THE PLAINS CO₂ REDUCTION PARTNERSHIP: CO₂ INJECTION UPDATE AND RESULTS OF ADAPTIVE MANAGEMENT APPROACH

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Since 2003

- Nine U.S. states
- Four Canadian provinces
- 120+ partners and growing
- Regional expertise/global applications
- Demonstrating carbon capture and storage (CCS)
PCOR PARTNERSHIP OBJECTIVES

• Safely and permanently achieve CO₂ storage on a commercial scale.
• Establish a relationship between the CO₂ enhanced oil recovery (EOR) process and long-term storage of CO₂.
• Establish monitoring, verification, and accounting (MVA) methods to effectively monitor CO₂ storage.
• Use commercial oil/gas practices as the backbone of MVA strategies, and augment with additional cost-effective techniques.
• Share lessons learned for the benefit of similar projects across the region.
The Bell Creek oil field is operated by Denbury Onshore LLC.

CO₂ is sourced from ConocoPhillips’ Lost Cabin natural gas-processing plant and ExxonMobil’s Shute Creek gas-processing plant.

The Energy & Environmental Research Center (EERC), through the PCOR Partnership, is studying CO₂ storage associated with commercial CO₂ EOR.
FIELD DEVELOPMENT

- Primary production and waterflooding produced ~37.5% original oil in place (OOIP).
- Estimated 40–50 million incremental bbl of oil.
- Estimated 12.7 million tonnes of CO₂ stored.
**CO₂ INJECTION**

As of February 2017

- Oil Produced: ~3.5 million barrels  
  *(source: Montana Board of Oil and Gas Database)*

- CO₂ Stored: ~3.7 million tonnes  
  *(source: Denbury Purchase Volume)  
  *Corrected for gas composition.*

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**Cumulative Associated CO₂ Storage, MMscf**

*Source: Denbury (March 2017)*  
*CO₂ volumes corrected for gas composition.*

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**Monthly Oil Production, bbl**

*Source: Montana Board of Oil & Gas Conservation (February, 2017)*

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**Networked Technologies**

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**Critical Challenges.**

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**Practical Solutions.**
ADAPTIVE MANAGEMENT APPROACH
SITE CHARACTERIZATION ACTIVITIES COMPLETED

• Reviewed historic well files and operations data
• Collected and analyzed lidar (light detection and ranging) data
• Investigated outcrops
• Drilled characterization wells
• Analyzed core
• Conducted 104-km$^2$ (40 mi$^2$) 3-D seismic survey
• Collected baseline 3-D vertical seismic profiles (VSPs)
• Collected pulsed-neutron logs (PNLs)
BELL CREEK RISK MAPPING

- Under the most likely scenario, all of the 31 project technical risks mapped within either the Low (green) or Transition (yellow) fields.

- None of the risks in the risk register mapped into the High (red) category or represented an unacceptable level of risk.
MVA

- 16 techniques
- 1.5 years of preinjection monitoring
- 3+ years of operational monitoring

Demonstrate and validate monitoring techniques and their associated economics to inform viable MVA strategies for commercial-scale CCS.

Building off of the backbone of commercial operations data.
### MVA ADDRESSING PROJECT RISKS

<table>
<thead>
<tr>
<th>MVA Technologies</th>
<th>Subsurface Technical Risks Addressed</th>
<th>Containment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Vertical Migration</td>
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<td>C\text{O}_2</td>
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<td>Soil Gas</td>
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<tr>
<td>Soil gas profile stations (SGPS)</td>
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<td>Water</td>
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<td>Surface water</td>
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<tr>
<td>Groundwater wells</td>
<td></td>
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<tr>
<td>Fox Hills/Hell Creek wells</td>
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<td></td>
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<tr>
<td>Production/Injection Rates</td>
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<td>Pressure/Temperature</td>
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<td>Wellhead P&amp;T</td>
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<td>Downhole P&amp;T</td>
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<tr>
<td>Distributed fiber optic temperature</td>
<td></td>
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<td>Bottomhole pressure</td>
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<tr>
<td>Geophysics</td>
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<tr>
<td>3-D surface seismic</td>
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<td>3-D vertical seismic profile (VSP)</td>
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<td></td>
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<td>Passive seismic</td>
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<td>Pulsed-Neutron Logs (PNLs)</td>
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SIMULATION-GUIDED MVA

- Simulation was used to predict location and saturation of CO₂.
- 2-D seismic line used to confirm ability of seismic to detect CO₂ in the reservoir.
- Results supported decision to conduct large 3-D survey.
• Pressure and fluid communication revealed by 4-D seismic helped explain Phase 1 model history-matching issues.

• A combined Phase 1 and 2 was developed in response.

CO₂ Banking Against Permeability Barrier

CO₂ and Pressure Moving Updip Away from the Injector Toward Producer

Pressure Buildup from Water Injection

Higher Amplitude in Phase 2 Relative to Phase 1 due to Higher Pressure Buildup

Fluid and Pressure Communication Between Phases 1 and 2

Southeastern Extension of the Permeability Barrier

MVA-GUIDED SIMULATION
MVA FOR MODEL VALIDATION – PULSED-NEUTRON LOGGING

05-01 Saturations
04-04 Saturations
04-03 Saturations

Water
Oil
Gas

Gas saturation

0
0.2
0.4
0.6
0.8
PASSIVE SEISMIC MONITORING

- 50-level geophone array.
- Near-continuous monitoring since May 2013 – 3 years of data (~100 TB).
- Data processing is ongoing – early analysis suggests that all events are <M1 and related to surface or well activity.
FUTURE OF MONITORING

- Integrated
  - Improve performance forecasts
  - Inform operational decisions
  - Address risks
- Actionable results
- No impact on operations
- Low environmental impact
- Focus on fast processing
- Semiautonomous
- Scalable
- Efficient and strategic acquisitions
- Cost-efficient/enhanced value
- Intelligent monitoring
- Key indicators vs. robust solutions
DEMONSTRATION OF EMERGING GEOPHYSICAL MONITORING TECHNIQUES

**SASSA**

*A NEW way to track CO₂*

- Autonomous receivers and semipermanent stationary source
- Interpret boundary of CO₂ front
- Monitor CO₂ progression between wells or around sensitive areas
- Monitoring of overlying zones

**K-Wave**

*A NEW subsurface signal to possibly track CO₂*

- Scalable
- Potential autonomous operation
- Rapid processing
- Low impact
- Reduced acquisition cost
- Guide timing and extent of other surveillance
- Inform timely operations
  - Conformance
  - Pattern analysis
  - Intelligent monitoring systems
- Viable long-term monitoring

- Wellhead-mounted sources and receivers
- Monitor CO₂ progression between wells
COMPARING CO₂ EOR TO "REGULAR" OIL

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