ENERGY & ENVIRONMENTAL RESEARCH CENTER AT THE UNIVERSITY OF NORTH DAKOTA

EERC

PCOR Partnership

Plains CO_2 Reduction (PCOR) Partnership

Fact Sheet

Practical, Environmentally Sound CO_2 Sequestration

Bell Creek Project – Enhanced Oil Recovery Resulting in Associated CO_2 Storage

The Plains CO_2 Reduction (PCOR) Partnership is studying associated carbon dioxide (CO_2) storage incidental to a commercial enhanced oil recovery (EOR) operation. The PCOR Partnership Phase III project is a collaborative effort with the operator of the Bell Creek oil field, Denbury Onshore LLC (Denbury), which began in 2010.

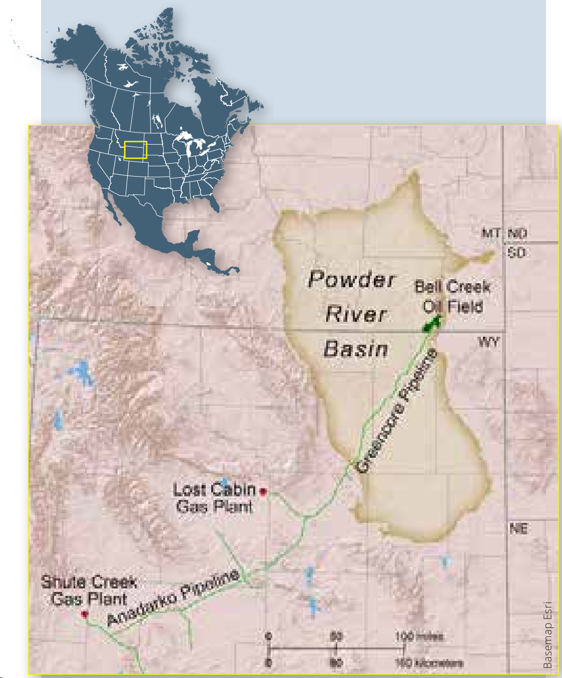
Objectives and Results to Date

The project is designed to 1) understand and predict the behavior of CO_2 in the reservoir, including how associated storage of CO_2 occurs during EOR; 2) validate that CO_2 can be effectively contained within oil-bearing sandstone formations; and 3) develop and demonstrate practical, cost-effective monitoring, verification, and accounting (MVA) techniques that can be adapted into commercially viable strategies for monitoring the performance of both EOR and associated CO_2 storage incidental to hydrocarbon recovery.

Notable achievements thus far include:

- A computer model of the geologic formations that make up the EOR complex (oil reservoir and cap rocks) based on data from rigorous geologic, geotechnical, and hydrogeologic characterization.
- Performance forecasts that use the geologic model to simulate the fluid and reservoir behavior under various CO_2 injection and operating scenarios.
- A research monitoring program that has demonstrated that associated CO_2 storage incidental to EOR is effective and safe.
- Integration of MVA techniques as part of an overall monitoring strategy that provides faster, more reliable, lower-cost, lower-impact, actionable results that inform operational decisions.
- A rigorously characterized test site, which has enabled the development of new, low-impact, near-real-time geophysical CO_2-monitoring techniques, such as Krauklis seismic wave (K-wave) and scalable, automated, semipermanent seismic array (SASSA).

Fast Facts



Project Type: CO_2 Enhanced Oil Recovery
Location: Southeast Montana, United States
Injection Zone: Lower Cretaceous Muddy (Newcastle) Formation
Depth: 4300–4500 feet (1300–1370 meters)
CO_2 Source: Gas-processing plants, Wyoming
CO_2 Injection Began: May 2013
Associated CO_2 Stored: 4.2 million tonnes (as of August 2017)

Partners: Denbury, PCOR Partnership, U.S. Department of Energy

MVA strategies developed at Bell Creek can be adapted to other operations injecting anthropogenic CO_2 and can help address the threat of climate change.

Approach

The Bell Creek oil field was discovered in 1967. Oil was produced during both primary production and a subsequent waterflood prior to the start of CO_2 injection for EOR in May 2013. The operational and production history of the field combined with preexisting geologic data served as the backbone for the project. Enhanced site characterization; comprehensive monitoring, modeling, and simulation activities; and development of verification and accounting strategies were integrated as part of the research project to understand associated CO_2 storage. These activities are undertaken in iterative phases that gather information, test techniques, assess results, and determine next steps.

