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Geologic CO2 storage using pre-injection brine production in tandem reservoirs: A strategy for improved storage performance and enhanced water recovery

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CO_2 Summit II: Technologies and Opportunities
Session: CO_2 Utilization - I

Geologic CO_2 Storage using Pre-Injection Brine Production in Tandem Reservoirs: A Strategy for Improved Storage Performance and Enhanced Water Production

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Outline

- Introduction/Motivation
- Objectives
- Pre-injection brine-production, tandem-reservoir approach
- Model results
  - Testing the efficacy of brine removal for a real geologic setting: Tubåen Fm. at Snøhvit
  - Brine storage/utilization options
- Conclusions

Introduction/Motivation

- Key challenges for saline-reservoir geologic CO_2 storage (GCS)
  - Pressure buildup drives storage risks that can limit storage capacity and permanence
    - ✓ Induced seismicity
    - ✓ Caprock fracture
    - ✓ CO_2 and brine leakage
  - Until large amounts of fluid move into or out of a reservoir, estimates of storage capacity and permanence are subject to large uncertainty
  - Reducing this uncertainty is likely to be necessary prior to securing financing for CO_2 capture and transportation infrastructure
  - CO_2 capture can be water intensive

Introduction/Motivation

- Proactive reservoir management can address these challenges
  - Key need is to remove brine from the storage formation
  - Consumptive use of brine reduces the quantity of brine to be reinjected
    - but water recovery factors are often low, necessitating reinjecting much of the brine
    - quantities of brine moved will be much greater than the quantity of stored CO_2
  - A second permeable formation is needed to handle the brine
  - Enhanced water recovery (EWR) prior to, during, and after the CO_2 storage period
  - Moving brine enables *active reservoir selection and characterization*
    - determine storage capacity and permanence prior to CO_2 injection
    - provide assurance that storage integrity can be managed before incurring the risks associated with CO_2 injection

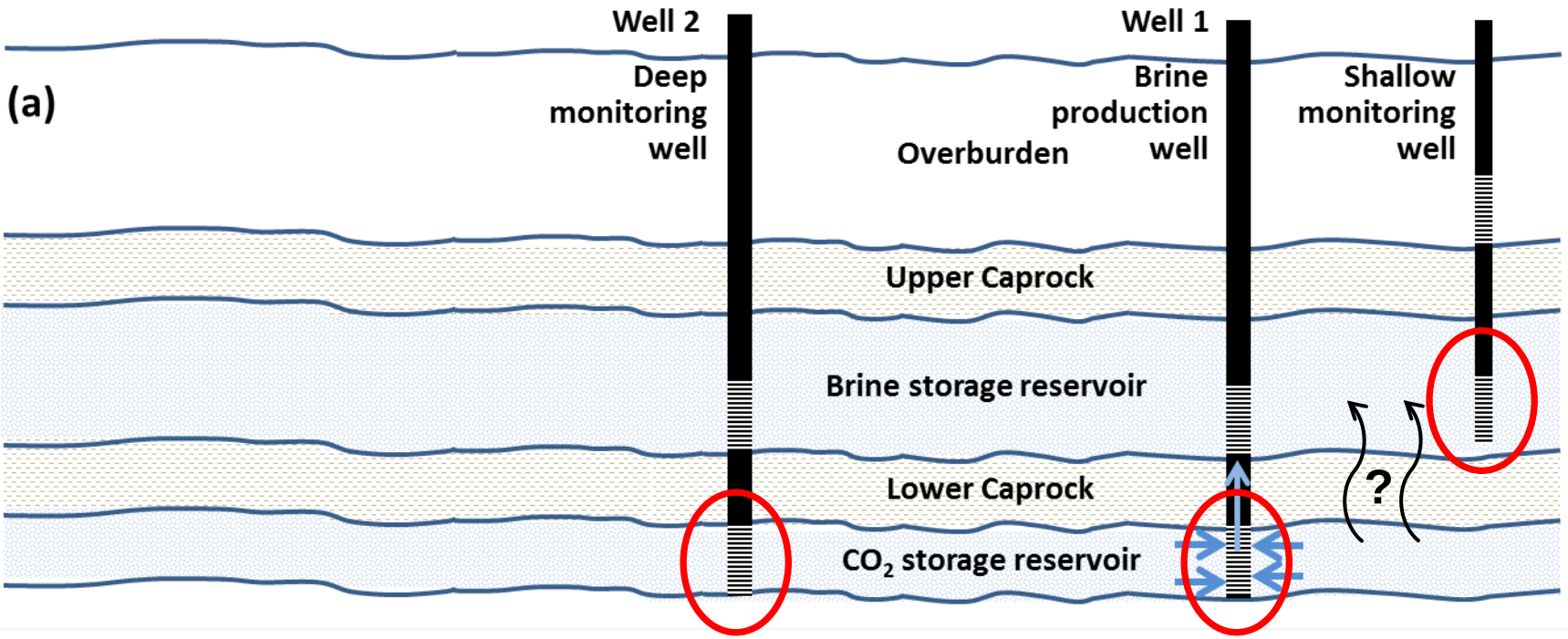
Using two reservoirs in tandem provides flexibility

- CO_2 storage reservoir
  - High seal integrity is required
  - Low total dissolved solids (TDS) is preferred, but not required
  - Produce brine prior to injecting CO_2, using same well
- Brine storage reservoir
  - High seal integrity not required – a leaky seal helps with pressure relief and storage capacity
  - Lag storage – brine can be injected into and extracted from this reservoir to avoid surface storage and to increase water recovery
  - Low TDS is preferred for efficient water recovery, but not required with high storage capacity
  - Mineral exploitation can be included in selection criteria
  - Can create a hydraulic barrier above the CO_2 reservoir

