal variability
  - Strong correlation with wind speed and air temperature
- Source of migrating gases: ~300–400 m BGS
  - Isotopic composition of CH_4 shows biogenic w/ oxidation
- Estimated emissions: 0.07–0.7 m^3 of CH_4 per day
- Long-term measurement and higher spatial resolution needed for better emission estimate

Atmospheric Pollution Research
Volume 12, Issue 6, June 2021, 101094

Spatiotemporal variability of fugitive gas migration emissions around a petroleum well

N.A. Fleming [a], T.A. Morais [a], K.U. Mayer [b], M.C. Ryan [a]



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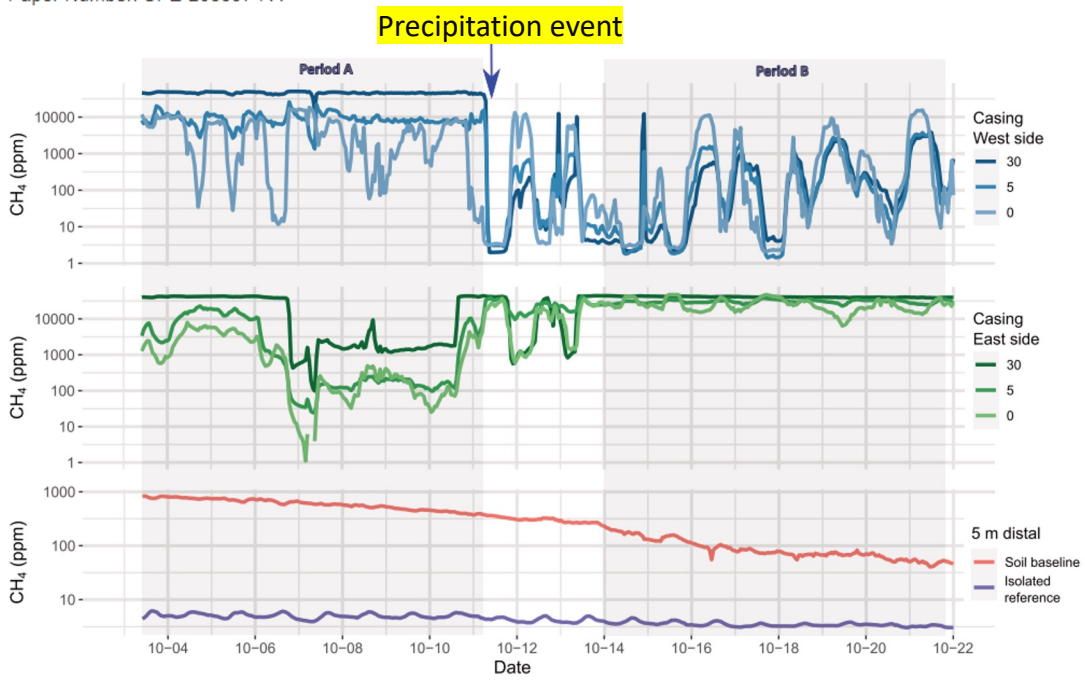
Phase 2: Fugitive Gas Emissions

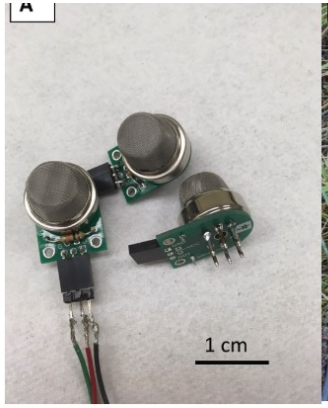
- Significant variation in CH_4 concentration with depth
  - Observed at all depths
  - Several orders of magnitude
- Higher concentrations and lower variability with depth
- Variations correlated to meteorological factors
  - Wind speed
  - Soil moisture / Water level table
- Implications
  - Meteorological factors should be considered
  - Better detection and less variation for greater depths
  - Snapshot GM surveys vs Depth

