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Integrating CO_2 EOR and CO_2 Storage in the Bell Creek Oil Field

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Abstract

The Plains CO_2 Reduction Partnership is working with Denbury Resources to evaluate the efficiency of large-scale injection of carbon dioxide (CO_2) into the Bell Creek oil field for simultaneous CO_2 enhanced oil recovery (EOR) and long-term CO_2 storage. Discovered in 1967, the Bell Creek Field in southeastern Montana has produced approximately 133 million barrels (MMbbl) of oil from the Cretaceous Muddy Formation sandstone. The original oil in place (OOIP) for the field was estimated to be approximately 353 MMbbl of oil. Through primary and secondary production, about 37.7% of the OOIP has been produced, leaving an estimated 220 MMbbl of oil in the reservoir. It is estimated that CO_2 flooding will produce an additional 35 MMbbl of incremental oil, while simultaneously storing large volumes of CO_2 in the deep subsurface.

Approximately 50 million cubic feet of CO_2 a day will be captured at the ConocoPhillips Lost Cabin gas-processing plant in central Wyoming and transported via a 232-mile pipeline to the Bell Creek Field. Plans are under way to build compression facilities adjacent to the Lost Cabin gas plant to compress the CO_2 from 50 to 2200 psi, allowing for injection-ready pressures at the project site. The CO_2 will then be injected through multiple injection wells into the Muddy Formation at a depth of approximately 4500 feet.

A baseline CO_2-monitoring program is currently under development to establish preinjection CO_2 concentrations at the surface and in the shallow subsurface. Additionally, pressure and fluid saturations will be measured in the reservoir to establish preinjection conditions, so that repeat measurements can be used to better quantify the amount and location of the injected CO_2.

The Bell Creek integrated CO_2 EOR and storage project provides a unique opportunity to develop a set of cost-effective monitoring techniques for large-scale (>1 million tons a year) storage of CO_2 in a mature oil field with EOR. The results of the Bell Creek project will provide insight regarding the impact of large-scale CO_2 injection on sink integrity, monitoring techniques, and regional applicability of implementing successful CO_2 storage projects within the context of EOR.

Introduction

The Plains CO_2 Reduction (PCOR) Partnership, led by the Energy & Environmental Research Center (EERC), is working with Denbury Onshore LLC (Denbury) to determine the effect of the large-scale injection of carbon dioxide (CO_2) into a deep clastic reservoir for the purpose of simultaneous CO_2 enhanced oil recovery (EOR) and CO_2 storage at the Bell Creek oil field, which is owned and operated by Denbury. A technical team that includes Denbury, the EERC, and others will conduct a variety of activities to determine the baseline characteristics and risk assessment of the injection site and surrounding areas and establish long-term monitoring protocols for the injected CO_2.

Denbury will carry out the injection and production as part of a CO_2 EOR operation. The EERC will provide support for the site characterization, modeling and simulation, and risk assessment related to CO_2 storage and will aid in the development of the monitoring, verification, and accounting (MVA) plan to address CO_2 leakage risks or mitigation strategies. The Bell Creek demonstration project will provide a unique opportunity to develop a set of cost-effective MVA protocols for large-scale (>1 million tons a year) combined CO_2 EOR and CO_2 storage operations in a clastic formation. The baseline geological characterization work that will be conducted over the course of this project will also provide valuable data to support the design and implementation of an injection/production scheme for large-scale CO_2 EOR and storage at the Bell Creek oil field.

The field demonstration project conducted in the Bell Creek oil field will evaluate the potential for simultaneous CO_2 EOR and CO_2 storage. The CO_2 will be obtained from the ConocoPhillips Lost Cabin gas-processing plant in Fremont County, Wyoming, which currently generates approximately 50 million cubic feet of CO_2 a day (Figure 1). The CO_2 will be transported to the site and injected into an oil-bearing sandstone reservoir in the Lower Cretaceous Muddy (Newcastle) Formation at a depth of approximately 4500 feet (1372 meters). The activities at Bell Creek will inject an estimated 1.1 million tons of CO_2 annually, much of which will be permanently stored.

The PCOR Partnership is developing a philosophy that integrates site characterization, modeling and simulation, risk assessment, and MVA strategies into an iterative process to produce meaningful results for large-scale CO_2 storage projects (Figure 2). Elements of any of these activities are crucial for understanding or developing the other activities. For example, as new knowledge is gained from site characterization, it reduces a given amount of uncertainty in geologic reservoir properties. This reduced uncertainty can then propagate through modeling, risk assessment, and MVA efforts. Because of this process, the PCOR Partnership Program is in a strong position to refine characterization, modeling, risk assessment, or MVA efforts based on the results of any of these activities.

The EERC's modeling of the subsurface aids in understanding and predicting the behavior of the injected CO_2 and reservoir fluids over the injection and postinjection periods. The modeling is also a highly valuable tool for assessing potential scenarios of fluid migration to the surface or into usable water resources. This type of assessment is an essential input to the risk assessment and MVA plans, and it lays the foundation for a project-specific, risk-based, goal-oriented MVA plan. The goal of the MVA plan is to effectively monitor the behavior of the CO_2 in the subsurface and help ensure that the maximum benefit to the EOR process is achieved in a safe and efficient manner.

