Active CO_2 Reservoir Management

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U.S. Department of Energy

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Transforming Technology through Integration and Collaboration

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Presentation Outline

- Benefit to the program
- Goals and objectives
- Brine production strategy
- Retrospective pressure-management analysis of Snøhvit
- Two aquifer study: Brine production and reinjection
- Accomplishments
- Synergy opportunities
- Summary
- Appendix

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Benefit to the Program

- Carbon Storage Program goals addressed by our project
  - Support industry's ability to predict CO_2 storage capacity to within ±30%
  - Develop and validate technologies to ensure 99% storage permanence
  - Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness
  - Develop Best Practice Manuals for monitoring, verification, accounting, and assessment; site screening, selection, and initial characterization; well management activities; and risk analysis and simulation

Benefit to the Program

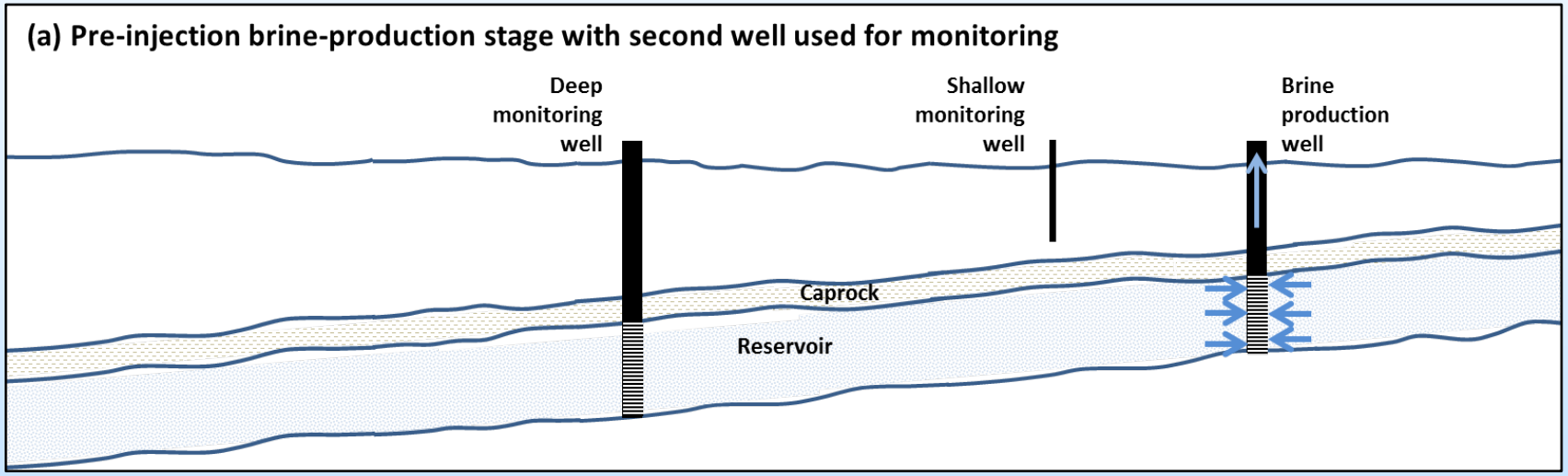
- Our project directly benefits all 4 Carbon Storage Program goals
  - Pressure drawdown caused by pre-injection brine production is highly diagnostic of CO_2 storage capacity and permanence
  - Removing brine from the storage formation and moving some or all of it to overlying formations can increase CO_2 storage capacity and reduce CO_2 leakage potential
  - Using the same well initially for monitoring and then to produce brine prior to injecting CO_2 is an efficient pressure-management strategy
    - fewer wells are required
    - greatest pressure relief benefit per unit of removed brine
  - Pre-injection brine production is useful for site screening, selection, and characterization; it also can be used to inform well-management activities

Project Overview: Goals and Objectives

- Develop a reservoir pressure management strategy to support all 4 Carbon Storage Program goals and be used during all stages of CCS development for
  - Site screening, selection, and characterization
  - Estimating CO_2 storage capacity and guiding well-field operations
  - Efficiently limiting the magnitude and duration of overpressure
- Test the efficacy of this strategy with a reservoir model constrained by data from a large-scale CCS test
- Develop brine production and reinjection strategies
- Look for site-demonstration opportunities
  - Site selection and partnering
  - Modeling support for reservoir operational planning
- Look for synergistic opportunities for CCUS

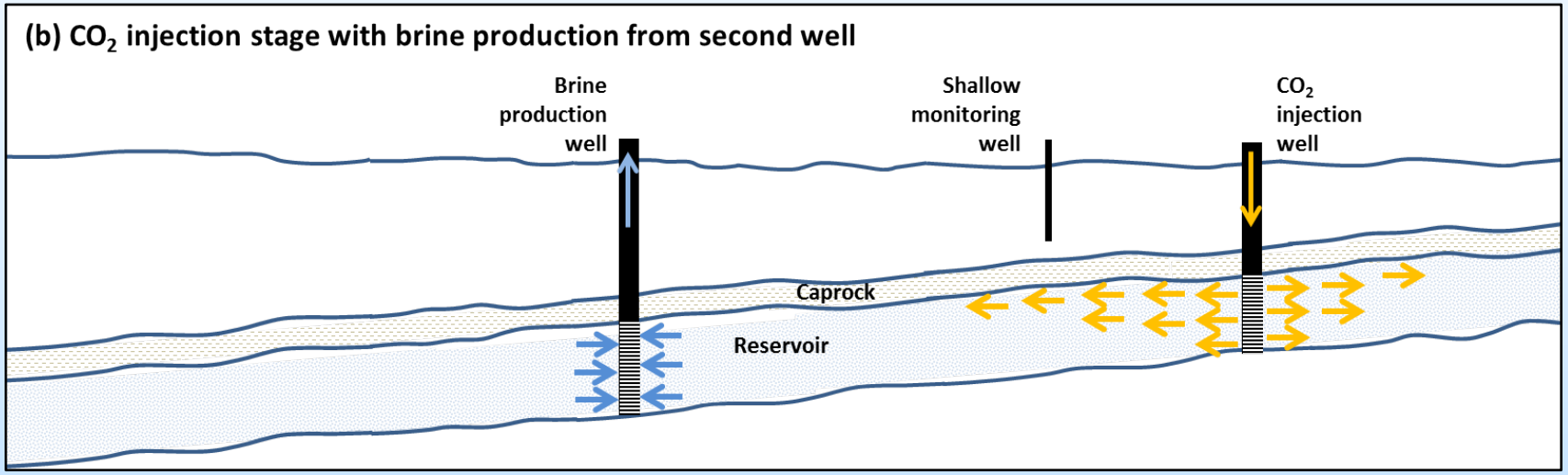
Pre-injection brine production

- Monitor pressure drawdown in deep and shallow wells to assess
  - CO_2 storage capacity and compartmentalization
  - CO_2 leakage potential
- Reservoir information is greatest where needed most: at the center of CO_2 storage



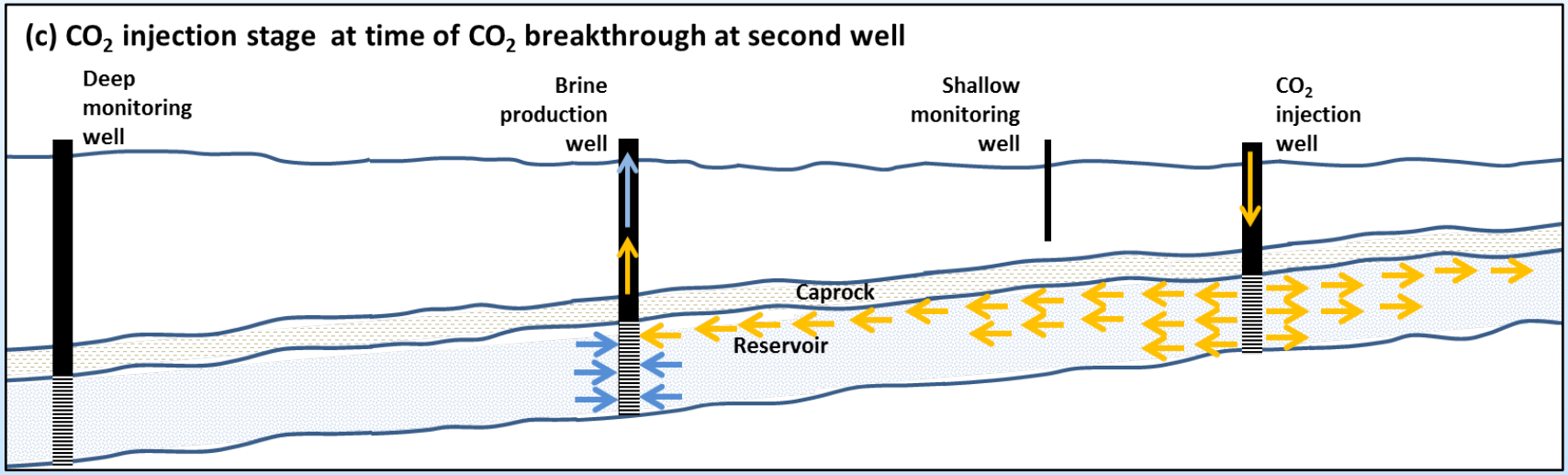
Co-injection brine production

- Pre-injection pressure drawdown "buys time" so pressure relief from neighboring well can develop, which allows for
  - greater spacing between wells (fewer wells overall)
  - ongoing pressure-management planning
- Pressure relief is greatest where needed most: at the center of CO_2 storage



