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## ***Plains CO<sub>2</sub> Reduction (PCOR) Partnership Update***

**2011 Carbon Storage Program Infrastructure Annual Review Meeting  
Pittsburgh, Pennsylvania  
November 15–17, 2011**

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Senior Research Manager**



# Acknowledgements

**PCOR  
Partnership  
2003 – Present**



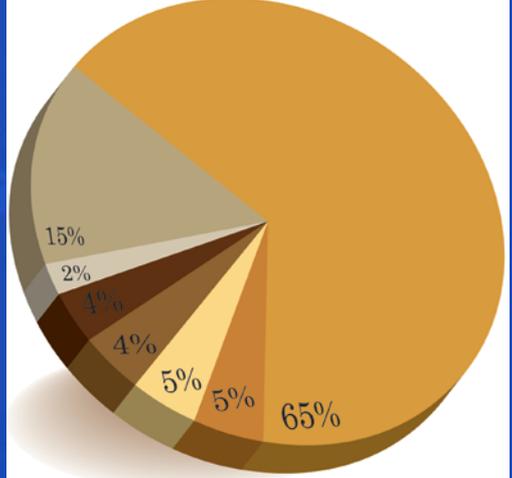
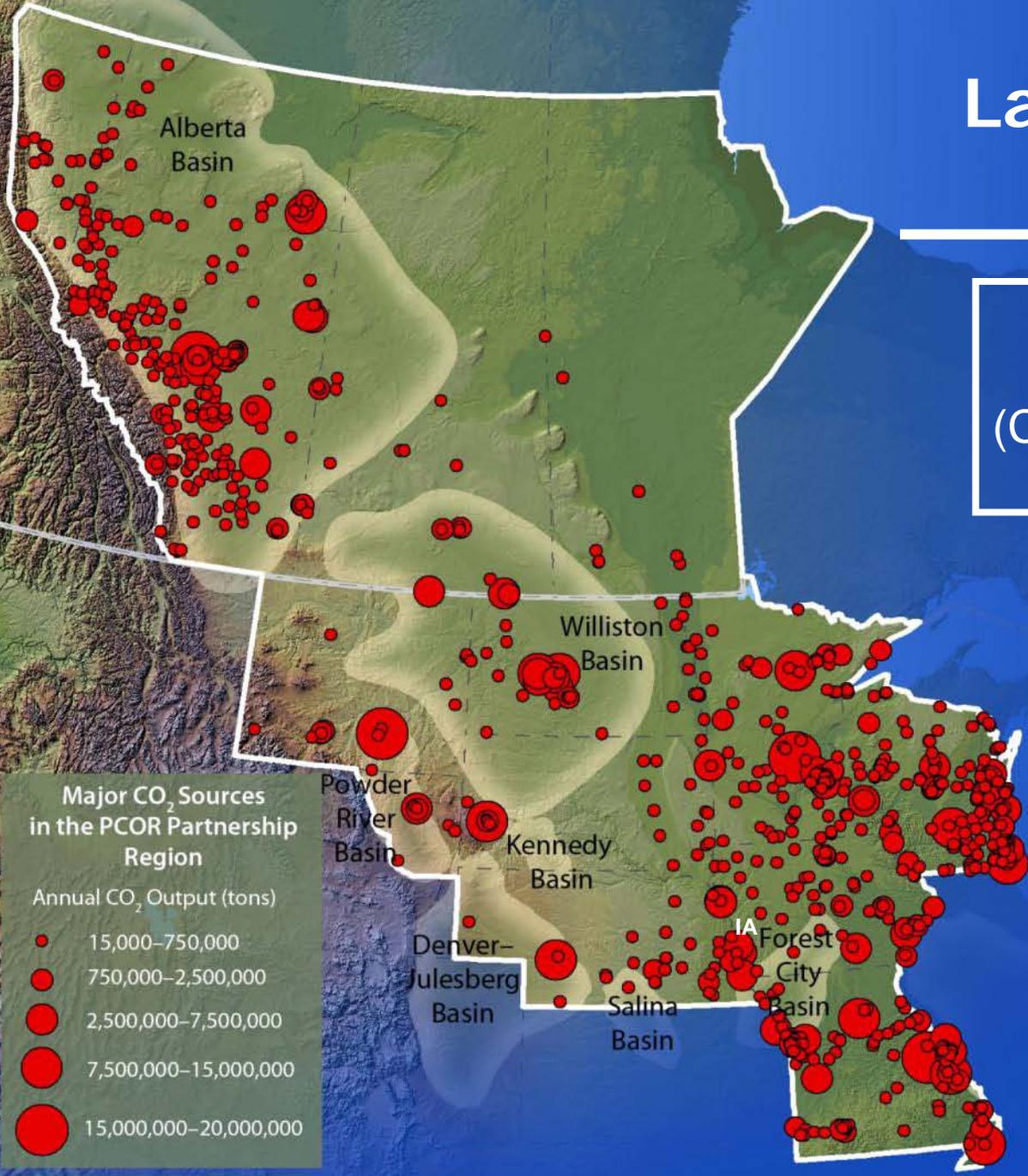
# What Is the PCOR Partnership Doing?



The PCOR Partnership has brought together key stakeholders from nine states and four provinces to develop a shared vision for carbon management in our region.

# Large Stationary Sources

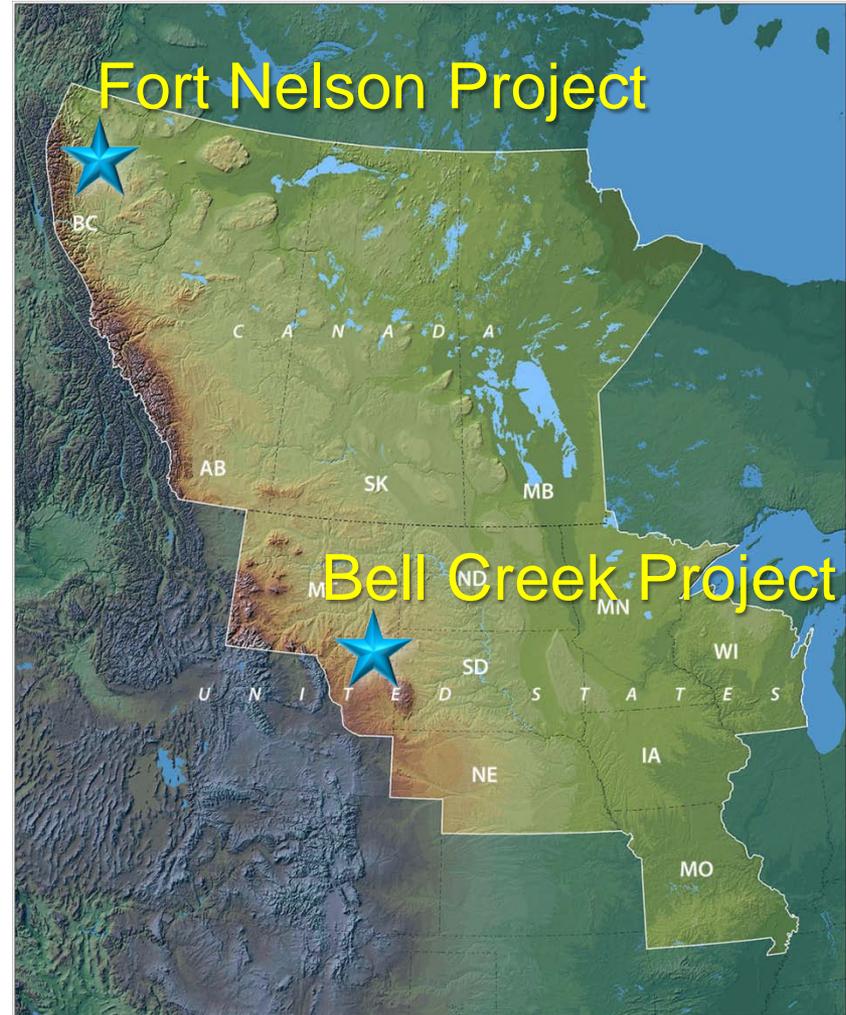
927 stationary sources  
 Total carbon dioxide (CO<sub>2</sub>) emissions:  
 ≈562 millions tons/yr



- Other
- Cement/Clinker Production
- Petroleum & Natural Gas Processing
- Paper & Wood Products
- Petroleum Refining
- Ethanol Manufacturing
- Electric Generation