Background

Carbon capture and storage (CCS) in geologic media has been identified as an important means for reducing anthropogenic greenhouse gas emissions into the atmosphere (Bradshaw et al. 2006). Several means for geologic storage of CO_2 are available, including depleted oil and gas reservoirs, deep brine-saturated formations, CO_2 flood EOR operations, and enhanced coalbed methane recovery. The U.S. Department of Energy (DOE) is pursuing a vigorous program for demonstration of CCS technology through its Regional Carbon Sequestration Partnership (RCSP) Program, which entered its third phase (Phase III) in October 2007. This phase is planned for a duration of ten U.S. federal fiscal years (October 2007 to September 2017), and its main focus is the characterization and monitoring of large-scale CO_2 injection into geologic formations at CCS sites. Regional characterization activities conducted by the PCOR Partnership indicate that oil reservoirs represent significant opportunities in North America for both long-term storage of CO_2 and incremental oil production through EOR (Peck et al. 2007).

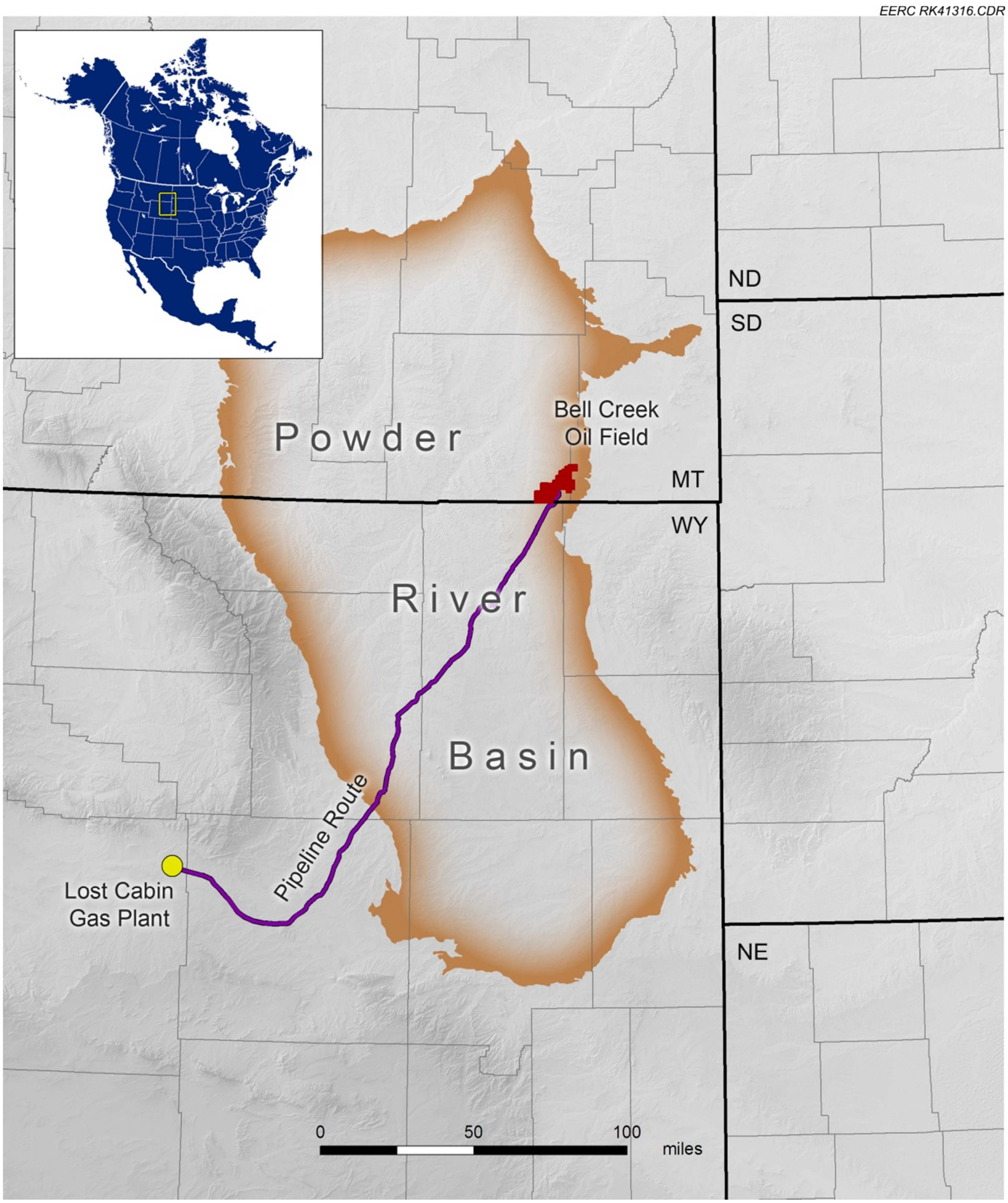

Figure 1. Location of the Lost Cabin gas plant and Bell Creek oil field in Wyoming and Montana.