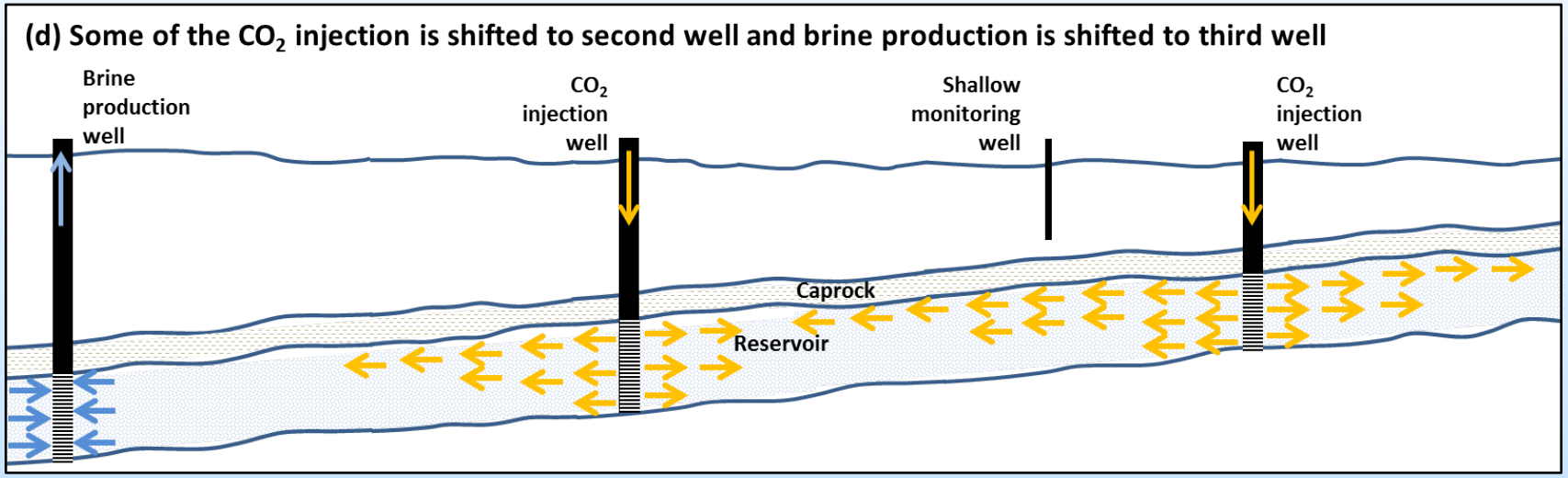
Co-injection brine production

- After CO_2 breakthrough, a brine production well becomes a CO_2 injector
- Each successive deep well goes through three stages:
  - exploration and monitoring
  - brine production
  - CO_2 injection



Co-injection brine production

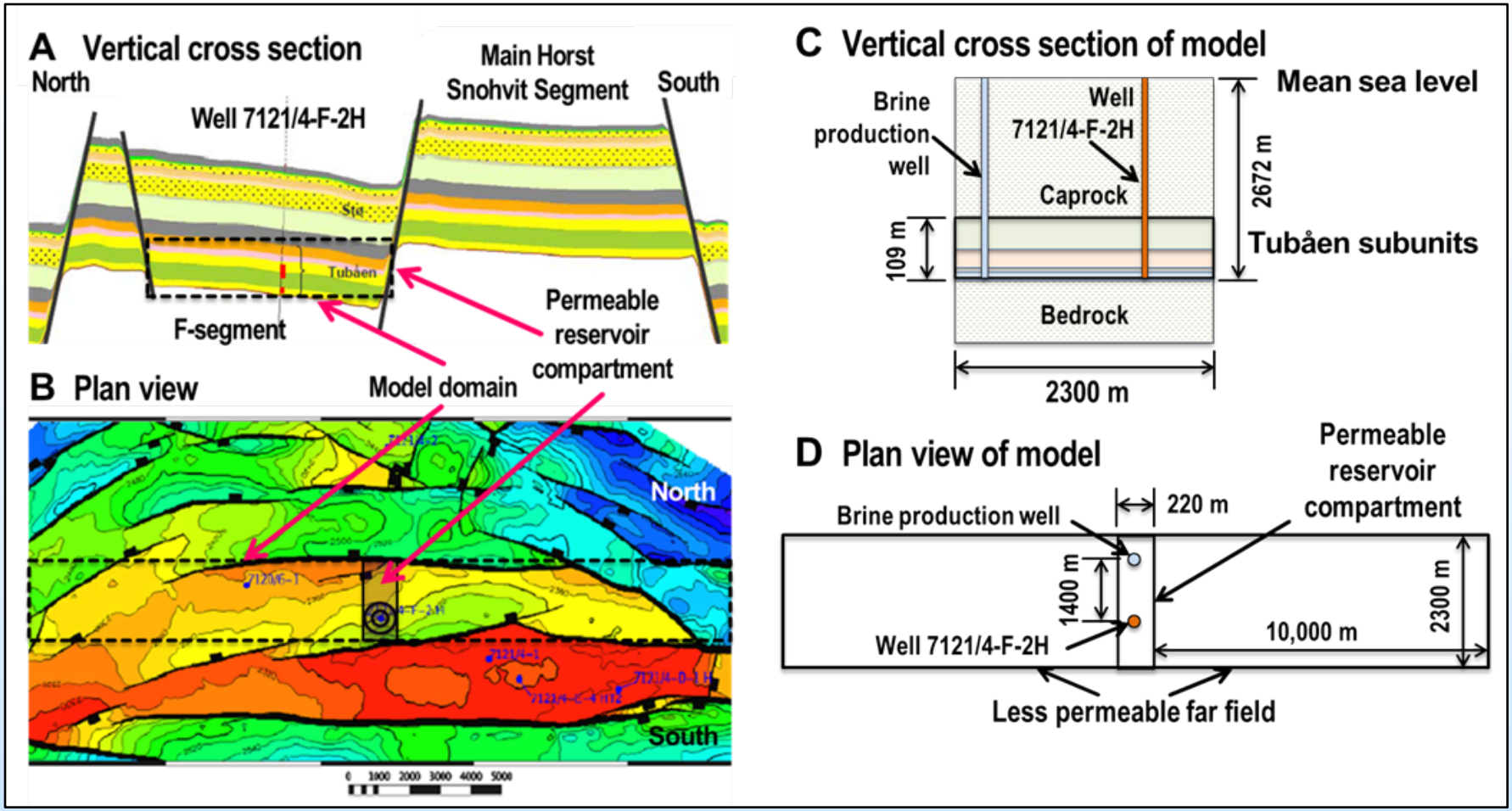
- Each additional deep well can be located and operated with the greatest amount of knowledge of the reservoir
- CO_2 storage operations can be managed proactively and more efficiently



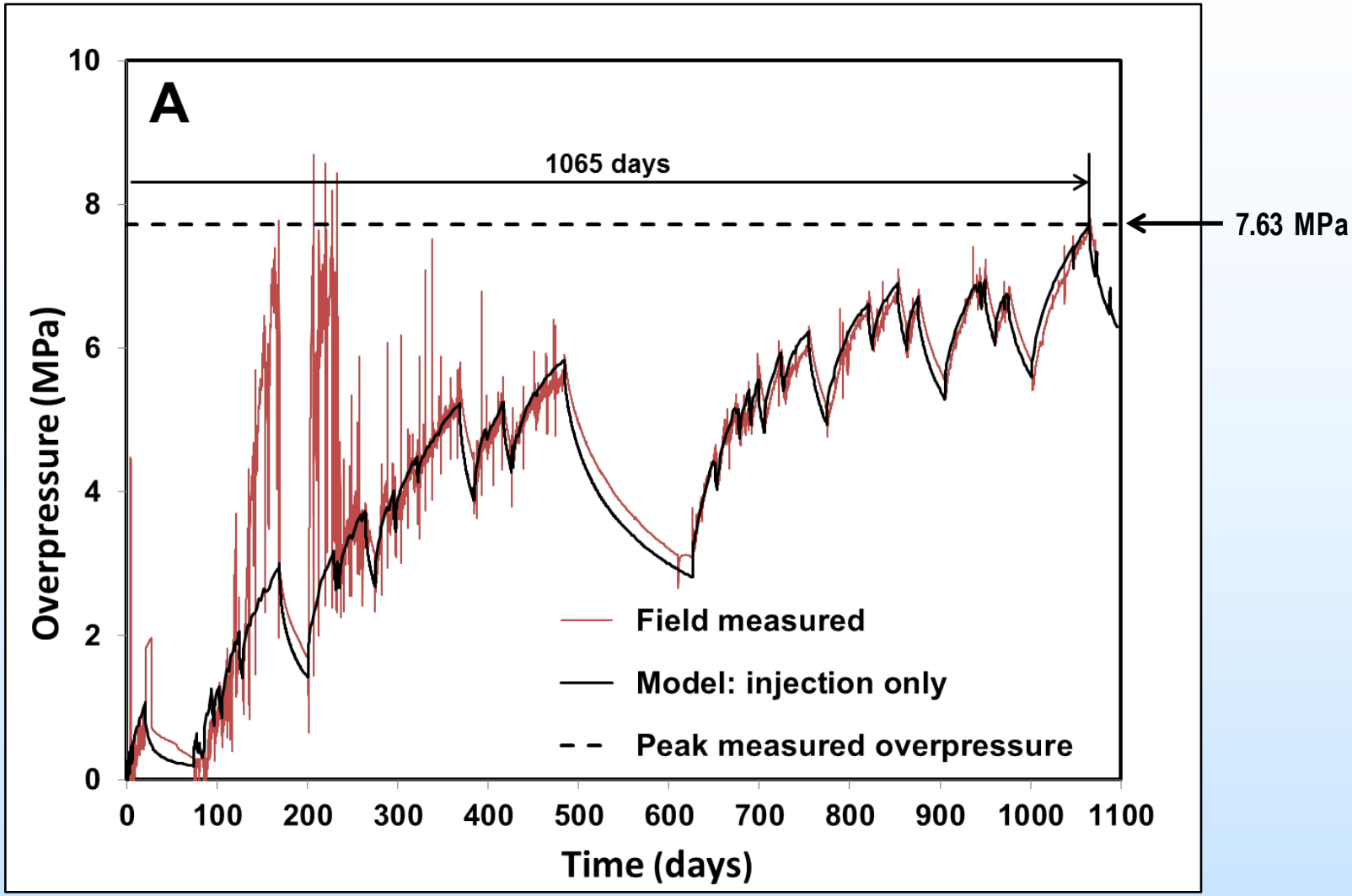
Retrospective pressure-management analysis of Snøhvit CO_2 storage test

- A reservoir model, using the NUFT code, was calibrated for 3 years of injection of 1.09 MT of CO_2 into Tubåen Formation
  - Snøhvit data package from Statoil, including thickness, porosity, and permeability
  - CO_2 injection-rate and bottom-hole pressure for injection well
  - Conceptual model developed from structural geology and 4-D seismic difference amplitude maps, which show overpressure and CO_2 migration controlled by long fluvial channels in 3 permeable subunits of the Tubåen
  - Production logging tool (PLT) data show 80% of injection going into lower perforated zone
- Initial conceptual model was a 220 m x 2000 m compartment, with leaky lateral boundaries, bounded by low-permeability seal units
  - After calibration, final conceptual model has a 220 m x 2300 m compartment
  - After calibration, a permeability ratio of 0.01 between the far field and permeable compartment was determined