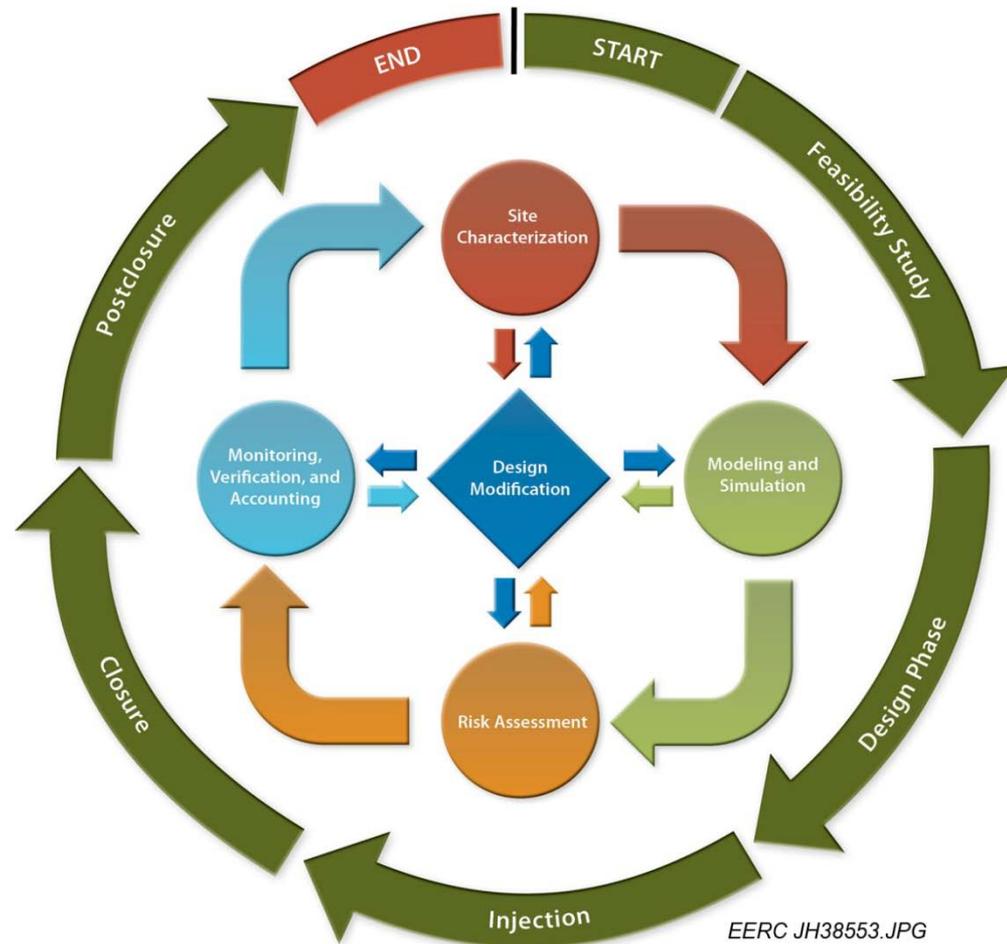
# Commercial-Scale Demonstration Phase

- Two 1-million-ton/year-or-greater-scale demonstrations
  - Saline
  - Enhanced oil recovery (EOR)
- Ongoing and effective public outreach
- Continuing regional characterization
- Continued involvement in other carbon dioxide (CO<sub>2</sub>) storage projects in the region.
- Continued involvement in carbon capture and storage (CCS) and CO<sub>2</sub>/EOR regulations



# PCOR Partnership Objectives and Approach

- Develop an approach to effectively monitor injected CO<sub>2</sub> to ensure long-term site security.
- This approach integrates site characterization; modeling; risk assessment; and monitoring, verification, and accounting (MVA) to achieve high-quality results.

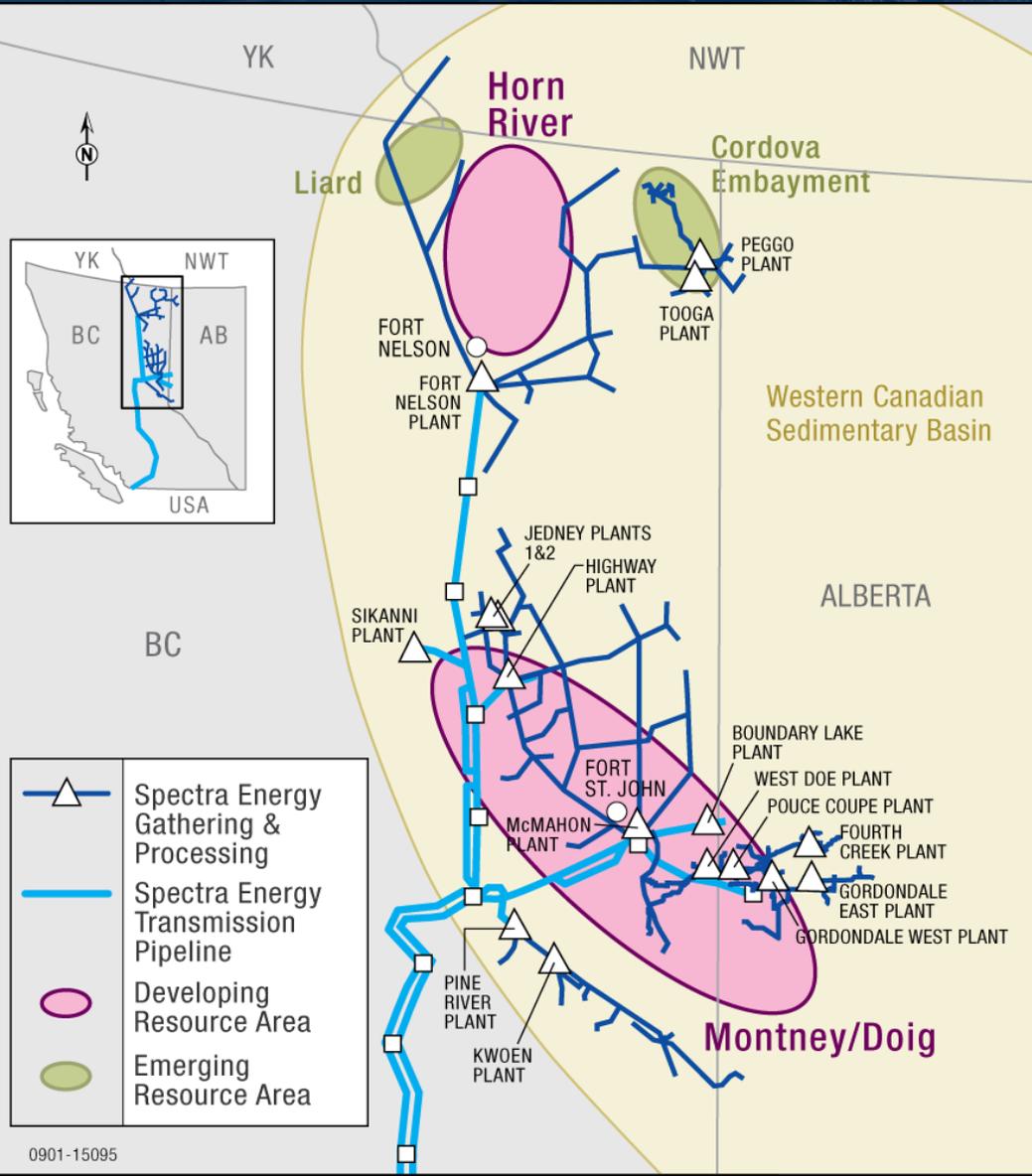


# Fort Nelson CCS in a Deep Saline Formation



Drill rig and camp site near Fort Nelson, British Columbia, Canada

# Fort Nelson Gas Plant

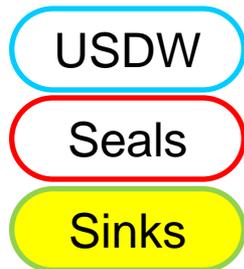


- 1 Bcf/d raw gas-processing capacity – largest facility of its kind in North America.
- Spectra Energy gathering and processing assets are strategically positioned in the growing Horn River Basin, processing both conventional and unconventional shale gas resources.
- The proposed Fort Nelson CCS project is a potential solution to mitigate CO<sub>2</sub> emissions as shale gas production grows.