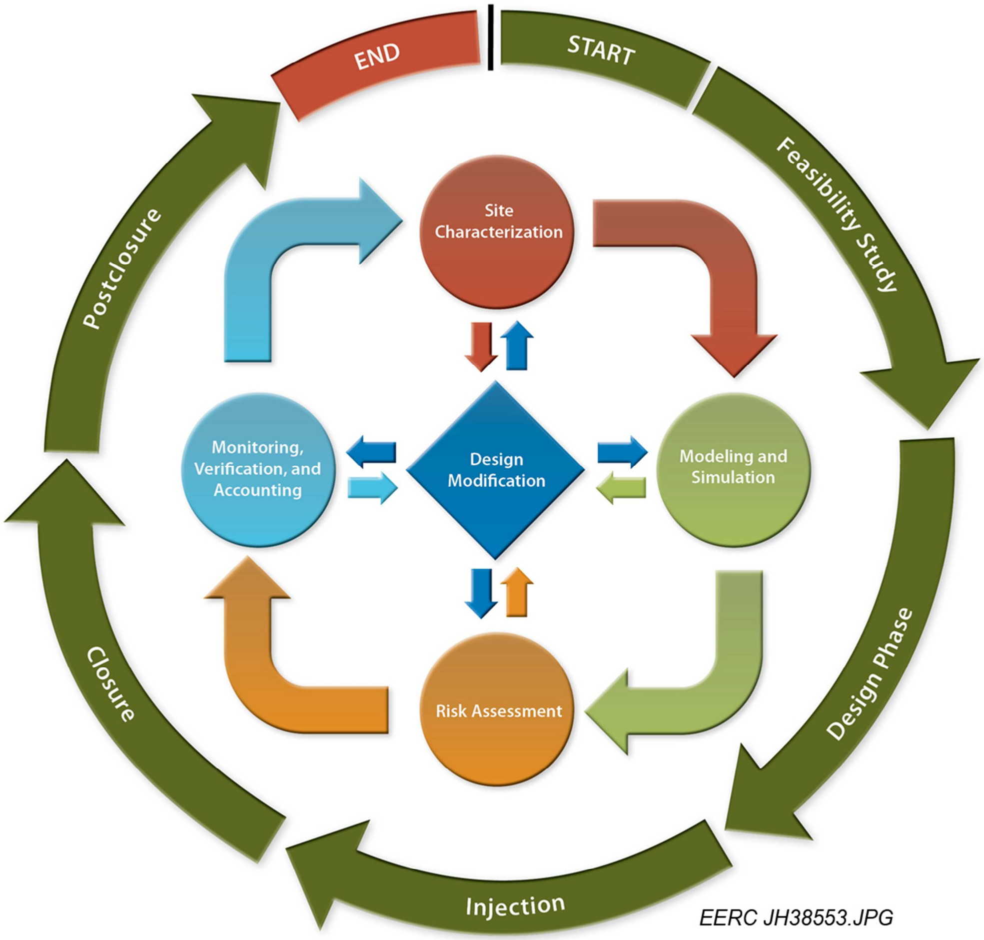

Figure 2. Project elements of the Bell Creek CCS project. Each of these elements feeds into another, iteratively improving results and efficiency of evaluation.

The PCOR Partnership, covering nine U.S. states and four Canadian provinces, is assessing the technical and economic feasibility of capturing and storing CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership's goal is to identify and test CCS opportunities in the central interior of North America. The Partnership comprises numerous private and public sector groups from nine states and four provinces. The Phase III program proposed by the PCOR Partnership includes a demonstration of the efficacy of large-scale CO_2 storage coupled with commercial EOR operations at the Bell Creek oil field. It is anticipated that the results generated at the Bell Creek oil field will provide insight and knowledge that can be directly and readily applied to similar projects throughout the world. The Bell Creek oil field is one of many oil and gas reservoirs in the PCOR Partnership region that has the potential to store significant amounts of CO_2. Initial estimates suggest that approximately 14 million tons of CO_2 may be stored in the Bell Creek oil field as a result of EOR activities. The results of the proposed Phase III testing will be broadly applicable throughout the PCOR Partnership region:

- Ten of the 13 state/provincial jurisdictions in the region have oil fields within their boundaries.
- Regional characterization activities conducted under the PCOR Partnership Program suggest that there are hundreds of oil fields in the region that may be suitable for CO_2-based EOR operations.
- Early results indicate that oil and gas fields in the PCOR Partnership region have a storage capacity of over 3.5 billion tons of CO_2. Many of these fields are suitable for CO_2-based EOR (Peck et al. 2010).
- Oil fields generally offer the best opportunities to implement large-scale CO_2 storage projects in a timely manner because they are generally better characterized than saline formations; are already legally established for the purpose

of safe, large-scale manipulation of subsurface fluids; and offer a means to offset the considerable costs of CO_2 capture and transportation through the sale of incrementally produced oil.

Developing cost-effective approaches to predict and determine the fate of the injected CO_2 is an important aspect of implementing large-scale CCS technology. Baseline characterization, modeling, risk assessment, and MVA activities are critical components of geological CCS projects for three key reasons: 1) the public must be assured that geological storage of CO_2 is a safe operation; 2) to facilitate the establishment and trading of carbon credits, markets need assurance that credits are properly assigned, traded, and accounted for; and 3) state and federal agencies require that certain criteria are met prior to permitting, approval, and closure of a CCS-related project. To accomplish these goals, integrated injection and evaluation programs must be devised. The integrated approach starts with a detailed characterization program that allows for accurate evaluation of a potential storage reservoir. From this characterization program, injection simulations, risk assessments, and MVA programs can be built upon to better evaluate the injection program.

Demonstrating the technical and economic viability of implementing cost-effective, risk-based MVA strategies at a large-scale (>1 million tons of CO_2 a year) commercial CO_2 EOR project such as the Bell Creek project will provide stakeholders with the real-world data necessary to move CCS technology deployment forward. The results generated by the Bell Creek project will provide stakeholders, including policy makers, regulators, industry, financiers, and the public, with the knowledge necessary to make informed decisions regarding the real cost and effectiveness of CCS as a carbon management strategy, especially in the context of a CO_2 EOR operation.

Baseline Geology

The Bell Creek oil field in southeastern Montana (Figure 1) lies near the northeastern edge of the Powder River Basin. Exploration activities for mineral and energy resources in the area over the last 55 years have yielded a significant amount of information about the geology of southeastern Montana. The sedimentary succession in the Bell Creek area consists primarily of sandstones and shales. A stratigraphic column of the portion of the Powder River Basin to which the Bell Creek oil field is in close proximity is provided in Figure 3.

