Assessing Impacts of CO_2 Leakage on Groundwater Quality and Monitoring Network Efficiency: Case Study at A CO_2-EOR site

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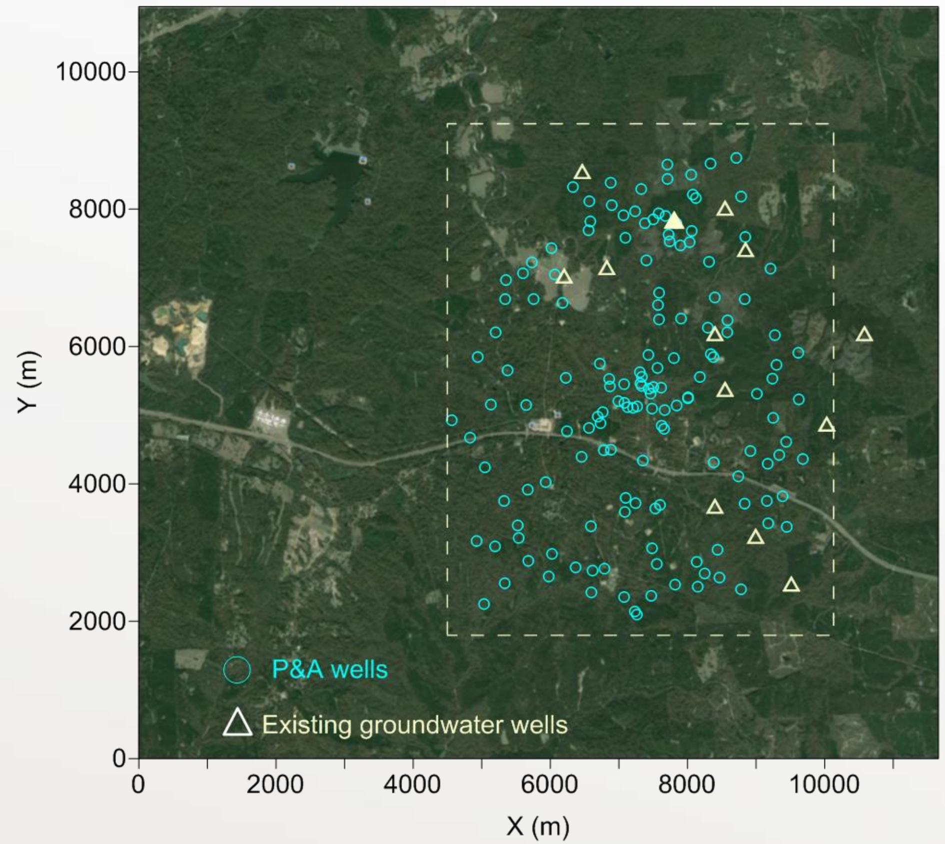
Previous research

- Field campaigns for groundwater sampling
- Lab experiments of water-rock-CO_2 interactions
- Single-well push-pull test



No CO_2 leakage signals have been detected.

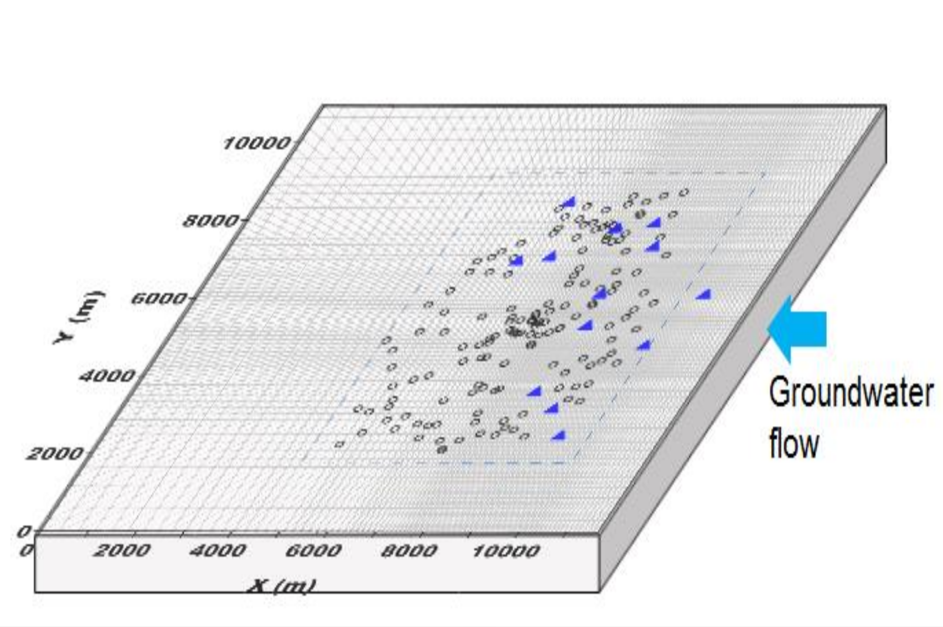
Objectives

Use reactive transport modeling

- Assess impacts of CO_2 leakage on groundwater chemistry;
- Evaluate monitoring network efficiency

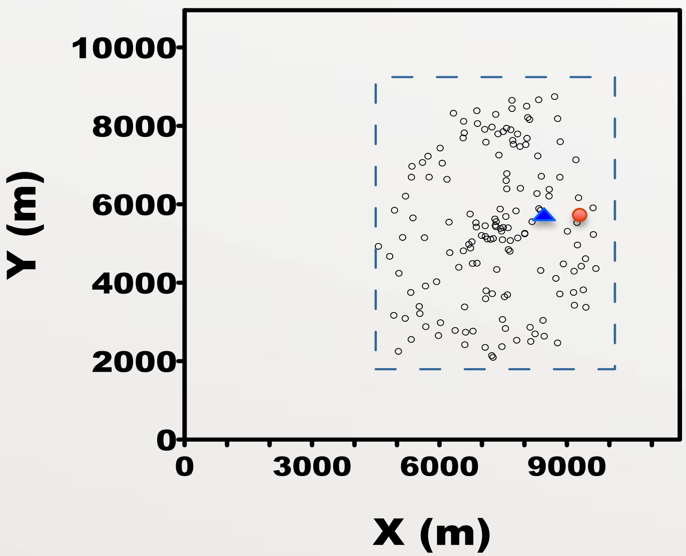
Regional-Scale Reactive Transport Modeling (RSRTM)