Site Characterization

Characterization efforts incorporated preexisting data and knowledge, including well logs, drilling reports, pressure and injectivity tests, and production histories. Data gaps were identified, and understanding was enhanced through additional data collection and expanded characterization efforts. Well locations and elevation data were corrected using a lidar survey. Several vintage 2-D seismic and vertical seismic profile (VSP) data sets were reprocessed, and baseline pulsed-neutron logs (PNLs) were collected to improve petrophysical and structural interpretation of the reservoir and overlying zones.[1] 3-D seismic data improved structural interpretation of the injection zone and overlying seals. This work provided a foundation for understanding how fluids, including injected CO_2, move and interact in the subsurface.

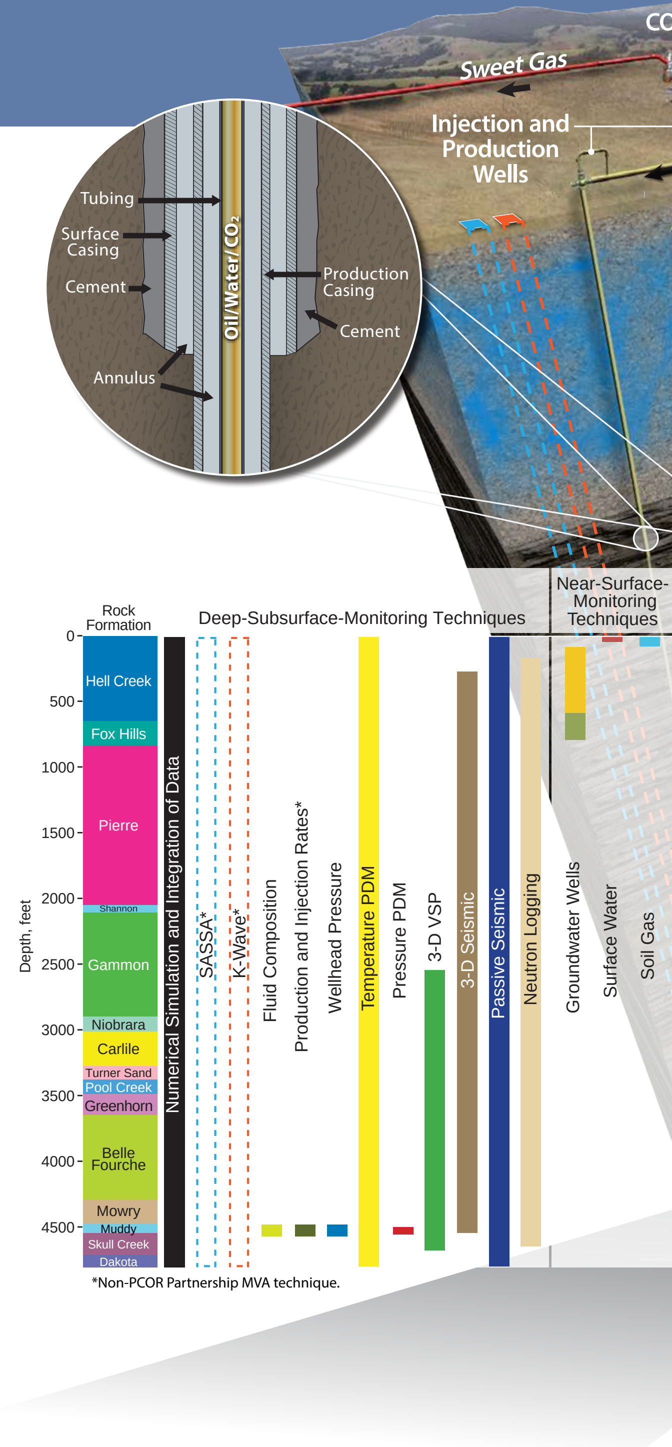
Monitoring

A variety of monitoring techniques were used to collect baseline data to establish the natural variability of soil gas and water chemistry in the near-surface environment; track CO_2 movement within the EOR complex; and demonstrate safe, effective associated CO_2 storage. Monitoring of surface water, groundwater, and soil gas chemistries provides data that can be used to both show that these environments are not adversely impacted by injection of CO_2 and understand anomalies and natural variability in the system should they occur.[2] Subsurface monitoring focuses on fluid behavior in the EOR complex using the techniques listed in the illustration at right. Injected and produced fluid rates, pressures, and compositions are monitored to understand performance and calibrate the geologic and forecast models. Information from MVA techniques is used to inform operational decisions and could be used in a similar way for dedicated storage projects in non-EOR sites.