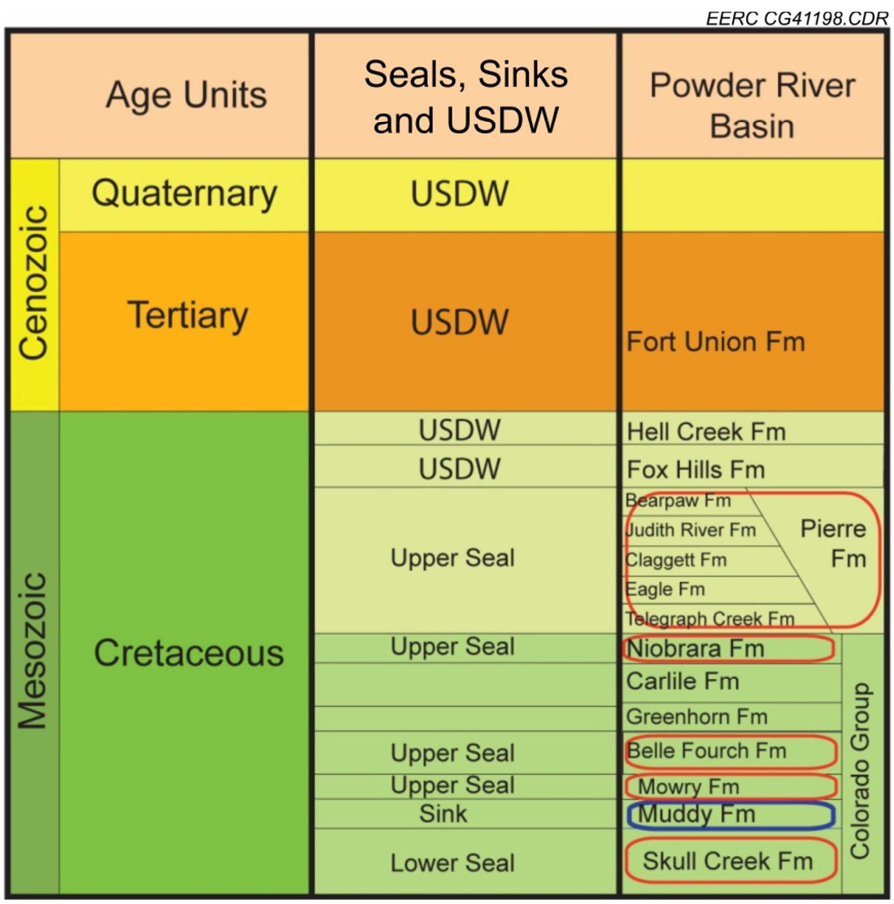

Figure 3. Stratigraphic column of the Powder River Basin, Montana. Sealing formations are circled in red, and the primary sink formation is circled in blue. Formations bearing underground sources of drinking water (USDW) are also identified.

Hydrocarbon production in the Bell Creek area, in the form of crude oil and natural gas, is primarily from stratigraphic traps in the Lower Cretaceous-age Muddy Formation sandstone, sometimes referred to as the Newcastle Formation. While the two terms are used interchangeably and both have been used to describe the reservoir at Bell Creek, this report will refer to the rock unit as the Muddy Formation. The clastic reservoirs within the Muddy Formation will be the target injection zone for the Bell Creek CO_2 EOR and storage project.

In the Bell Creek area, the Muddy Formation is dominated by clean, high-porosity and high-permeability sandstones deposited in a near-shore marine environment that should be ideal for large-scale CO_2 injection. Structurally, the Bell Creek oil field is a monocline with a 1° dip to the northwest and whose axis trends southwest to northeast for a distance of approximately 20 miles. Stratigraphically, the Muddy Formation in the Bell Creek oil field features an updip facies change from sand to shale that serves as a trap. The sand bodies of the reservoir are dissected and, thus, somewhat compartmentalized by intersecting shale-filled channels.

The shale formations of the overlying Upper Cretaceous Mowry Formation will provide the primary seal, preventing fluid migration leakage to overlying USDW and the surface. Overlying the Mowry Formation are thousands of feet of low-permeability shale formations, including the Upper Cretaceous-age Belle Fourche, Greenhorn, Niobrara, and Pierre shales, which will provide additional layers of protection to the surface or USDWs.

No areas of faulting or fracturing have been identified in the Bell Creek study area. However, the intermontane nature of the Powder River Basin, which is known to have areas of significant faulting and fracturing, suggests that such features may exist, and efforts will be made to identify whether or not any of these features are present in the project area.

The Bell Creek oil field is an ideal candidate for a CO_2 tertiary recovery project for a variety of reasons. First, the reservoir has adequate temperature and pressure conditions for maintaining injected CO_2 in a dense-phase state and may support the maintenance of miscibility of CO_2 and oil. Also the high-porosity and high-permeability conditions of the reservoir allow for high CO_2 injection rates and a rapid production response. Finally, the Bell Creek oil reservoir is overlain by multiple units of thick, competent shales that will serve as seals to prevent vertical migration of CO_2.

Site Characterization

The overall purpose of the PCOR Partnership characterization activities at the Bell Creek site is to understand the reservoir and seal to 1) improve oil recovery, 2) predict CO_2 movement with modeling and simulation, 3) identify areas of risk and potential leakage pathways, and 4) develop an effective MVA plan for both CO_2 EOR and CO_2 storage aspects of this project. This will be accomplished by determining the following:

- Baseline geology
- Rock mineralogy and composition of formation water
- Baseline hydrogeology
- Flow characteristics of the reservoir and surrounding strata
- Mechanical rock properties and stress regime
- Nature of geochemical interactions between the formation, injected fluids, reservoir rock, and cap rock
- Nature of wellbore integrity and leakage potential
- Seasonal background CO_2 fluxes in soil and groundwater
- Original and current hydrocarbon volumes and properties

Key characteristics affecting the long-term mobility and fate of the injected CO_2 will be evaluated at three different scales (Figure 4):

- Pool scale (unit of the Bell Creek oil field into which injection will occur)
- Field scale (the entire Bell Creek oil field)
- Regional or subbasin scale (northeastern portion of the Powder River Basin)

Work at the pool scale will focus on a specific development phase within a specific area unit of the Bell Creek oil field. Phase 1 (former Unit D) will be the initial pool targeted for injection. Stratigraphic characterization activities at this scale will only include the reservoir and seals directly overlying and underlying the reservoir.