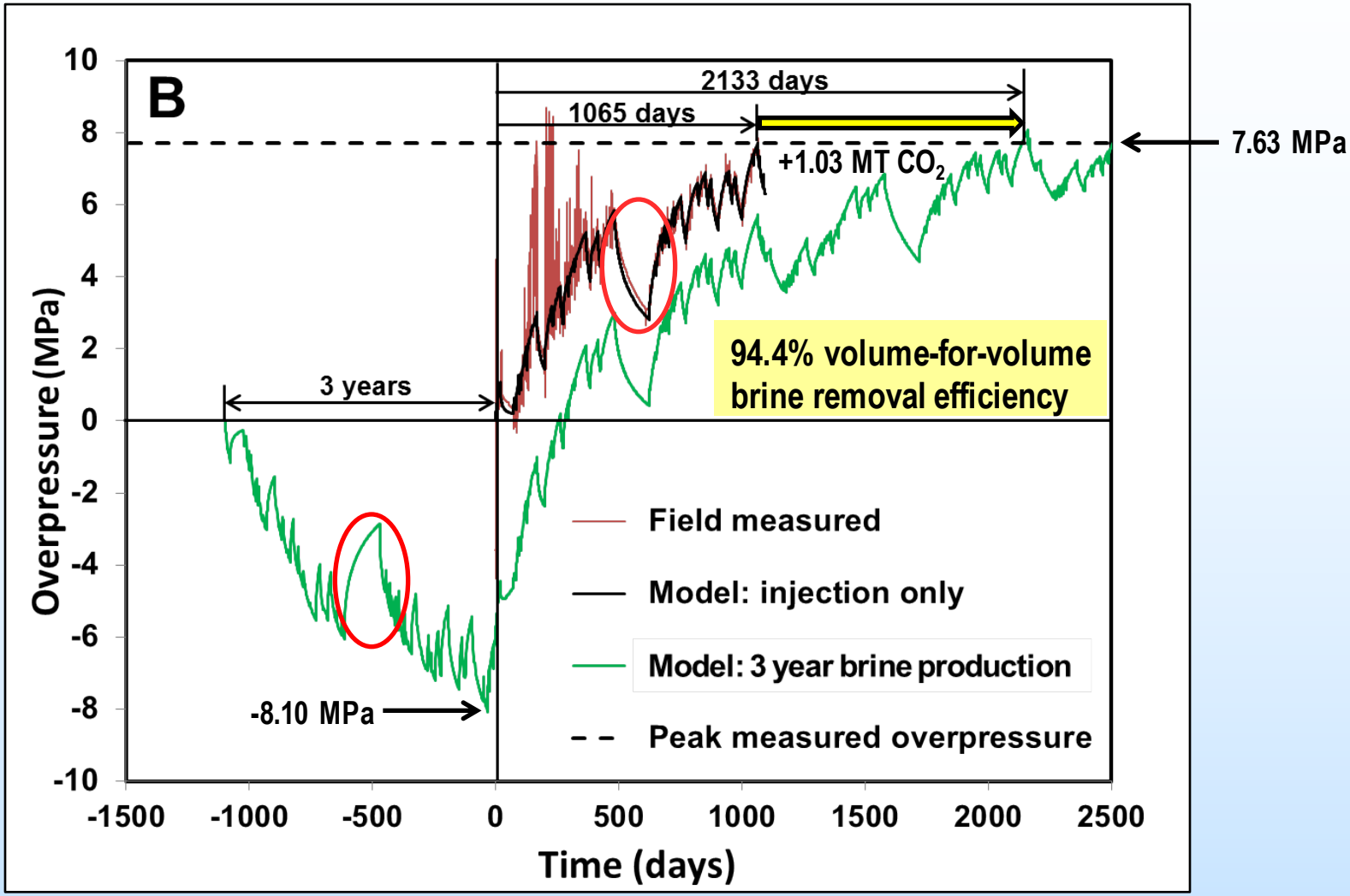
Geology and reservoir model of Snøhvit



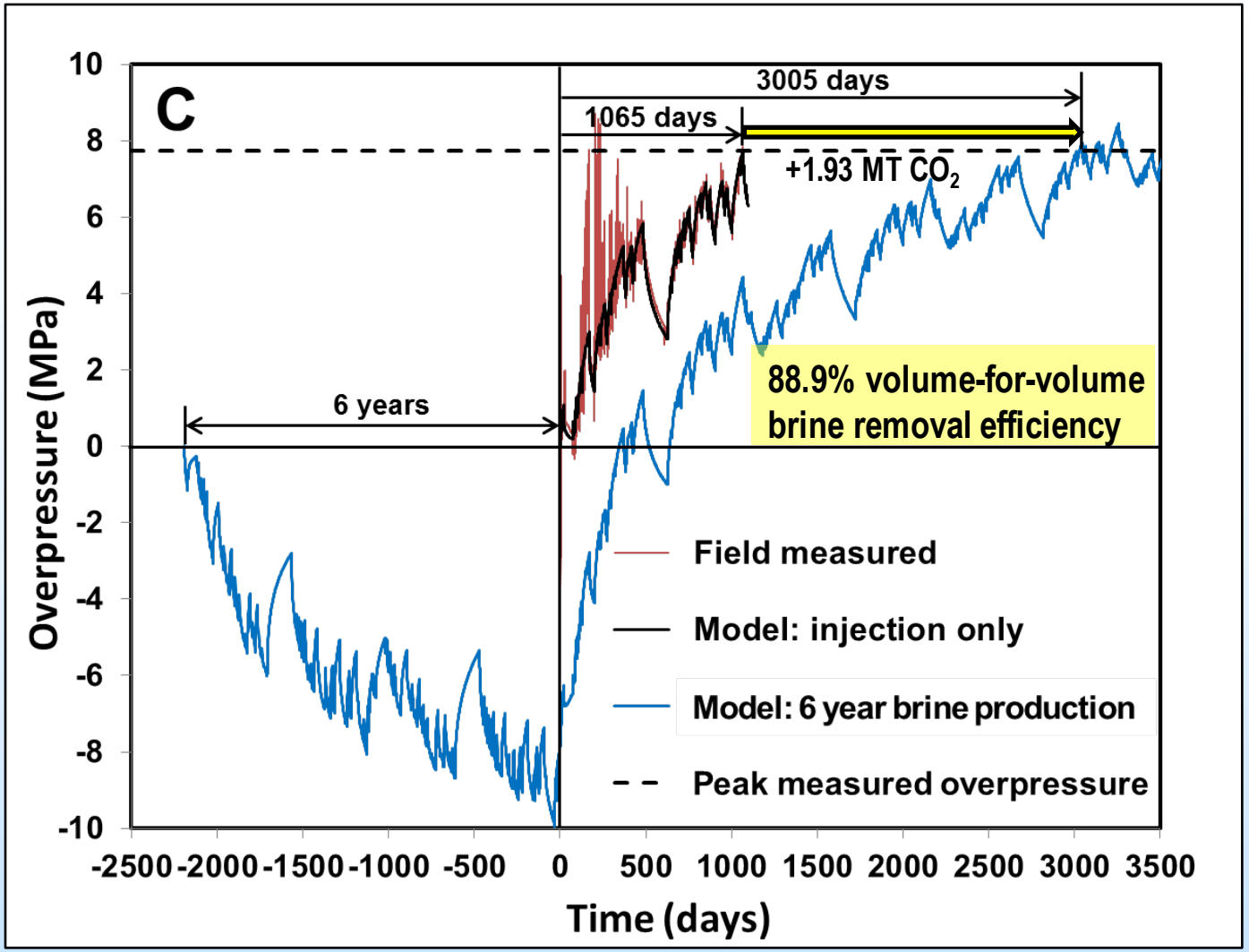
Calibrated reservoir model of Snøhvit



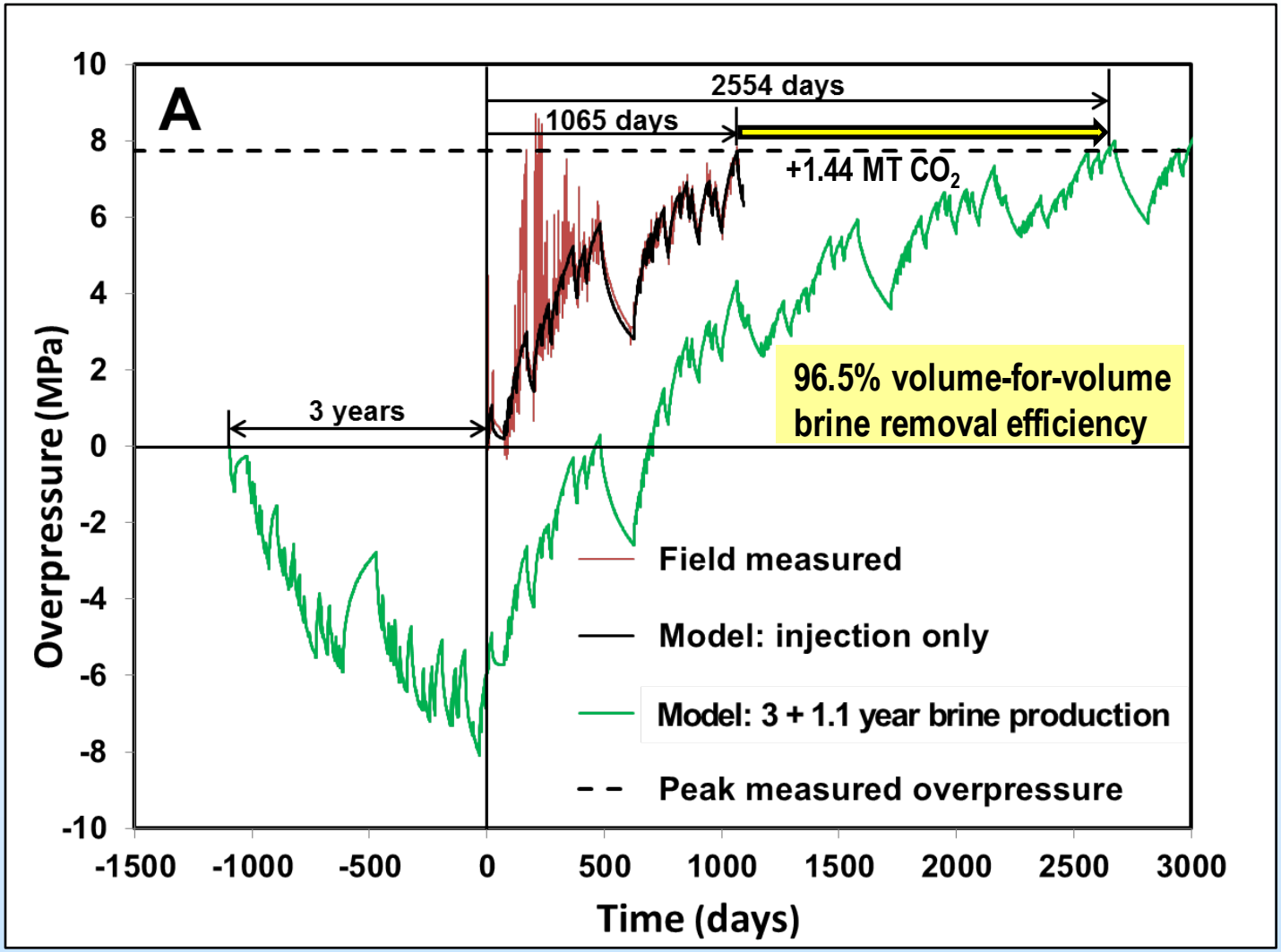
Snøhvit study: Pre-injection brine production