Low-Cost Sensors Provide Insight into Temporal Variation in Fugitive Methane Gas Concentrations Around an Energy Well

Neil A. Fleming; Tiago A. Morais; M. Cathryn Ryan

SPE J. 1–18.
Paper Number: SPE-208597-PA





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Phase 3: GW Impacts

- Plume of dissolved CH_4 and higher TDS in the shallow GW zone in the vicinity of the well
- Dissolved CH_4 concentrations controlled by
  - GW flow direction
  - Low permeability soils
- Preferential pathway around the well
- CH_4 is likely being dissolved into the shallow GW as fugitive free-phase gas moves
  - Upwards along the well casing
  - Horizontally along low K layers
- Shifts in water chemistry and microbial community in the vicinity of the well

Science of the Total Environment 908 (2024) 168246

Contents lists available at ScienceDirect

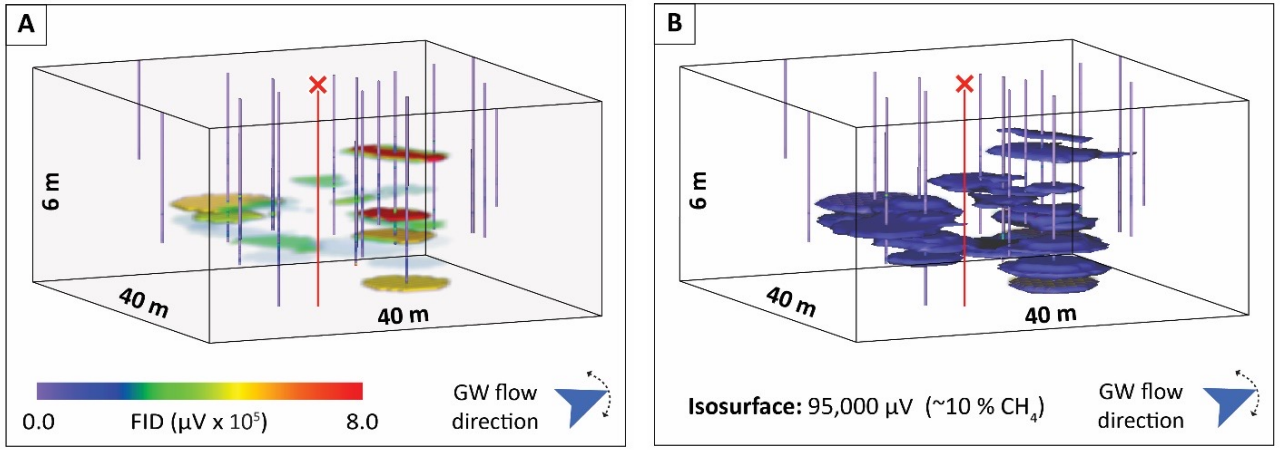
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Field investigation of the transport and attenuation of fugitive methane in shallow groundwater around an oil and gas well with gas migration

Tiago A. Morais [a,*], Neil A. Fleming [a], Dinu Attalage [a], Bernhard Mayer [a], K.U. Mayer [b], M. Cathryn Ryan [a]

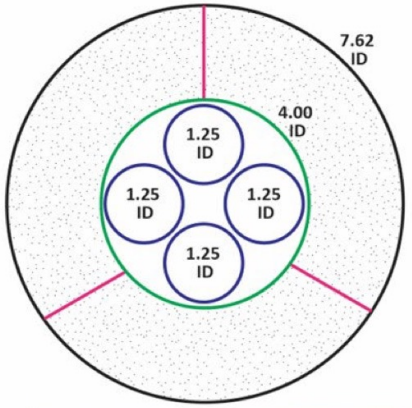
[a] Department of Department of Earth, Energy and Environment, University of Calgary, Calgary, Alberta, Canada
[b] Department of Earth, Ocean and Atmospheric Science, University of British Columbia, Vancouver, British Columbia, Canada