Work at the field scale will cover the entire Bell Creek oil field. Stratigraphically, the entire sedimentary succession from the basement to the surface will be evaluated locally.

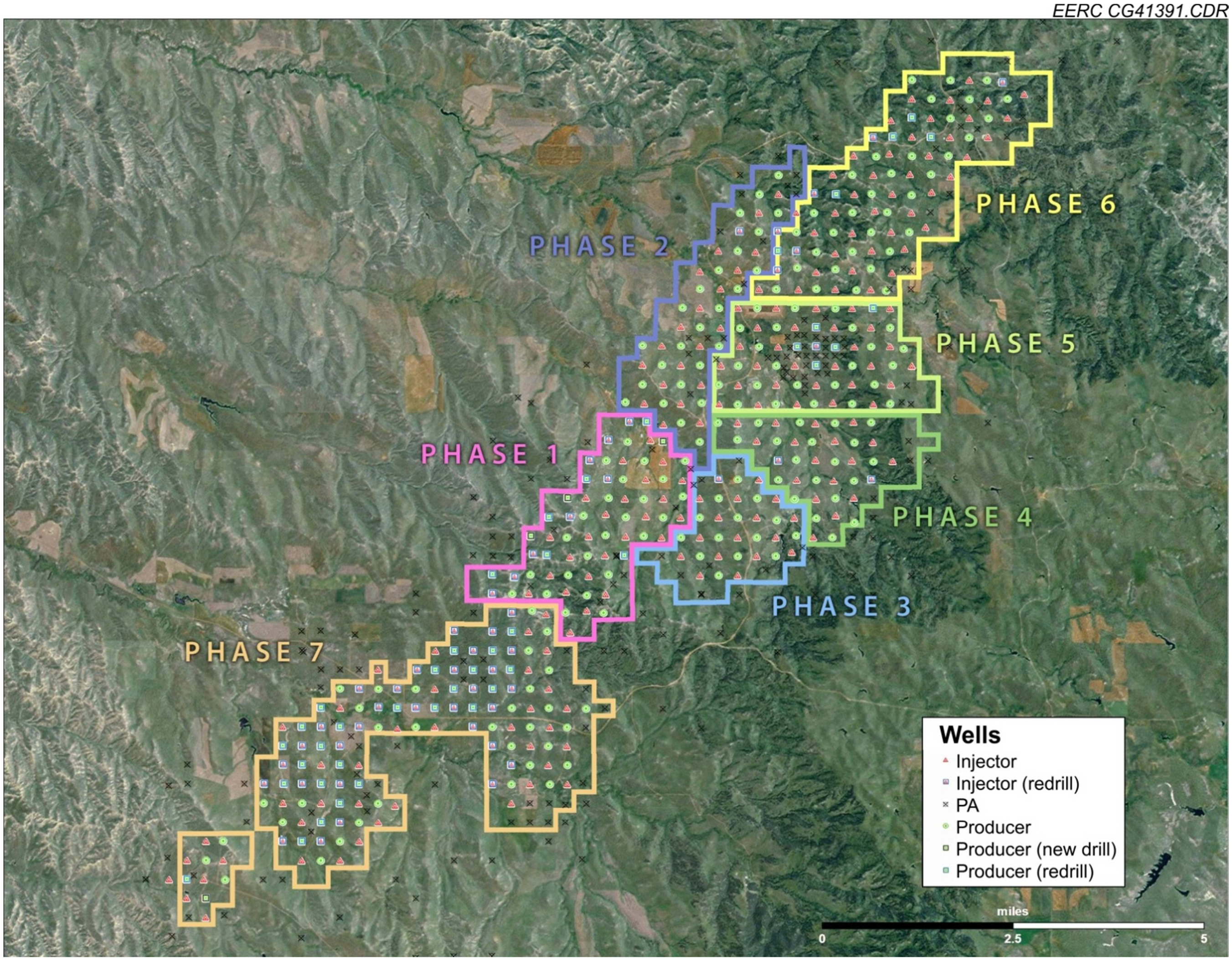

Figure 4. Map of the Bell Creek oil field and associated development phases (PA means plugged and abandoned).

Work at the regional, or subbasin, scale will evaluate relevant data and information on key geologic formations over the northeastern portion of the Powder River Basin. Hydrogeological systems and the regional continuity of key sealing formations will be the focus of studies at this large scale.

Baseline Reservoir and Surface Characterization

A host of information is available from historic and ongoing oil and gas operations within the Bell Creek oil field that will aid in reservoir and field characterization efforts. Supplementary and previously unavailable data will also be acquired through the drilling of a monitoring well within the Phase 1 area of the Bell Creek oil field and baseline surface and near-surface characterization of seasonal background CO_2 flux. Combined, these data (which include well files; well logs; seismic data; drilling reports; pressure and injectivity tests; production and injection; chemical analysis and fluid testing of reservoir fluid, groundwater, and soil gas) will be utilized to meet site characterization goals and to establish a baseline geologic model which can be utilized for the iterative Bell Creek characterization, modeling, and monitoring plan.