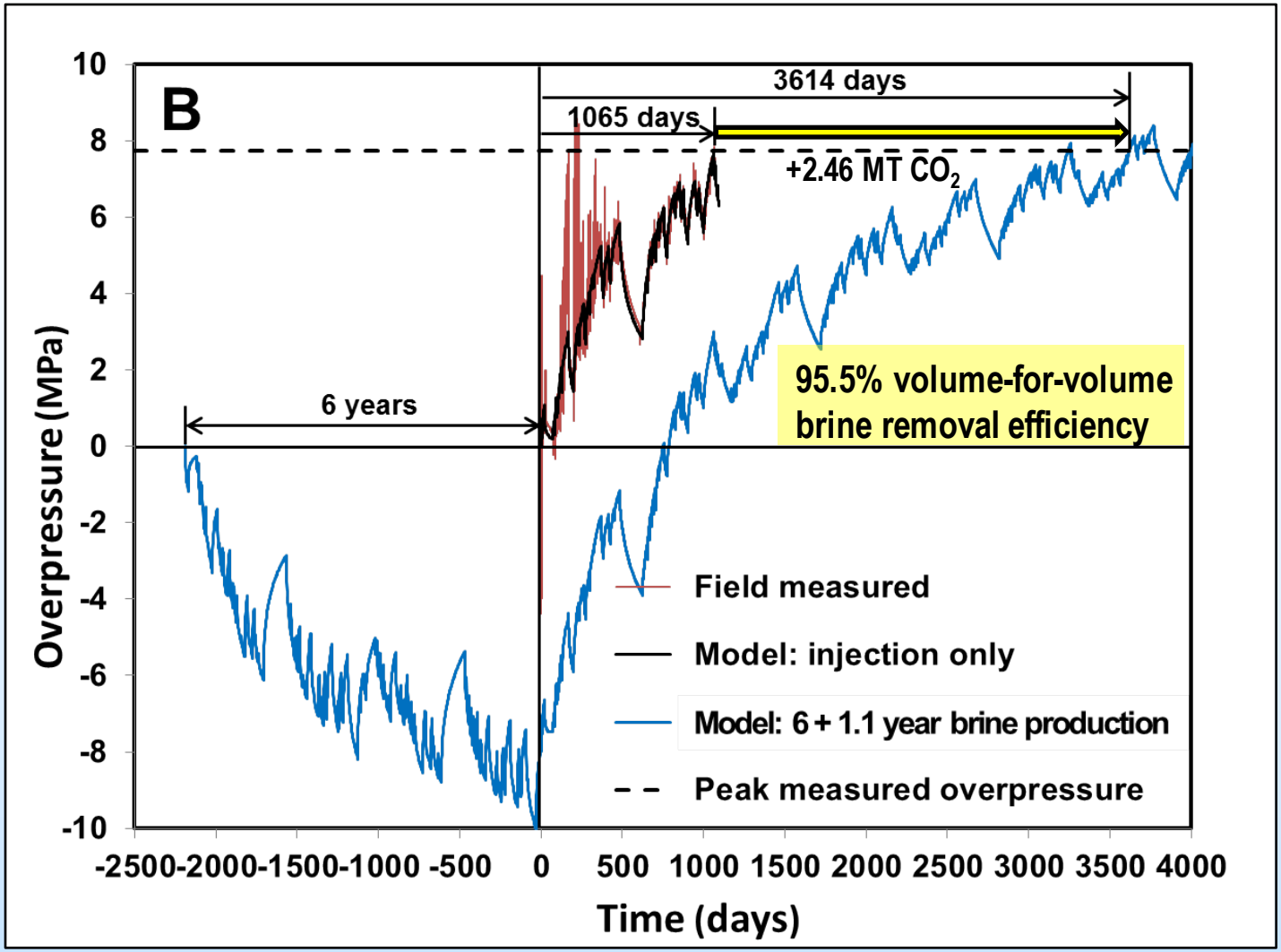
Snøhvit study: Pre-injection brine production



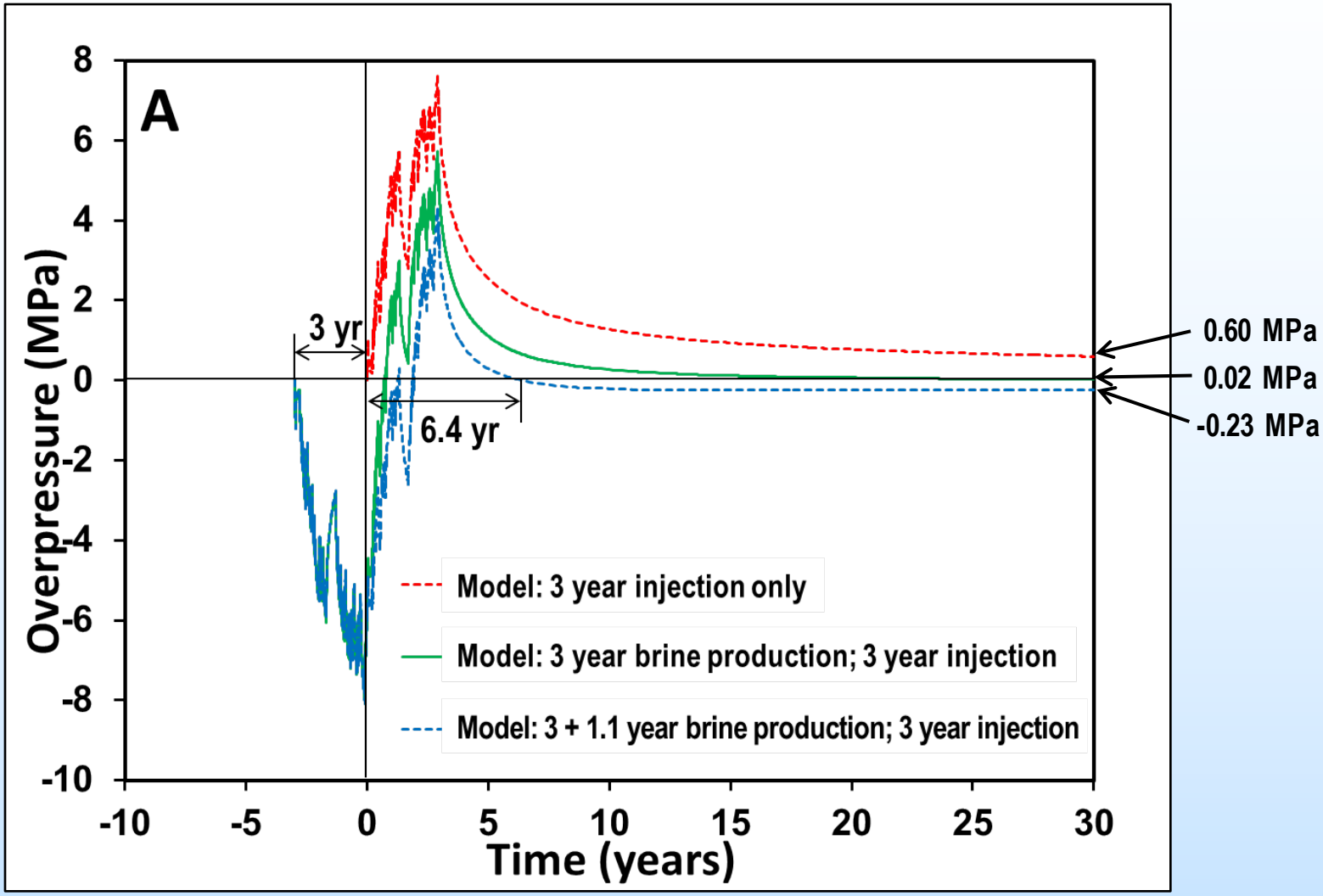
Snøhvit study: Pre-/co-injection brine production