Pre-Injection Brine-Production Tandem-Reservoir Approach

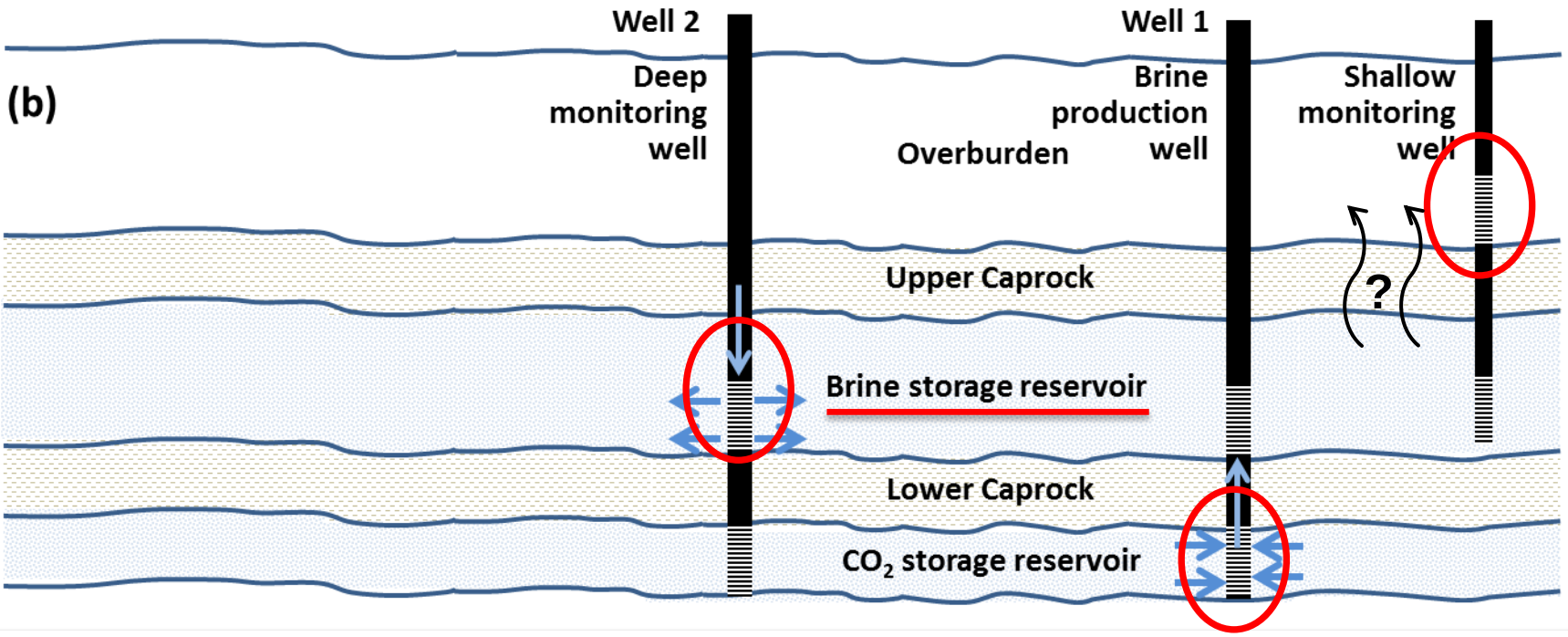
Pre-injection brine production

- Monitor pressure drawdown to assess
  - CO_2 storage capacity and compartmentalization
  - CO_2 leakage potential
- Reservoir diagnostics where needed most: at the center of CO_2 storage



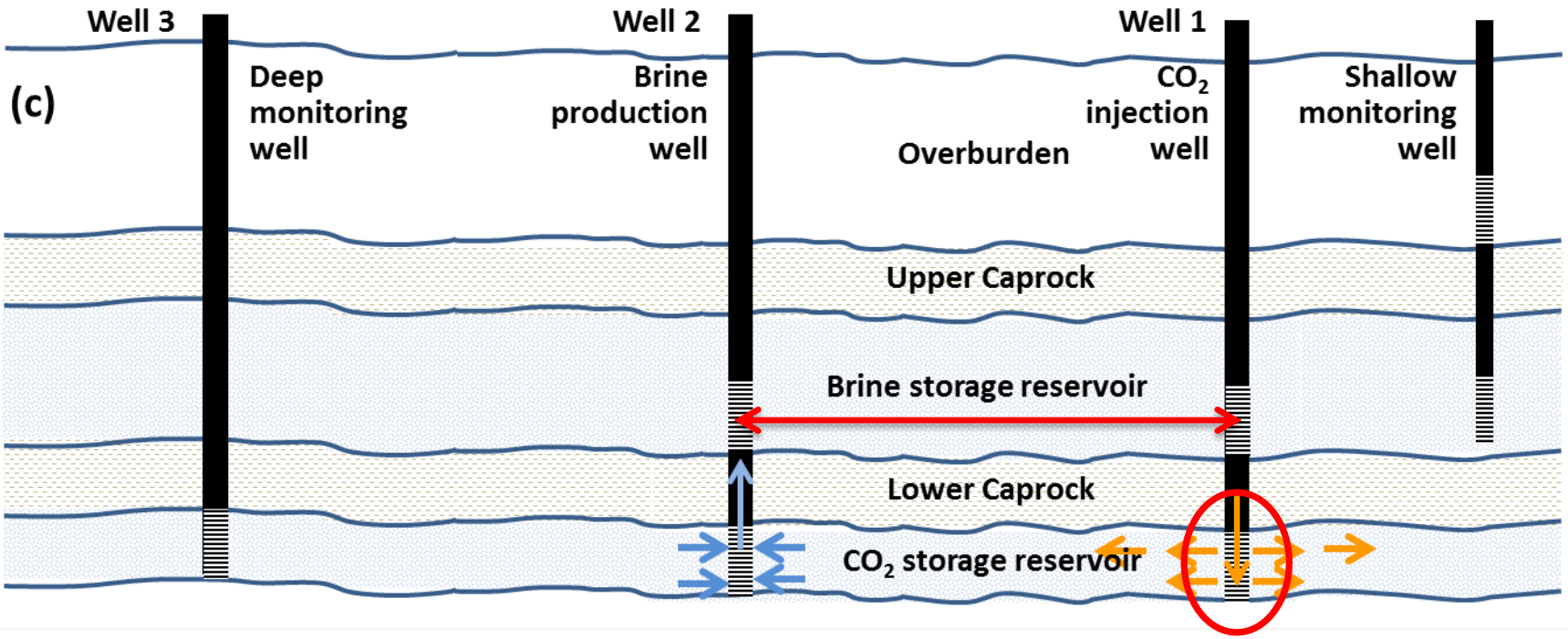
Pre-injection brine production and reinjection

- Produced brine may be reinjected in an overlying brine-storage reservoir
- Measuring pressure buildup from brine reinjection can determine
  - Brine reservoir storage capacity
  - Brine leakage potential



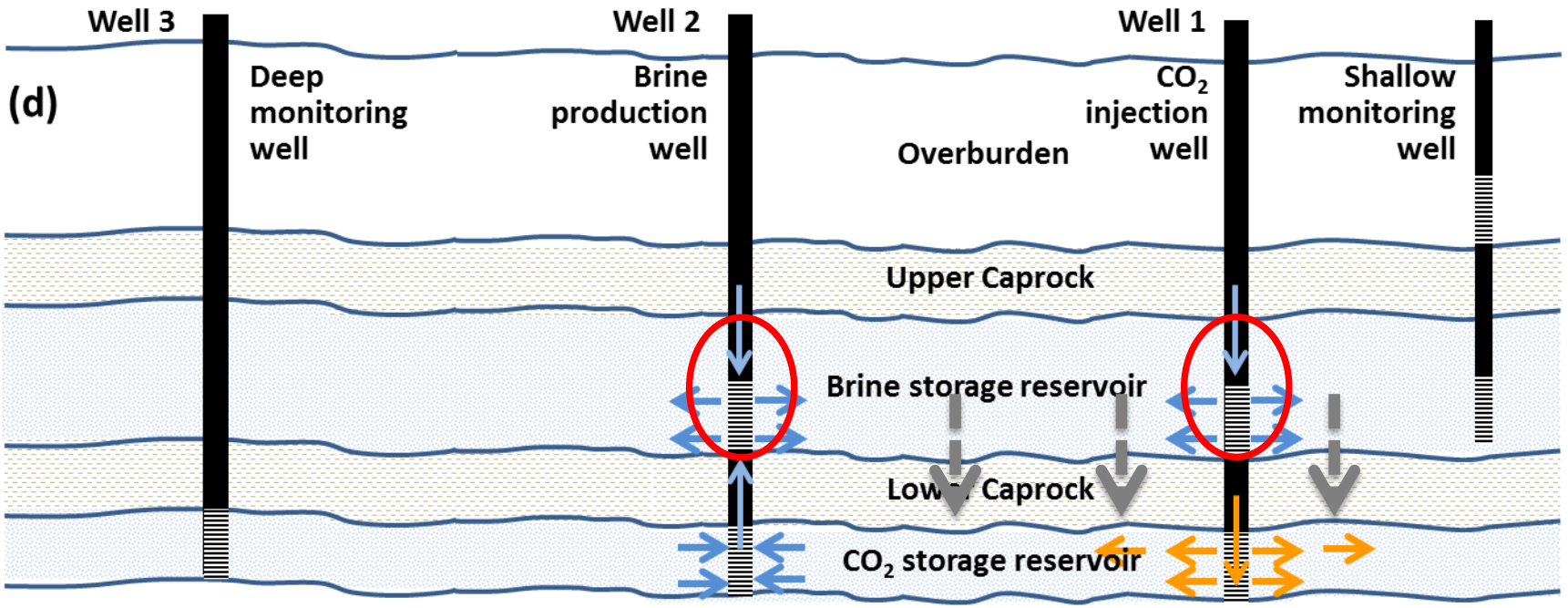
Co-injection brine production

- Pre-injection pressure drawdown allows
  - greater spacing between injectors and producers (fewer wells overall)
  - ongoing pressure-management planning
- Pressure relief is greatest where needed most: at the center of CO_2 storage



