Science of Geologic Sequestration

Project Number: LANL FE10-003 Task 3

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U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Transforming Technology through Integration and Collaboration

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Contributors

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Presentation Outline

- Benefit to the program
- Project overview
- Project technical status
- Accomplishments to date
- Future Plans
- Appendix

Benefit to the program

- Program goals being addressed:
  - Develop and validate technologies to ensure 99 percent storage permanence.
  - Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
- Project benefit:
  - Develop science basis that can be used to assess impacts of CO_2 leakage in shallow aquifers and to characterize leakage through faults. This technology contributes to the Carbon Storage Program's effort of ensuring 99 percent CO_2 storage permanence in the injection zone(s).
  - Develop science basis to characterize CO_2 storage potential in Residual Oil Zones (ROZs)

Project Overview:
Tasks

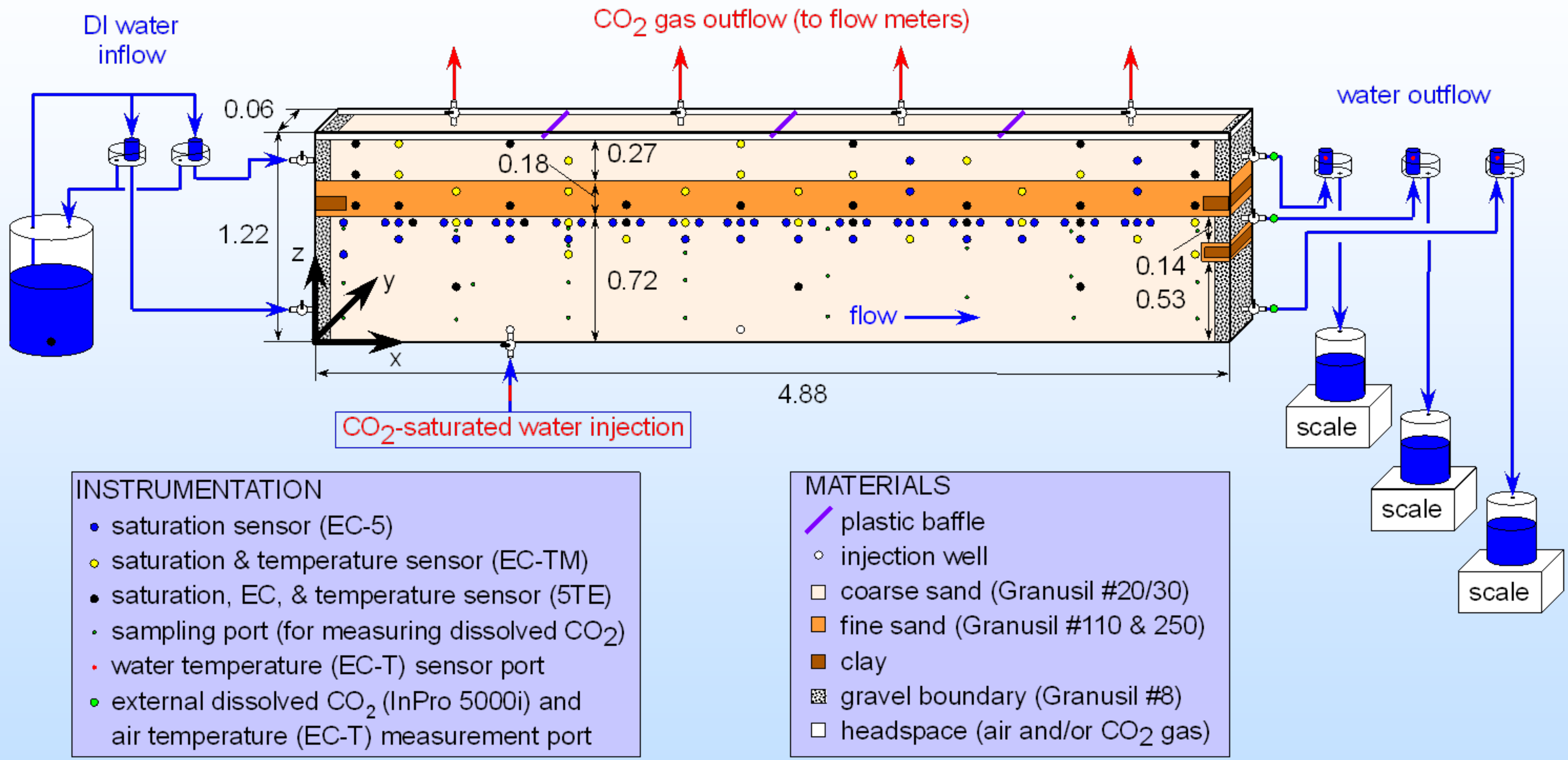
1. Characterize multi-phase CO_2 flow in groundwater aquifers through an integrated experimental-simulation approach
2. Characterize multi-phase CO_2-brine flow through faults
3. Characterize CO_2 storage potential in Residual Oil Zones

Characterization of CO_2-water multi-phase flow

Goals & Objectives

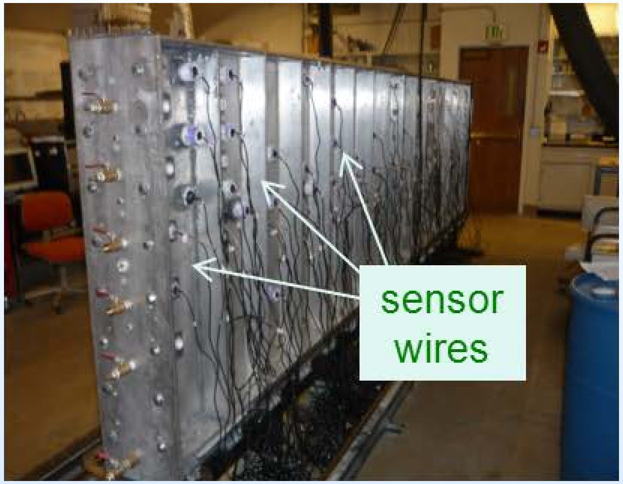
- Understand the process of gas exsolution, gas phase expansion and CO_2 migration to characterize the impacts of CO_2 & CO_2-dissolved water leakage in groundwater aquifer as well as to deploy efficient monitoring/mitigation approaches
  - What factors affect the spatiotemporal evolution of CO_2 migration
  - What role does heterogeneity play
  - Data to develop theory
- Integrated approach: intermediate scale experiments (1D column, 2D tank) coupled with numerical simulations