# Fort Nelson Stratigraphy

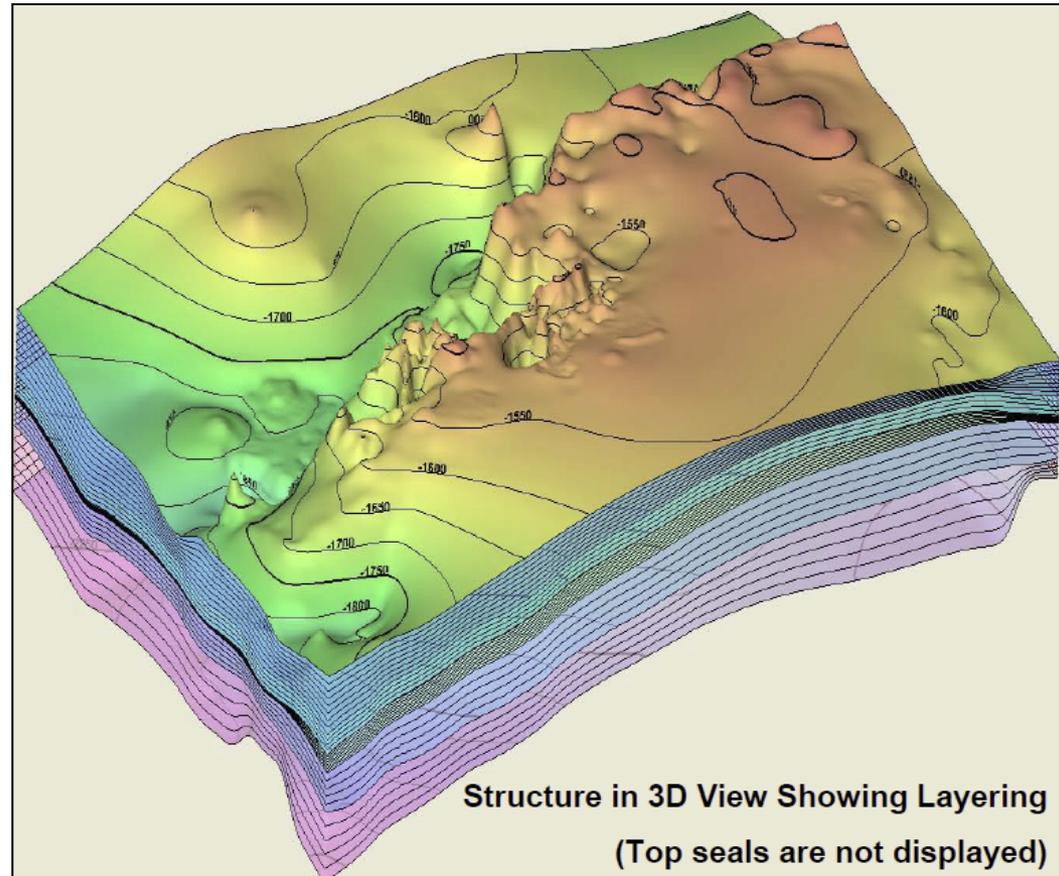
Age Units	Rock Formations	
Cenozoic	Quaternary	
Mesozoic	Cordilleran Drift	
	Wapiti Group	
	Kotaneelee	
	Dunvegan	
	Sully Sikanni	
	Buckinghorse	
	Mississippian	Debolt
		Shunda
		Pekisko
		Banff
Paleozoic	Exshaw Kotcho	
	Tetcho	
	Trout River	
	Kakisa/Redknife	
	Jean Marie	
	Fort Simpson	
	Muskwa	
	Waterways	
	Slave Point	
	Fort Vermilion	
	Watt Mountain	
	Sulphur Pt. Muskeg	
	Lower Keg River	
Chinchaga		
Pre-Cambrian		

- The primary injection horizon is the Sulphur Point Formation (Fm), with the Slave Point and Keg River Fms as secondary targets.
  - Injection horizon is 2200 m deep.
- The Fort Simpson and Muskwa Shales will provide the primary seals.
  - Ranges from 450 to 615 m thick.



# Fort Nelson Characterization

- Exploratory well drilled, cored, tested, and logged.
- Two rounds of geologic modeling, predictive simulation, and subsurface risk assessment completed.
- Additional characterization and modeling efforts ongoing.
- Developing a cost effective MVA program to monitor the injected CO<sub>2</sub>.



# Fort Nelson Status and Next Steps

## Status

- Drilled test well winter 2008–2009
- Cored and logged test well
- Reentered test well winter 2009–2010
- Acquired existing 2-D and 3-D seismic data
- Completed two rounds of modeling
- Completed two rounds of risk assessment

## Next Steps

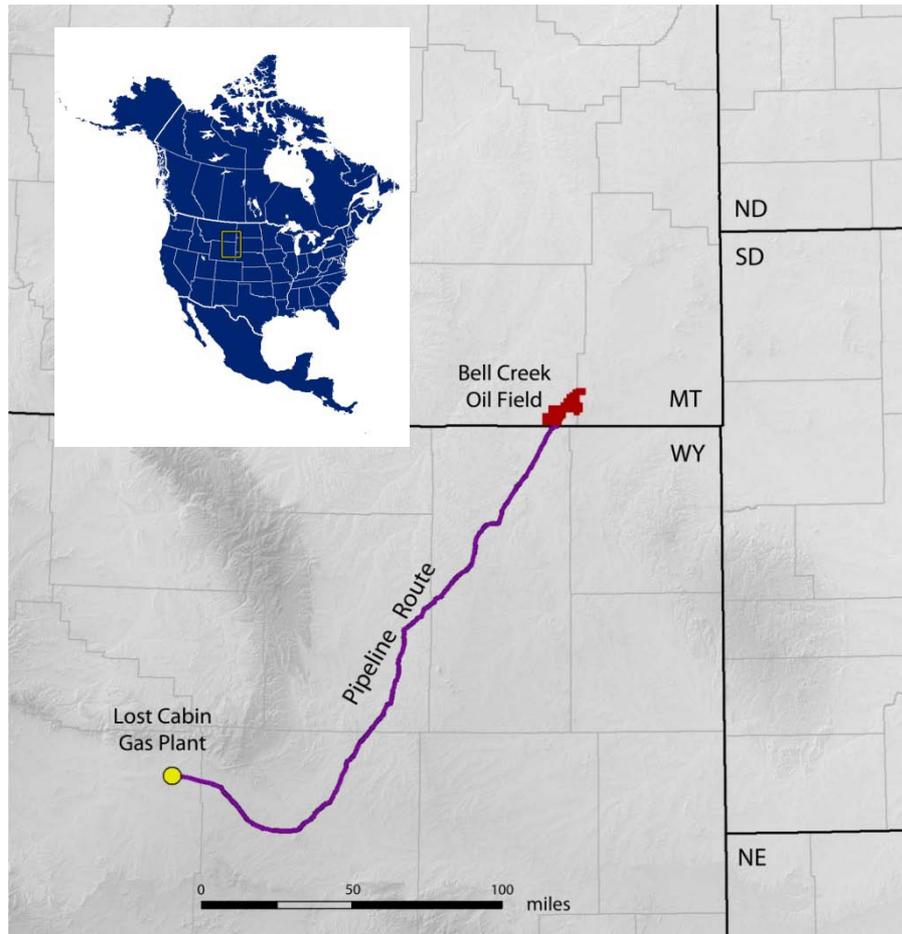
- Develop initial MVA plan
- Drill a second test well winter 2011–2012
- Shoot 3-D seismic survey
- Update geologic model based on additional data
- Rerun predictive simulations
- Conduct a third round of risk assessment
- Adjust MVA plan

# Bell Creek Integrated CO<sub>2</sub> EOR and CO<sub>2</sub> Storage Project

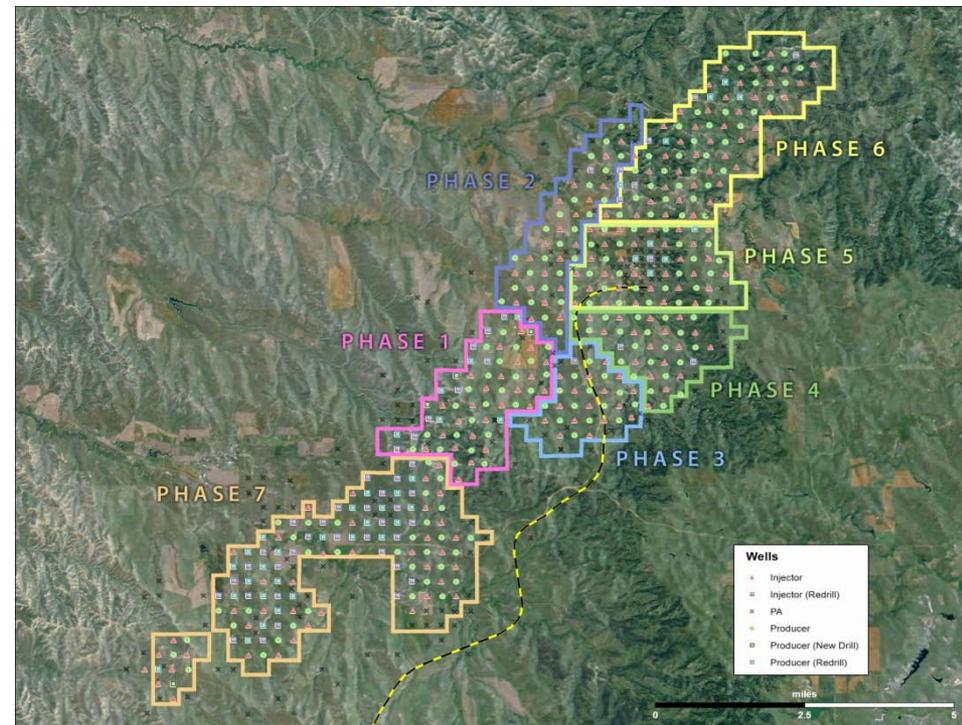


# Bell Creek Logistics

232-mile pipeline operational by December 2012.