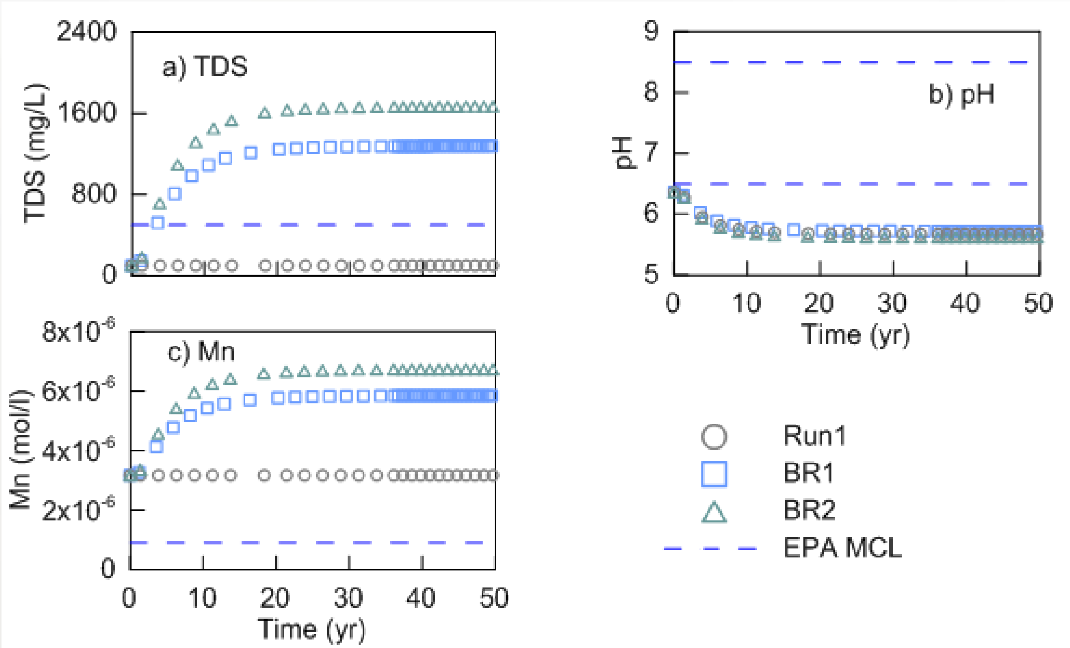
- Aquifer simplification (shallow, confined, homogeneous, groundwater flows from right to left);
- Geochemical interactions of water-rock-CO_2 tested and validated with laboratory experiments & the field test



- CO_2 as dissolved phase in either fresh groundwater or brine
- CO_2 leakage rate from 0.9 to 100 metric ton/yr