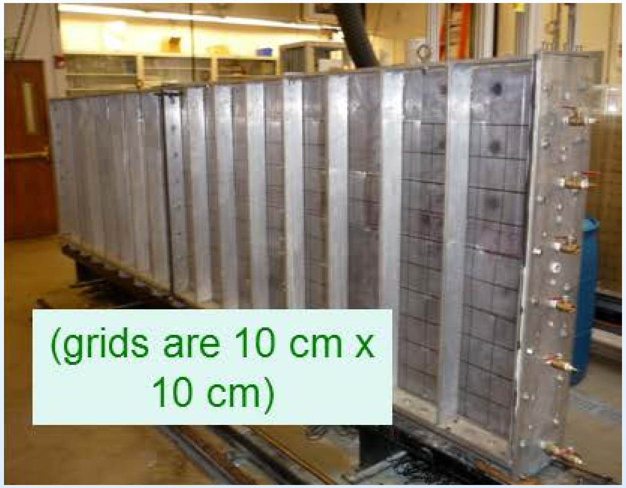
2-D Tank Experimental Setup

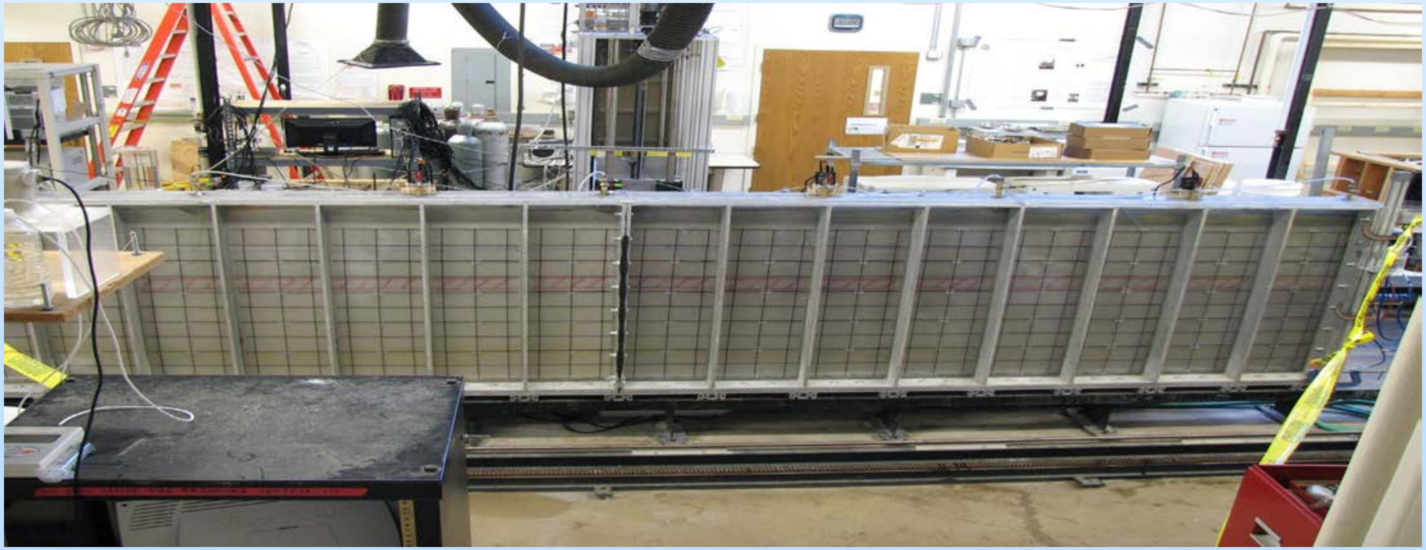


- Measurements taken from sensors, flow meters and scales every minute
- Aqueous phase samples taken at various intervals and analyzed for dissolved CO_2 with an Ion Chromatograph