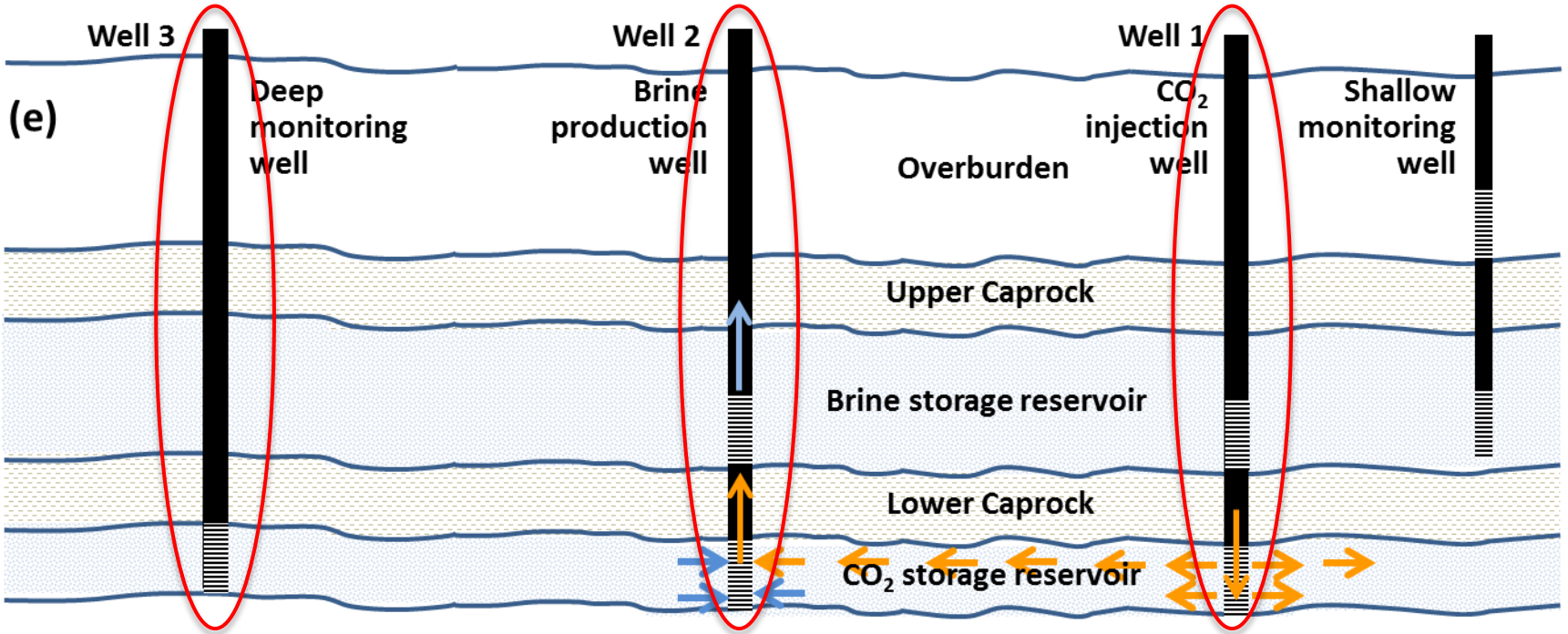
Co-injection brine production and reinjection

- Brine that is not consumed can be reinjected into a brine-storage reservoir
- Reinjecting in an overlying brine-storage reservoir can reverse the overpressure gradient and reduce CO_2 leakage potential



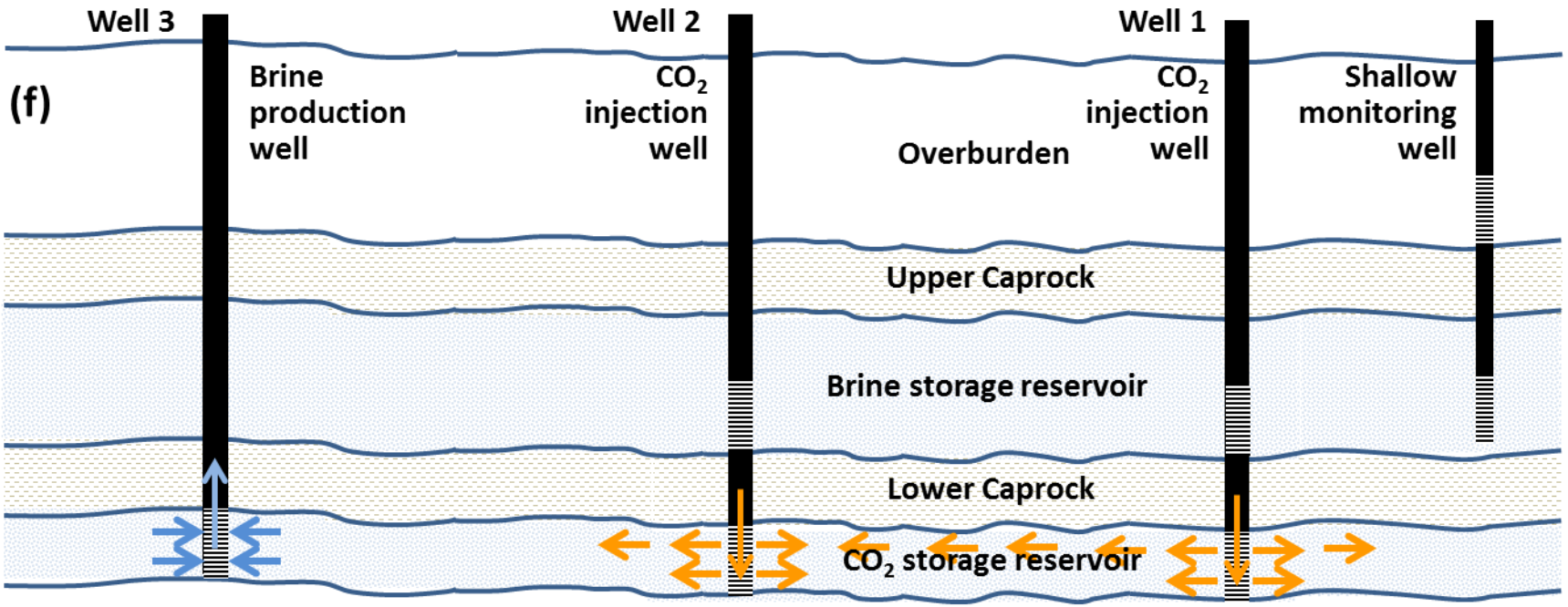
Co-injection brine production

- After CO_2 breakthrough, a brine producer can become a CO_2 injector
- Each successive well goes through three stages:
  - monitoring
  - brine production
  - CO_2 injection