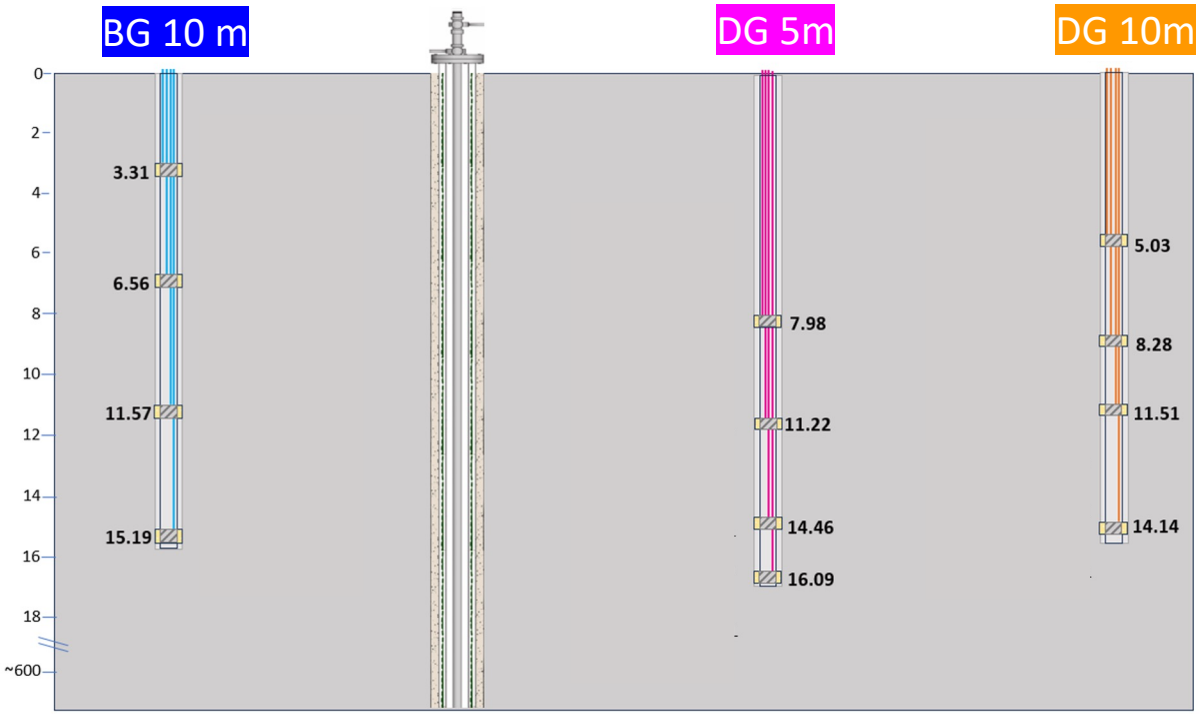
Isosurface:~ 10% CH_4

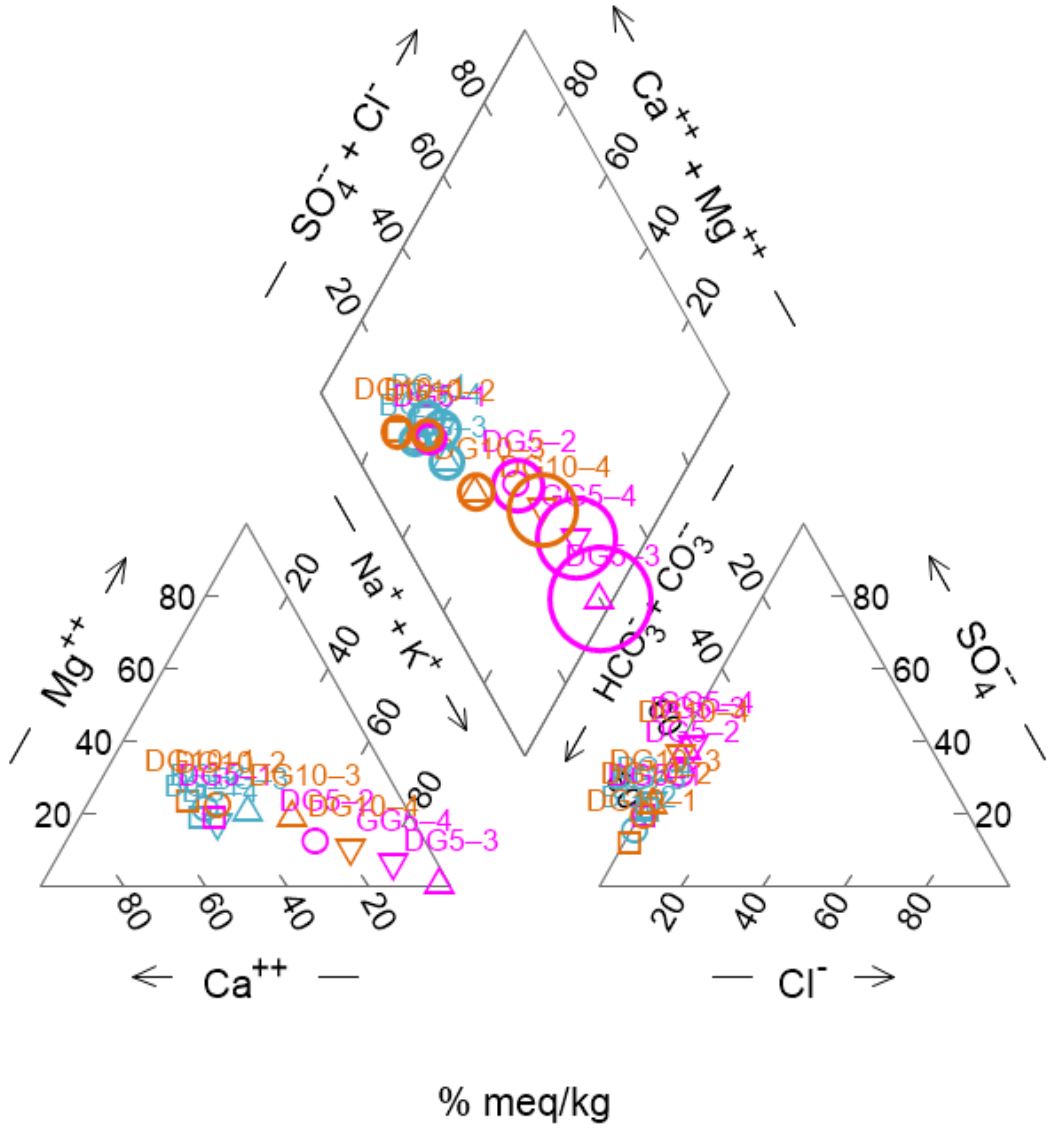
Phase 4: Monitoring Network

- 3 multilevel wells (12 ports)
  - Field parameters
  - Dissolved ions and metals
  - Dissolved gases (N_2, O_2, CO_2, Ar, H_2, CH_4)
  - Noble gases (including Rn)
  - Microbial community
- Core logging during drilling
  - Moisture content and grain size analysis
- Monthly sampling campaigns
  - August 2023 – August 2024