Experimental Setup

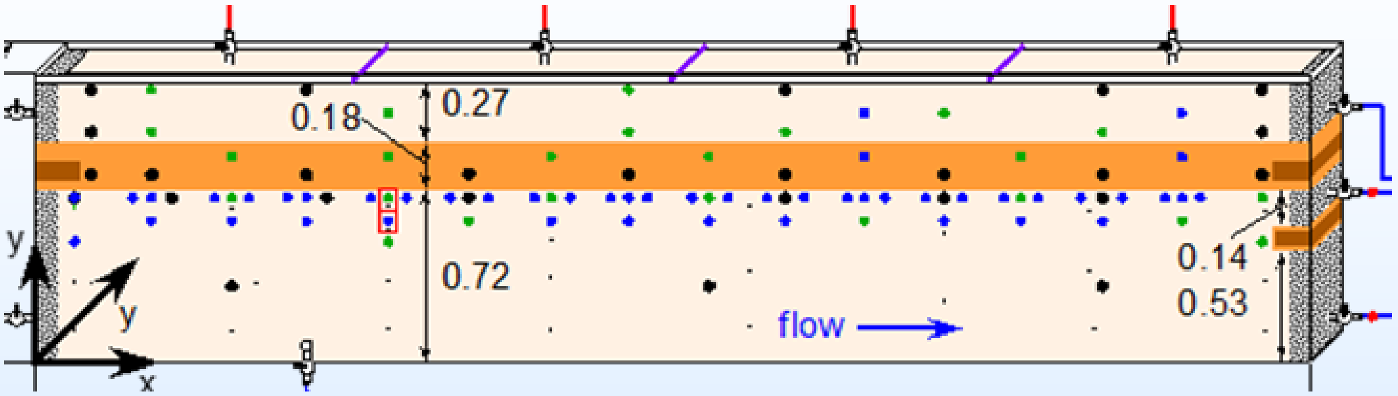




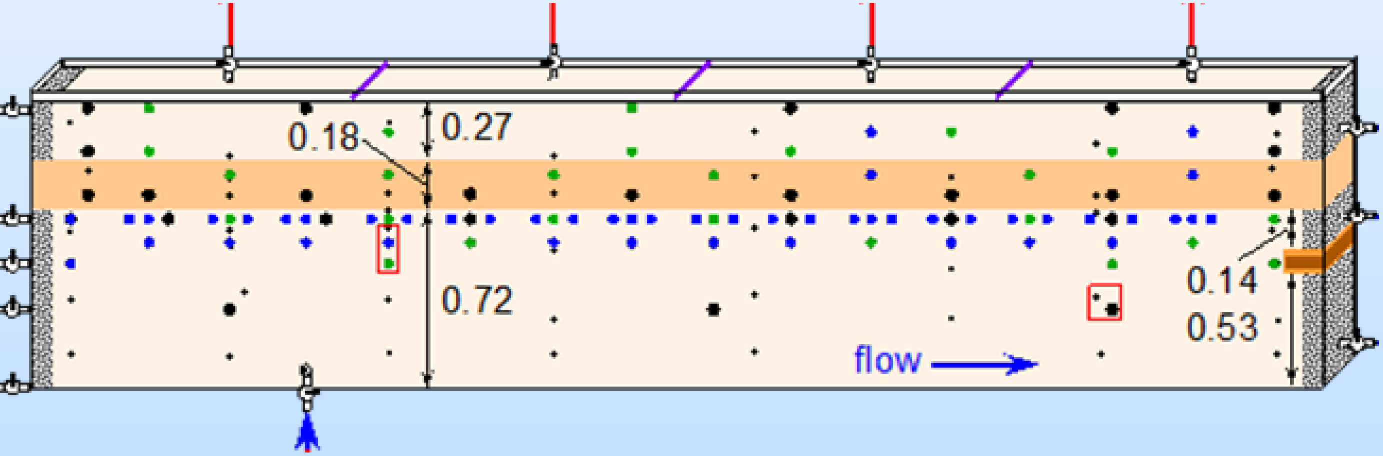


~ 3 months to pack and configure the tank

Effect of permeability heterogeneity on CO_2 exolution and migration

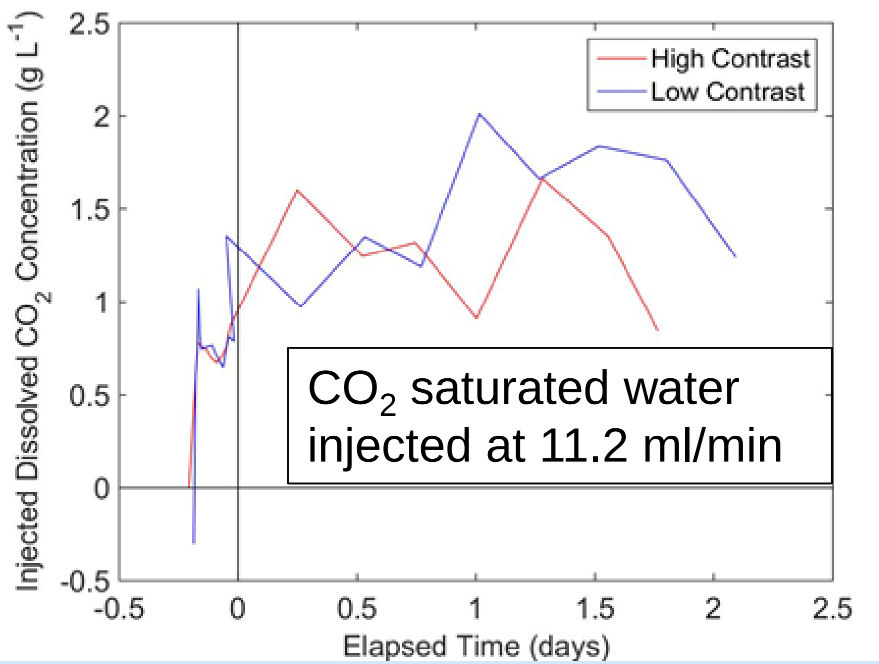


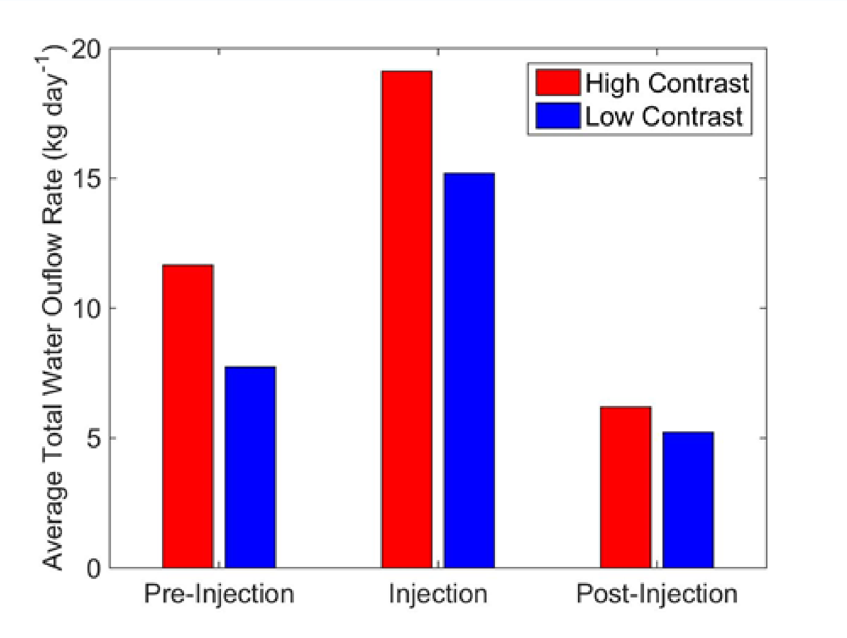
High permeability contrast

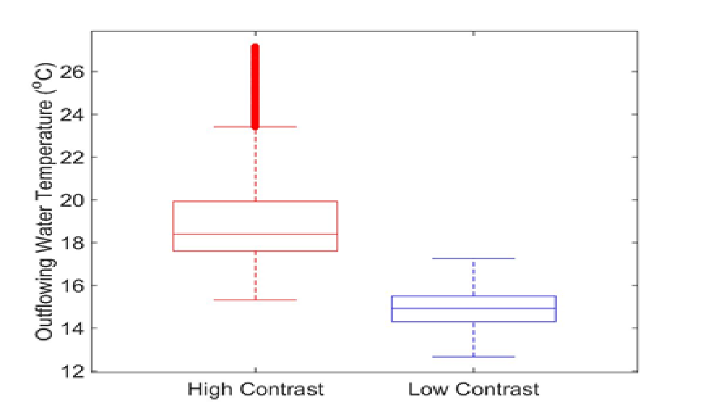


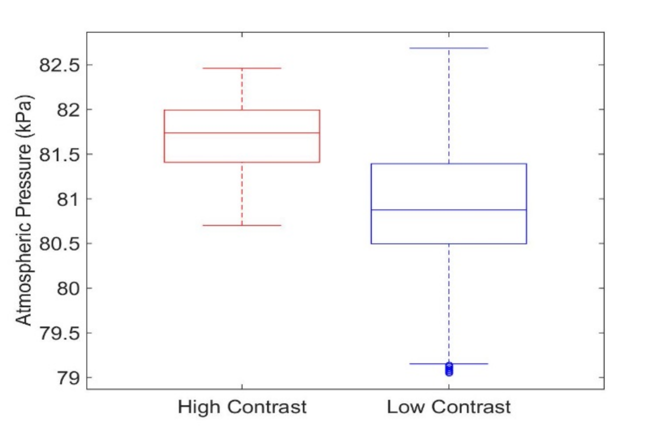
Low permeability contrast