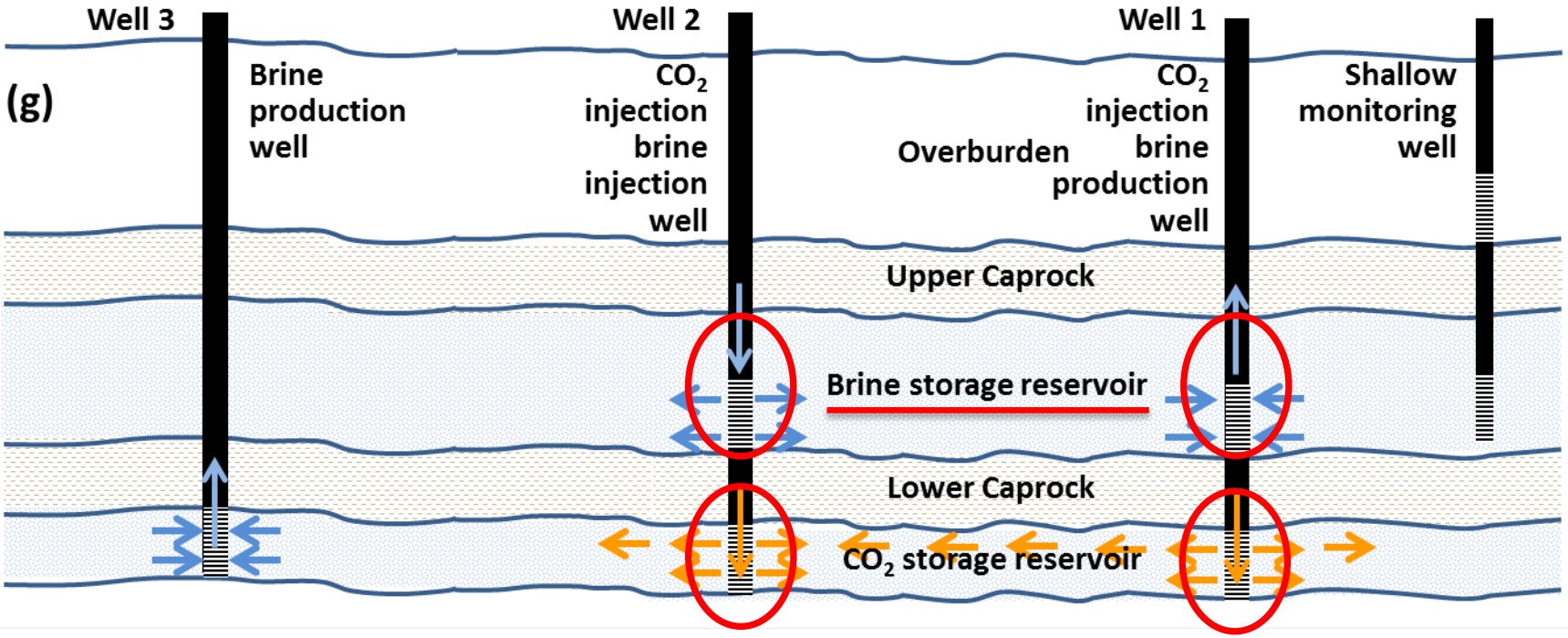
Co-injection brine production

- Each additional well can be located and operated with the most information
- CO_2 storage operations can be managed proactively and more efficiently



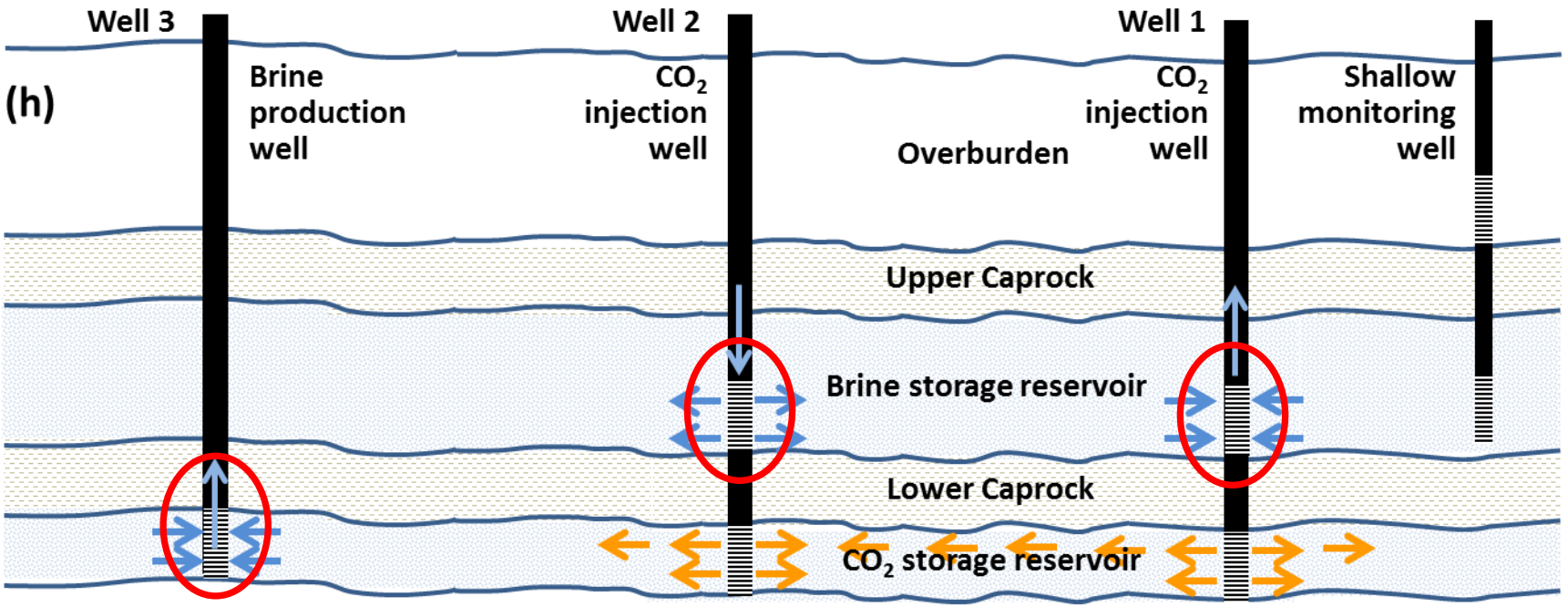
Co-injection brine production and reinjection

- Isolating well intervals with packers can enable simultaneous
  - CO_2 injection
  - brine production or reinjection
- The brine-storage reservoir may be selected on the basis of its TDS or mineral-exploitation potential



Post-injection brine production

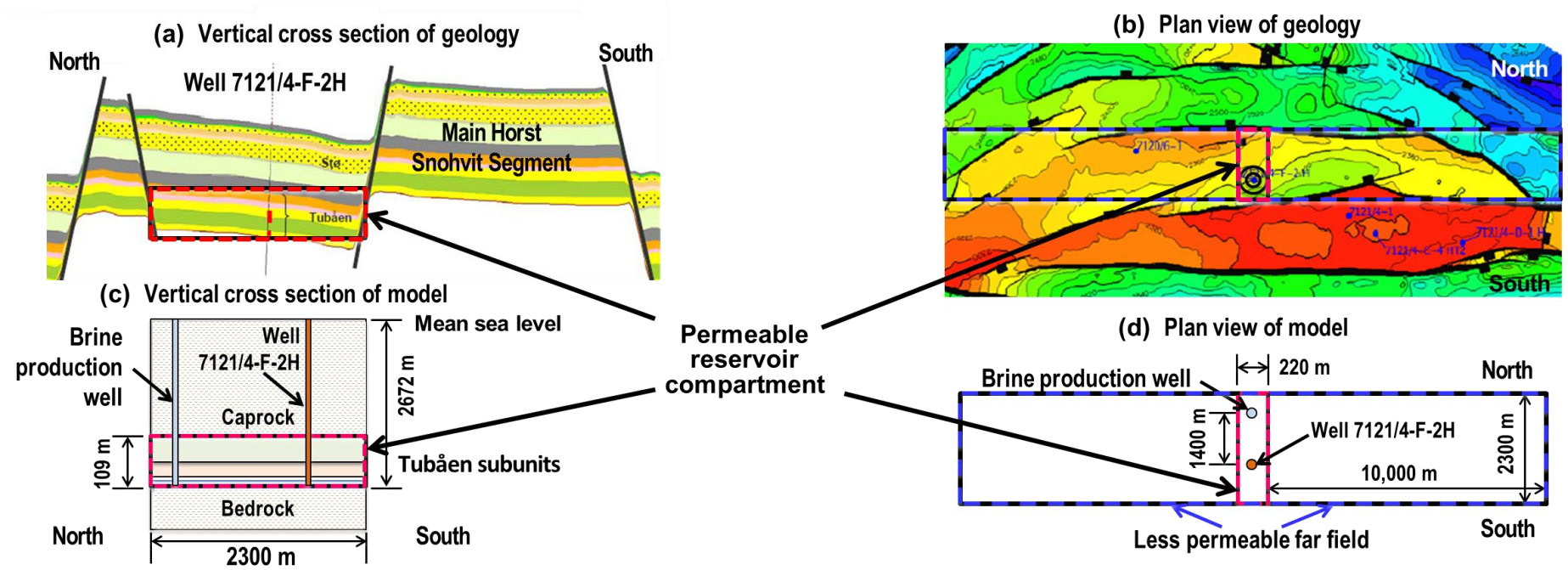
- In the CO_2-storage reservoir, brine production can continue post-injection to nullify overpressure
  - reducing the areal and temporal extent of site care and monitoring
- In the brine-storage reservoir, production and reinjection can also continue post-injection for EWR and mineral extraction