CO<sub>2</sub> injection to begin in December 2012.



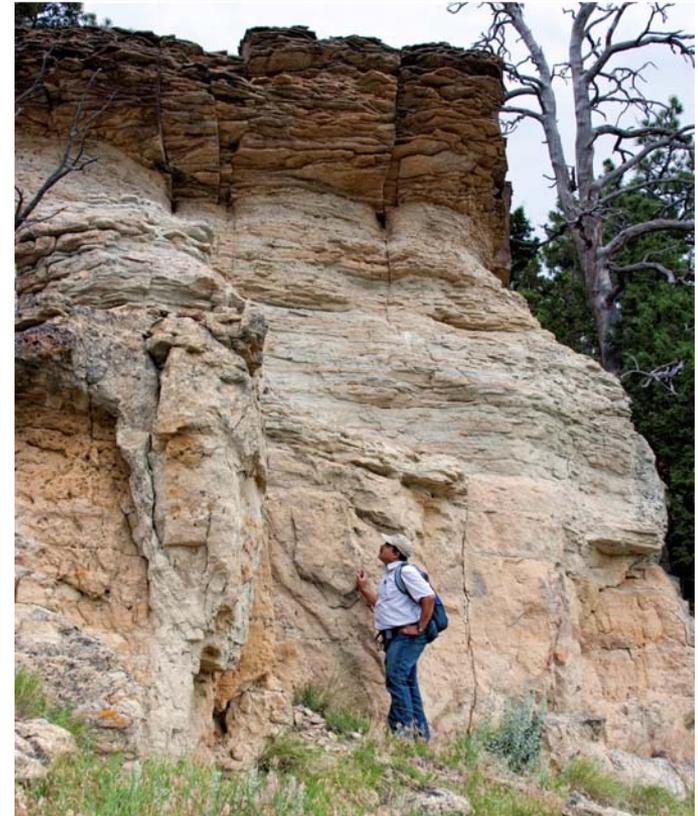
Bell Creek Project Benefits

**35 million barrels**  
of incremental oil

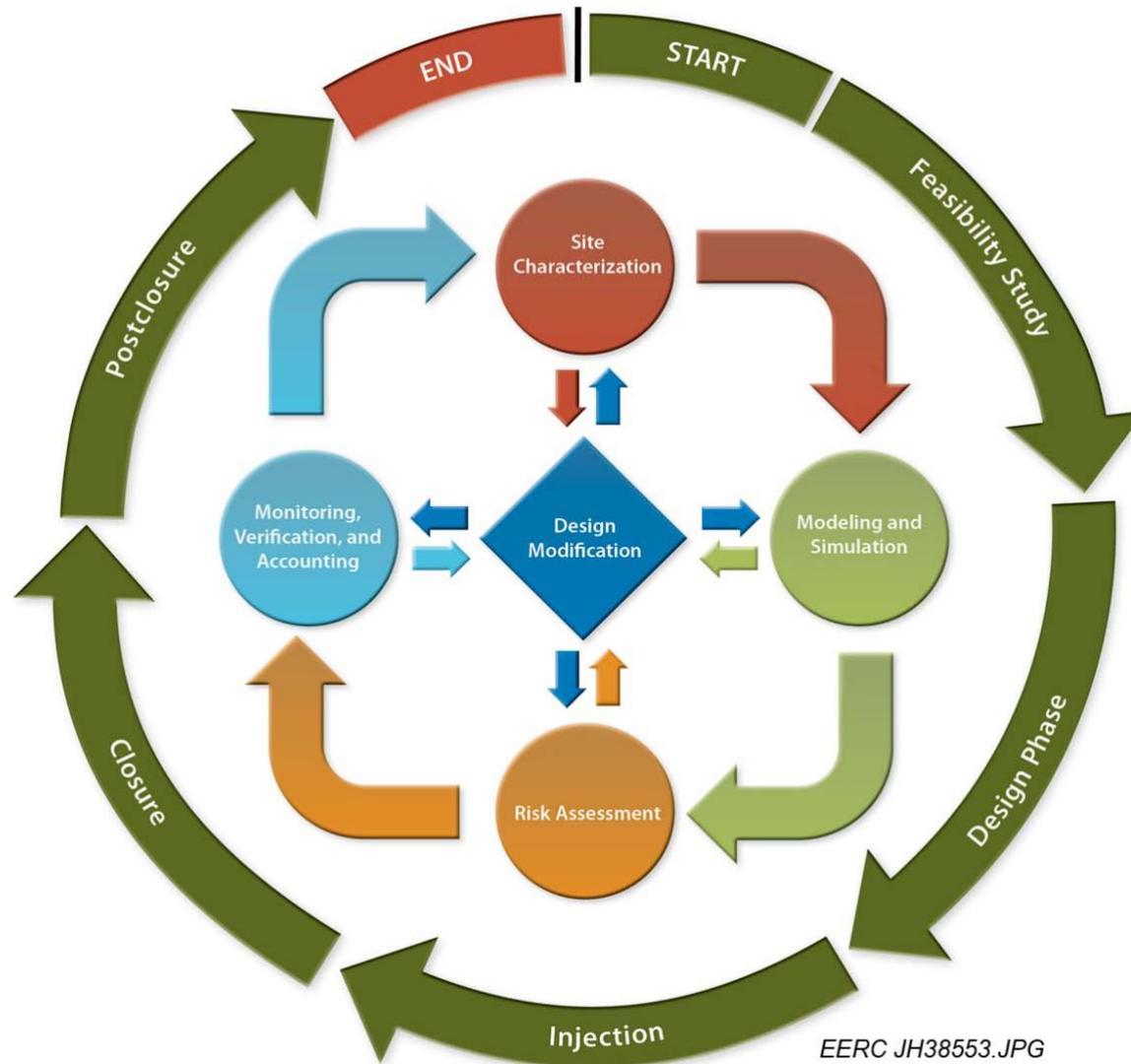
... millions of tons of CO<sub>2</sub>  
safely in storage