Experimental Conditions



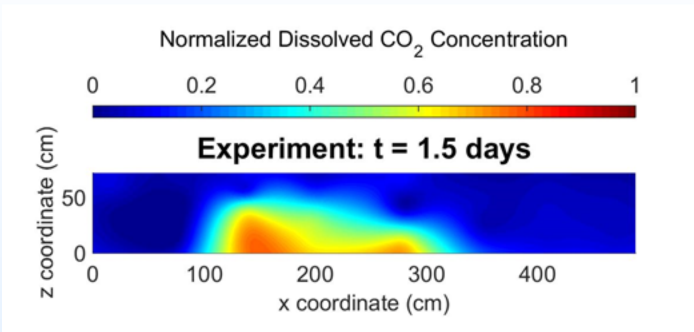


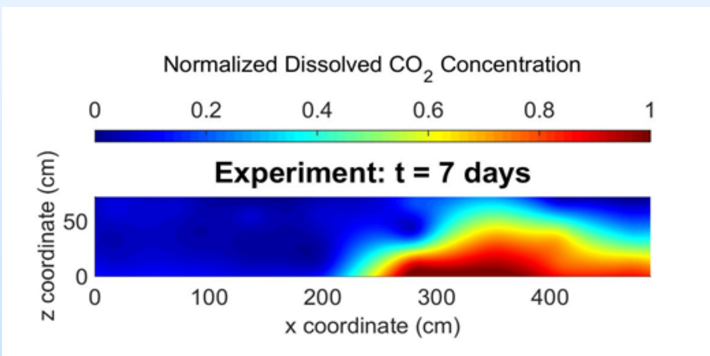


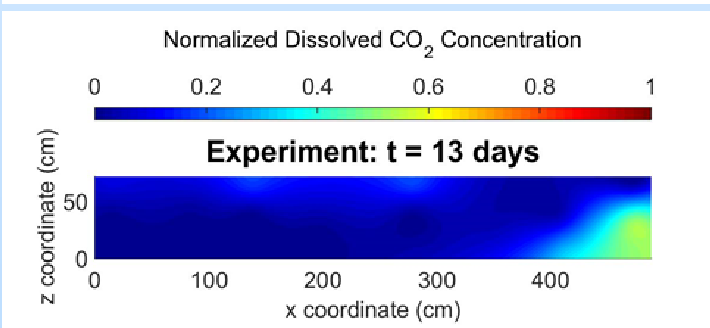


Effect of permeability heterogeneity on CO_2 migration: dissolved CO_2

High permeability contrast







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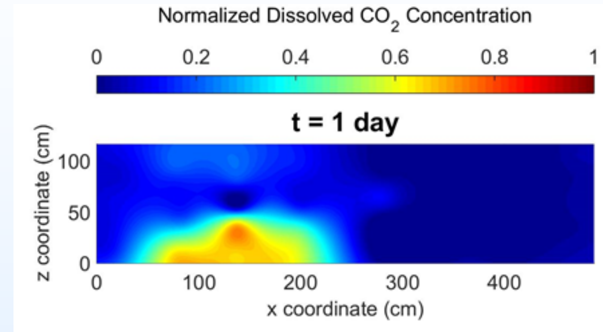
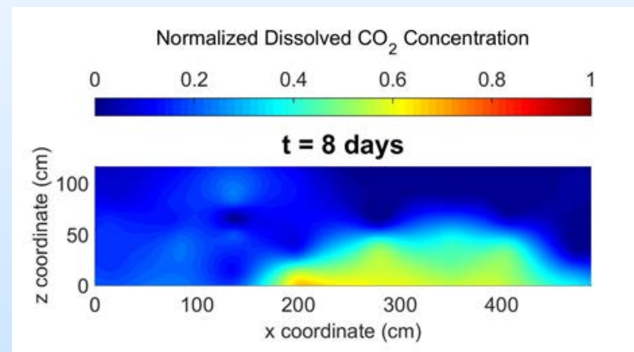
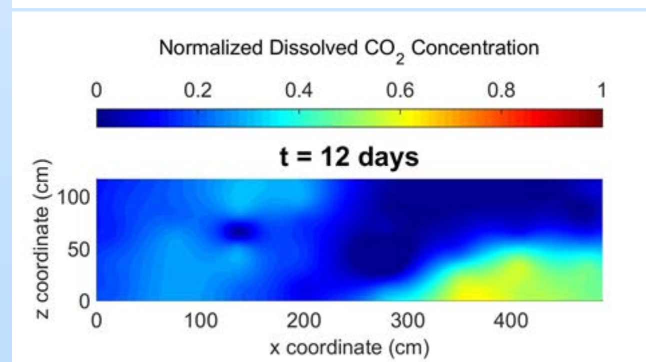