Testing the efficacy of brine removal for a real geologic setting: Tubåen Fm. at Snøhvit

Calibrated reservoir model of phase 1 of Snøhvit CO_2 project

- Reservoir model, using the NUFT code, was calibrated for 3 yr of injection of 1.09 MT of CO_2 into Tubåen Fm with data provided by Statoil
  - thickness, porosity, and permeability
  - CO_2 injection-rate and bottom-hole pressure for injection well
  - structural geology and 4-D seismic difference amplitude maps
  - production logging tool data show 80% of injection going into lower perforated zone

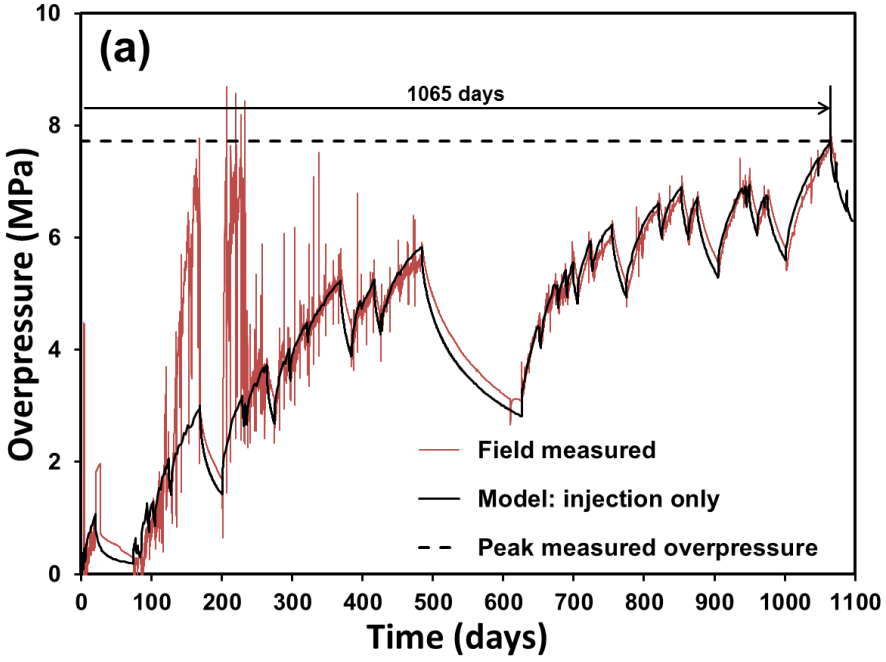


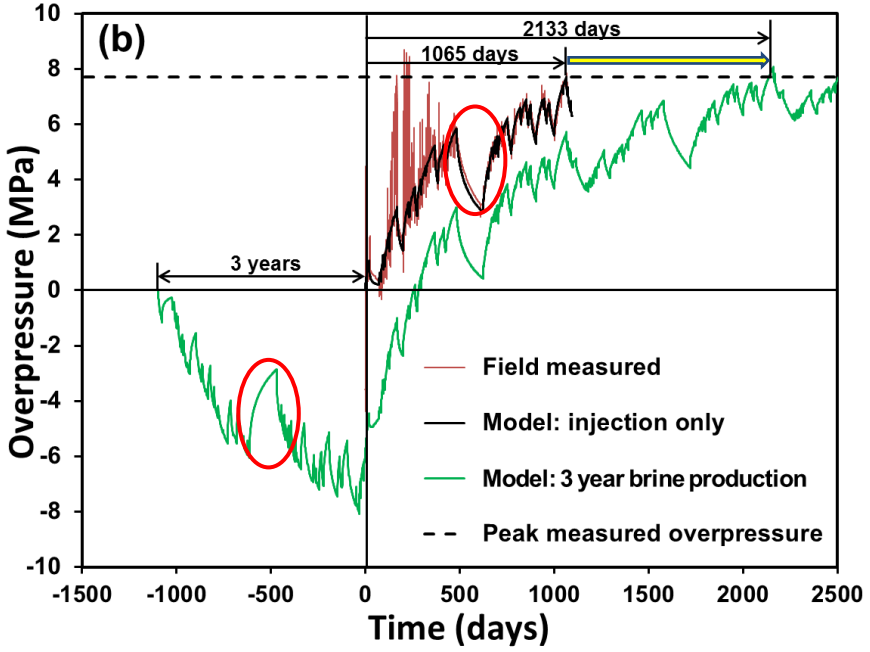
Pressure-management analyses with calibrated model

- Tested pre-injection brine production strategy for a real geologic setting
- Calibrated model agrees with measured overpressure trend of phase 1
- Pressure drawdown is diagnostic of pressure buildup during CO_2 injection and storage capacity

- Producing a brine volume equal to the injected CO_2 volume allows injecting an additional 1.03 MT of CO_2, 94.4% efficient on a volume-per-volume basis

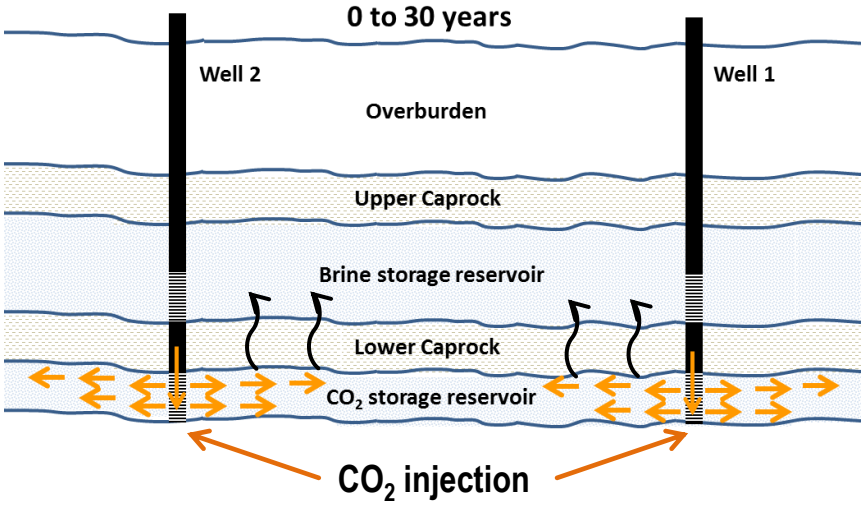
Buscheck, T.A., White, J.A., Carroll, S.A., Bielicki, J.M., and Aines, R.D., 2016a. Managing geologic CO_2 storage with pre-injection brine production: A strategy evaluated with a model of CO_2 injection at Snøhvit, *Energy and Environmental Science*, **9**: 1504-1512.