Water Chemistry





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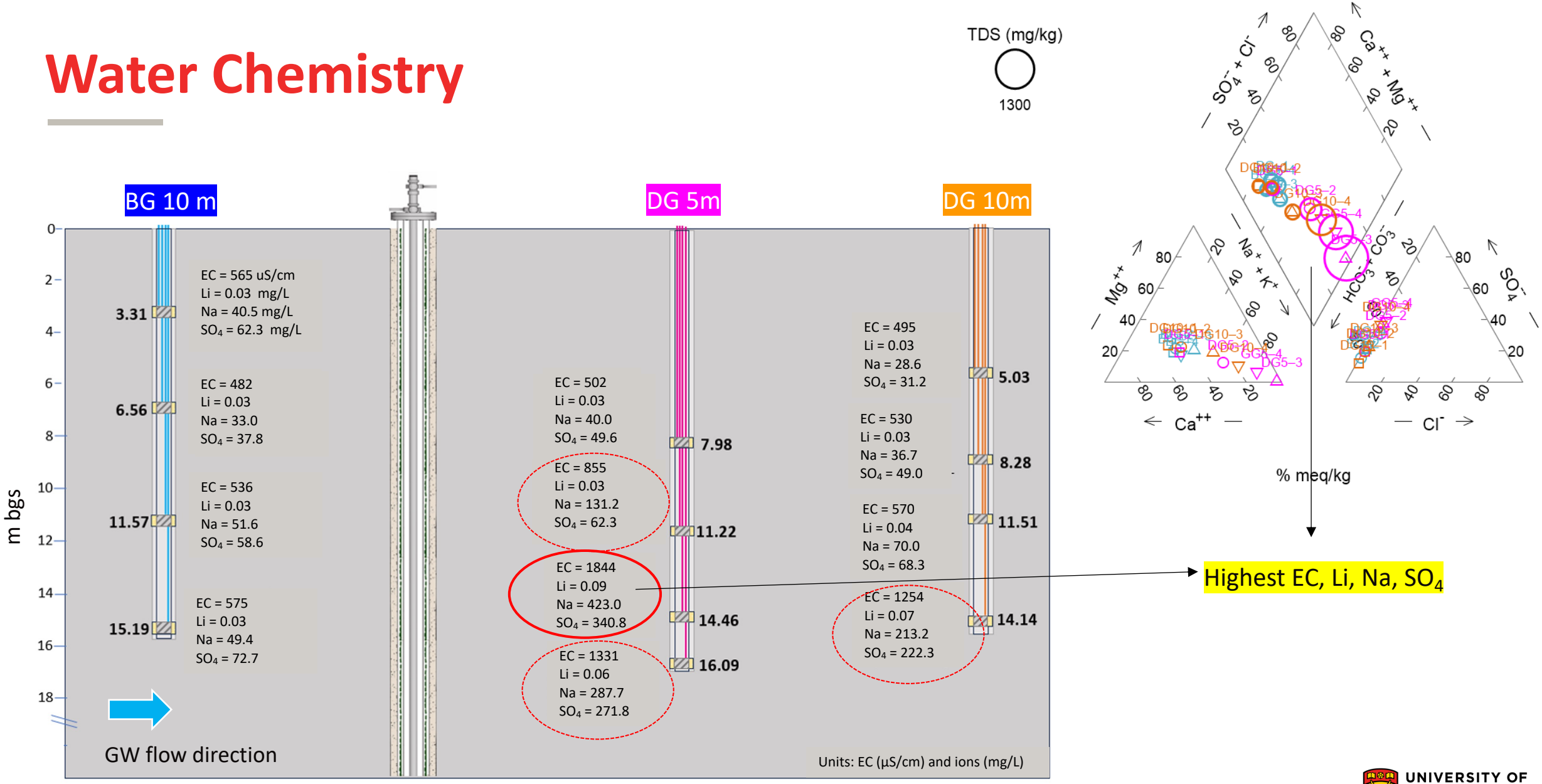
Water Chemistry