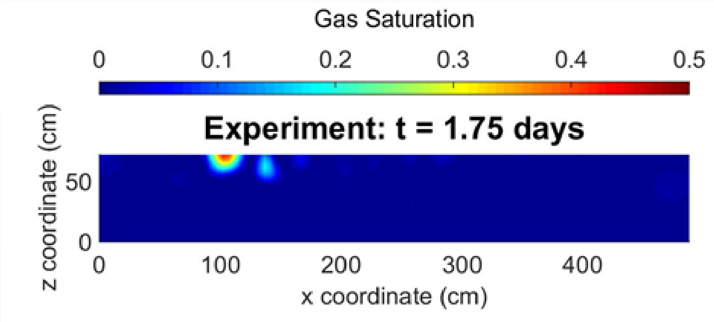


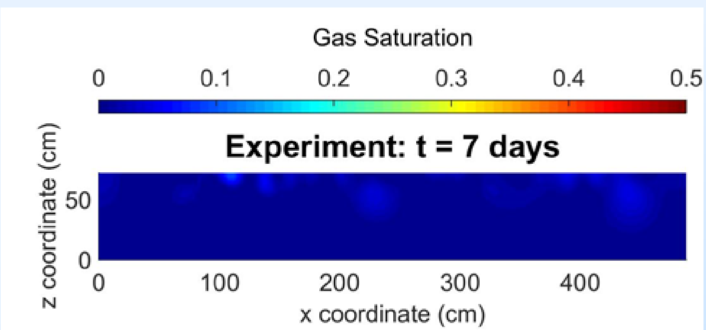


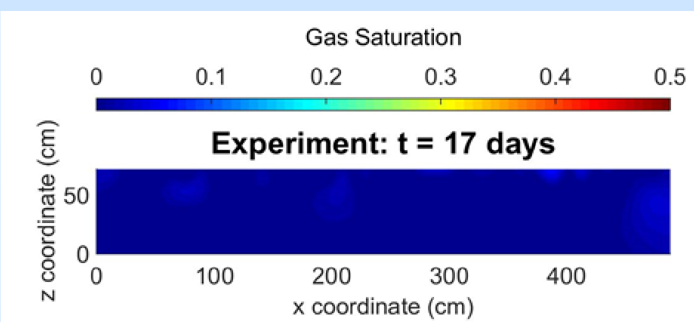
only the "lower aquifer" is shown

Effect of permeability heterogeneity on CO_2 migration: free phase CO_2

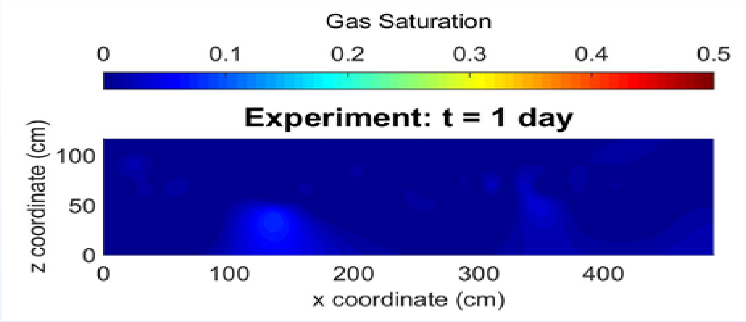
High permeability contrast

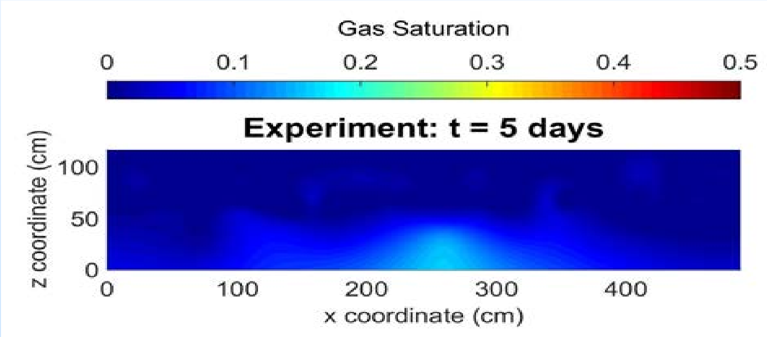


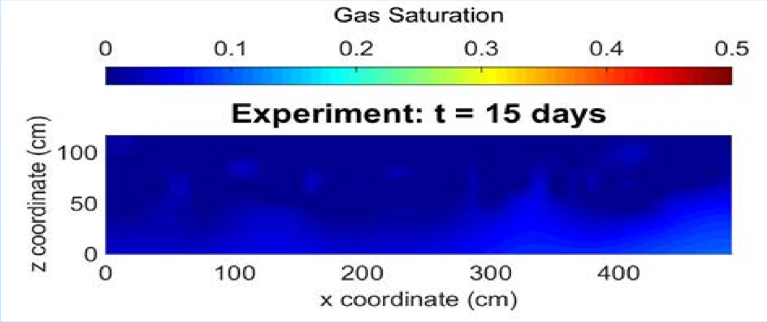




Low permeability contrast

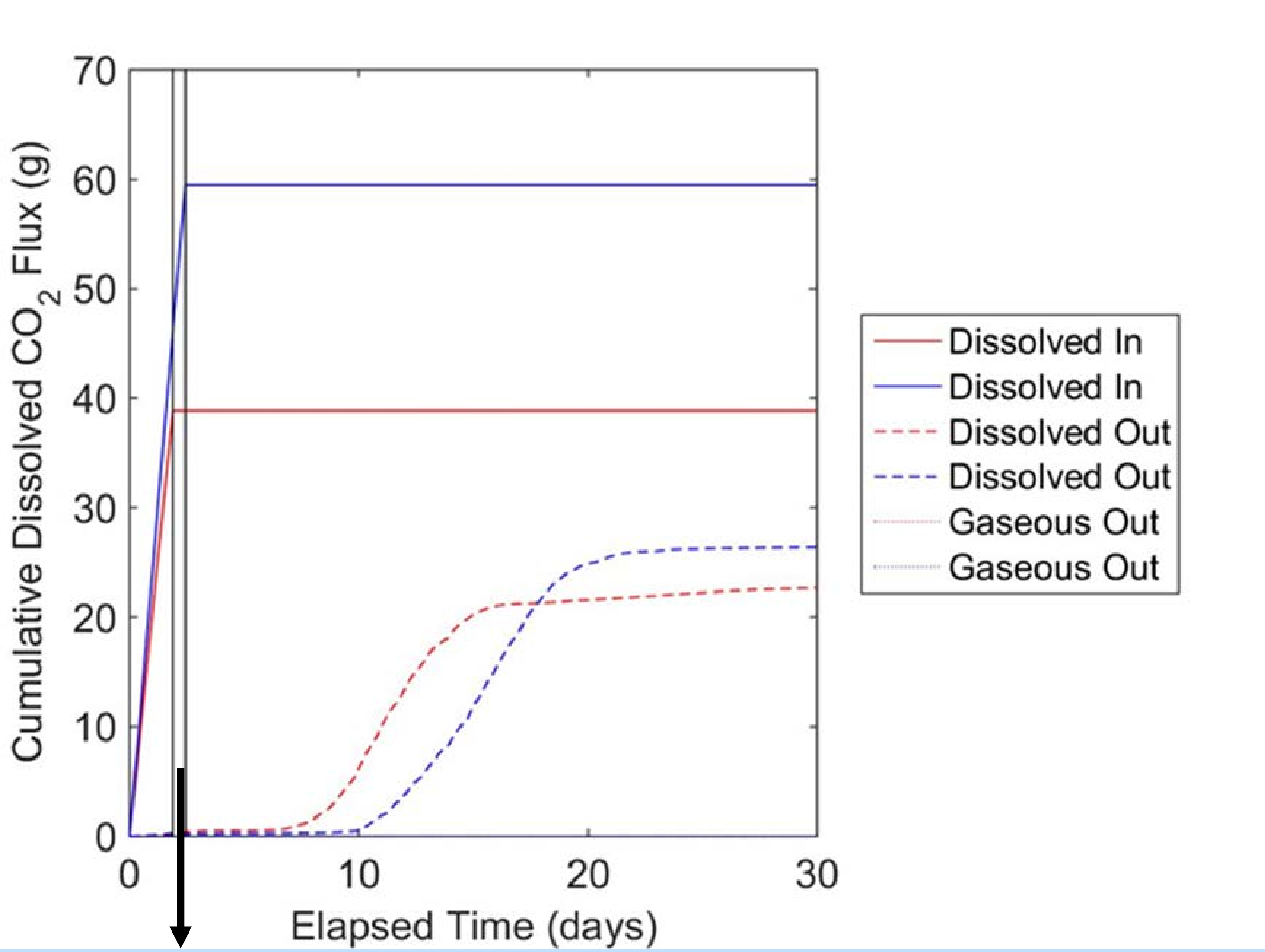






only the “lower aquifer” is shown

Macroscopic CO_2 Mass Balance



Injection stopped

Negligible release of gas phase CO_2 to the atmosphere

Key Findings

- Permeability contrast (heterogeneity) affects CO_2 migration
- Background flow affects the existence of free-phase CO_2:
  - Higher fraction of CO_2 in dissolved-form
- Dissolved CO_2 plume primarily remains at the bottom
- CO_2 remains in the water (primarily dissolved) well after leakage stops
- Important implications on monitoring and mitigation

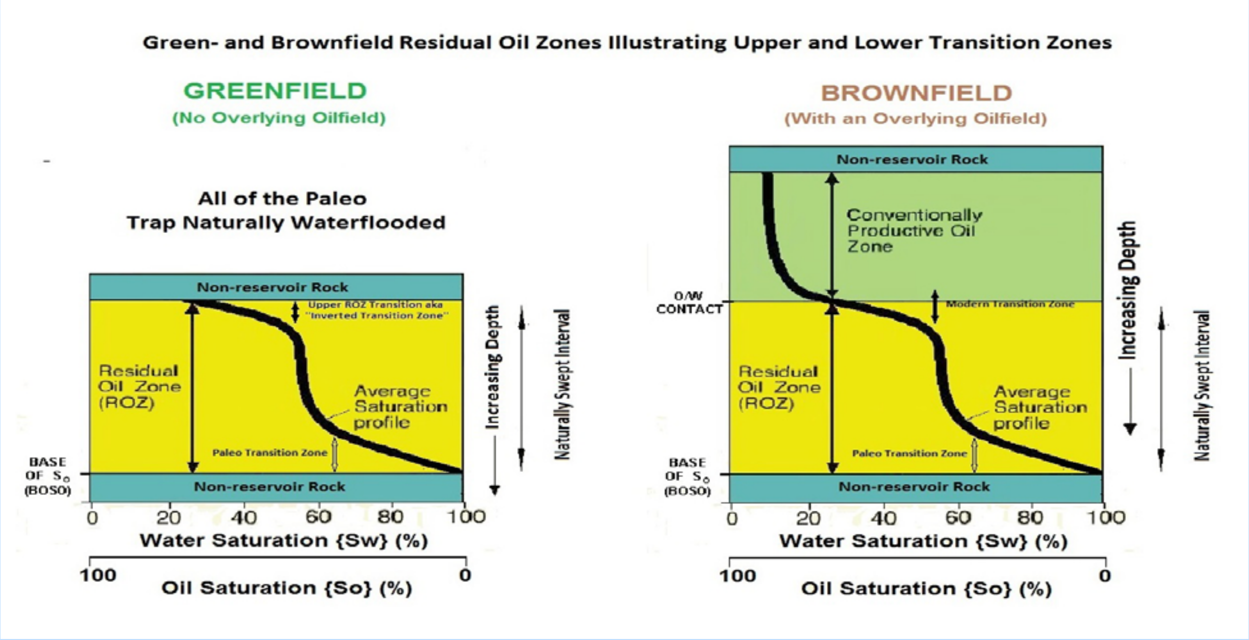
Next Steps

- Numerical simulation of experiments and extension of observations to real-world aquifer conditions

Characterization of CO_2 storage in ROZs

Residual Oil Zones (ROZs)

- ROZs are defined as those zones where oil is swept over geologic time period (natural flush) and exists at residual saturation