The surface- and near-surface-monitoring program characterized natural CO_2 variability in the near-surface environment.

Monitoring and Injection Activities

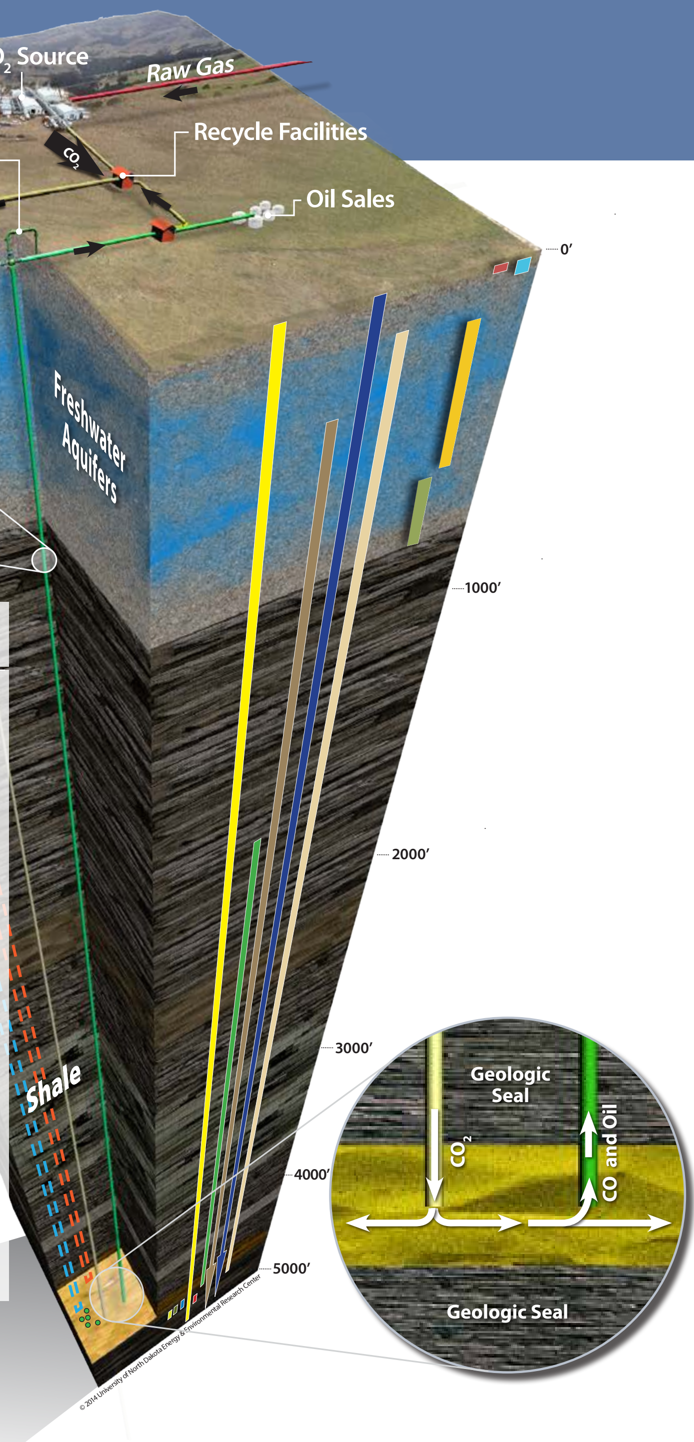
The research-monitoring program leverages 1.5 years of prei
to validate individual MVA tools as well as to investigate, deve
applicable to EOR and understanding associated CO_2 storage

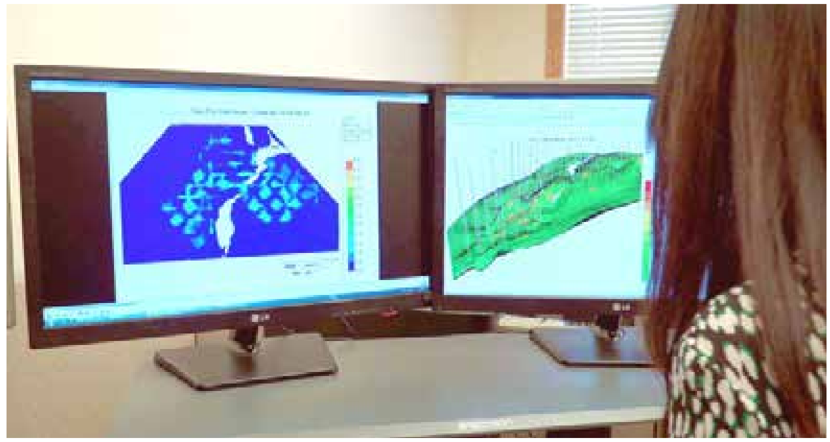


Path Forward

Project activities at Bell Creek have transitioned from validating
cost-effective MVA strategies that combine appropriate high-v
MVA approach.

njection and over 4 years of operational monitoring data
elop, demonstrate, and validate MVA strategies broadly
incidental to EOR.