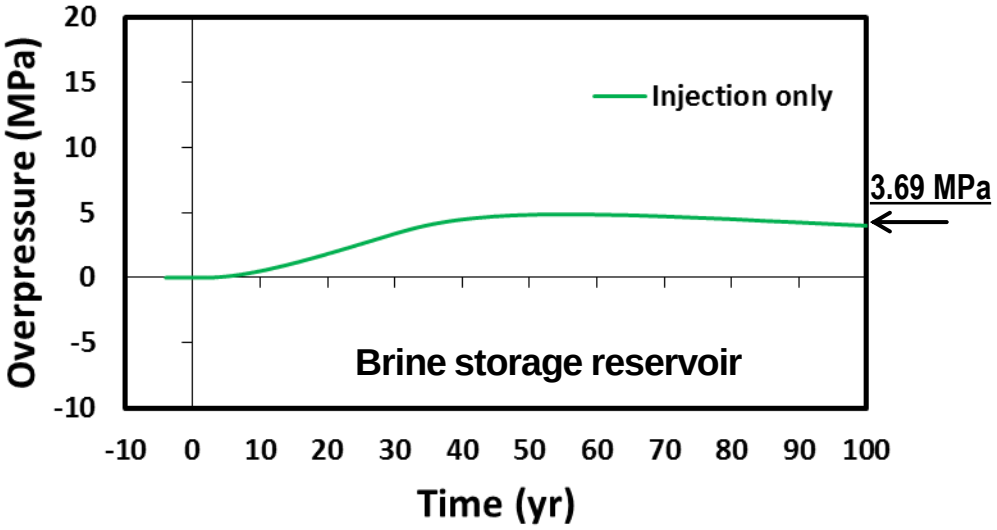


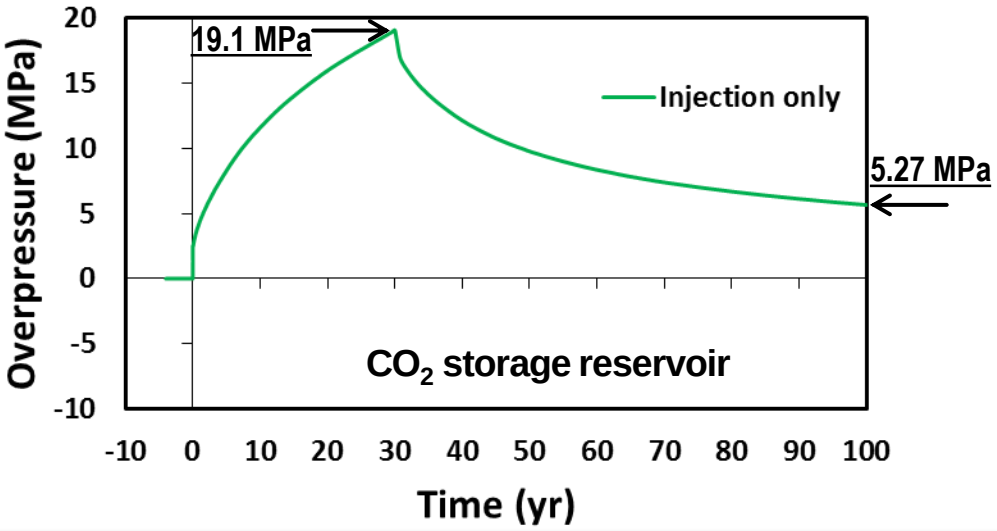


Brine Storage/Utilization Options

Injection only







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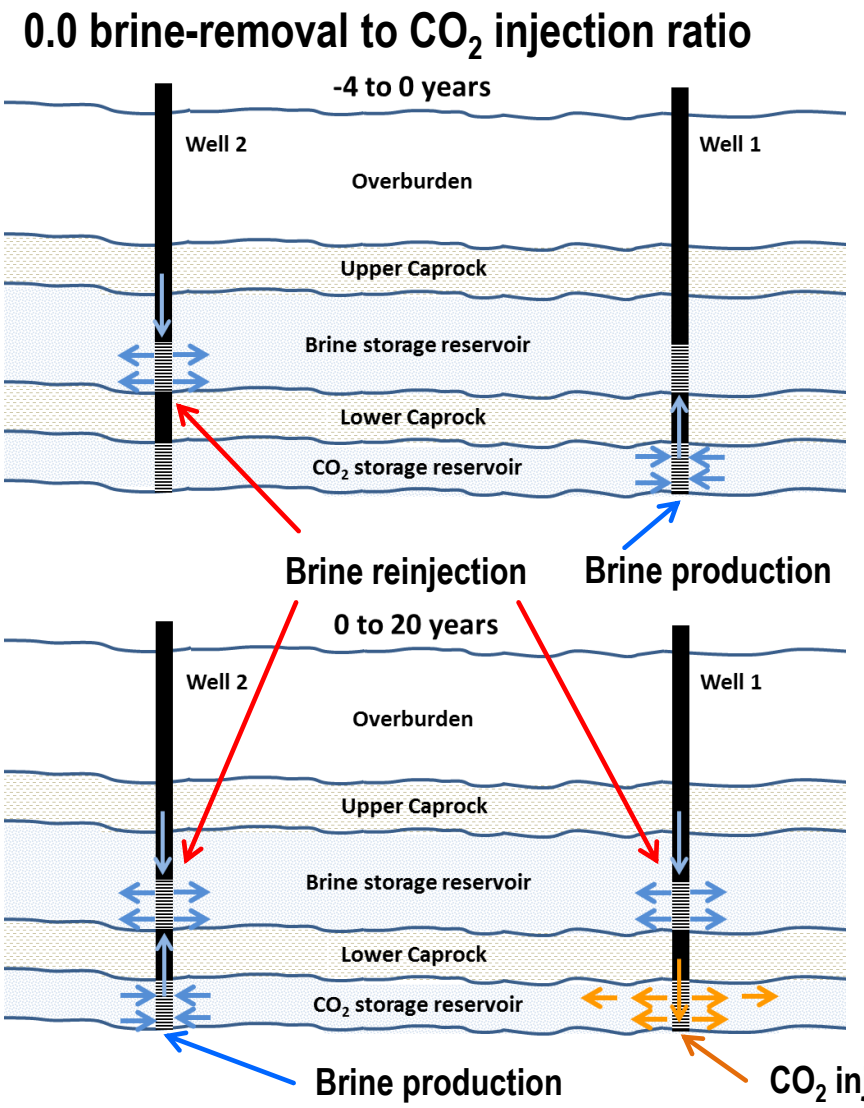
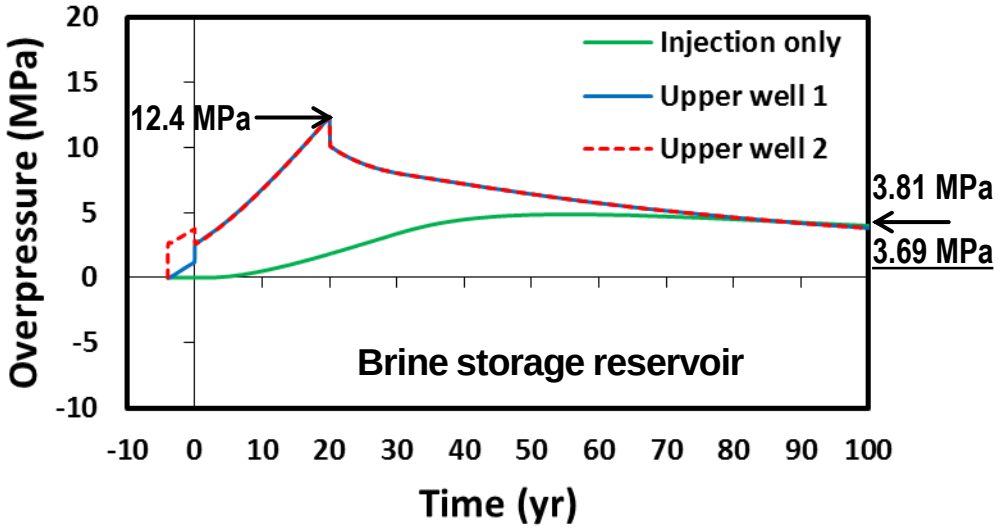
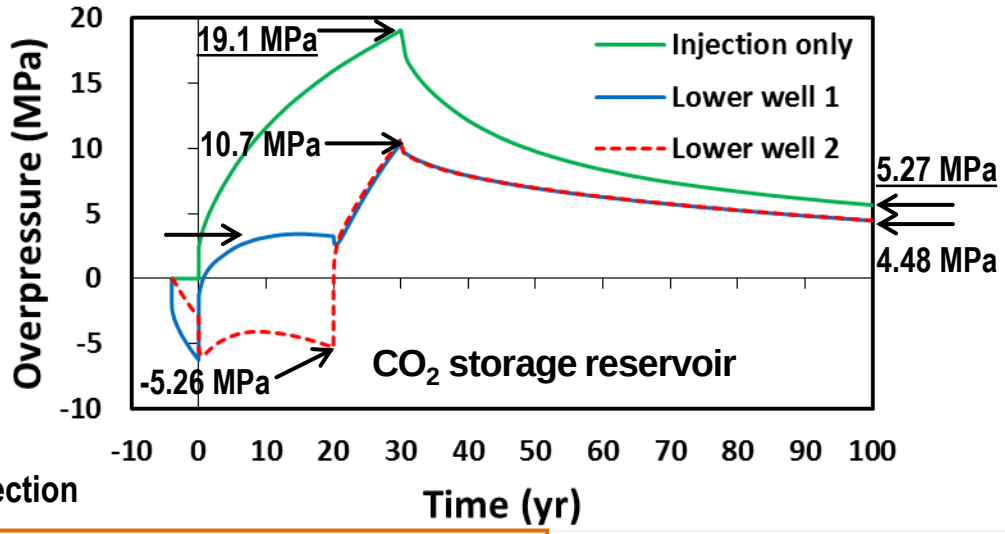
Brine disposition: 0% consumption, 100% reinjection