# Bell Creek Field History

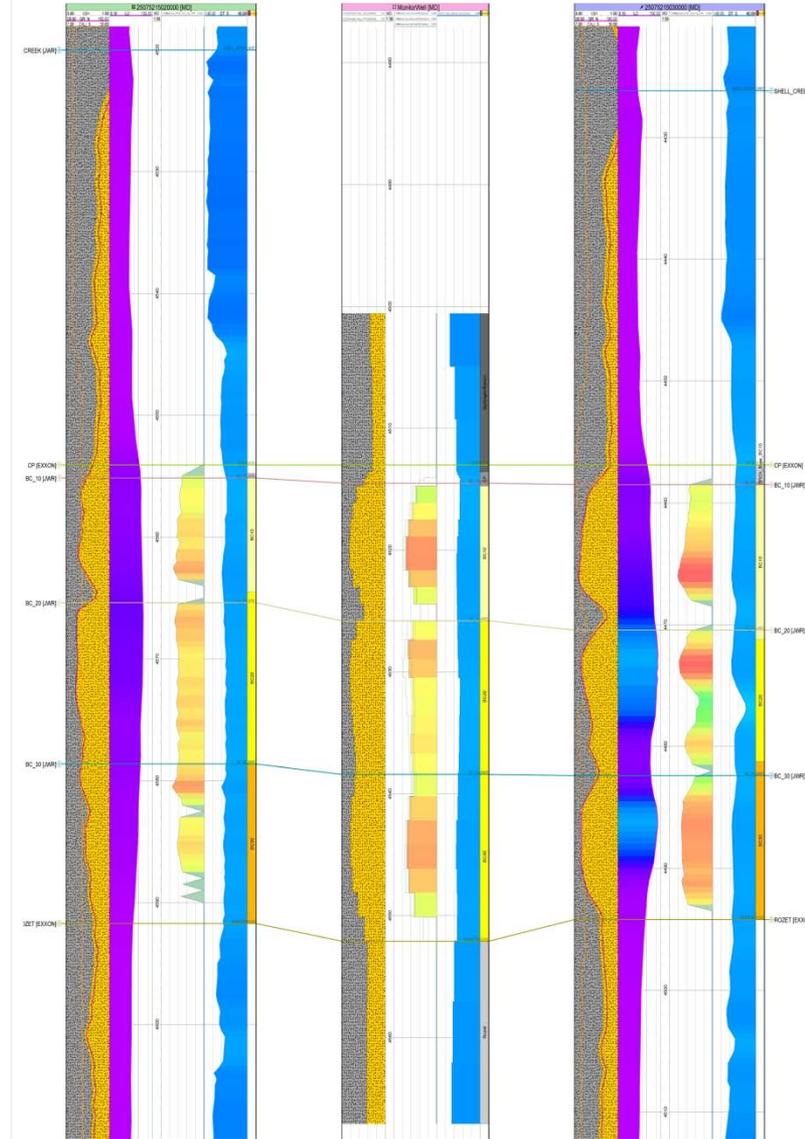
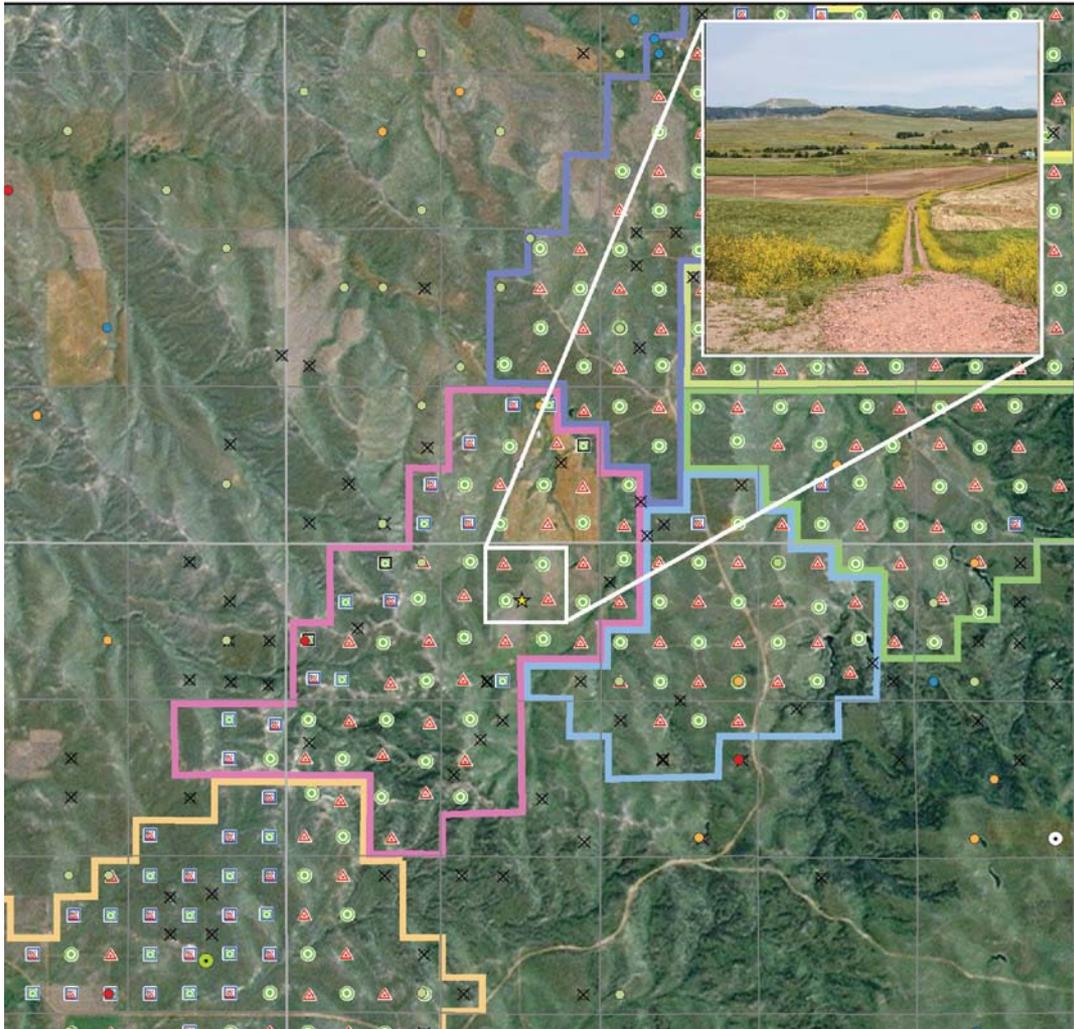
- Discovered in 1967 and covers 21,771 acres (15 x 3.5 miles)
- 450 Wells, peak production of 56,000 barrels of oil per day
- Current production of 1125 barrels of oil per day
- Cumulative production totals 133 million barrels of oil (MMbo) (38% recovery)
- The Muddy Sandstone (only producing reservoir):
  - Depth = 4300–4500 ft
  - Gross thickness = 30–45 ft (three to four lenticular zones)
  - Permeability averages: 425–1175 mD
  - High porosity = 25%–35% (loosely consolidated)
  - Stock tank original oil in place (STOOIP) = 353 MMbo (32–41° API oil)



# Integrated Workflow



# Characterization and Monitoring Well



# Characterization and Monitoring Plan

## Monitoring Well

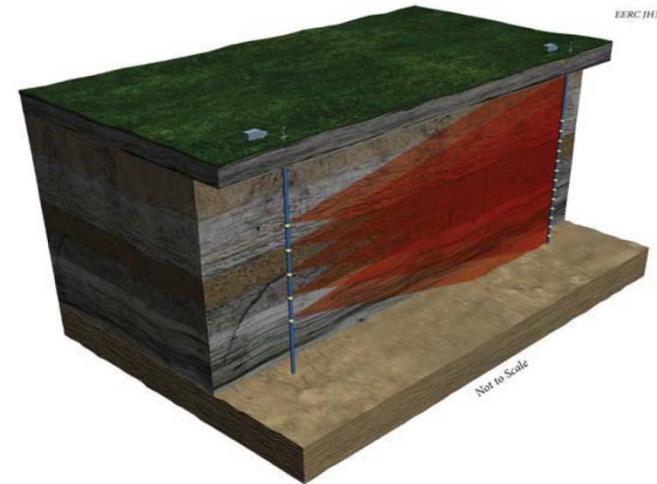
- Drilling of a monitoring well (November–December 2011)
  - Comprehensive well-logging package
  - Formation pressure testing
  - Core acquisition and analysis
    - Mowry Shale (upper seal)
    - Muddy Sand (reservoir)
    - Skull Creek Shale (lower seal)
  - Permanent downhole monitoring equipment (PDM)
    - Multizone pressure (no wellbore perforations required)
    - Distributed temperature
  - Baseline and time-lapse monitoring data
    - 3-D or walk-away vertical seismic profile (VSP)
    - Crosswell seismic
    - Pulsed neutron
    - Continuous pressure and temperature data



# Characterization and Monitoring Plan

## Monitoring Well (continued)

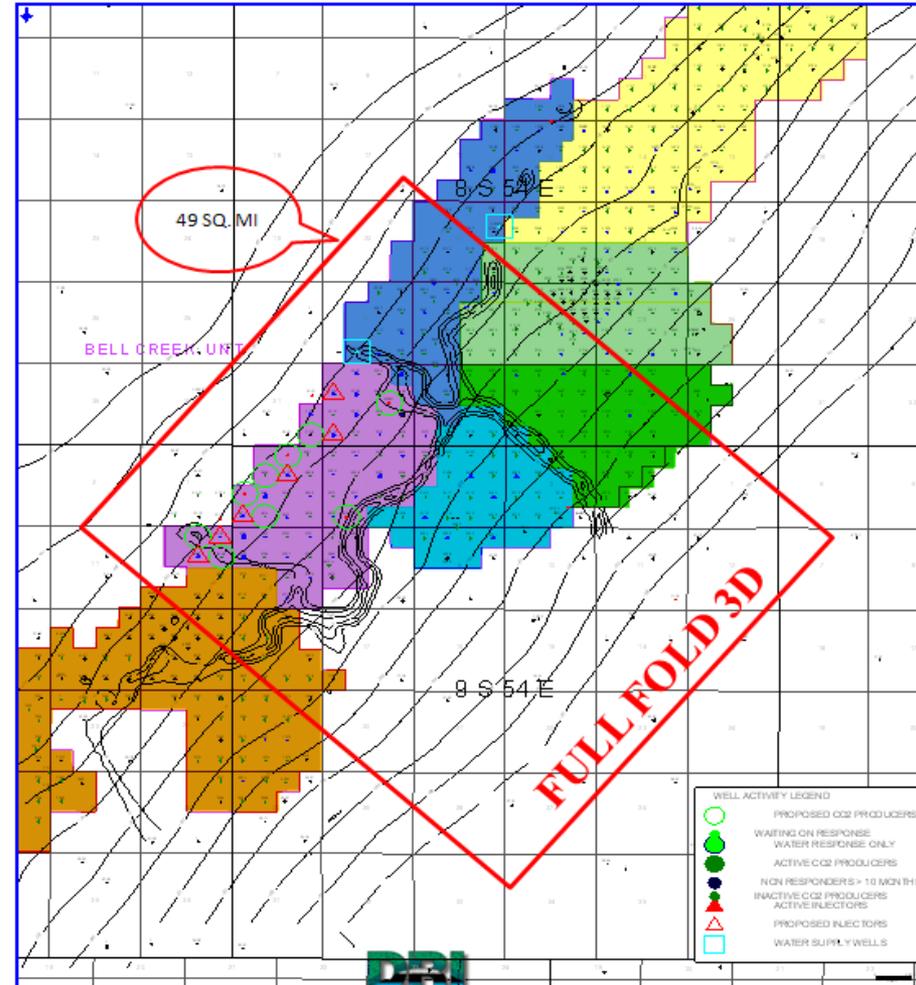
- Staged monitoring program
  - PDM continuous pressure and distributed temperature
    - Provide in situ history match data
    - Provide an indication of CO<sub>2</sub> contact with wellbore
  - Pulsed neutron
    - Confirm CO<sub>2</sub> contact with wellbore and saturation estimates
    - Identify any out-of-zone vertical CO<sub>2</sub> migration near wellbore
  - VSP and crosswell seismic
    - Areal extent and vertical cross section of CO<sub>2</sub> plume
    - Aid in history matching and flood efficiency estimates
    - Identify out-of-zone migration