Potential impacts of CO_2 leakage on groundwater chemistry





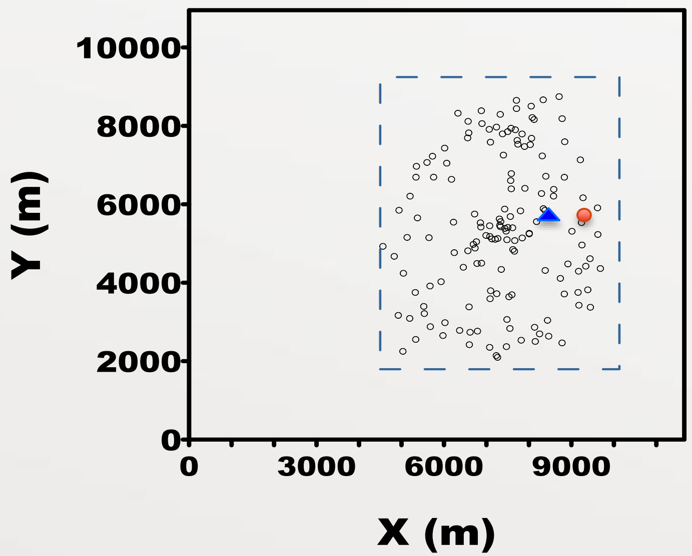
Leakage rate
metric ton/yr

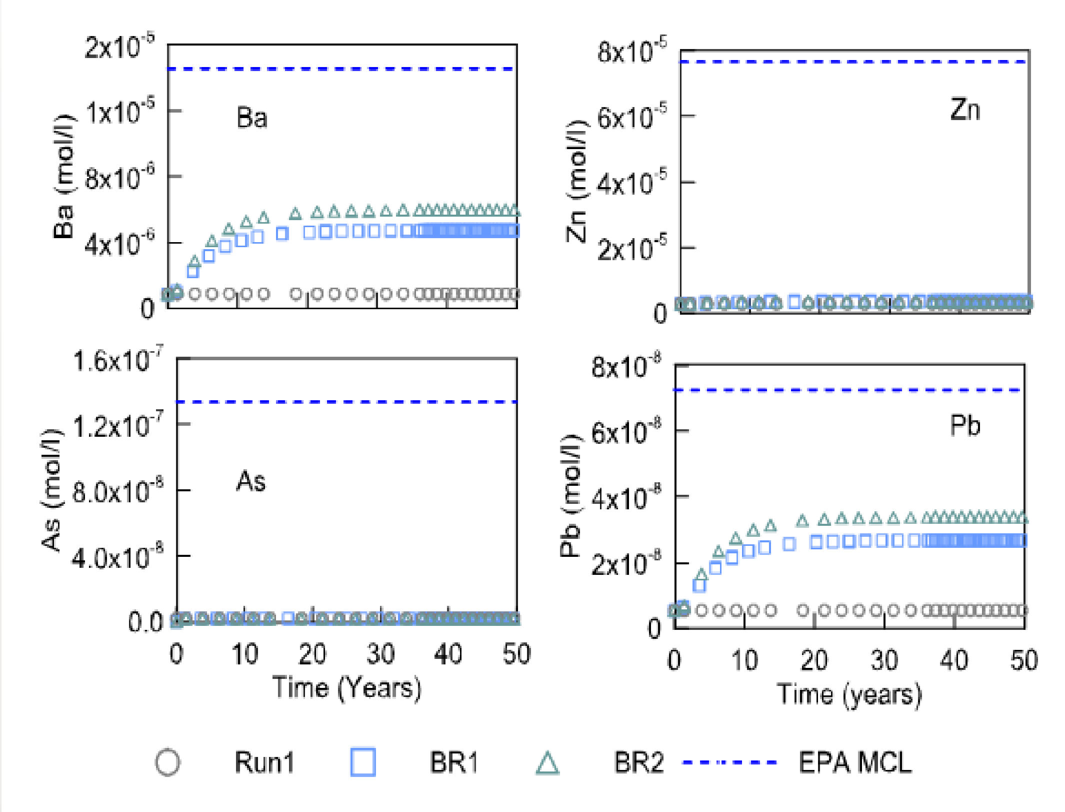
Run1: 50.3
BR1: 37.3
BR2: 50.3

J=0.5%

- TDS exceeds the EPA MCL if brine is leaked;
- pH degradation
- Mn is a concern

Potential impacts of CO_2 leakage on groundwater chemistry





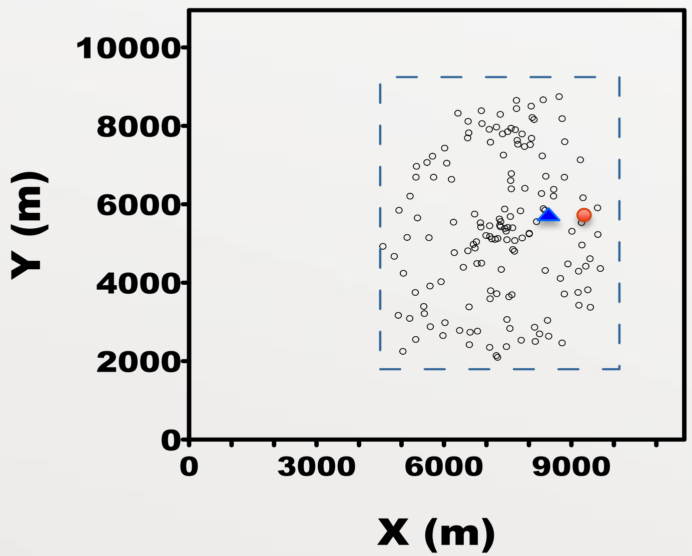
Leakage rate
metric ton/yr

Run1: 50.3
BR1: 37.3
BR2: 50.3

J=0.5%

- Simulated conc. < EPA MCL
- Ba and Pb increase caused by brine leakage

Potential impacts of CO_2 leakage on groundwater chemistry



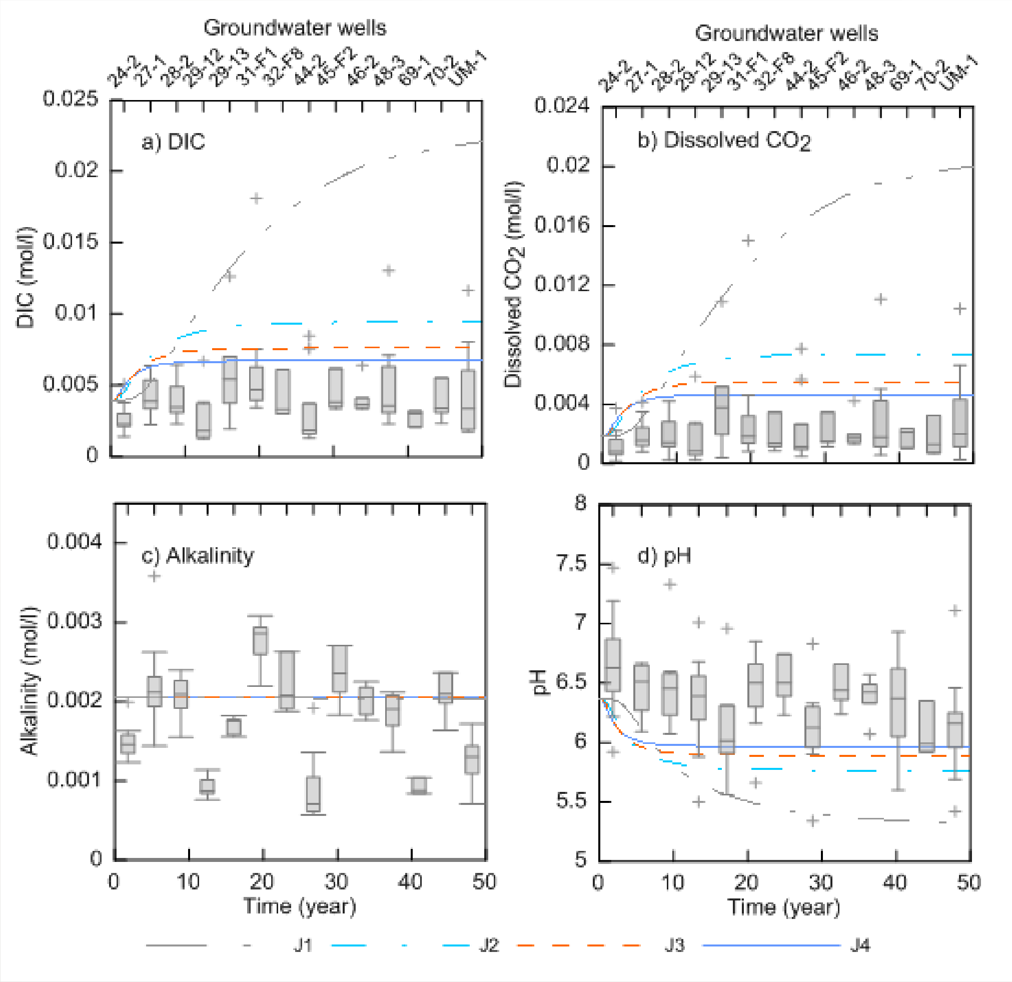
Regional hydraulic gradient

J1: 0.1%

J2: 0.5% (in the shallow aquifer)

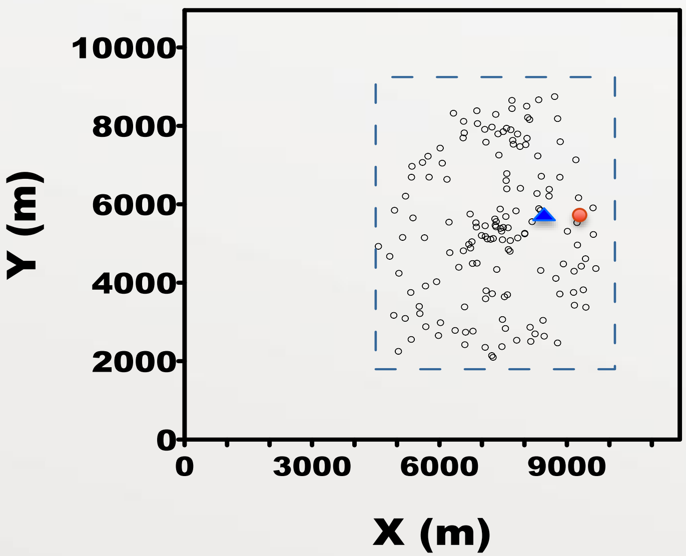
J3: 0.8%

J4: 1.0%



Leakage rate: 37.7 metric ton/yr

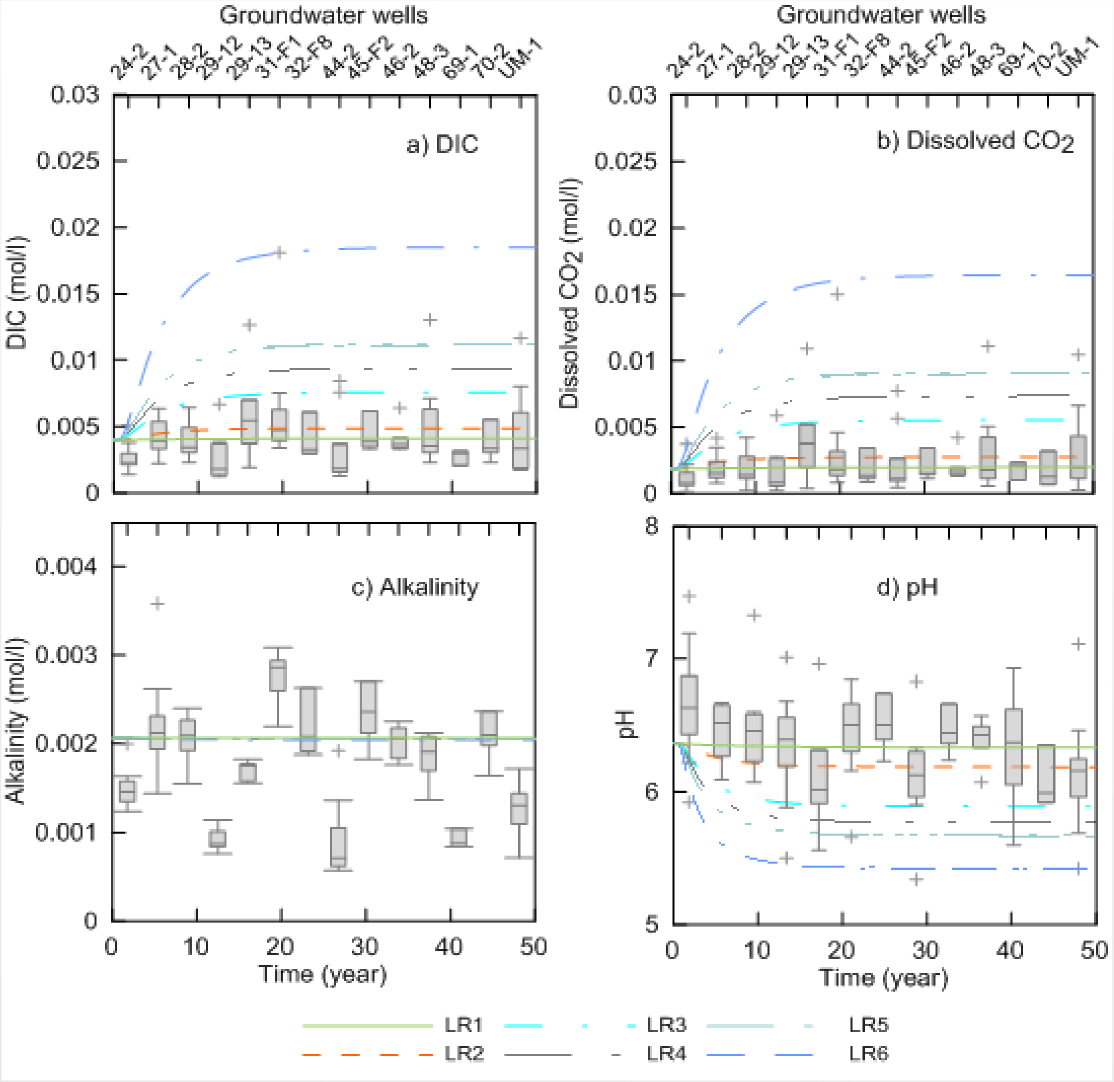
Potential impacts of CO_2 leakage on groundwater chemistry