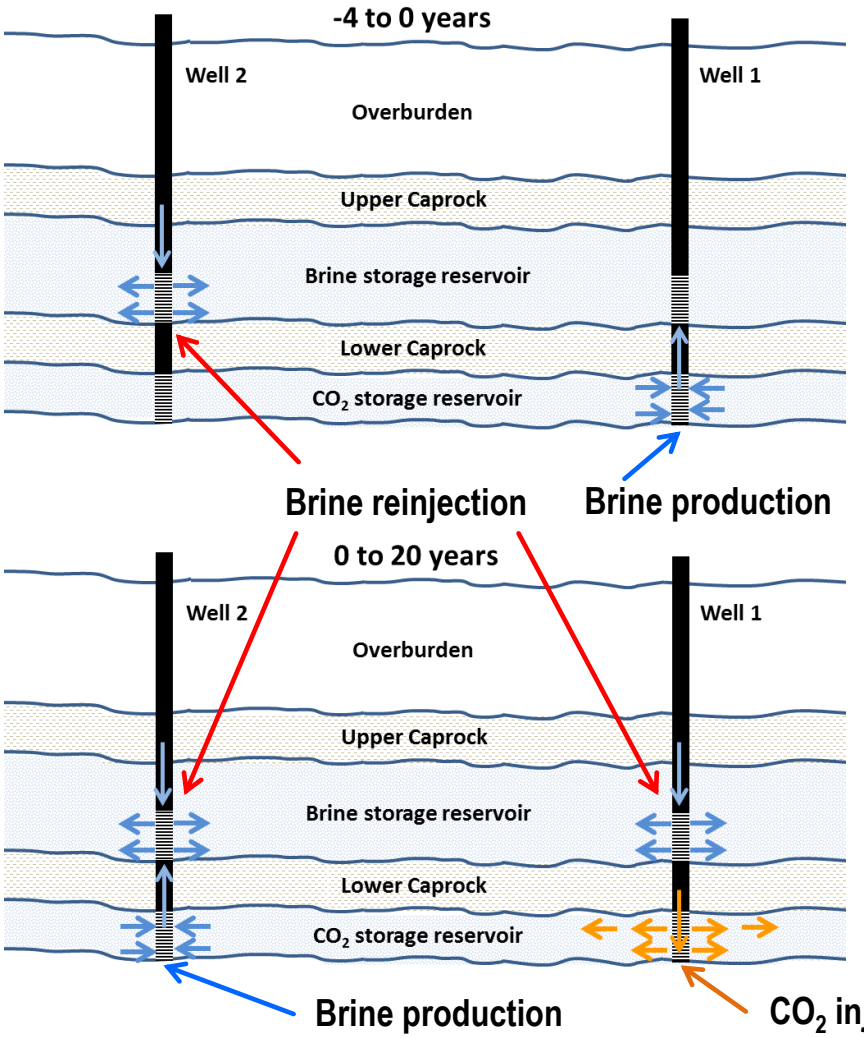


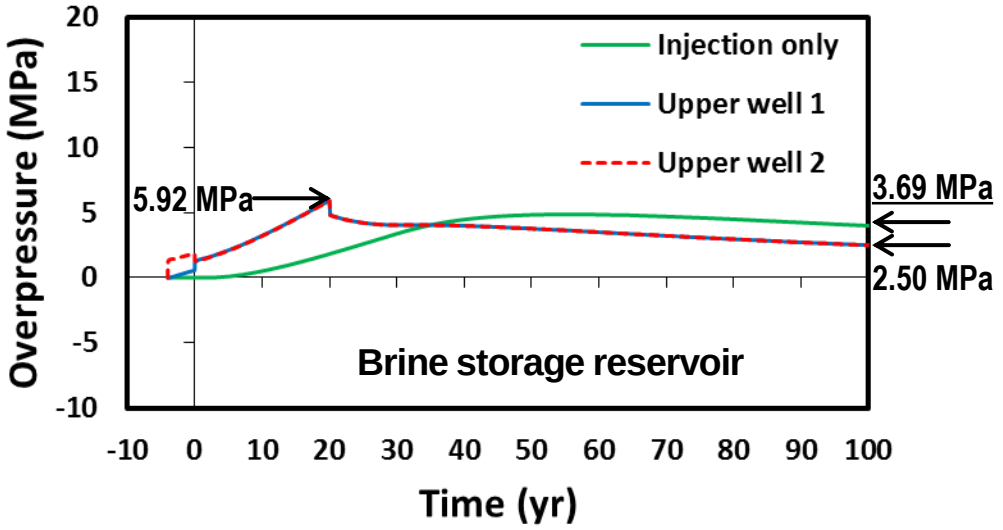


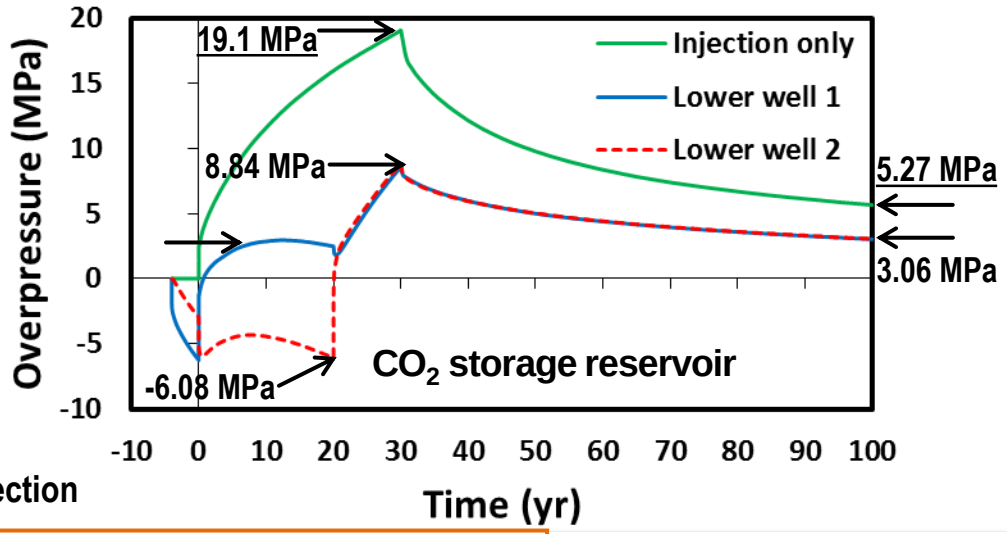
From 20 to 30 years, CO_2 is injected into both wells