Modeling Plan

In order to accurately evaluate potential injection scenarios, fluid migration pathways, EOR recovery and CO_2 storage efficiencies, reservoir injection response, and potential risk, accurate geologic models and injection simulations are required.

At the pool and field scales, a geological model of the strata associated with the Lower and Middle Cretaceous clastic formations will be created to evaluate reservoir properties, geometry, and internal architecture. The overlying/surrounding cap rock will also be evaluated, as well as the underlying saline aquifer systems that may provide reservoir support. Information about the geology of the injection zone and confining strata (e.g., structural setting, stratigraphy, general lithology, thickness, and areal extent) will be collected, processed, and interpreted for the field-scale area.

At the regional scale, the geology, stratigraphy, and lithology will be evaluated, delineated, and described for the entire sedimentary succession from the base of the Lower Cretaceous (lower confining unit) to the surface (Upper Cretaceous/Lower Paleocene Montana group and Quaternary drift) for the northeastern Powder River Basin. In addition, the structural elements in the area, from the basement to the surface, will be investigated to identify any faults and/or fractures that may potentially allow migration of reservoir and injected fluids.

Risk Assessment

Risk assessment plays an integral role in site characterization and monitoring activities at the Bell Creek demonstration project. By identifying key project risks and performing additional characterization, the monitoring program can be focused on areas with the greatest uncertainty or highest risk potential. Primary risks include wellbore leakage, out-of-zone fluid migrations, and early breakthrough or CO_2 channeling during the injection project. Initial steps to address these identified risks have been incorporated into the monitoring plan.

With over 450 wellbore penetrations into the storage reservoir within the Bell Creek oil field, direct leakage of CO_2 from the reservoir to the surface is a potential concern. Periodic collection and analysis of soil gas, surface water, and groundwater samples, along with continuous pressure monitoring at active injection and production wells, will allow for the early identification of injectivity or wellbore integrity issues. These anomalies can then be targeted by remediation activities, if necessary.

Out-of-zone fluid migration is of concern both from a storage and an EOR standpoint. CO_2 migration out of the intended injection zone, either vertically into overlying strata or horizontally out of the project area, will impact both project economics and site security. CO_2 that migrates outside of the injection zone (either vertically or horizontally) is not actively contributing to the EOR process. Furthermore, it may be difficult to determine the ultimate fate of CO_2 should it migrate into overlying strata. In either case, resources would not be effectively allocated, resulting in the monitoring of areas not impacted by the injection process. Prior to injection, simulation activity will help to identify areas that may be susceptible to out-of-zone migration, allowing for modification of the injection design or the deployment of additional monitoring technologies. In the field, out-of-zone migration, should it occur, will be identified through a variety of monitoring activities such as repeat borehole and surface seismic surveys, pressure and temperature monitoring, and well logs.

Another concern is early breakthrough or CO_2 channeling to the production well, which could reduce both the effectiveness of the EOR project and the storage efficiency of the reservoir. Several monitoring activities are planned to help identify any early breakthrough issues, including borehole seismic surveys, time-lapse well logs, and the drilling of a monitoring well directly between an injection and production well. In case an early breakthrough event occurs, data acquired through the monitoring program could allow for modification of the injection scheme over the entire field to mitigate a reoccurrence.

Data acquired from site characterization and monitoring activities will be utilized to update modeling and simulation work, thereby reducing uncertainty in the overall injection scheme. In turn, the risk assessment will be modified with the revised simulation data as part of an ongoing iterative programmatic design modification process. Periodically updating each of the four components of the design process allows for ever-decreasing uncertainty regarding the ultimate fate of injected CO_2 and reduction of potential project risks.

MVA Plan

Monitoring of the surface, near-surface, and deep subsurface environment is an essential component of any carbon storage project. The objective of such a program by the PCOR Partnership is to provide critical data that can be used to verify site security, assess variances to the injection program, and determine the fate of injected CO_2.

The purpose of surface and near-surface monitoring is twofold: 1) to establish preinjection conditions for naturally occurring CO_2 levels and flux present in surface water, soil, and shallow groundwater aquifers in the vicinity of the Bell Creek oil field and 2) to provide a source of data to show that surface environments remain unaffected or to quantify the impact of an unexpected fluid migration event. Providing an explanation of the occurrence and distribution of CO_2 levels currently in these environments or identifying other constituents related to hydrocarbon exploration and production is not the objective of this monitoring program.

The primary purpose of deep subsurface monitoring is to track the movement of CO_2 in the subsurface in order to evaluate the recovery efficiency of the CO_2 EOR program and to predict the ultimate fate of CO_2 within the storage reservoir. Additional benefits of the deep subsurface monitoring program include 1) early detection of wellbore leakage or identification of potential leakage pathways which may require remediation; 2) identification of potential injectivity issues; and 3) the ability to monitor and account for injected CO_2.

Surface and Near-Surface Monitoring. The surface and near-surface monitoring plan presented here comprises three parts: sampling of soil gas concentrations in the vadose zone, sampling of surface water features, and sampling of shallow groundwater aquifers. Sampling these three zones will provide a preinjection baseline concentration of CO_2 , which can later be used to help determine if a CO_2 concentration found in any of these mediums postinjection is due to natural occurrence (is within preinjection baseline) or may be the result of CO_2 leakage. Chemical analyses performed during monitoring efforts may also aid in determining the source of CO_2 found in these shallow or surface environments.

