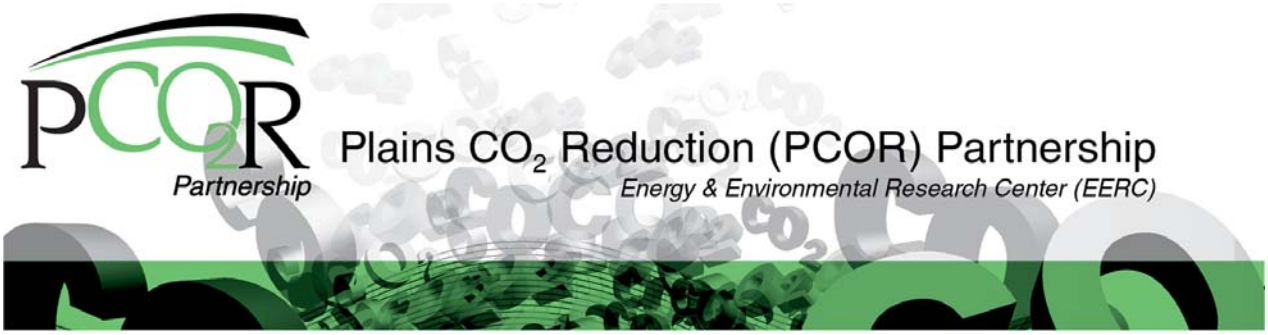

ANNUAL ASSESSMENT REPORT

Plains CO_2 Reduction (PCOR) Partnership Phase III
Task 12 – Deliverable D57

(for the period October 1, 2013, through September 30, 2014)

Prepared for:

Andrea M. Dunn

National Energy Technology Laboratory
U.S. Department of Energy
626 Cochrans Mill Road
PO Box 10940
Pittsburgh, PA 15236-0940

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Prepared by:

Charles D. Gorecki
John A. Harju
Edward N. Steadman
Lucia Romuld
John A. Hamling
James A. Sorensen
Lisa S. Botnen
Daniel J. Daly
Melanie D. Jensen
Wesley D. Peck
Steven A. Smith
Ryan J. Klapperich
Katherine K. Anagnost
Tami J. Votava

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

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Approved

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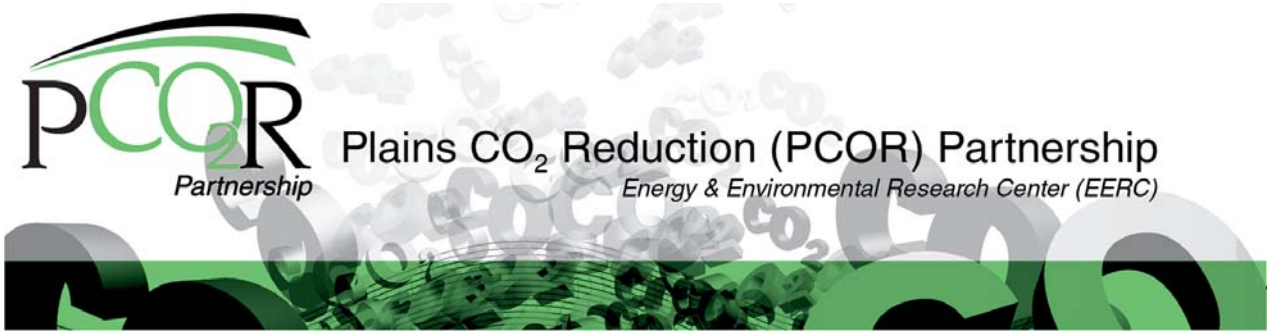


ANNUAL ASSESSMENT REPORT

EXECUTIVE SUMMARY

The Plains CO_2 Reduction (PCOR) Partnership is one of seven Regional Carbon Sequestration Partnerships (RCSPs) competitively awarded by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) in 2003 as part of a national plan to mitigate greenhouse gas emissions. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota in Grand Forks, North Dakota, and includes over 90 stakeholders from the public and private sector in Phase III. The PCOR Partnership region includes all or part of nine U.S. states and four Canadian provinces.

Phase III, the 10-year (2007–2017) development phase, is an extension of the characterization (Phase I) and validation (Phase II) phases and is intended to confirm that commercial-scale carbon dioxide (CO_2) capture, transportation, injection, and storage can be achieved safely, permanently, and economically over extended periods in the PCOR Partnership region.

