Monitoring One Year's Worth of CO_2 Injection and Incidental Storage at the Bell Creek Oil Field

John Hamling,[1] Charles Gorecki,[1] Ryan Klapperich,[1] Nicholas Kalenze,[1] Daniel Stepan,[1] Edward Steadman,[1] John Harju,[1] Howard Miller,[2] Jim Rawson,[2] Russell Welch,[2] and Fred Walsh[2]

[1]Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

[2]Denbury Resources Inc.
5320 Legacy Drive
Plano, TX 75024

Abstract

The Plains CO_2 Reduction (PCOR) Partnership, led by the Energy & Environmental Research Center (EERC), is working with Denbury Resources Inc. (Denbury) to study incidental carbon dioxide (CO_2) storage associated with CO_2 enhanced oil recovery (EOR) at the Bell Creek oil field, which is operated by Denbury Onshore LLC. The Bell Creek oil field covers approximately 22,000 acres (89 km^2), contains over 450 wells, and has produced over 130 million barrels of oil since its discovery in 1967.

Denbury is injecting a planned volume of approximately 50 million cubic feet (1.4 million cubic meters) of CO_2 a day, sourced from the ConocoPhillips-operated Lost Cabin natural gas-processing plant in Fremont County, Wyoming. The CO_2 is being transported to the Bell Creek oil field via the 232-mile (373-km)-long Greencore pipeline and injected into an oil-bearing sandstone reservoir in the Lower Cretaceous Muddy (Newcastle) Formation at a depth of approximately 4500 feet (1372 meters) for the purpose of CO_2 EOR. The Muddy Formation is characterized by a high-porosity (15%–35%), high-permeability (150–1175-mD) barrier bar sandstone sequence. The activities at Bell Creek are injecting an estimated 1 million tons of CO_2 annually, which began in May 2013. Much of the injected CO_2 will remain in the reservoir via incidental storage at the conclusion of EOR operations.

The PCOR Partnership is pioneering an integrated adaptive management philosophy for CO_2 storage combining site characterization; modeling and simulation; risk assessment; and monitoring, verification, and accounting (MVA) strategies into an iterative process to assess project performance and guide monitoring strategies. Elements of any of these activities are crucial for understanding and developing the other activities. Ultimately, the results of the study will provide commercial operators with the information required to make informed decisions regarding site-specific monitoring and operation of commercial-scale storage projects.

Characterization and simulation work was initiated in 2011 utilizing historic data. Data included well logs, core analysis, production rates, and pressure surveys that have been conducted in the field since 1968 when it was first developed. Geologic models and numerical simulation results indicated that the Bell Creek oil field is an ideal candidate for long-term incidental CO_2 storage in terms of reservoir capacity, flow properties, and confinement. Modeling and simulation work is being continually updated throughout the lifetime of the study, as part of an adaptive management approach, in order to assess technical risks and guide monitoring strategies.

Monitoring of the surface, near-surface, and deep subsurface environment is an essential component of any carbon storage study (Figure 1). The primary objectives in this study are to select monitoring techniques that are designed to both address site-specific technical risks and provide complementary data sets which minimize measurement uncertainty. This is done to obtain data critical for verification of site security, measurement of project performance, and assessment of variances within the predicted injection program. Specifically, the MVA plan has been divided into separate near-surface and deep subsurface monitoring plans. The purpose of the near-surface monitoring program, which includes soil gas- and water-monitoring activities, is to establish naturally occurring baseline soil gas and water chemistries from the near-surface environment to provide a source of data to compare baseline and operational conditions during the study's lifetime and validate containment.

The goals of the deep subsurface monitoring program are to track and account for the movement of CO_2 in the reservoir, evaluate the recovery efficiency of the CO_2 EOR program, evaluate the effective storage capacity and storage efficiency of the storage complex, identify fluid migration pathways, provide a scientific data set to demonstrate site security, and determine the ultimate fate of injected CO_2. The deep monitoring program uses a combination of data from a large and ongoing time-lapse pulsed-neutron logging program, casing-conveyed pressure- and temperature-monitoring systems, passive seismic monitoring, and time-lapse seismic monitoring surveys to accomplish these goals.