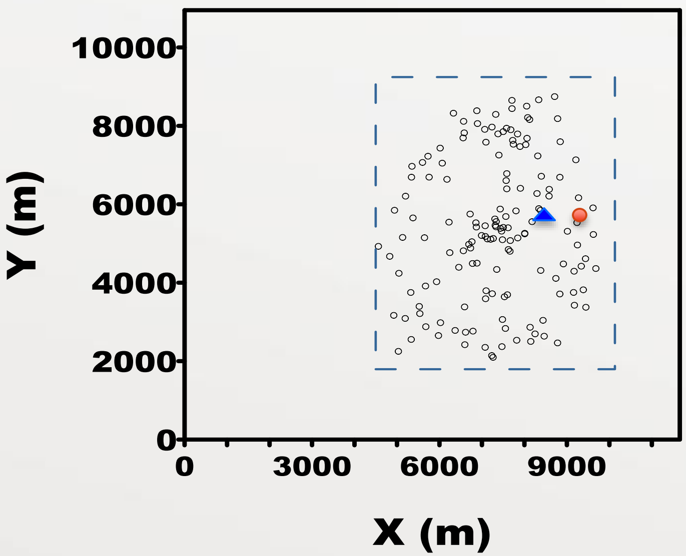
Leakage rate: metric ton/yr

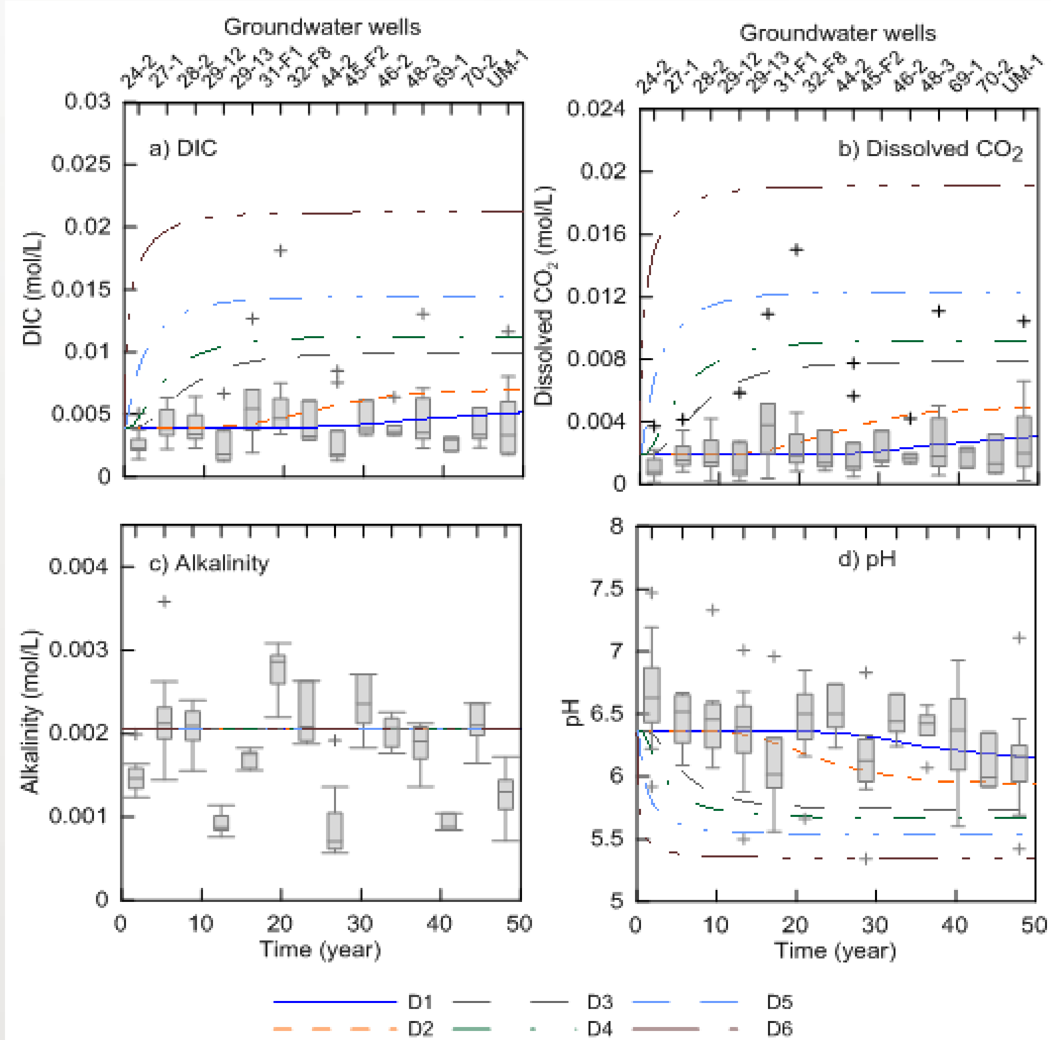
LR1: 0.94
LR2: 6.28
LR3: 25.1
LR4: 37.7
LR5: 50.3
LR6: 100