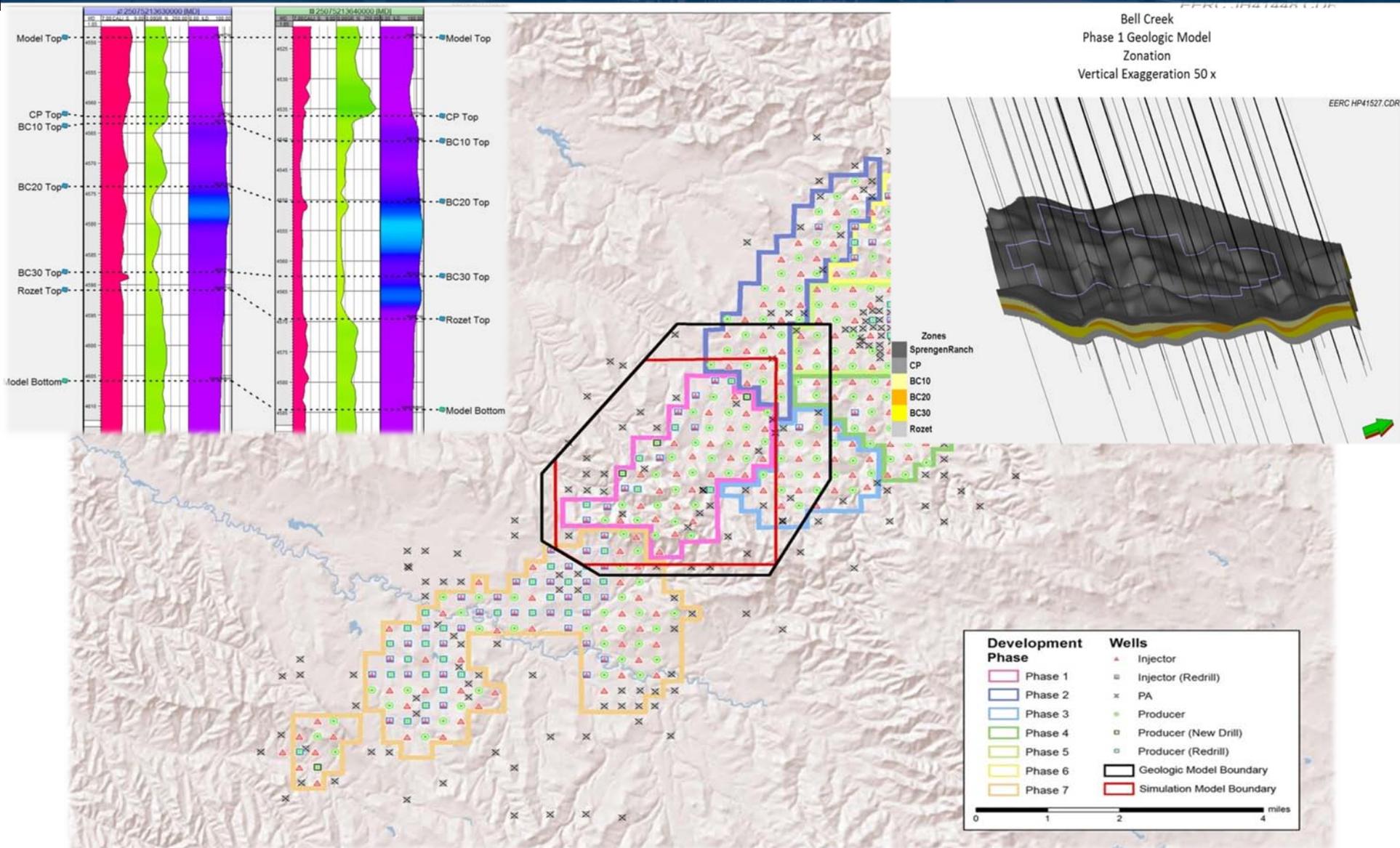
# Characterization and Monitoring Plan

## Proposed Baseline 3-D Seismic

- Assist with updip/downdip boundaries
- Provide baseline data for time-lapse seismic plume tracking
- Check shot program being planned for fall 2011



# Modeling and Simulation



# Monitoring Plan (Existing Wellbores)

- Well re-entry
  - Additional temporary monitoring points in other development phases
  - Supplement MVA data acquired through monitoring well
- Injection and production wells
  - All active wells will be outfitted with real-time pressure sensors



# Soil Gas and Groundwater Sampling

- Provide baseline seasonal flux data
- Water samples analyzed for
  - CO<sub>2</sub>
  - Metals
  - Isotopic signatures
  - pH
  - Conductivity
  - Dissolved oxygen
  - Dissolved solids
  - Oxygen reduction potential
- Soil gas samples
  - Analyzed on-site with a portable gas chromatograph
    - CO<sub>2</sub>, N<sub>2</sub>, and CH<sub>4</sub> concentrations and ratios
    - C1–C6
    - Carbon dioxide, methane, nitrogen, and oxygen ratios



# Bell Creek Status and Next Steps

## Status

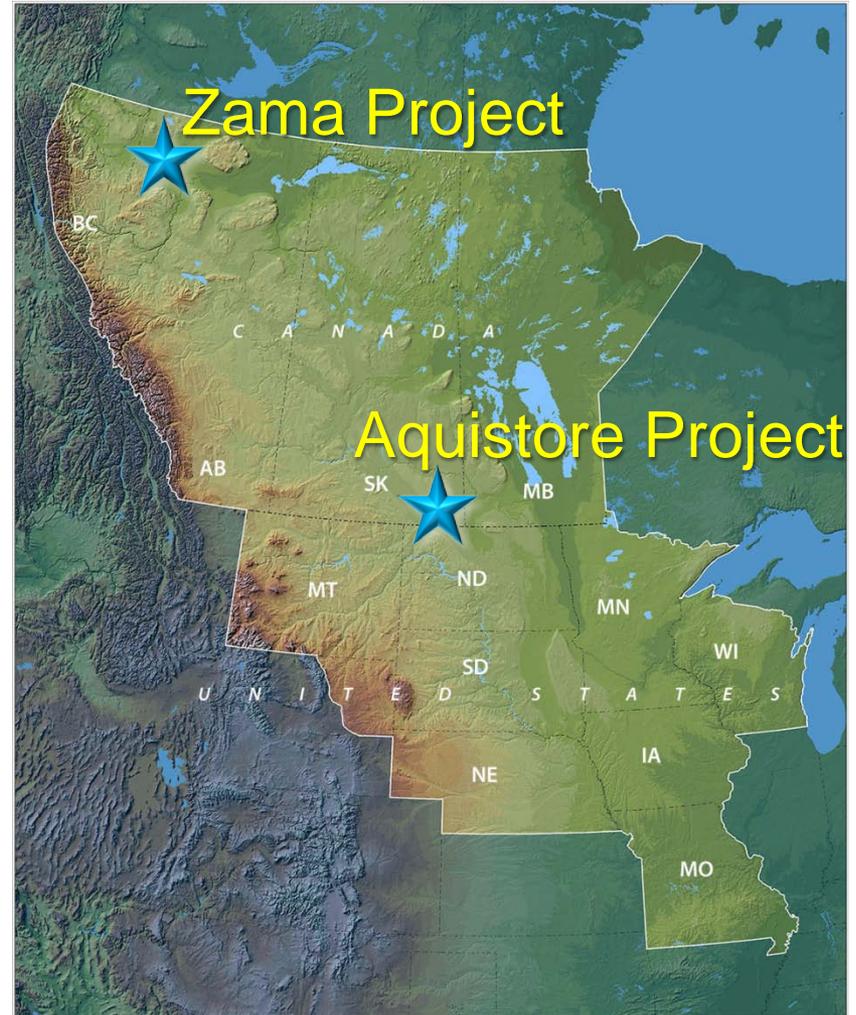
- Public and proprietary data acquired
- Conducted several field trips to representative outcrops
- First round of surface and near surface monitoring complete
- First round of geologic modeling and simulation underway
- Pipeline construction is underway
- Phase I of the field is being prepped for injection

## Next Steps

- Drill deep monitoring well November – December 2011.
- Conduct follow-up baseline surface and near surface sampling quarterly.
- Shoot 3-D seismic survey Summer 2012.
- Re-enter existing wells in field to use as additional deep monitoring points.
- Pipeline to be completed December 2012.
- Injection to begin 1<sup>st</sup> quarter of 2013.