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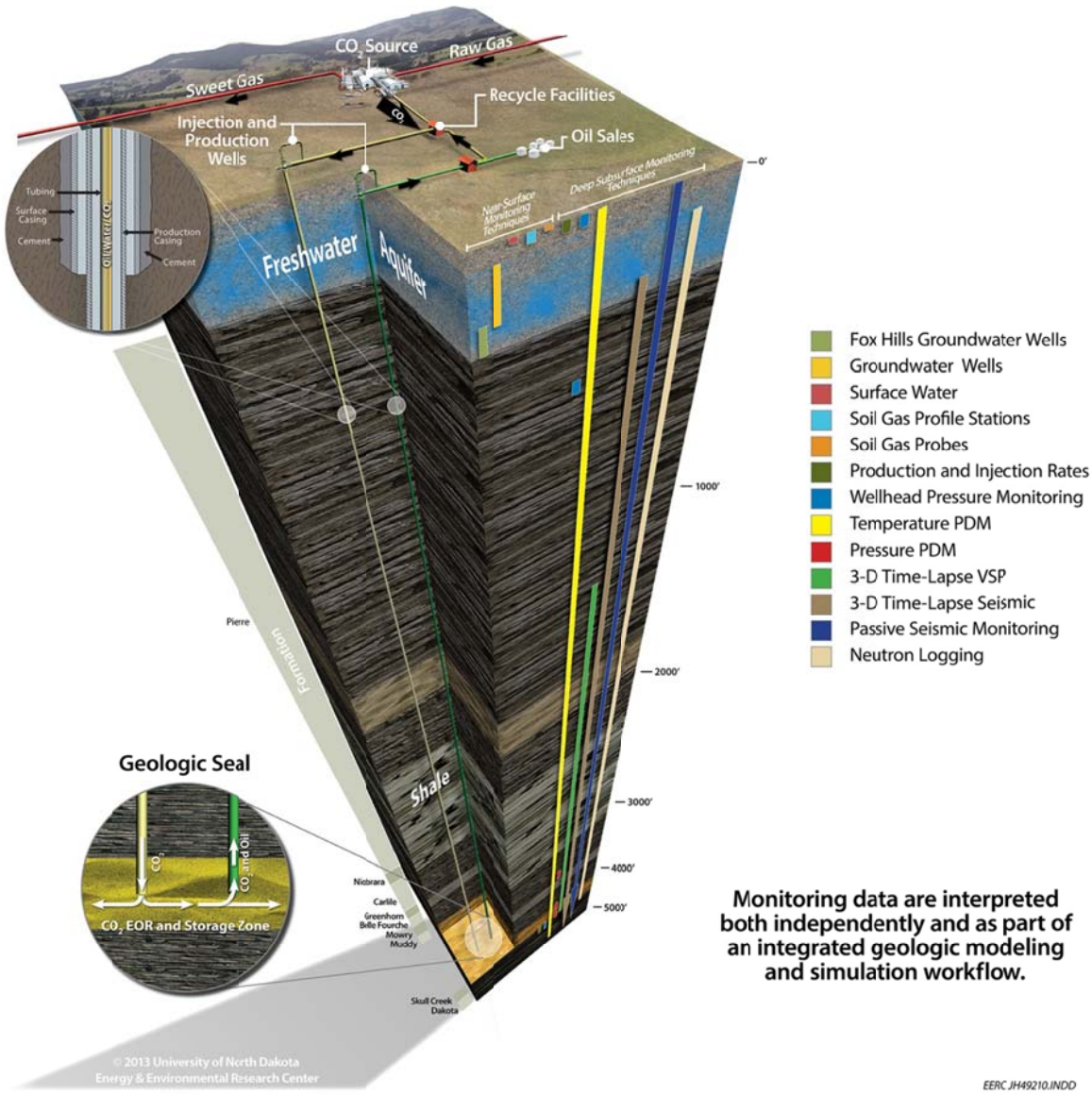

Figure 1. Effective vertical monitoring ranges of the various monitoring technologies deployed at the Bell Creek study as part of the near-surface and deep subsurface monitoring programs (PDM is permanent downhole monitoring).