J=0.5%



Potential impacts of CO_2 leakage on groundwater chemistry





Distance to the leakage well

- D1: 6.1 km
- D2: 3.6 km
- D3: 1.0 km
- D4: 0.67 km
- D5: 0.3 km
- D6: 70 m

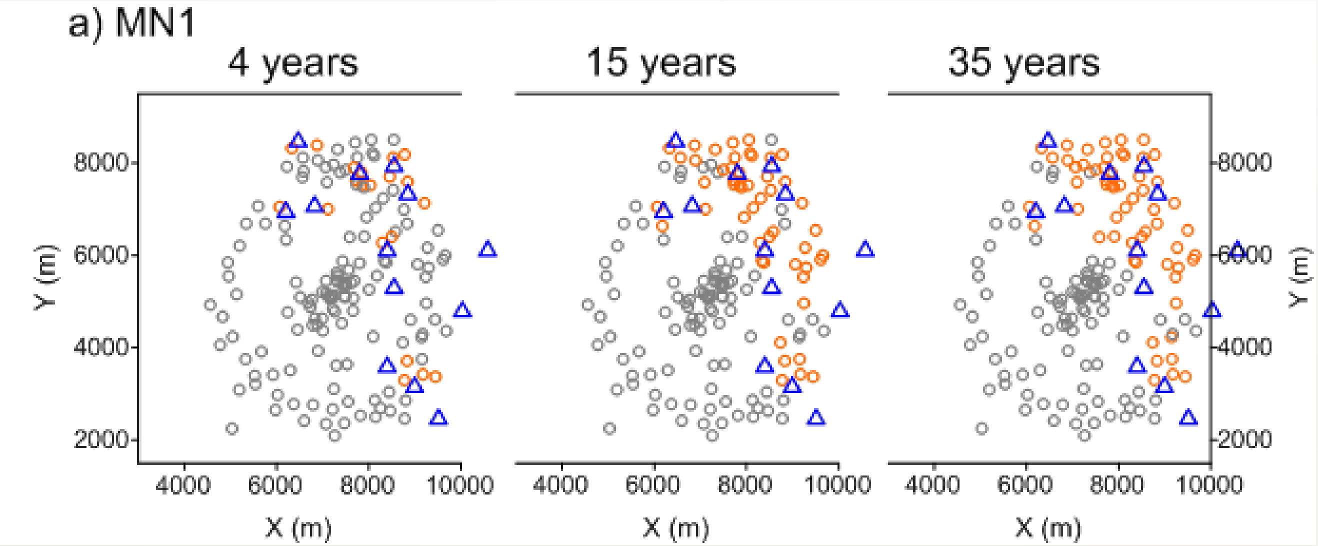
Leakage rate: 37.7 metric ton/yr

J=0.5%

Monitoring Network Efficiency

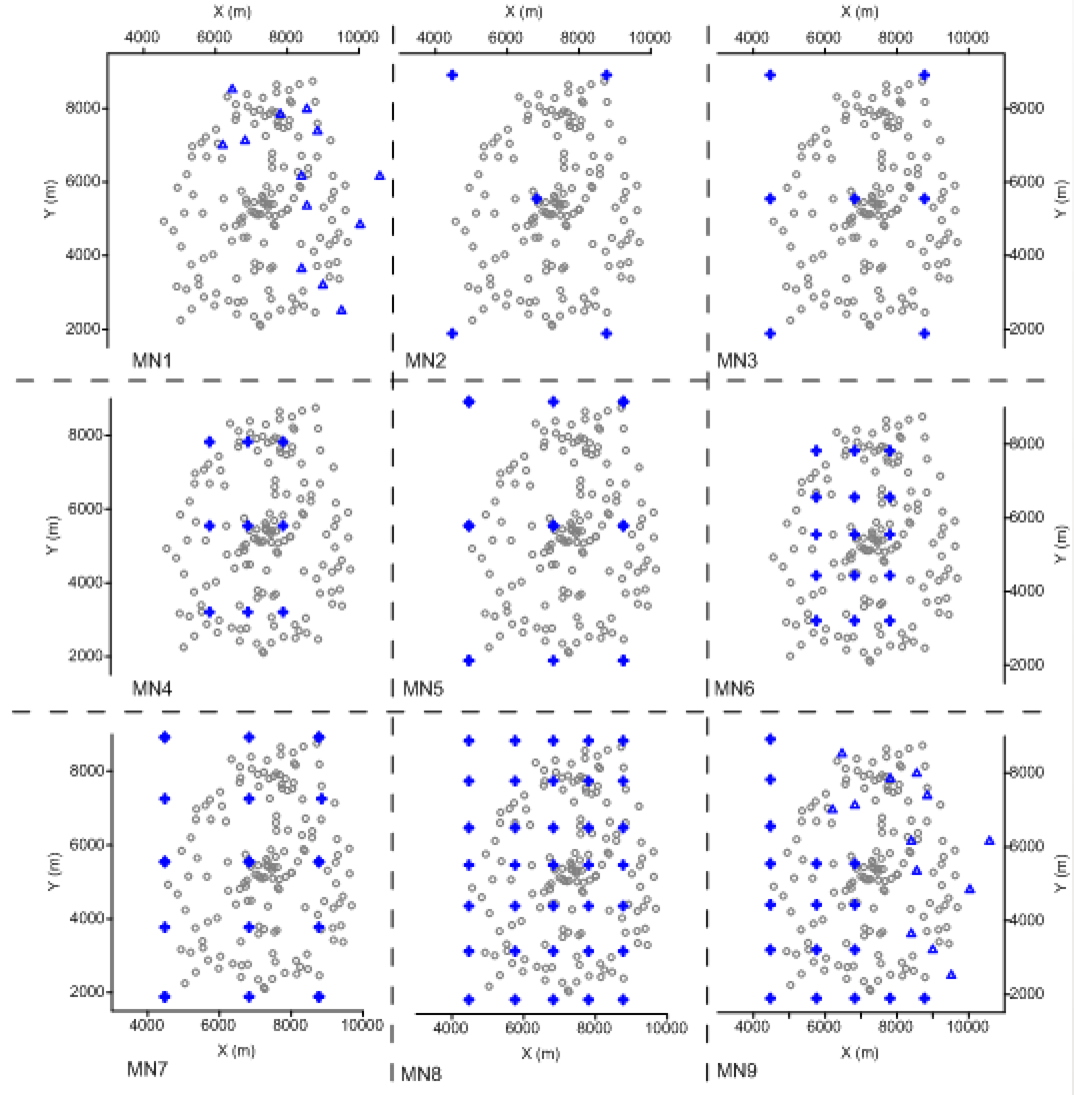
$$ME = \frac{w^d}{w^T}$$

- 20/151=0.13 by 4 years
- 50/151=0.33 by 15 years
- 58/151=0.38 by 35 years



CO_2 leakage from a P&A well is detected by a monitoring net work if change in DIC, dissolved CO_2, or pH in any one of wells of the monitoring network is higher than one standard deviation of the groundwater chemistry data collected in the shallow aquifer over the last 6 years.