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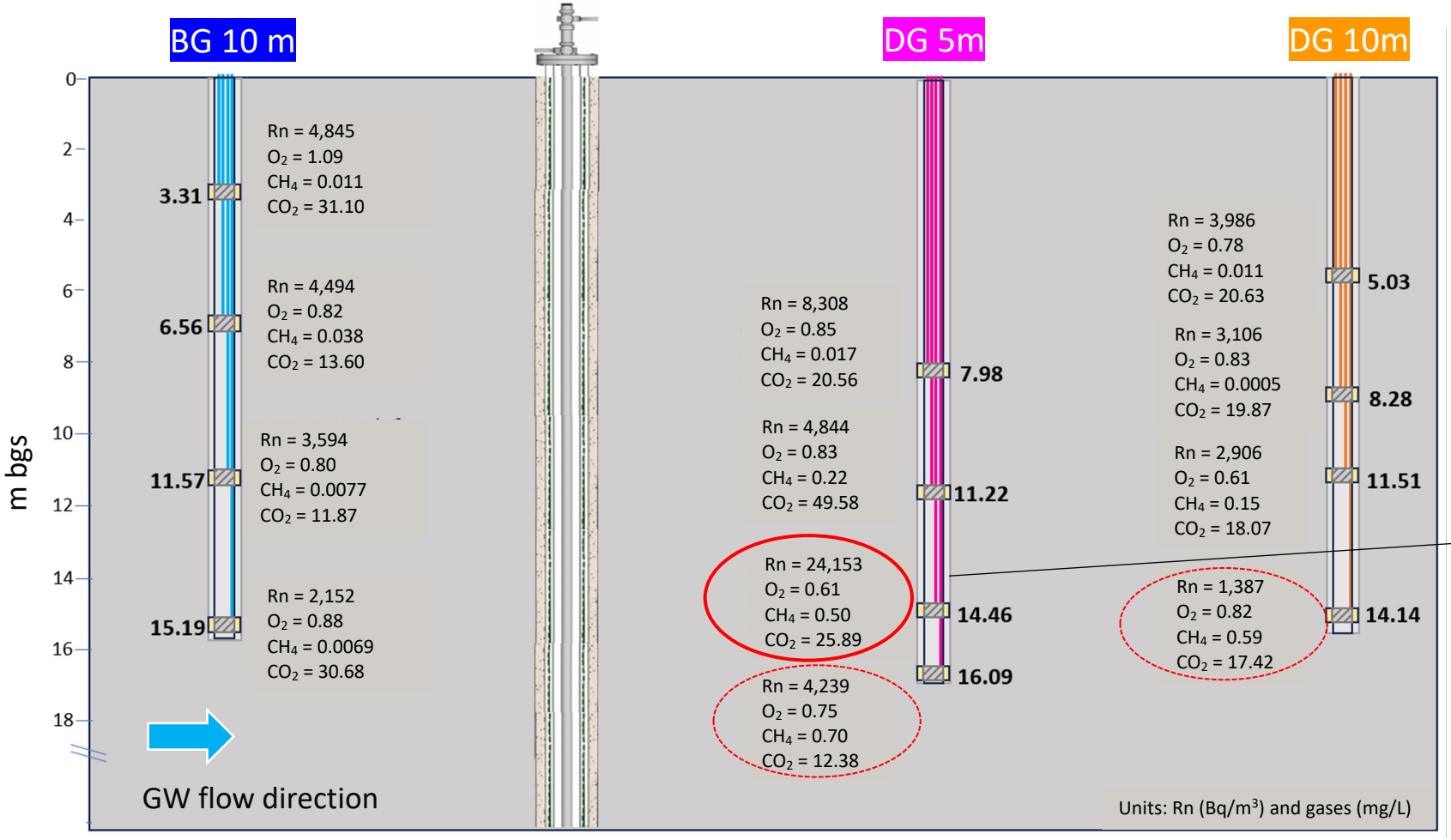
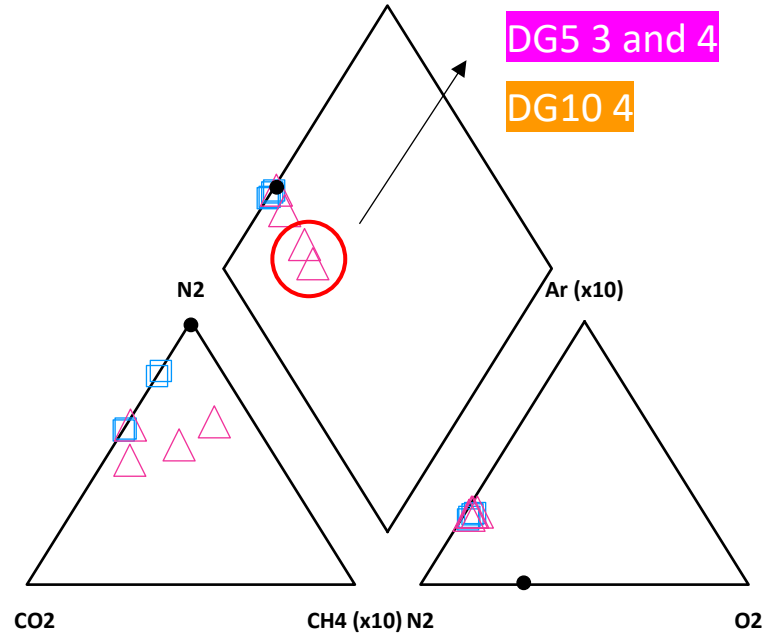
Dissolved Gases