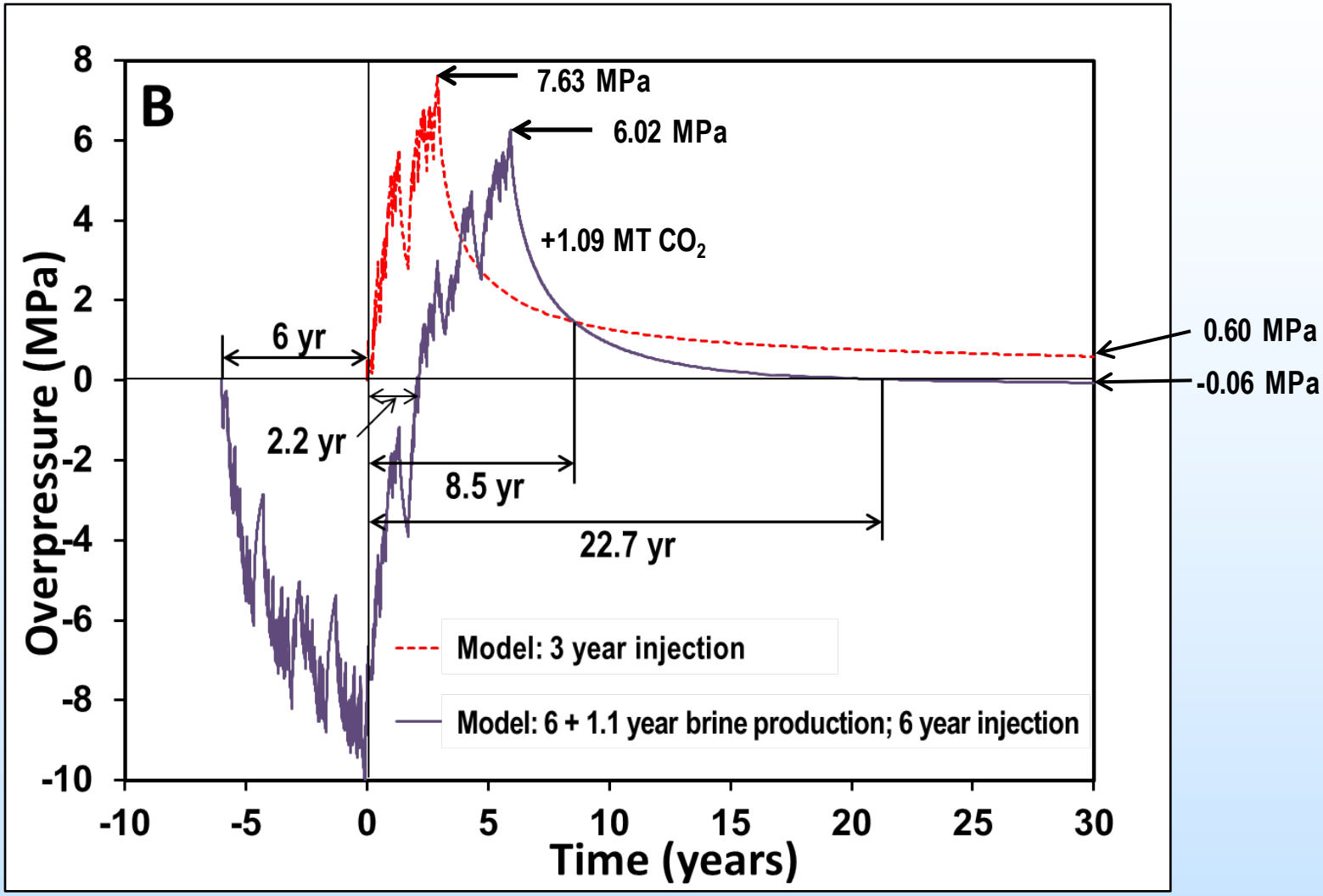
Snøhvit study: Pre-/co-injection brine production



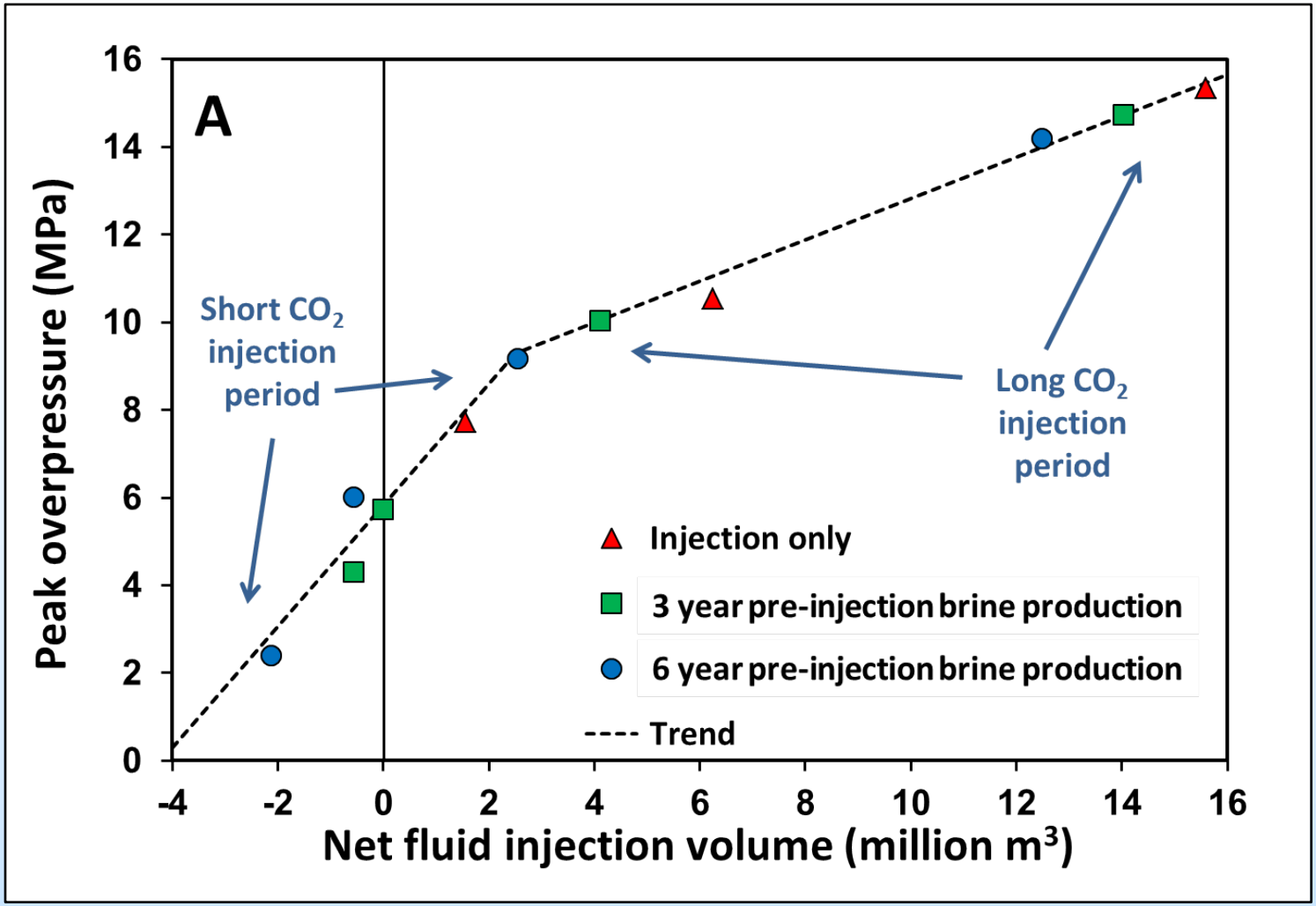
Snøhvit study: Post-injection pressure decline



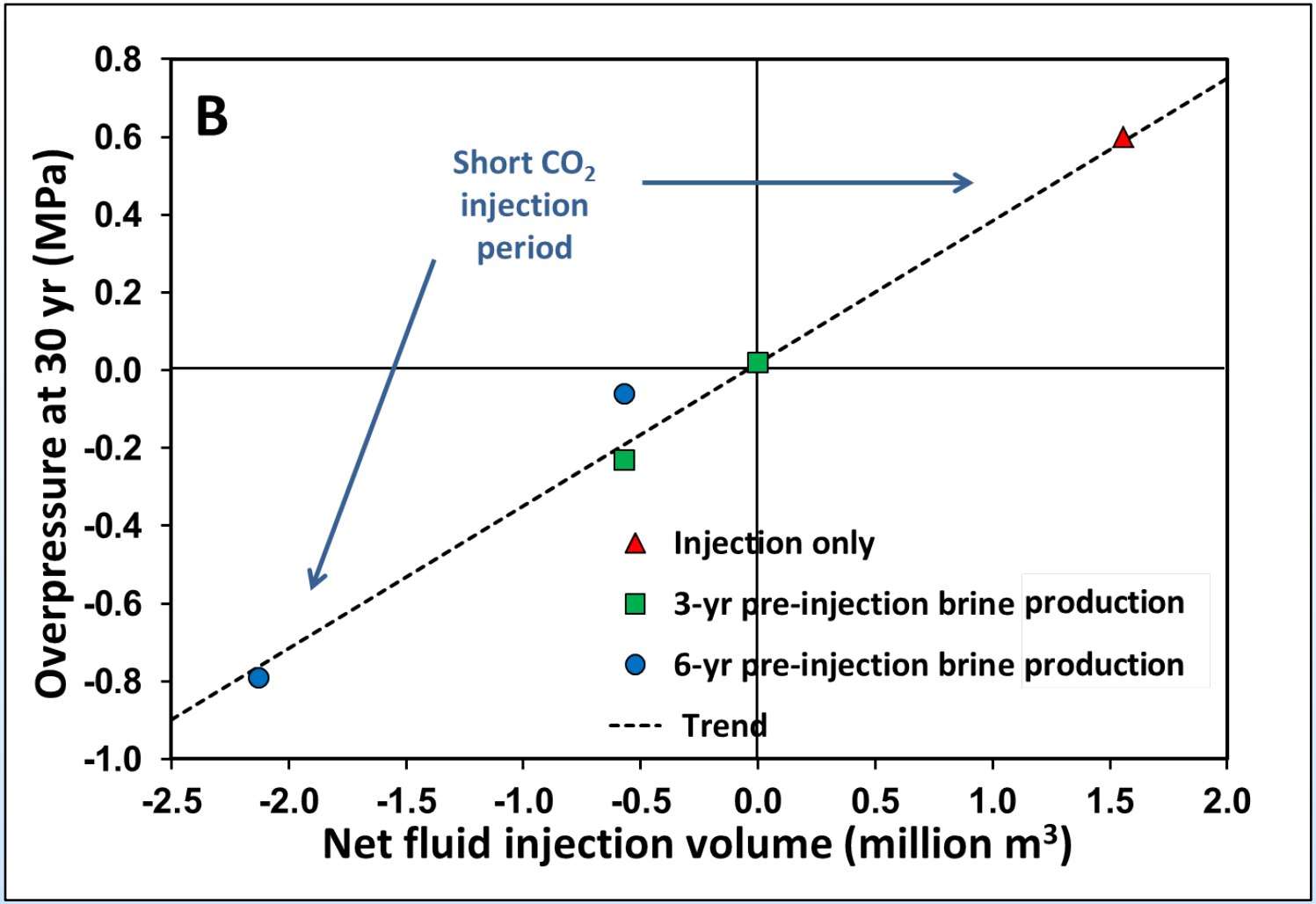
Snøhvit study: Post-injection pressure decline