  - Brownfield: ROZ underlies a Main Pay Zone (MPZ)
  - Greenfield: no Main Pay Zone (MPZ) above ROZ



Graphic source: http://melzerconsulting.aptapb.com/residual-oil-zones/

Residual Oil Zones (ROZs)

- ROZs are being increasingly exploited using CO_2-EOR:
  - Multiple on-going commercial field operations in Permian Basin
  - Significant potential for oil recovery
  - Observed in other locations (e.g. Wyoming)
- Greenfield ROZs can be potentially explored for CO_2 storage:
  - With a side benefit of incremental oil recovery
- Brownfield ROZ CO_2-EOR could lead to CO_2 storage similar to conventional EOR

Residual Oil Zones (ROZs)

- ROZs tend to have characteristics that are similar to saline reservoirs which are primary targets for CO_2 storage:
  - Thick target intervals
  - High porosity
- ARI and Melzer Consulting have performed studies to estimate potential CO_2 storage potential in the Permian Basin ROZ (preliminary studies):
  - Preliminary estimates indicate potentially high storage capacity
  - Capacity estimates need to be further refined with focused studies

Objectives

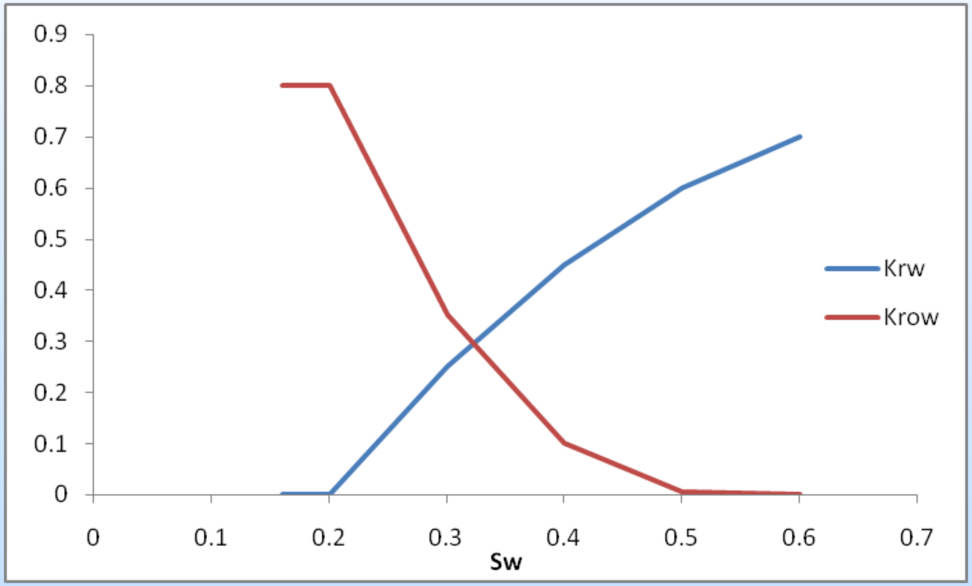
- Using numerical simulations we aim to characterize:
  - CO_2 storage potential (primarily in Greenfield ROZ)
  - Long-term CO_2 fate
  - Assess uncertainties and data needs (limited data currently available)