Computer Modeling and Simulation

Preexisting characterization data (well log, core, and fluid data) were used to develop a first-generation model of the geology and fluids in the EOR complex. The model was then validated using available injection and production data and newly acquired MVA data. As new data became available, the model was further refined, eliminating inconsistencies between predictions and real-world observations. As a result, the simulations of the second- and third-generation models are more accurate in predicting how the CO_2 will behave over time based on a given injection scenario. Improved forecasts provide the ability to better evaluate the relationship between oil recovery and associated CO_2 storage; plan when, where, and how to effectively apply monitoring techniques; and provide feedback on the performance of monitoring techniques. The calibrated forecast models also provide the ability to predict performance under several operational scenarios in order to determine how the project can be operated to tune performance.

Monitoring, Verification, and Accounting

Initial monitoring efforts comprised preinjection and documenting the first million tonnes of associated CO_2 storage. This effort focused on understanding the viability of individual monitoring techniques applicable to commercial-scale CO_2 injection projects (i.e., >1,000,000 tonnes per year of CO_2 injected).[3] Subsequent monitoring work focuses on developing, validating, and demonstrating MVA strategies (how groups of monitoring techniques can be combined to cost-effectively meet several monitoring objectives) applicable to commercial-scale projects. Data acquired through the MVA program are used to calibrate and refine the accuracy of simulation predictions. This integrated process generates more accurate predictions that, in turn, are used to target future MVA strategies.

applications for individual MVA tools to focusing on developing
alue techniques to yield a more commercially viable long-term

Building on the Bell Creek Project

Individual MVA techniques are being evaluated to provide insight into how they can be integrated as part of cost-effective monitoring strategies for nonoilfield commercial carbon storage projects. Insights from the Bell Creek project enabled the development of and provided an ideal environment to demonstrate two emerging geophysical techniques, referred to as K-wave and SASSA. These techniques show promise for providing more cost-efficient, lower-impact, near-real-time solutions for long-term monitoring. The results of the research at Bell Creek are expected to benefit both dedicated CO_2 storage—where eliminating emissions of anthropogenic CO_2 is the primary purpose of underground injection—and associated storage of either anthropogenic or geologic CO_2 that occurs as a natural part of CO_2 EOR operations.

CO_2 EOR and Associated Storage

Injecting CO_2 into an oil-producing zone is called CO_2 EOR or CO_2 flooding. When CO_2 comes into contact with oil, it dissolves into the oil, reducing the oil's viscosity and increasing the oil's mobility. Combined with restoring the original pressure drive in the reservoir, this increases oil production rates and extends the operational life of the oil field. Because CO_2 dissolves into the oil, some of the injected CO_2 will come to the surface with the oil. Oilfield operators separate that CO_2 and reinject it along with new CO_2. Over the years of an EOR operation, there are many cycles of CO_2 injection. With each cycle, another portion of injected CO_2 becomes permanently stored in the oil reservoir through a combination of several trapping mechanisms. At the end of the project, nearly all of the purchased CO_2 remains naturally trapped in the reservoir. This is called associated CO_2 storage.

CO_2 EOR and Carbon Footprint

When the carbon dioxide for CO_2 EOR comes from an anthropogenic or man-made source, the CO_2 EOR operation sequesters CO_2 that would otherwise be released to the atmosphere. The carbon content of the oil itself is not changed. But because all of the CO_2 is ultimately stored at the end of the project, the overall carbon footprint of the process is reduced.[4] Oil with this reduced-life-cycle carbon footprint is called "greener." The Bell Creek Field is one of a small number of CO_2 EOR floods using anthropogenic CO_2 and, as a result, produces oil with a lower overall carbon footprint.

Bell Creek has been a development and demonstration site for CO_2-monitoring technologies, which are validated using more conventional and proven monitoring.

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The Plains CO_2 Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of storing CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:

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Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

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