Brine disposition: 50% consumption, 50% reinjection

0.35 brine-removal to CO_2 injection ratio



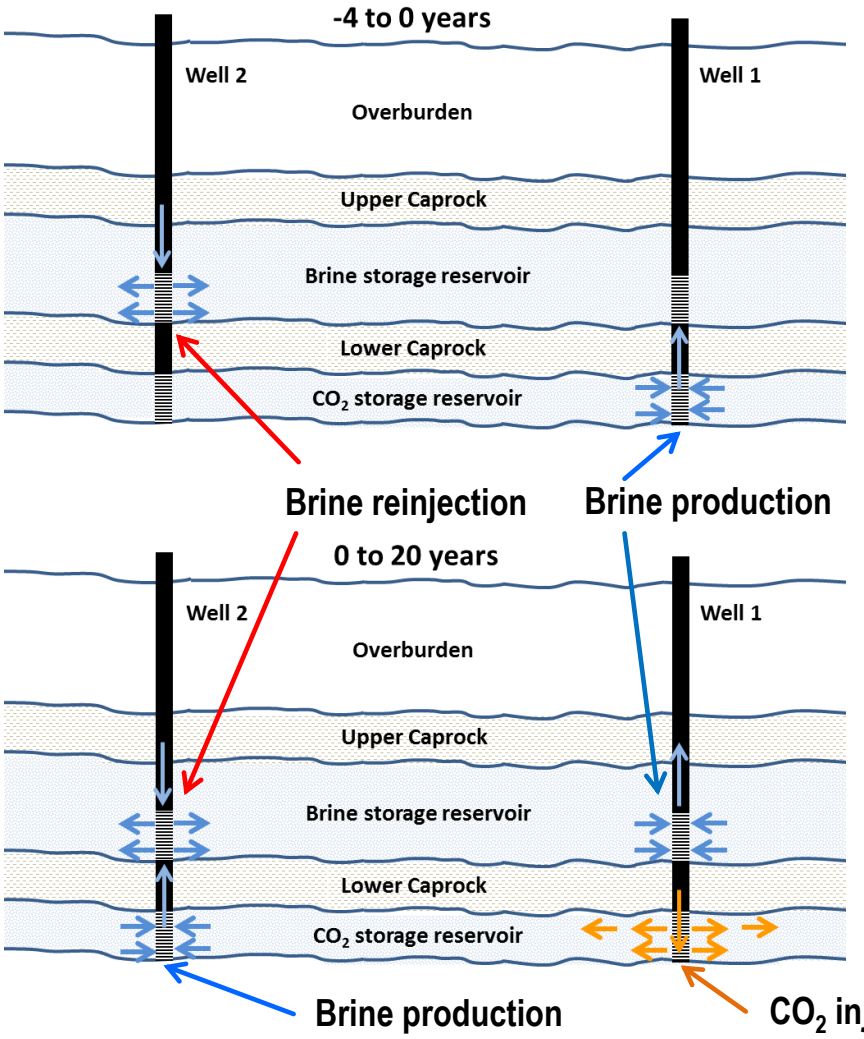


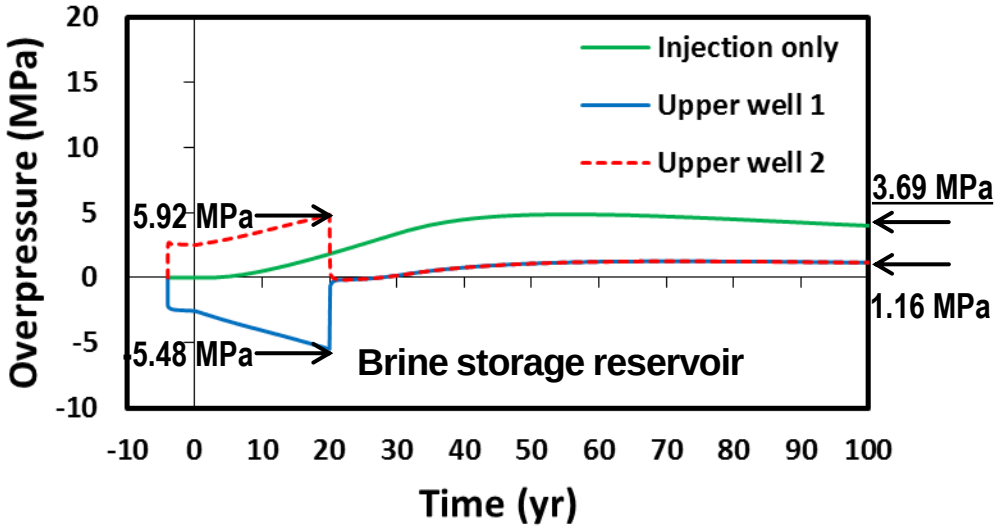


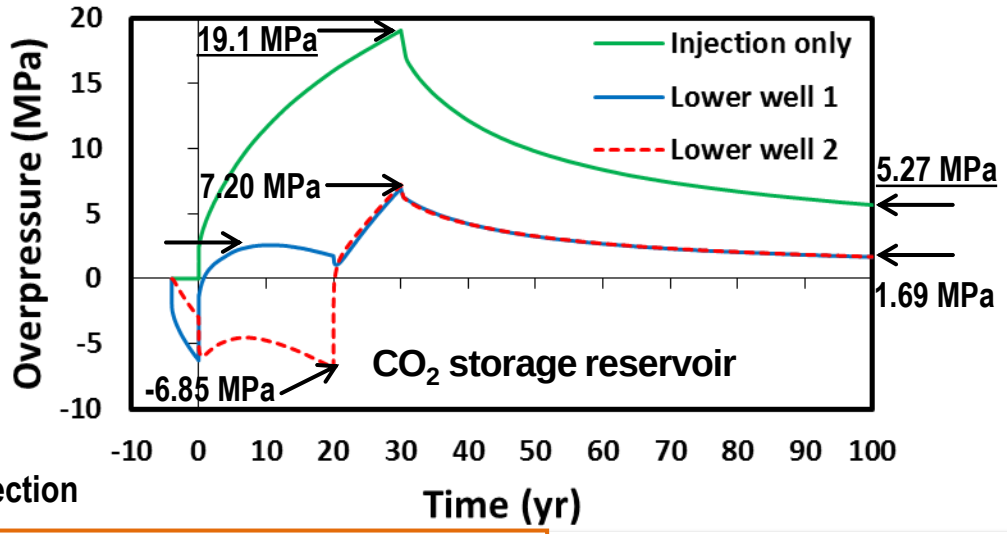
From 20 to 30 years, CO_2 is injected into both wells

Brine disposition: 100% consumption, zero net injection

0.70 brine-removal to CO_2 injection ratio







From 20 to 30 years, CO_2 is injected into both wells

Conclusions

- Pre-injection brine production in tandem reservoirs is a proactive approach to increase operational flexibility and efficiency by
  - Using two reservoirs with complementary attributes – one emphasizing safe and secure CO_2 storage, and the other emphasizing efficient brine treatment
  - Preparing a saline aquifer to perform like a depleted oil and gas reservoir
  - Moving brine prior to CO_2 injection for site selection and characterization
  - Leveraging more benefit from each well (monitoring, brine production, CO_2 injection)
- This approach can provide additional assurance to regulators, investors, insurers, stakeholders, and local populations that a well-informed reservoir-management plan is in place prior to CO_2 injection operations
- Because only one well is required for initial deployment, this approach is ideal for a pilot project

Thank you

Further reading

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