Monitoring Network Efficiency

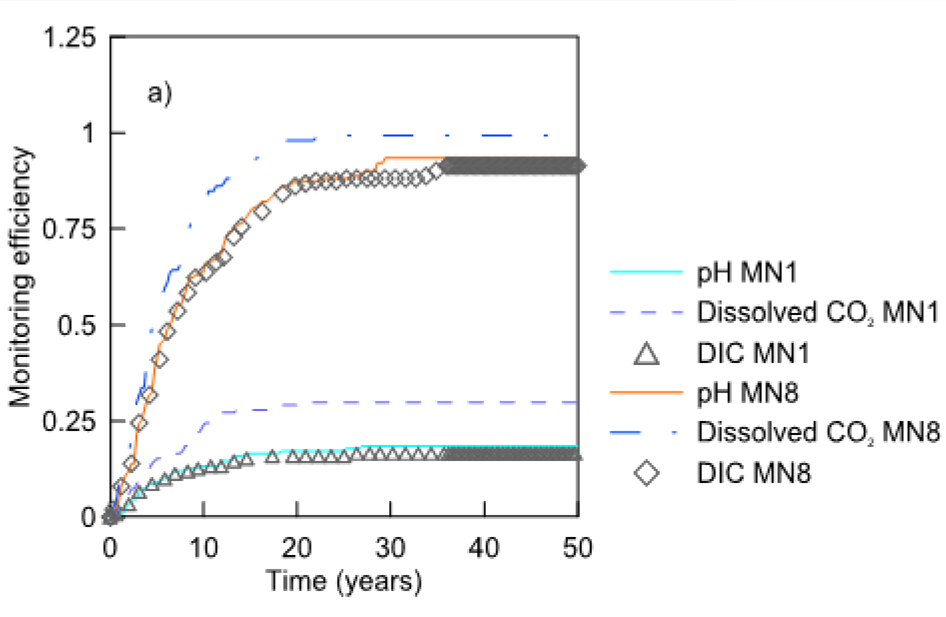


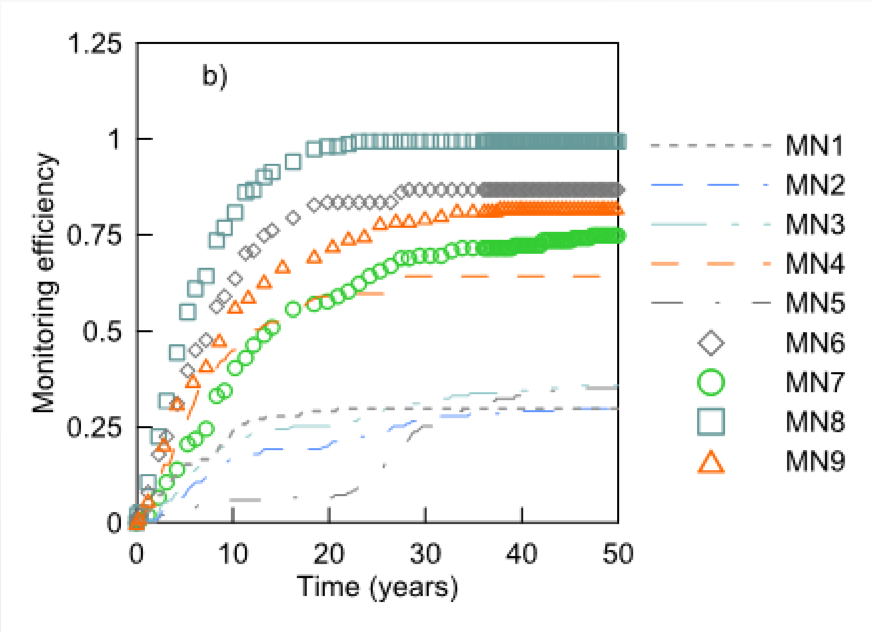
Unit: wells/km^2

MN1: 0.322
MN2: 0.124
MN3: 0.173
MN4: 0.223
MN5: 0.223
MN6: 0.371
MN7: 0.371
MN8: 0.866
MN9: 0.742

Monitoring Network Efficiency

Leakage rate=37.7 metric ton/yr; J= 0.5%



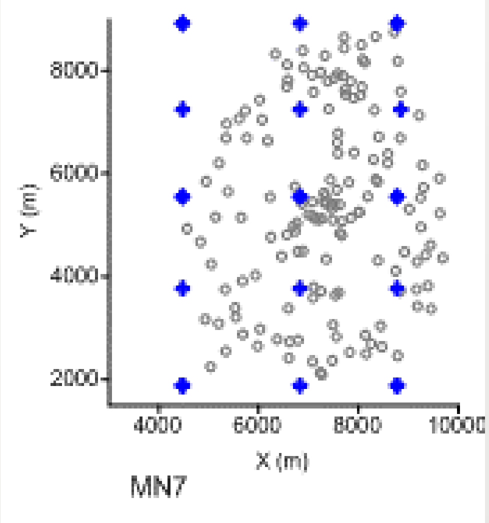


Comparison of ME for a) with pH, dissolved CO_2 and DIC as indicators for the two monitoring networks, MN1 and MN8

- Comparison of ME with dissolved CO_2 as indicator for the 9 monitoring networks
- Well densities for MN4 and MN5 are 0.223 wells/km2; ME of MN4 is ~2 times of ME of MN5, suggesting well locations are important