Soil gas sampling consists of extracting representative samples of the gases present within the soil, which often includes naturally occurring CO_2. Seasonal variations can dramatically impact the concentration of CO_2 in the vadose zone. Seasonal gas flux in near-surface soils is typically caused by plant respiration and decomposition and as part of the soil weathering process. The ratio of the stable carbon isotopes that make up the CO_2 may also vary with the seasons; thus sampling and analysis will be repeated several times a year before injection to capture these variations.

Water sampling will be carried out to measure the levels of CO_2 and other dissolved constituents naturally present in surface and subsurface environments. Publically available data, including data from the Montana Groundwater Information Center (GWIC) and the U.S. Environmental Protection Agency (EPA) STORET (STOrage and RETrieval system) sites will be reviewed to select a subset of wells and surface water locations that will best establish preinjection baseline conditions. Shallow groundwater sampling is proposed to be carried out via a network of existing public and private groundwater wells. Samples collected from these wells will be analyzed for the composition of the dissolved constituents, including CO_2 content, and for the isotopic signature of the dissolved CO_2. Surface water samples will be collected from ponds, streams, and rivers present on the site and will undergo similar analysis to the groundwater samples.

The MVA program will focus on the Phase I area; however, soil gas and groundwater samples will also be collected at select locations throughout the remainder of the Bell Creek oil field in order to provide fieldwide coverage, albeit at a lesser frequency and intensity than in the Phase I area. These sample locations will be determined through a detailed well review and will be identified in the MVA work plan. Soil gas, groundwater, and surface water samples will be collected quarterly, to cover seasonal variation, beginning in the fall of 2011. Injection is scheduled to begin in February 2013; this allows for six quarterly preinjection sample events. Once injection begins, groundwater and surface water will be sampled annually (during summer months to take advantage of optimal site access), and soil gas will be sampled as needed.

Deep Subsurface Monitoring. The deep subsurface monitoring plan will utilize a combination of wellbore technologies, such as pulsed neutron tools, pressure and temperature sensors, chemical analysis, and combined crosswell and/or 3-D vertical seismic profile (VSP) surveys to accurately track CO_2 movement and chemical interactions within the subsurface during the injection process. Production well fluid sampling and a surface-based 3-D seismic survey over the Bell Creek oil field Phase I area, plus an appropriate buffer, may also be deployed in order to enhance the reservoir characterization and monitoring programs pending further study.

Data acquired during the monitoring activities will be used to update modeling and simulation work on an iterative basis in order to identify and eliminate variances between the real-world physics of injection and predicted behavior of the CO_2, reservoir fluids, and rock matrix. This iterative update process will aid in the identification of fingering or premature CO_2 breakthrough (should it occur) during EOR activities, an accurate assessment of long-term site security, and the ability to predict CO_2 movement and chemical interactions within the reservoir after site closure.

Collection of accurate baseline measurements of fluid saturations, seismic velocities and amplitudes, current reservoir fluid compositions, temperatures, and pressures are necessary prior to injection. The baseline data will be utilized for later comparison of preinjection conditions with time-lapse data which will be acquired periodically once injection begins. Much of this baseline data will be acquired during the monitoring well characterization phase or during existing well reentry activities.

Monitoring Well(s). In order to facilitate the characterization and deep subsurface monitoring programs, a single monitoring well will be drilled in the fourth quarter of 2011 (Figure 5). Figure 5 shows the location for the monitoring well and associated completions. During the drilling, completion, and postcompletion process, modern data will be acquired in the form of wireline logs, in situ pressure and temperature surveys, and crosswell and/or VSP seismic surveys. Cement bond logs and casing integrity pressure tests will also be conducted in order to confirm zonal isolation between the storage reservoir and other porous formations. In addition to data acquisition, core will be retrieved for further testing and analysis. Once combined, this information will be utilized to better understand the target reservoir prior to the start of injection through calibration of historic well log data and enhancement of the modeling and numerical simulation work.