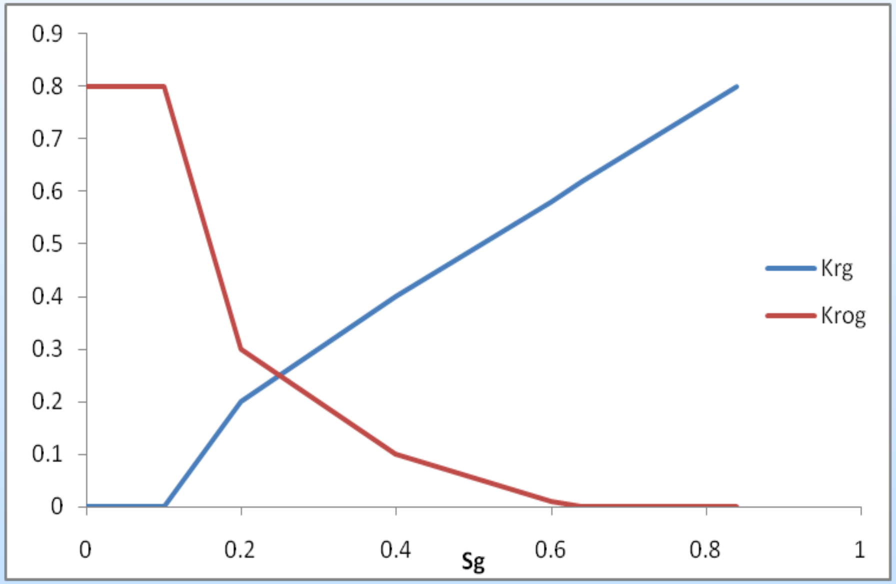
Numerical Simulations

- Numerical model based on the model developed for Goldsmith-Landreth San Andres Unit in the Permian Basin
  - DOE funded study by UT-PB, Melzer Consulting and ARI
  - Field operated by Kinder Morgan
  - CO_2 flooding in ROZ and MPZ since 2010
- Our model focuses only on the ROZ (Greenfield equivalent)
  - 4320 ft x 4320 ft x 120 ft (36x36x10)
  - Rock properties based on log and core data: Porosity 8% - 20%, Permeability 6.25 mD – 62.5 mD
  - Original oil saturation 40% (residual) with no free gas

Numerical Simulations

- Fluid-rock relationships based on Seminole Field data reported by Honarpour et al (2010, SPE-133089):
  - Further updated through field history match by UTPB study





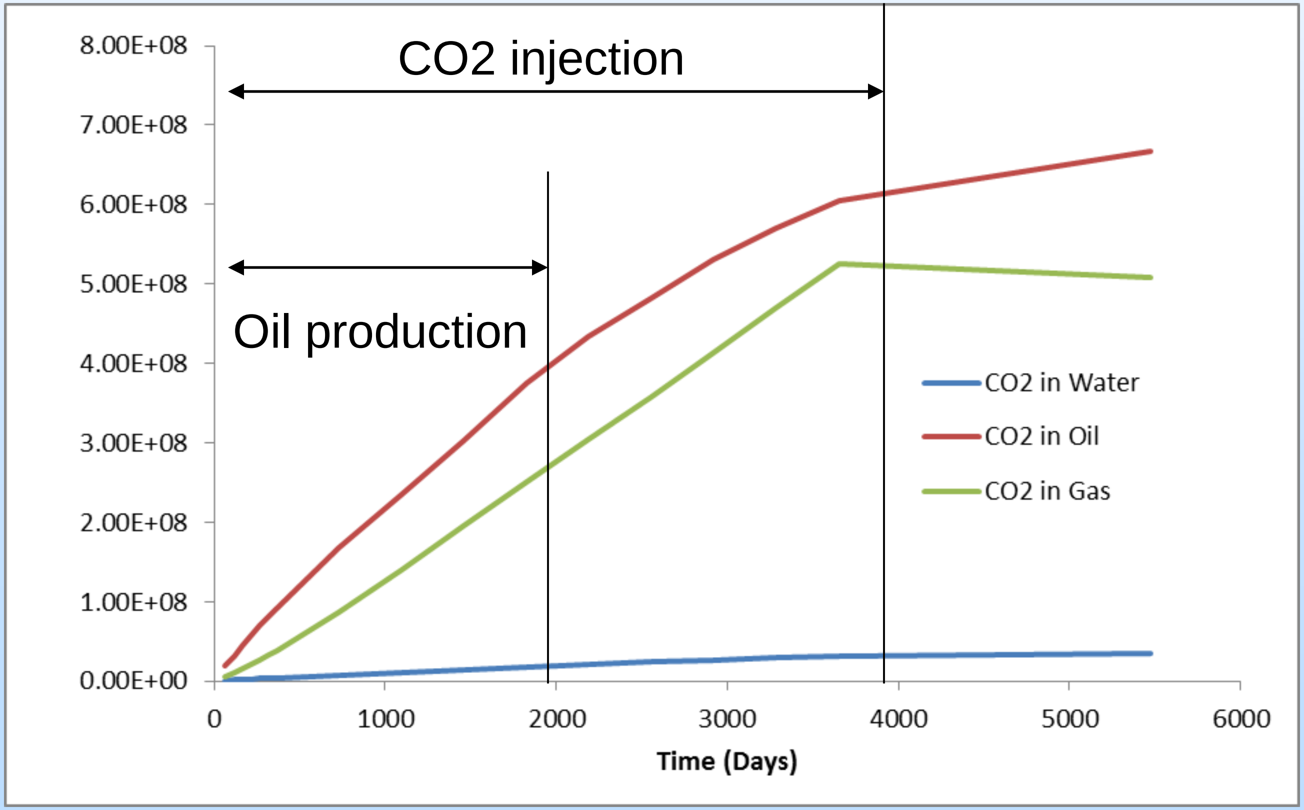
Sorm – 10%

Numerical Simulations

- Compositional simulations using E300
  - Oil composition based on field oil composition: represented as 10 component oil
  - Solubility of CO_2 in water taken into account
- Simulations of CO_2 injection with simultaneous oil production (injector and producer at opposite corners)
  - Total simulation run for 15 years
  - CO_2 injected at 90 tons/day for 10 years (max BHP 4000 psi)
  - Producer turned off after 5 years (produced at 500 psi BHP)