Snøhvit study: Effectiveness of brine removal

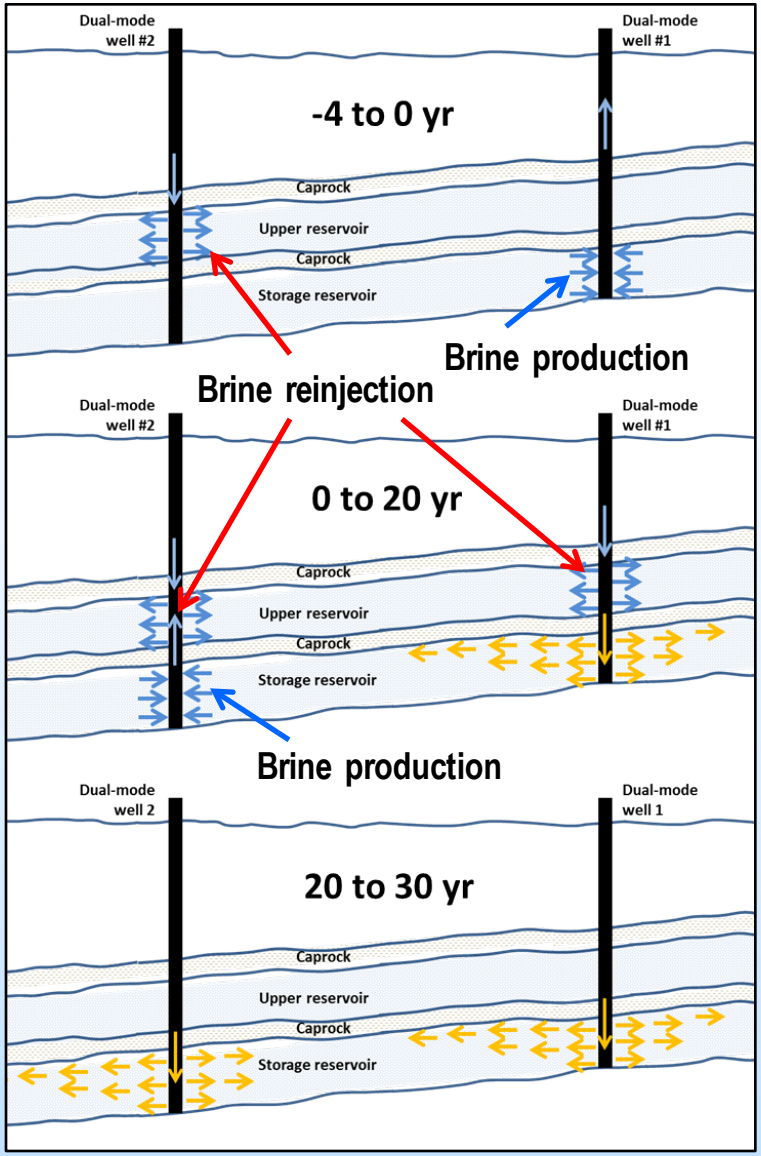


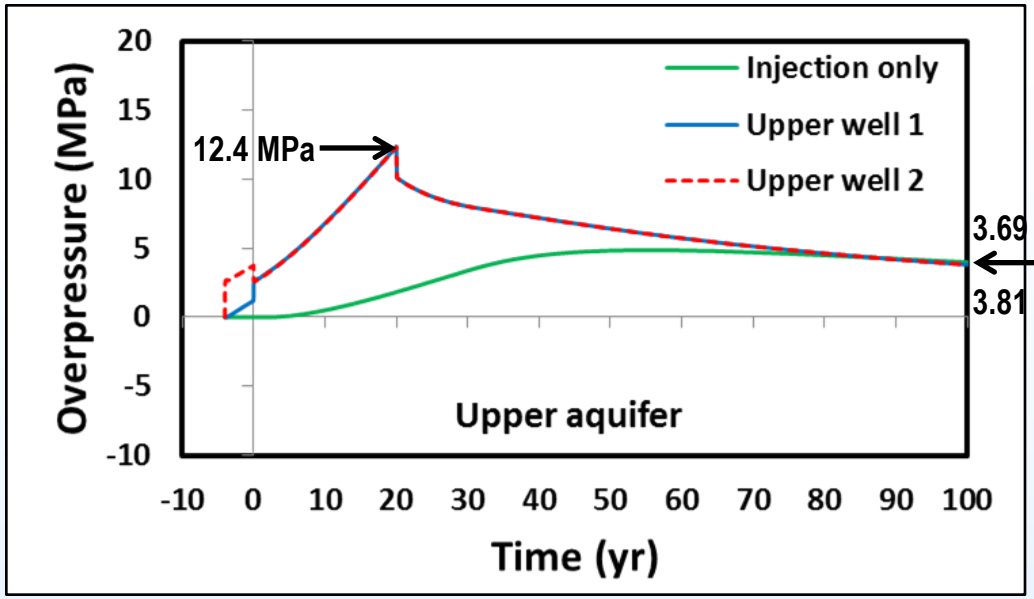
Snøhvit study: Effectiveness of brine removal