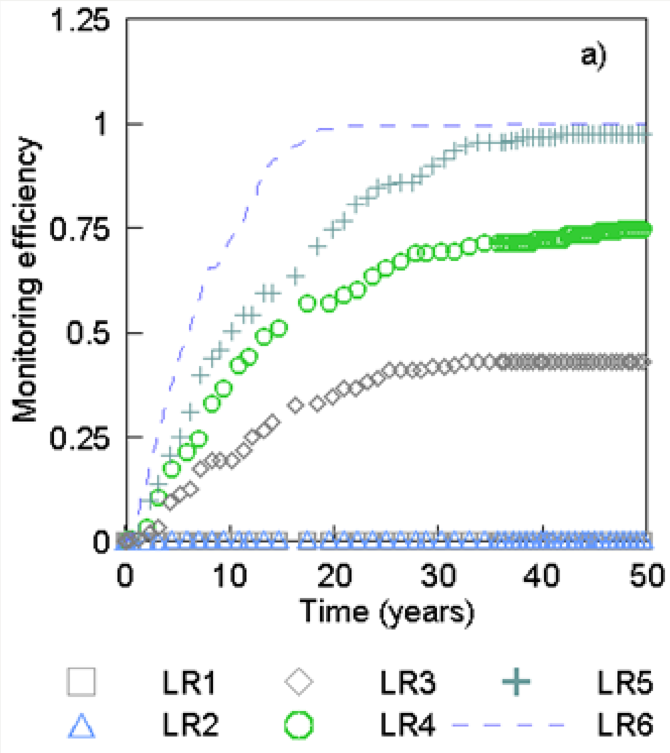
Monitoring Network Efficiency

Monitoring efficiency of MN7 with dissolved CO_2 as an indicator



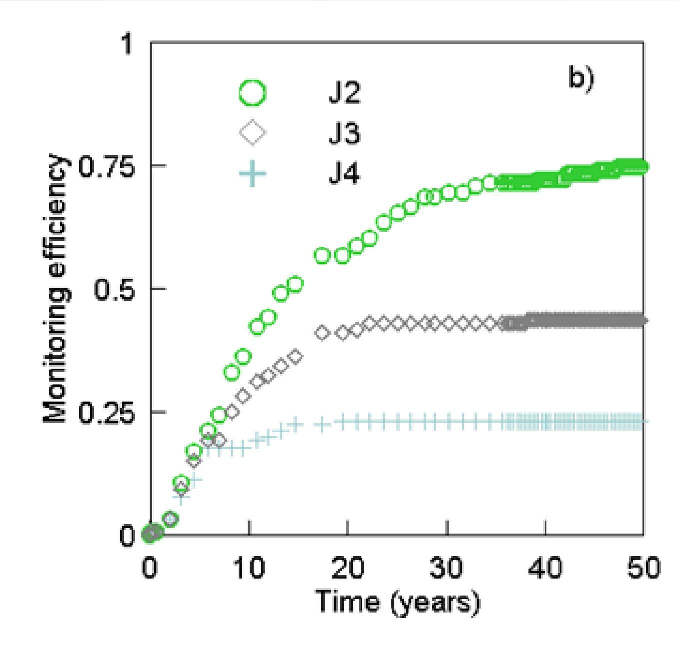
Leakage rate: metric ton/yr

LR1: 0.94, LR2: 6.28
LR3: 25.1, LR4: 37.7
LR5: 50.3, LR6: 100



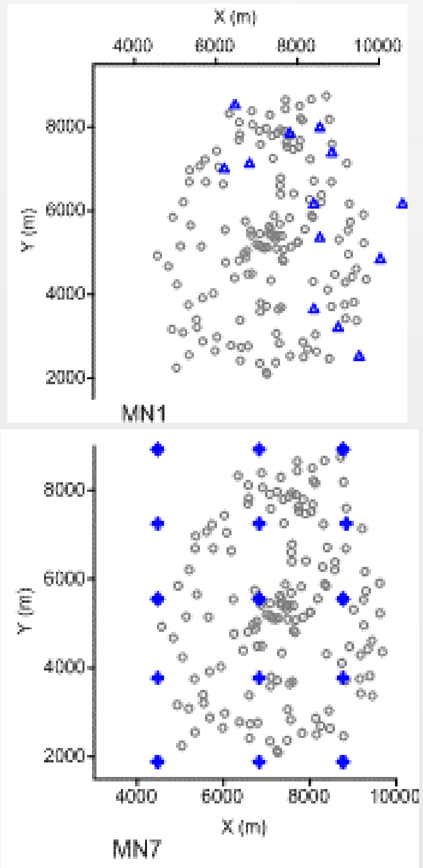
Regional hydraulic gradient

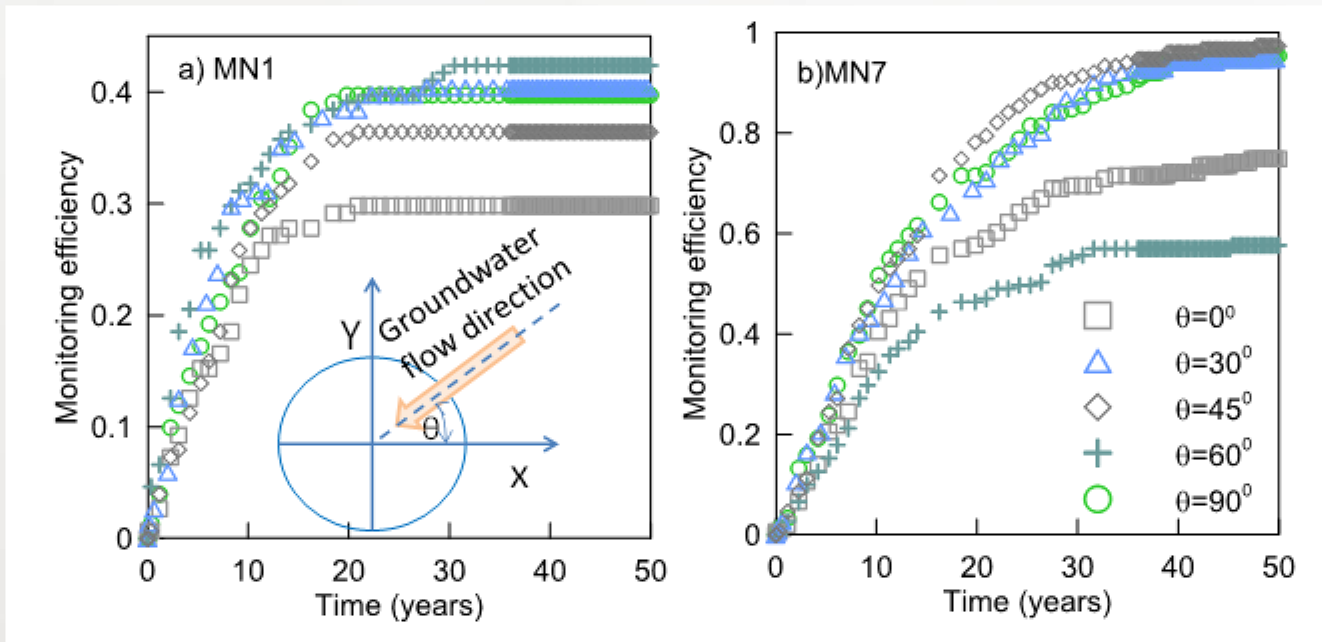
J2: 0.5% , J3: 0.8%
J4: 1.0%



Monitoring Network Efficiency

Groundwater flow direction



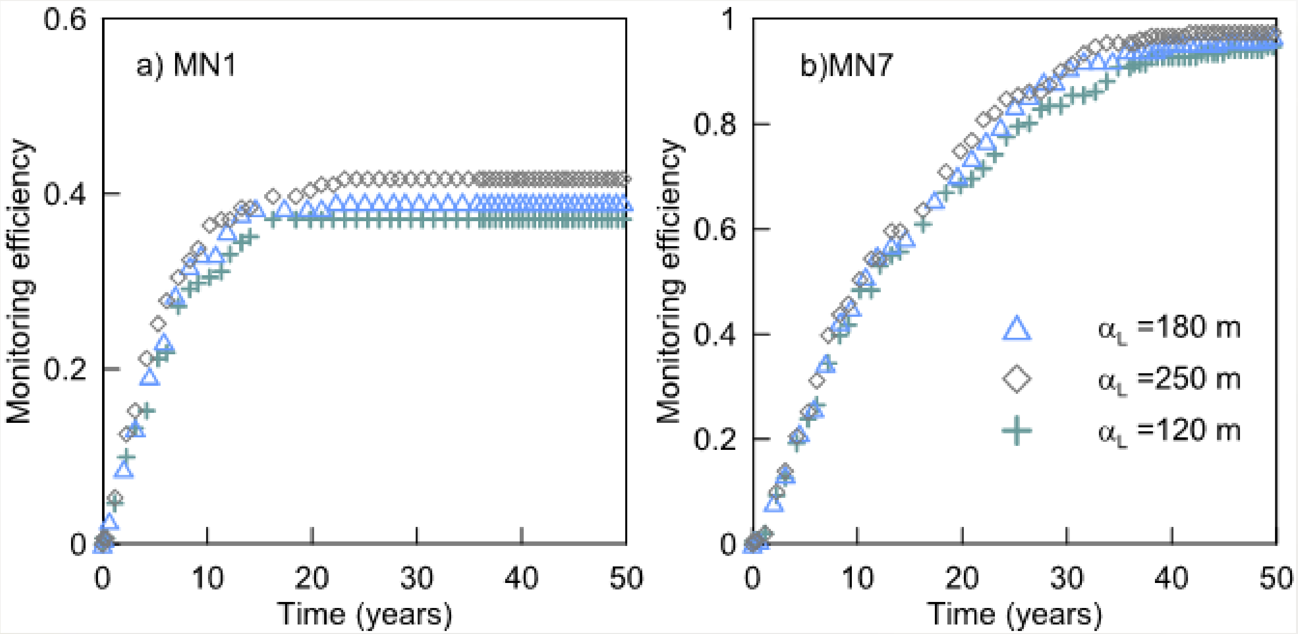


MN1 has the lowest ME for θ = 0º, the greatest ME for θ = 60º
MN7 has the lowest ME for θ = 60º, the greatest ME for θ = 45º,
Groundwater flow direction is important for a monitoring network design