Higher Rn, CH_4
Lower O_2

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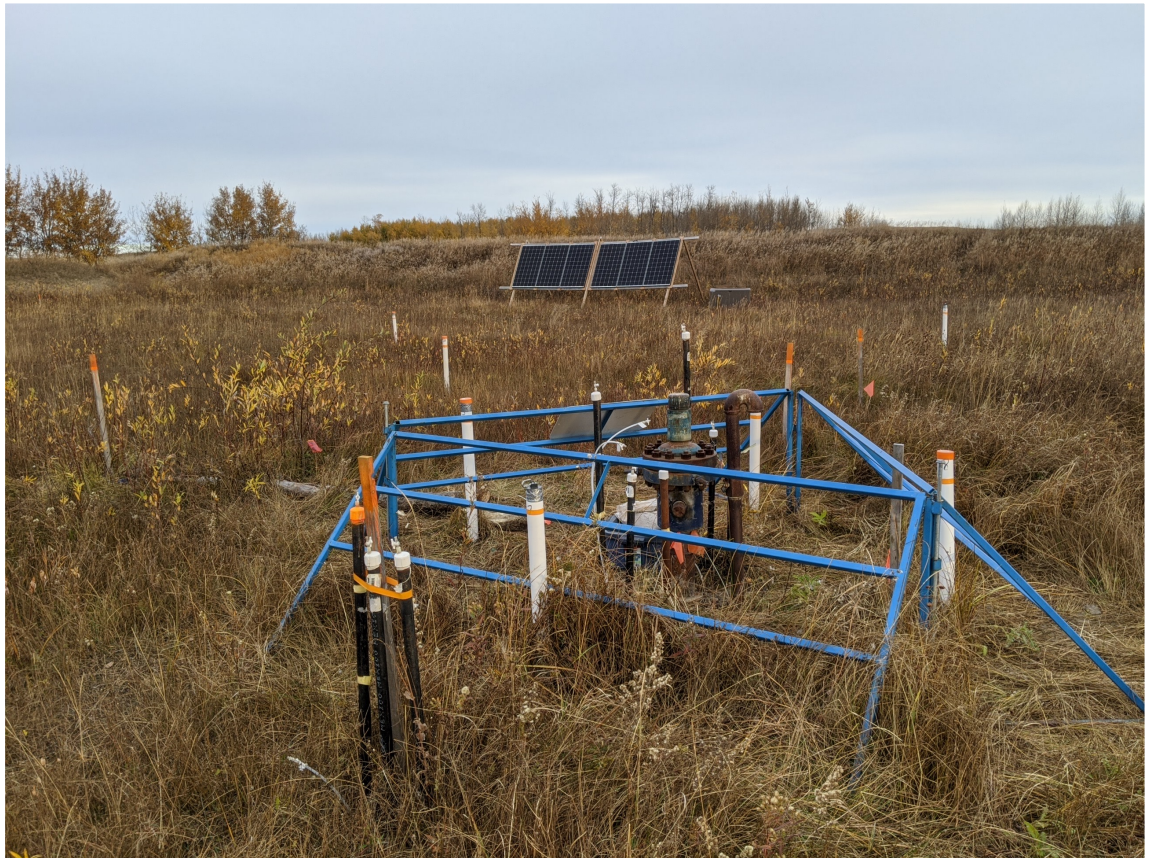
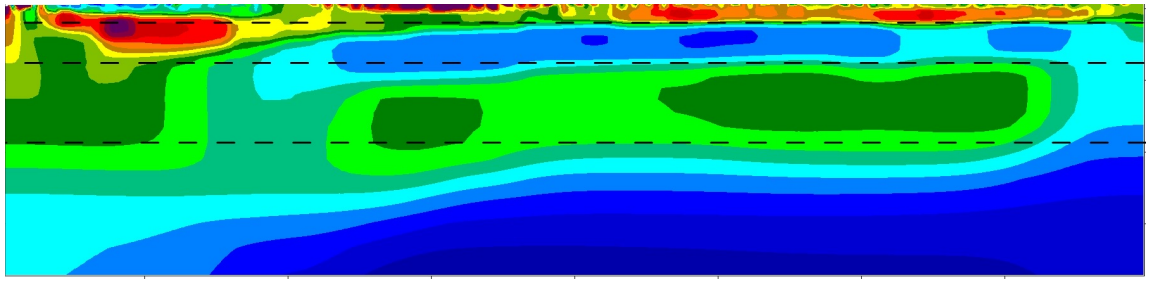
Next Steps