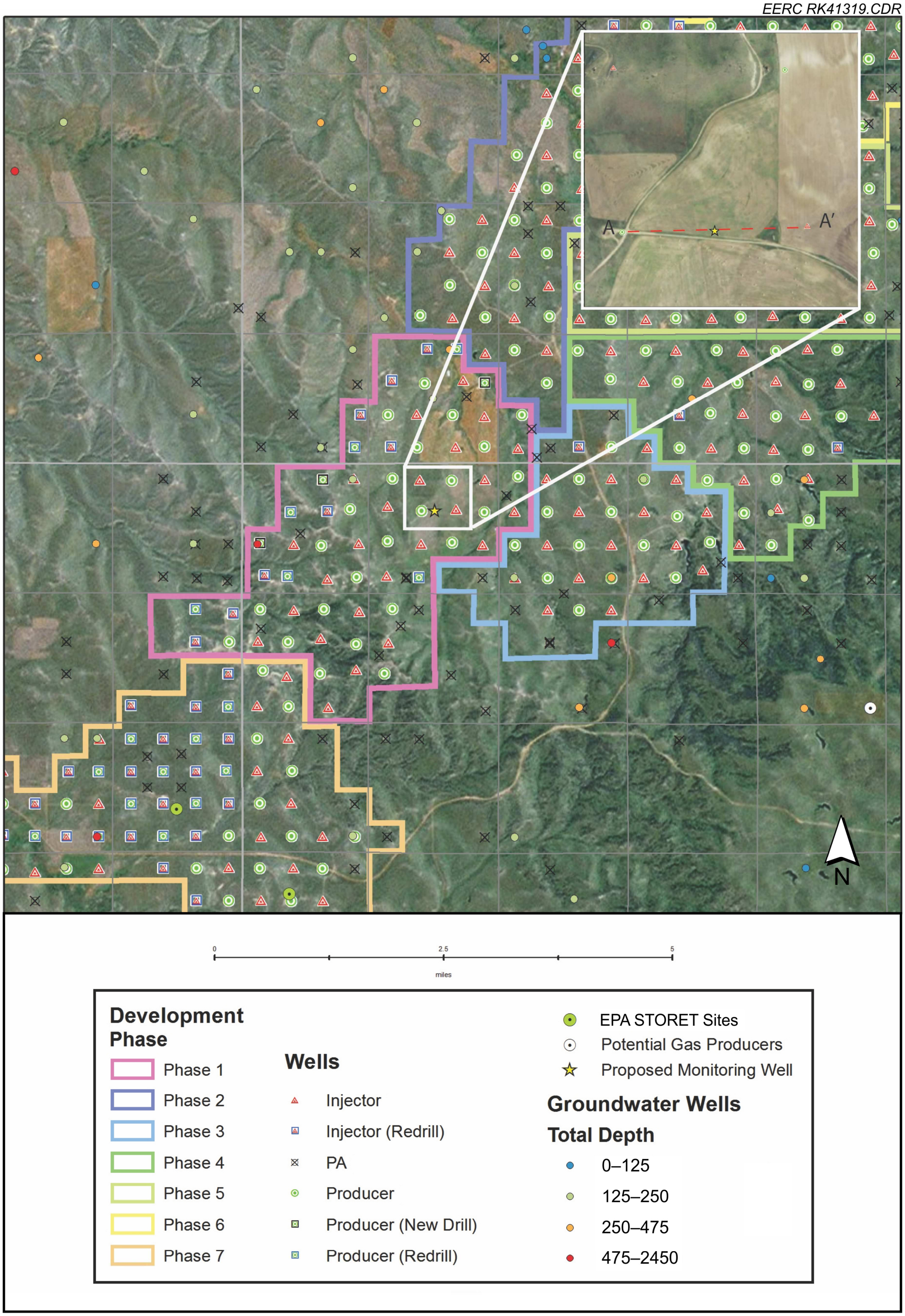

Figure 5. Map of the Bell Creek oil field Phase I area, including the location of the proposed monitoring well and other key wells.

In addition to the new monitoring well, one or more existing wells located outside of the Phase 1 area may be reentered to allow for additional baseline characterization work and monitoring activities that cannot be conducted in the new monitoring well because of technical risk during the drilling operation and interference with seismic monitoring activities. These activities may include step-rate tests, which will allow for characterization of fracture initiation, propagation, and closure pressures. Pressure sensors deployed in these perforated wellbores will also aid in the identification of compartmentalization between the field development phases if present.

Proposed Path Forward

An iterative update process between site characterization, modeling, simulation, risk assessment, and MVA activities is necessary to maximize the utility of the knowledge gained during the Bell Creek combined CO_2 EOR and storage project. This iterative process also ensures that project economics are optimized through targeting areas of key importance and that data are collected at optimal points in the injection time line or at optimal geographic locations. Currently, a first-round evaluation has been performed and is being used to identify additional characterization activities that are beneficial to the project and to update simulation work to help guide the selection of a site-specific injection strategy. Upon completion, specific injection scenarios can be evaluated in terms of criteria set forth by Denbury.

Once a final injection strategy has been defined, simulation results will be updated, which will, in turn, be used to guide specific MVA strategies. The updated MVA plan will include specific technologies, spatial locations of measurements, acquisition frequencies, and baseline data necessary to address critical project risk and regulatory requirements and to identify potential deviations from predicted conditions in a timely manner. Periodic updates will be necessary throughout the injection phase of the project in order to confirm system behavior and agreement between the physical injection and simulation results.

The iterative site characterization, modeling and simulation, risk assessments, and MVA program during the preinjection and injection phases of the project will ease transition and carry into the closure and postclosure phases of the project. The iterative process will allow postclosure activities to be selected that maximize data value while minimizing project resources.

Summary

The Bell Creek demonstration project provides a unique opportunity to evaluate a large-scale (>1 million tons a year) combined CO_2 EOR and CO_2 storage project in a clastic reservoir in southeastern Montana. Denbury, which owns and operates the Bell Creek oil field, will carry out all of the injection and production operations, and the EERC will provide support for the site characterization, reservoir modeling and simulation, assessment of the subsurface technical risks, and will aid in the development of the MVA plan to address site risks. To accomplish this task, the EERC will utilize an integrated and iterative approach to site characterization, modeling and simulation, risk assessment, and MVA that will allow the program to be adaptive in nature, thereby maximizing utility of the overall program.

Existing oil and gas operational and geologic data will be utilized to construct a base geologic model of the Bell Creek oil field, including structure and reservoir properties. From this base geologic model, the simulation, risk assessment, and monitoring programs will be initiated. Newly acquired data will be integrated into all facets of the project on an ongoing basis as they become available in order to better understand and evaluate oil recovery and CO_2 storage efficiencies, predict CO_2 movement with modeling and simulations, identify areas of subsurface risks and potential leakage pathways, and develop an effective and economic MVA plan for an integrated CO_2 EOR and CO_2 storage project.

The MVA plan, which will be guided by the characterization, simulation, and risk assessment activities, will consist of both near-surface and deep subsurface aspects. The near-surface monitoring goals are to establish preinjection baseline conditions and to provide a source of data to show that surface environments remain unaffected or to quantify the impact of a leakage event. The deep subsurface monitoring program is designed to track the movement of the CO_2 in the subsurface, to evaluate the recovery and storage efficiency of the injection process as well as allow the ability to check simulation results, and to identify potential injectivity issues or remediation targets. Data acquired during monitoring activities will in turn provide updates for the characterization and modeling activities.

Acknowledgments

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DOE Disclaimer

EERC Disclaimer

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