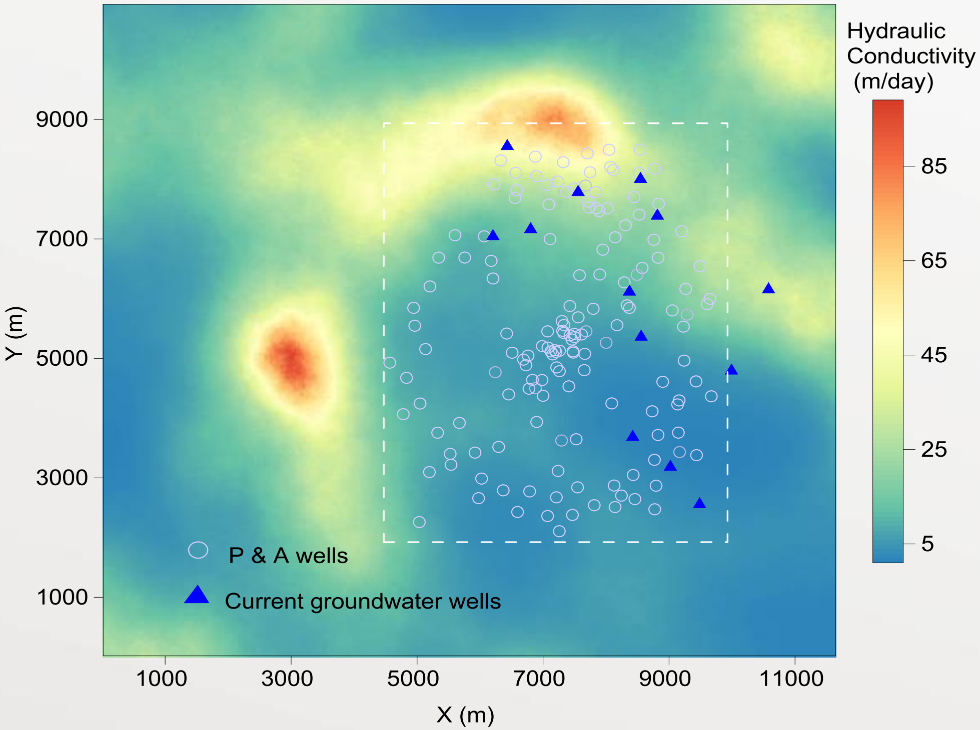
Monitoring Network Efficiency

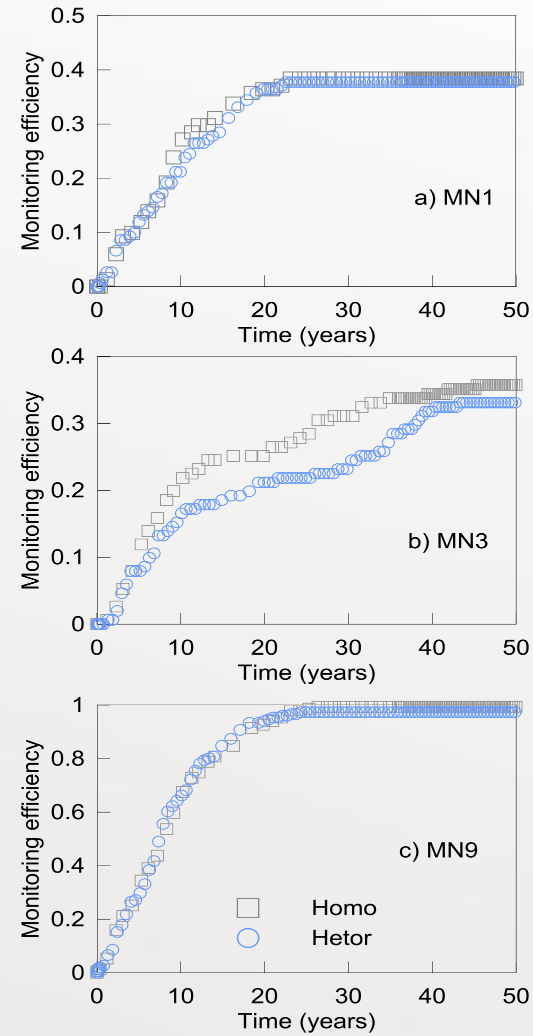
Dispersion coefficient

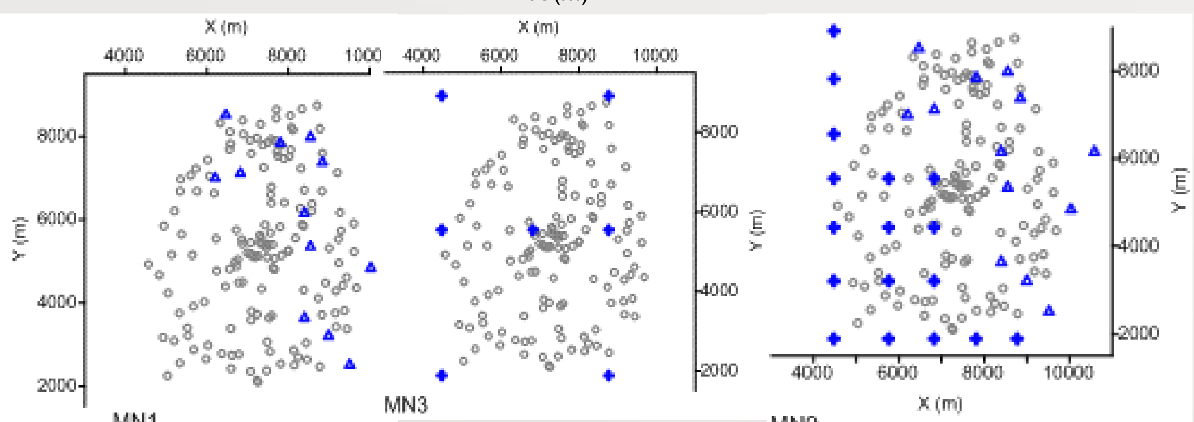
Dispersion coefficient can impact on lateral and longitudinal extension of a CO_2 plume in an aquifer



Monitoring Network Efficiency







Summary

- No obvious degradation in groundwater quality (except degradation in pH) if only CO_2 is leaked. Salinization would be problematic if brine+CO_2 are leaked.
- Dissolved CO_2 appears to be a better indicator than DIC, pH, alkalinity for CO_2 leakage detection at the CO_2-EOR site, however, dependent on regional hydraulic gradient, leakage rate.
- Monitoring network efficiency depends on regional hydraulic gradient, leakage rate, flow direction, and also aquifer heterogeneity. Impact of dispersion coefficient could be neglected.

Summary

- The existing groundwater wells can monitor CO_2 leakage from up to 60 P&A wells and MN8, the ideal monitoring network which consists of 35 water wells can detect CO_2 leakage from almost all P&A wells.
- Site characterization + lab experiments + single-well PPTs + RTM could be enough for risk assessment.
- Long-term geochemical monitoring for CO_2 leakage detection many not be very helpful because of complexity of the natural system, especially in a CO_2-EOR setting.

Thanks for your attention!