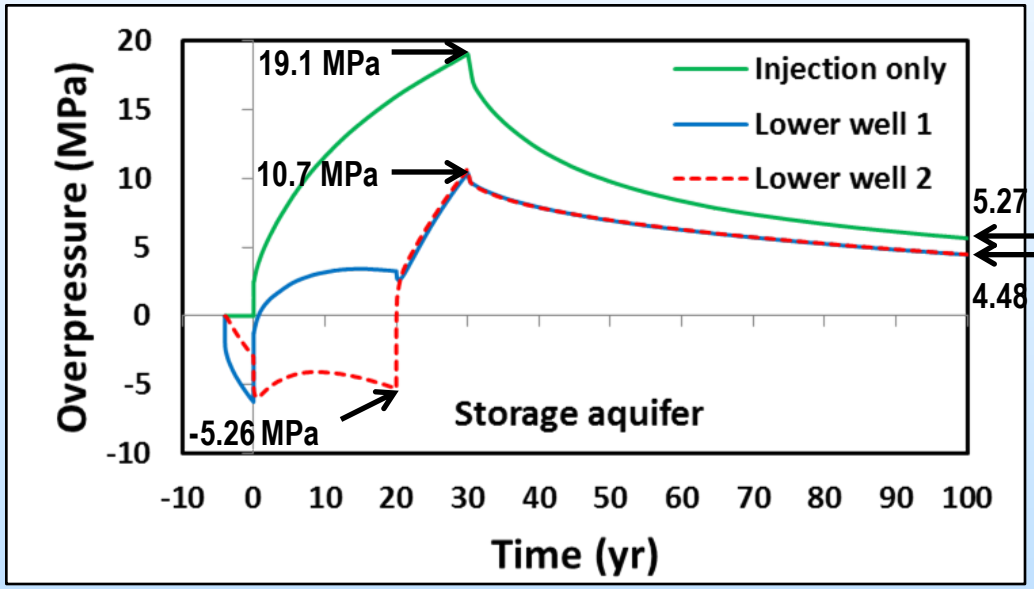


Two aquifer study: Brine production with 100% reinjection

0.0 brine-removal to CO_2 injection ratio

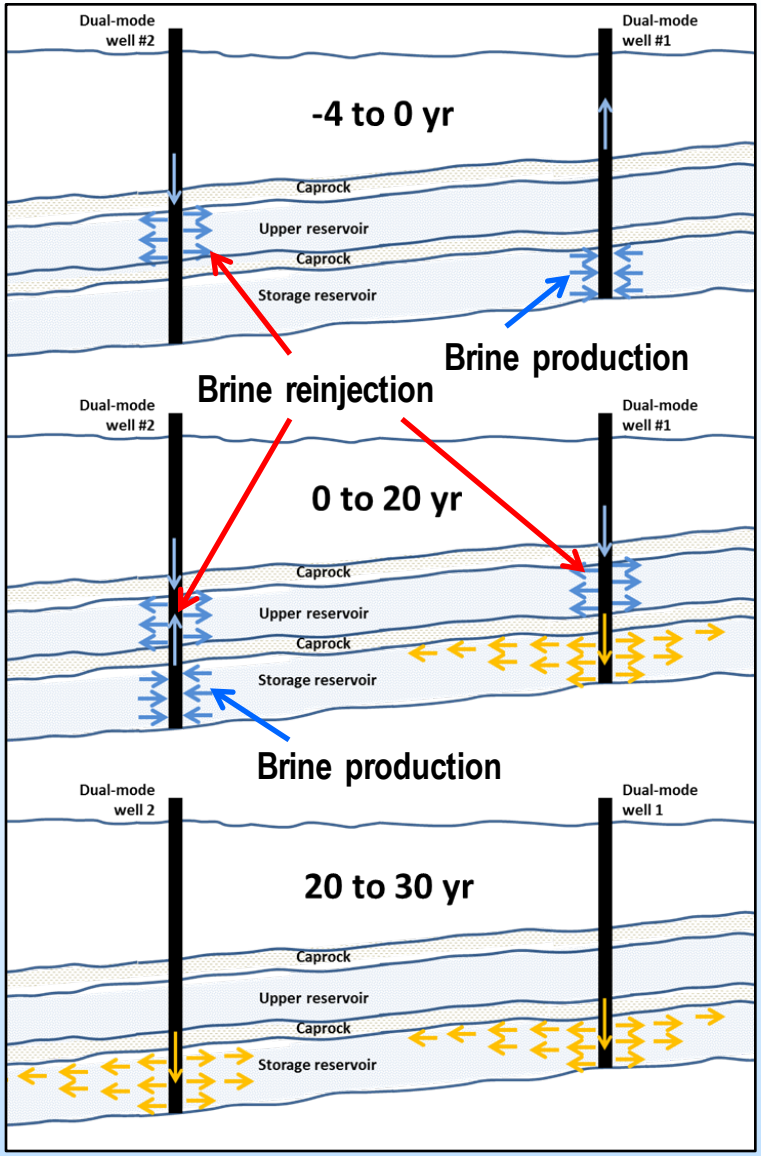


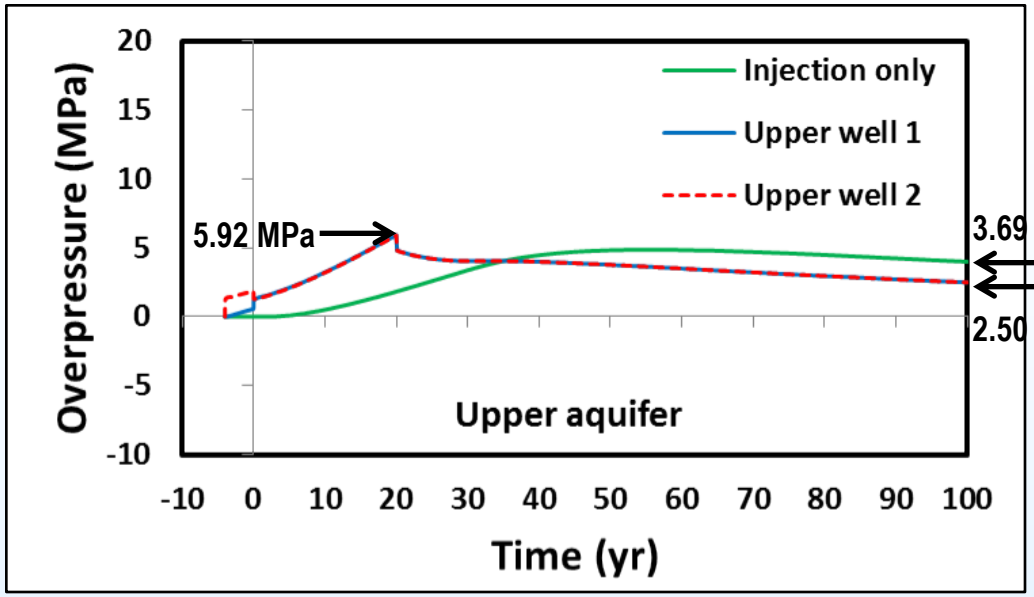


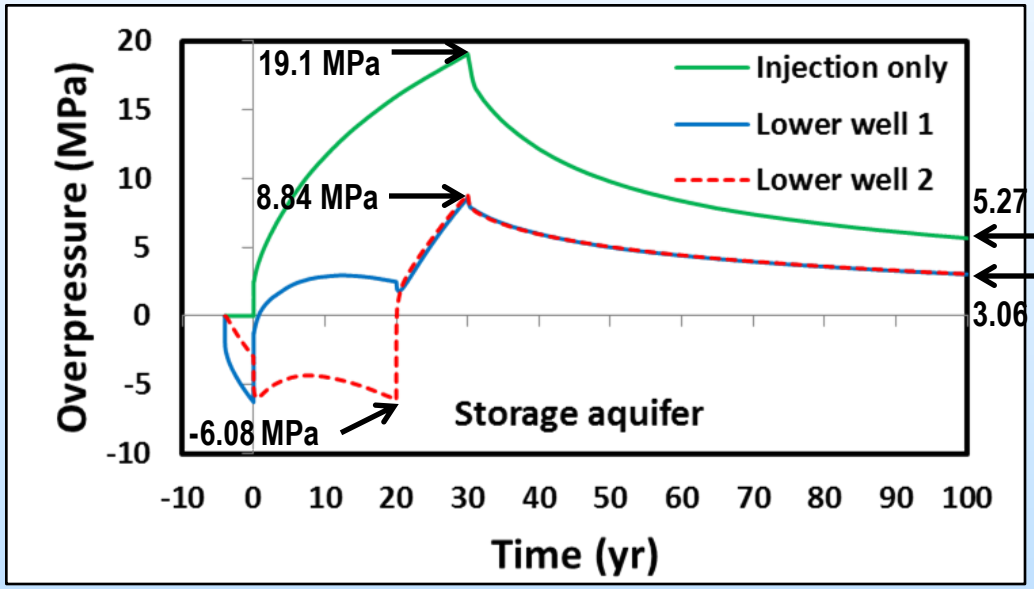


Two aquifer study: Brine production with 50% reinjection

0.40 brine-removal to CO_2 injection ratio

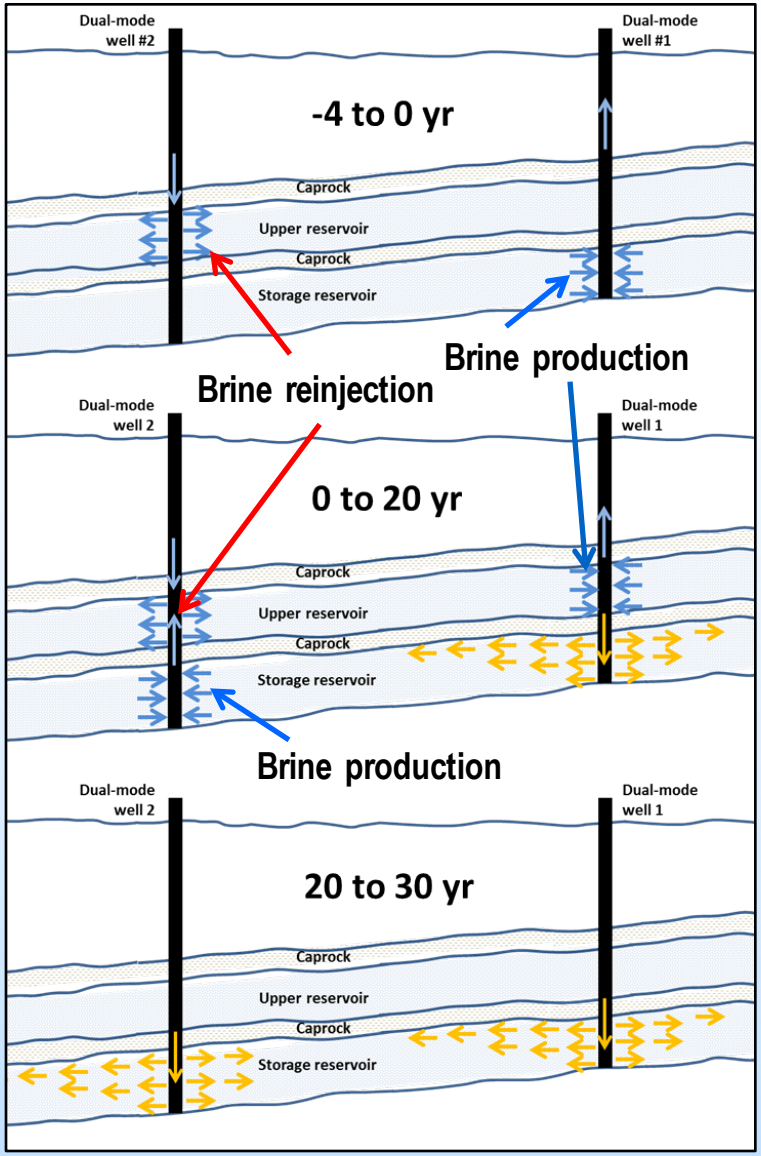


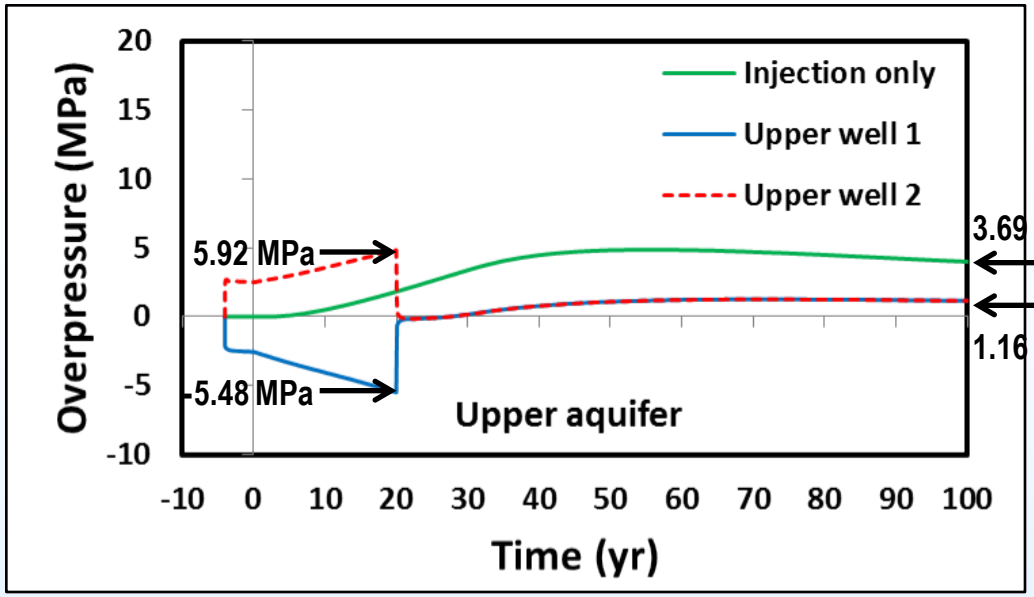


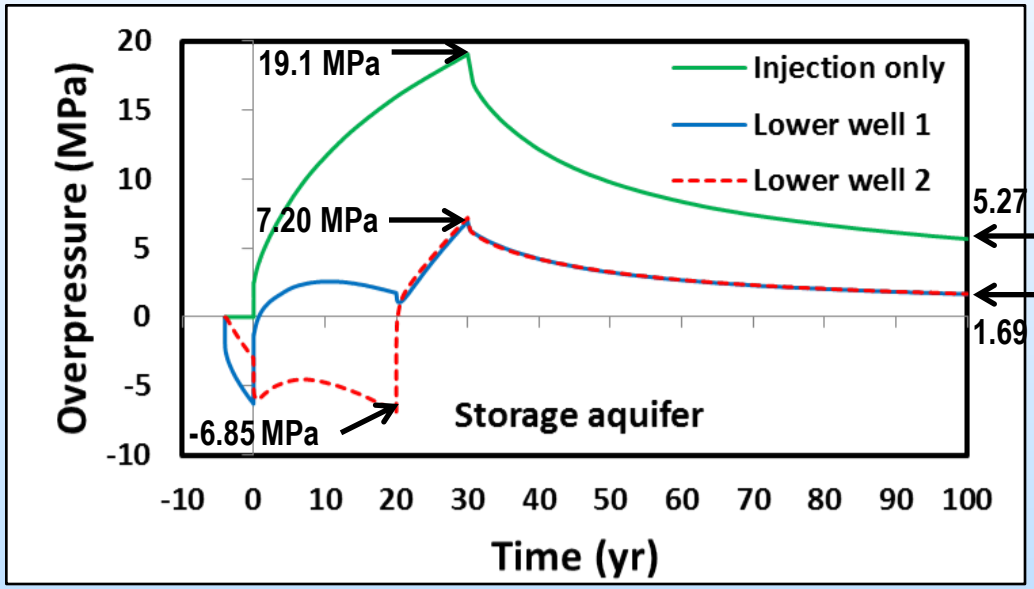


Two aquifer study: 2x brine production with 1x reinjection

0.80 brine-removal to CO_2 injection ratio







Accomplishments to Date

- Developed a reservoir pressure-management strategy that supports all 4 Carbon Storage Program goals and is applicable to all stages of CCS reservoir development and operation
- Used data supplied by Statoil for Snøhvit to calibrate a reservoir model to test and demonstrate the efficacy of pre-injection brine-production pressure-management strategy
- Analyzed reservoir pressure management with multi-aquifer brine production and reinjection
- Published 2 journal articles and preparing 2 more for submission
- Presented papers at 3 International Greenhouse Gas Technologies Conference meetings, published in Energy Procedia
- Invited paper accepted for publication in Cornerstone Journal