Numerical Simulations Results

- CO_2 injection leads to ~20% incremental oil recovery
  - 106 MSTB without, 127 M STB with
  - High water production (~4.9 MMSTB)
- 99% of injected CO_2 remains in the reservoir
- Majority of CO_2 dissolved in oil or present in gas phase (97%)

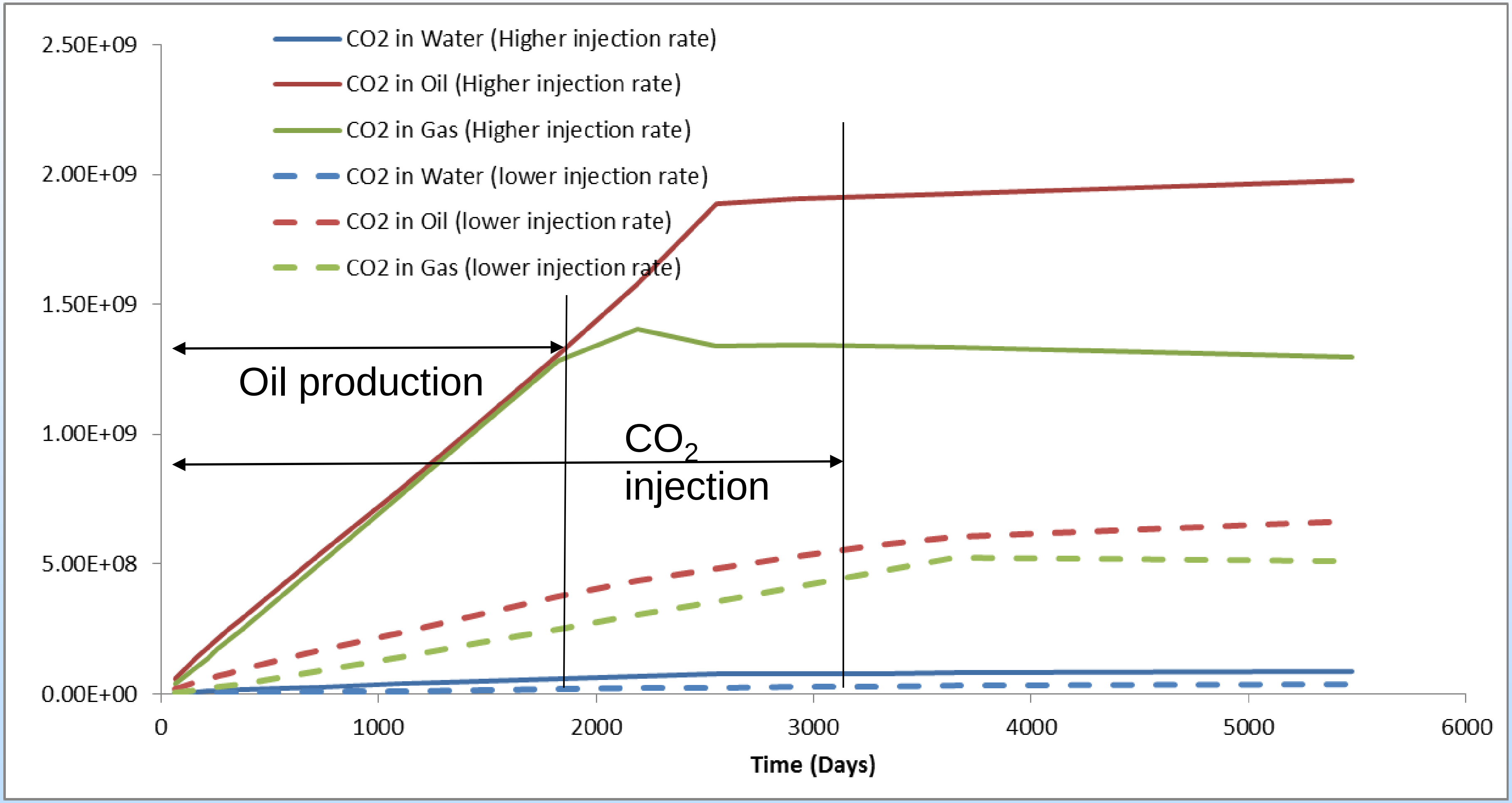


Effect of higher CO_2 injection rate

- 5 times the rate of base case (450 tons/day) with same BHP constraint (4000 psi)
  - BHP constraint limits total injection to 3 times of base case

	Base Case	**Higher Injection Rate**
Retained CO_2	99%	99%
Oil production	127 M STB	91 M STB
Water production	4.9 MM STB	8.27 MM STB

Effect of higher CO_2 injection rate



Accomplishments FY16

- Completed 2 sets of 2-D tank experiments on post CO_2 leakage multi-phase flow in groundwater aquifer
  - Results have significance on monitoring and mitigation strategies in groundwater aquifers
- Initiated preliminary studies on CO_2 storage potential of ROZ

Synergy Opportunities

- Collaboration on ROZ: UTPB, Melzer consulting, ARI

Key Findings, Future Plans

- Significant results with practical implications:
  - Groundwater leakage impacts
- Experimental data on CO_2-brine leakage in 1-D columns and 2-D tanks: available for model development and testing

Future Plans:

- Complete 2-D tank experiment related numerical simulations:
  - Data sets and parametric analysis on effect of groundwater hydrologic parameters on CO_2 migration and implications on monitoring/mitigation
- Continue work on characterization of CO_2 storage potential in ROZ

Appendix

Organizational Chart

- PI: Rajesh Pawar
- Program Manager: George Guthrie
- Team Members:
  - Prof. Tissa Illangasekare (Colorado School of Mines): CO_2 release experimental characterization
  - Michael Plampin (Colorado School of Mines): CO_2 release experimental characterization
  - Mike Porter: Numerical simulation of CO_2 release experiments
  - Elizabeth Keating: Fault flow characterization
  - Zhenxue Dai: ROZ CO2 storage potential characterization

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