The Phase III efforts of the PCOR Partnership include two large-volume, commercial CO_2 injection projects. One involves support of a saline formation injection project, while the other is looking at the feasibility of developing a CO_2 storage program incidental to a commercial enhanced oil recovery (EOR) operation. Other activities in Phase III include the following: 1) continue to gather regional characterization data to verify the ability of target formations to store CO_2, 2) facilitate the development of infrastructure to transport CO_2 from sources to injection sites, 3) facilitate sensible development of the rapidly evolving North American regulatory and permitting framework, 4) develop opportunities for PCOR Partnership partners to capture and store CO_2, 5) facilitate establishment of a technical framework by which carbon credits can be monetized for CO_2 stored in geologic formations, 6) continue collaboration with other RCSPs, and 7) provide outreach and education for CO_2 capture and storage stakeholders and the general public. The EERC is providing monitoring, verification, and accounting (MVA) and risk management support for Spectra Energy's Fort Nelson Carbon Capture and Storage (CCS) Feasibility Project. The project will involve the injection of CO_2 captured from one of the largest gas-processing plants in North America into a saline formation in northeastern British Columbia. While significant progress has been made with respect to project planning, MVA, and risk analysis, the Fort Nelson CCS Feasibility Project is currently lacking a commercial driver to move it forward. The Bell Creek demonstration involves investigating the efficacy of various MVA strategies as a means of developing a CO_2 storage project in conjunction with a commercial EOR operation. The Bell Creek project is operated by Denbury and injects CO_2 into the Muddy sandstone in the Powder River Basin in southeastern Montana.

Significant progress was made in Program Year (PY) 7 (October 1, 2013 – September 30, 2014) on the Bell Creek demonstration project. **CO_2 injection continued, and in July 2014, over 1,000,000 cumulative metric tons was injected!** Efforts were focused on completing the first 3-D vertical seismic profile repeat survey, the first full-repeat pulsed-neutron logging campaign, and a third-round risk assessment, as well as continued collection of groundwater-and soil-gas sampling data. Petrophysical and geochemical analyses were performed on various core samples.

There were no field activities performed for the Fort Nelson demonstration project; however, a comprehensive summary of all PCOR Partnership-related activities to date was included in a best practices manual on the carbon capture and storage feasibility study.

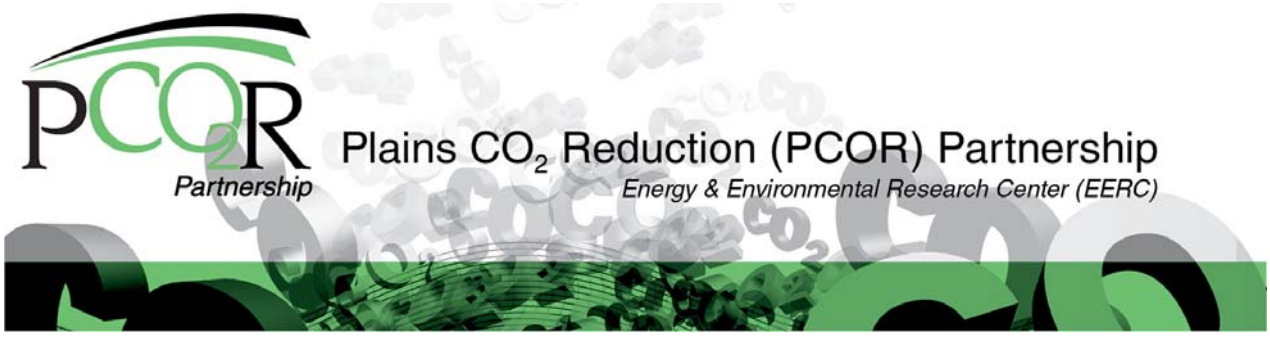
The PCOR Partnership submitted 31 abstracts, prepared nine conference papers, gave 87 presentations, completed 18 deliverable reports, achieved 17 milestones, and prepared six value-added products and 12 progress reports. The annual membership meeting was held in Denver, Colorado, and attracted 86 attendees representing 52 organizations.

Of significant note, DOE NETL required a third independent peer review of the RCSP Initiative in 2013. The expert panel was chaired by the IEA Greenhouse Gas R&D Programme. Overall findings of the panel were that all of the projects reviewed provided, and continue to generate, significant developments in CO_2 storage, and from an international perspective, there was unanimous agreement that the RCSP Initiative is a world-leading initiative that is generating valuable results and experience (IEAGHG, "2013 Peer Review of U.S. RCSP Phase III Projects," 2014--## April 2014). With respect to the PCOR Partnership review, the panel acknowledged that this project demonstrates a thoroughly comprehensive and integrated technical program and that the proactive public outreach component of the project is also notable.