Synergy Opportunities

- Management of brine-production and reinjection operations involves a range of economic and regulatory considerations, in addition to CO_2 reservoir performance
- Monitoring and analyzing pressure drawdown caused by brine production provides information on CO_2 storage capacity and leakage pathways through the caprock that can be used by reservoir and seal performance models
- The operation of wells that sequentially monitor, produce brine, and inject CO_2 can be guided using a reservoir-system optimization framework
  - Uncertainty reduction and reservoir diagnostic tools
  - Real-time decision making tools

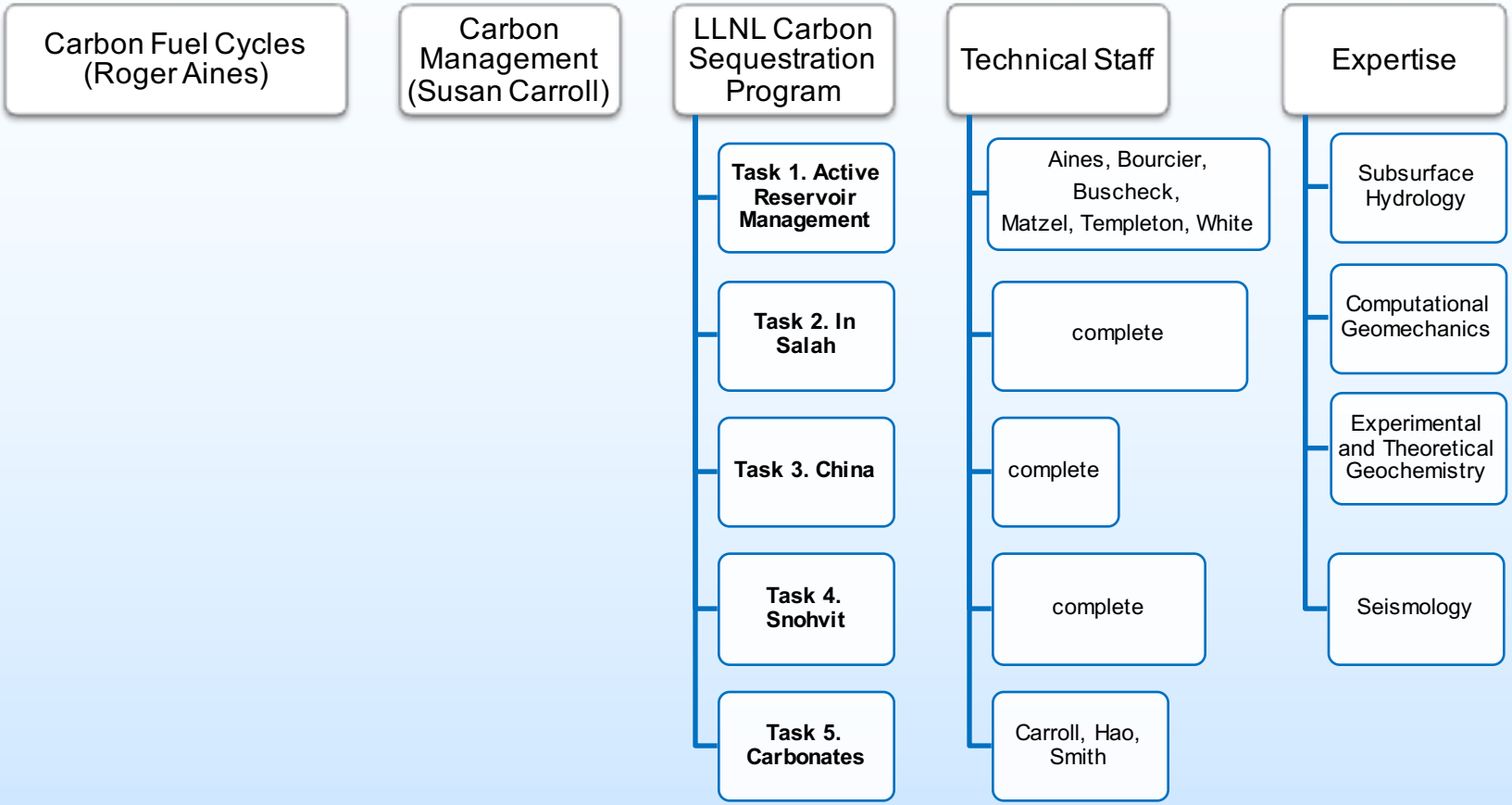
Summary

- Key Findings
  - Using a model constrained by the Snohvit CO_2 storage test, both pre-injection and pre-/co-injection brine production were found to be very effective at pressure management on a volume-for-volume basis
  - Reservoir pressure management with brine production can be implemented over a wide range of brine-reinjection options, from full reinjection of brine to zero-net-injection of fluid
- Lessons learned
  - Brine production has broader use than just pressure management, it can play a key role in estimating CO_2 storage capacity, evaluating storage permanence, and in risk management
- Future Plans
  - Identify and analyze field-demonstration opportunities
  - Field-demonstration partnerships
  - Develop risk-assessment and reservoir diagnostic (e.g., storage capacity) tools

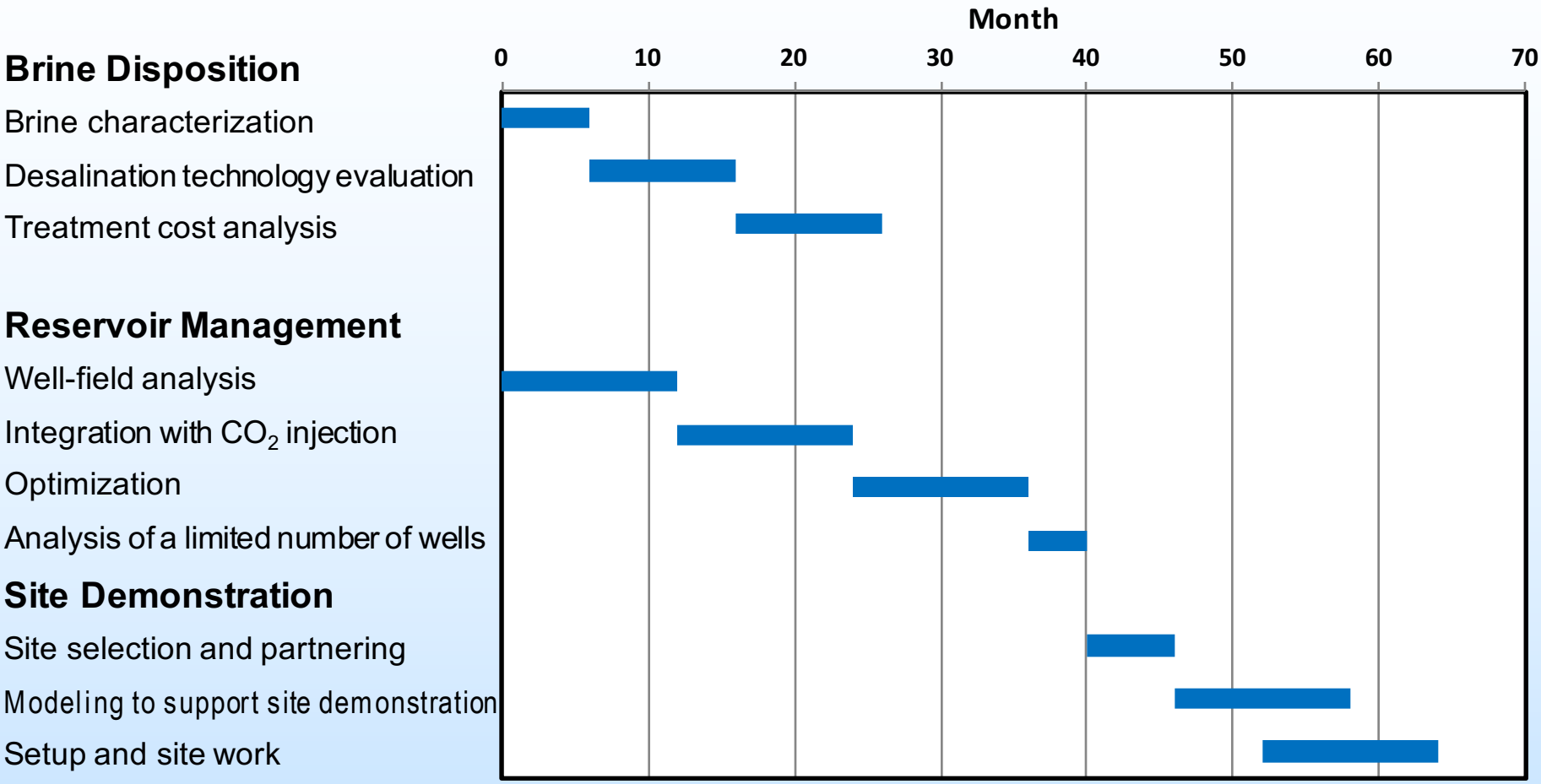
Appendix

- Organization chart
- Gantt chart
- Bibliography

Organization Chart: FEW0174



Gantt Chart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Brine Disposition
Brine characterization
Desalination technology evaluation
Treatment cost analysis
Reservoir Management
Well-field analysis
Integration with CO_2 injection
Optimization
Analysis of a limited number of wells
Site Demonstration
Site selection and partnering
Modeling to support site demonstration
Setup and site work

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