- Stable isotope composition water and gases
  - ^{18}O-H_2O and ^{2}H-H_2O, ^{34}S-SO_4 and ^{18}O-SO_4, ^{15}N-NO_3 and ^{18}O-NO_3
  - ^{13}C-CH_4 and ^{2}H-CH_4, ^{13}C-CO_2 and ^{18}O-CO_2
- Noble gas sampling (He, Ne, Ar, Kr, Xe, Rn)
- Review dissolved metal concentrations
- Complete the year-long monitoring campaign (Aug, 2024)
- Conduct slug tests to estimate hydraulic conductivity
- Abandon monitoring wells before August 31st?
- Possibly small environmental geophysical campaign?
- Additional microbial metagenomics for CH_4 oxidation activity?





Special thanks to industry partner

Questions?

PUBLICATIONS

Morais, T. A., N.A. Fleming, D. Attalage, D., B. Mayer, K.U. Mayer, and M.C. Ryan, 2024. Field investigation of the transport and attenuation of fugitive methane in shallow groundwater around an oil and gas well with gas migration. Science of The Total Environment 908:168246.

Fleming, N.A., T.A. Morais, and M.C. Ryan, 2022. Low-Cost Chemoresistive Sensors Provide Insight into Temporal Variation in Fugitive Methane Gas Concentrations Around an Energy Well. SPE Journal, SPE-208597-PA: 1-18.

Fleming, N.A., T.A. Morais, U. Mayer, and M.C. Ryan, 2021. Spatiotemporal variability of fugitive gas migration emissions around a petroleum well. Atmospheric Pollution Research, 12(6):101094.

Fleming, N., T. Morais, M.C. Ryan, and U. Meyer, 2020. Fugitive gas emission rates and distribution from efflux measurements around an energy well with gas migration [abstract]. GeoConvention 2020, Calgary.

Fleming, N., T.A. Morais, C. Kennedy, and M.C. Ryan, 2019. Evaluation of SCVF and GM measurement approaches to detect fugitive gas migration around energy wells. Geoconvention (poster) May 13-15; Calgary, Alberta.

Cathryn Ryan
cryan@ucalgary.ca