# Additional Projects

- ✓ Regional Characterization
- ✓ Basal Cambrian
- ✓ Aquistore
- ✓ Zama
- ✓ Water Working Group
- ✓ Outreach
- ✓ Regulatory Involvement



# Regional Characterization



- Alberta
  - Viking Formation
- Nebraska
  - Cedar Hills Sandstone
  - Maha Aquifer
- Iowa
  - Forest City Basin
- Williston Basin
  - Deadwood Formation
  - Madison Formation
  - Midale and Rival Formations in Rival Field

# Basal Cambrian Characterization



- Assessment of the Basal Cambrian aquifer system
- 1.1 million km<sup>2</sup>
- A goal of no boundary faults
- Working with:
  - Two countries
  - Three provinces
  - Four states

# Basal Cambrian Participants

## Canadian Organizations

- Alberta Innovates – Technology Futures
- Alberta Innovates – Energy and Environment Solutions
- Saskatchewan Industry and Resources
- Manitoba Water Stewardship
- Manitoba Innovation, Energy and Mines
- CanmetENERGY
- Natural Resources Canada
- TOTAL E&P Ltd.

## U.S. Organizations

- U.S. Department of Energy
- Energy & Environmental Research Center at the University of North Dakota
- Lawrence Berkeley National Laboratory
- Princeton University

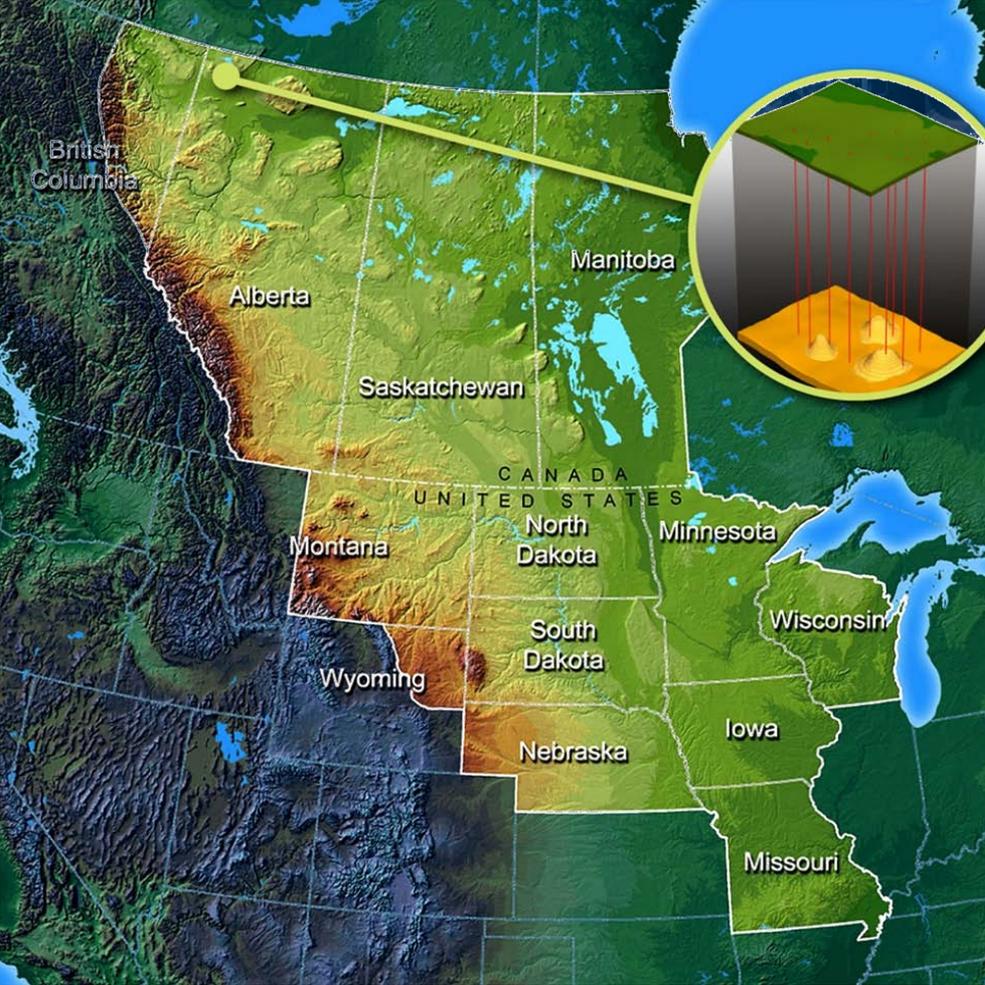


# Aquistore Project

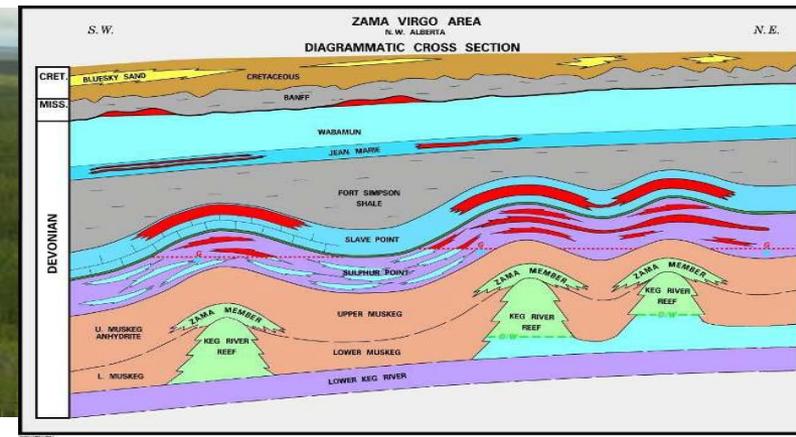
- CO<sub>2</sub> will be injected into a saline formation:
  - Deadwood Formation
  - Target depth of 3200 m (10,500 ft)
  - >50 m (>150 ft) in thickness
- Scheduled drilling of an exploratory well near Estevan, Saskatchewan, in winter 2011–2012.
- Anticipate CO<sub>2</sub> delivery via pipeline from Boundary Dam power plant near Estevan, Saskatchewan.



# Zama EOR & CCS Project

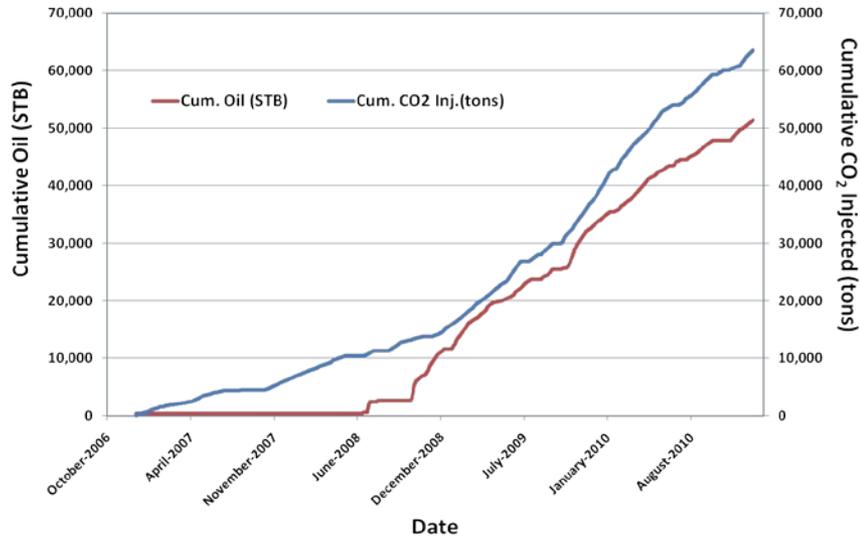


- Operated by Apache Canada Ltd.
- Injection of acid gas is ongoing and will continue as an EOR scheme.
- Implement a cost-effective approach for MVA.
- Pinnacle reef structure.
- Similar lithology found in the Williston and Powder River Basins.



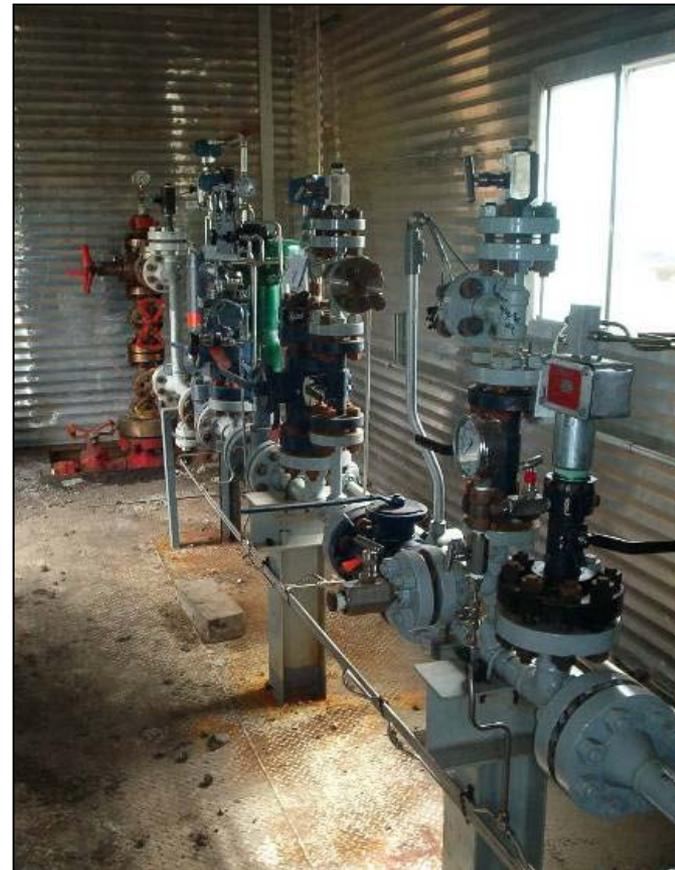
# Zama Operations & MVA

Cumulative Oil and Injected CO<sub>2</sub> Zama F Pool



- Injection began December 15, 2006
- Over 60,000 tons CO<sub>2</sub> injected
- Over 50,000 incremental bbl oil produced

***The Zama MVA program was developed using current Alberta regulatory framework for acid gas injection. Characterization activities were added to fully describe the system and provide confidence in the safe and secure storage of injected fluids.***

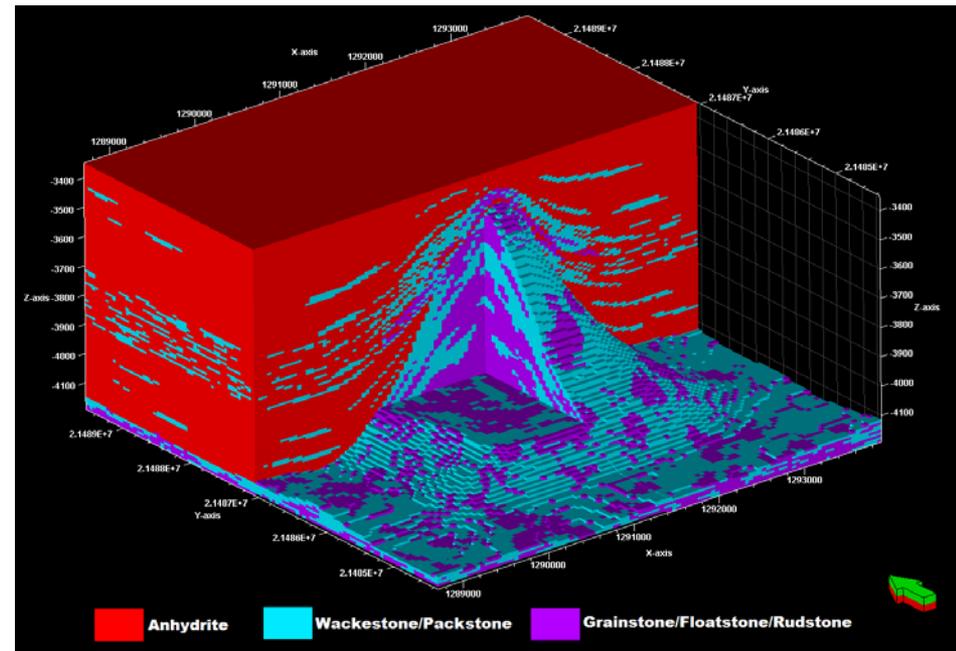


# Current Activities

## Static and Dynamic Geological Modeling

New laboratory work to determine:

- Steel degradation rates
- Cement integrity
- Mechanical changes before and after acid gas exposure.



# RCSP

Regional Carbon Sequestration Partnerships

# Water Working Group



RCSP Water Working Group (WWG) comprises scientists and engineers representing government, academia, and industry.

## Mission Statement

- To provide a resource of knowledge, insight, and guidance to stakeholders involved with water and water resources and their relationship to the developing technology of CCS.

# Nexus of Water and CCS

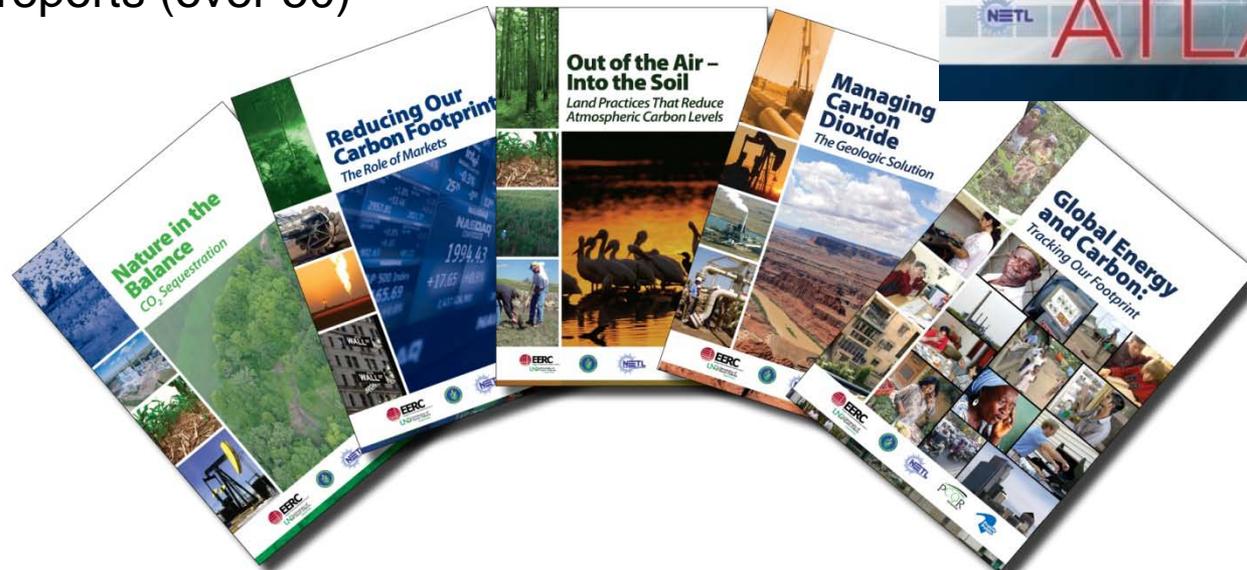
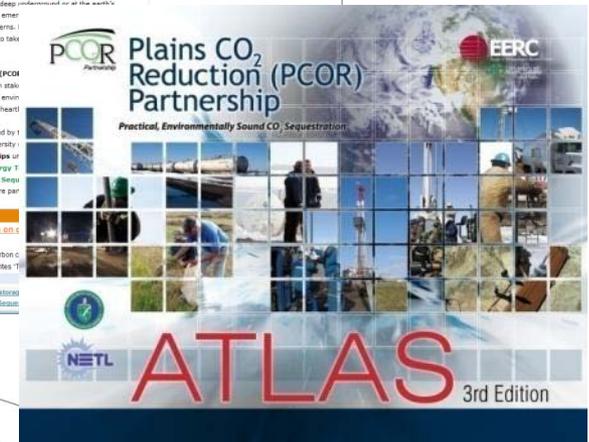


Man Turbo, 2007, CO<sub>2</sub> Compression Challenges, ASME Turbo Expo



# PCOR Partnership Outreach Support

- 65-page regional sequestration atlas
- Fact sheets on key topics and projects
- Variety of PowerPoint presentations
- Public Web site with streaming and downloadable materials
- Sequestration documentaries (television broadcasts, Web streaming, and DVDs)
- Video clips
- Technical reports (over 50)



# Active Involvement at the Regulatory Level

- **PCOR Partnership Regulatory Meetings**

June 16–17, 2009

July 21–22, 2010

June 29–30, 2011

- A gathering of regional regulatory officials to discuss existing and evolving regulatory frameworks for CO<sub>2</sub> transportation and storage.



# Monitoring Regulatory Developments

- Staying abreast of the latest regulatory developments is of the utmost importance to the PCOR Partnership. Examples:
  - Review and comment on provincial, state, and federal rulemaking
  - Review proposed and enacted provincial, state, and federal legislation
  - Participate in Interstate Oil and Gas Compact Commission's Geological CO<sub>2</sub> Sequestration Task Force and Pipeline Transportation Task Force
  - Participate in Presidential Interagency Task Force on CCS



# Conclusion

The PCOR  
Partnership region  
has huge CCS  
potential!





# Thanks!!



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