Overall, 13 tasks continued to effectively support program goals in PY7. In addition to the foregoing, regional characterization continued, and over 900 CO_2 sources, producing over 600 million short tons annually, were verified within the region. Outreach activities included distribution of print materials, oral and poster presentations, Web site updates, and documentary broadcasts. Since program inception, over 5200 PCOR Partnership atlases have been distributed, along with over 9600 documentary DVDs. The Sixth Annual Regulatory Roundup was held in summer 2014, and the PCOR Partnership led a task force with the Interstate Oil and Gas Compact Commission which provided recommendations and guidance on operational and postoperational liability issues. The RCSP Water Working Group was active, holding its sixth annual meeting in August 2014 and producing two new fact sheets. In addition, numerous activities in relation to the Petroleum Technology Research Centre Aquistore project (near Estevan, Saskatchewan) were performed, including updating the geologic model and running predictive simulations and analyzing core collected to develop an understanding of mineralogical composition and the petrophysical properties of the rocks below the site.

CO_2 injection at Bell Creek will continue in PY8. Operational monitoring and modeling activities will also continue to be performed to verify that injection operations do not adversely impact human health or the environment and that the CO_2 injected has been safely stored, with minimal risk of natural release. In PY8, ten tasks will continue to be implemented (Tasks 5, 7, 15, and 16 are or will be completed).

This report presents an update of Phase III PCOR Partnership activities from October 1, 2013, through September 30, 2014 (PY7) and planned activities for the following year.



ANNUAL ASSESSMENT REPORT

INTRODUCTION

The Plains CO_2 Reduction (PCOR) Partnership is one of seven regional partnerships operating under the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnership (RCSP) Program. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota (UND) in Grand Forks, North Dakota, and includes over 90 stakeholders from the public and private sector in Phase III. The Phase III membership as of September 30, 2014, is listed in Table 1. The PCOR Partnership region includes all or part of nine states (Iowa, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, Wisconsin, and Wyoming) and four Canadian provinces (Alberta, British Columbia, Manitoba, and Saskatchewan).

The PCOR Partnership falls within the infrastructure element of NETL's Carbon Storage Program and is a government–industry effort tasked with determining the most suitable technologies, regulations, and infrastructure needs for carbon capture, utilization, and storage (CCUS) on the North American continent.

The PCOR Partnership Program is implemented in three phases:

- Phase I – Characterization Phase (2003–2005): characterized opportunities for carbon sequestration.
- Phase II – Validation Phase (2005–2009): conducted small-scale field validation tests.
- Phase III – Development Phase (2007–2017): conducting large-volume carbon storage demonstration tests.

The PCOR Partnership's efforts are in support of NETL's Carbon Storage Program by helping to develop technologies to store carbon dioxide (CO_2) in order to reduce greenhouse gas (GHG) emissions without adversely influencing energy use or hindering economic growth.

The PCOR Partnership's efforts will help enable technologies to overcome a multitude of economic, social, and technical challenges, including cost-effective CO_2 capture through successful integration with fossil fuel conversion systems, effective CO_2 monitoring and verification, permanence of underground CO_2 storage, and public acceptance.

Table 1. PCOR Partnership Membership Phase III (October 1, 2007 – present, inclusive)

DOE NETL	Great River Energy	North Dakota Natural Resources Trust
UND EERC	Halliburton	North Dakota Petroleum Council
Abengoa Bioenergy New Technologies	Hess Corporation	North Dakota Pipeline Authority
Air Products and Chemicals, Inc.	Huntsman Corporation	Otter Tail Power Company
Alberta Department of Energy	Husky Energy Inc.	Outsource Petrophysics, Inc.
Alberta Department of Environment	Indian Land Tenure Foundation	Oxand Risk & Project Management Solutions
Alberta Innovates – Technology Futures	Interstate Oil and Gas Compact Commission	Peabody Energy
ALLETE	Iowa Department of Natural Resources	Petroleum Technology Research Centre
Ameren Corporation	Lignite Energy Council	Petroleum Technology Transfer Council
American Coalition for Clean Coal Electricity	Manitoba Geological Survey	Pinnacle, a Halliburton Service
American Lignite Energy	Marathon Oil Company	Prairie Public Broadcasting
Apache Canada Ltd.	MBI Energy Services	Pratt & Whitney Rocketdyne, Inc.
Aquistore	MEG Energy Corporation	Praxair, Inc.
Baker Hughes Incorporated	Melzer Consulting	Ramgen Power Systems, Inc.
Basin Electric Power Cooperative	Minnesota Power	RPS Energy Canada Ltd.
BillyJack Consulting Inc.	Minnkota Power Cooperative, Inc.	Saskatchewan Ministry of Industry and Resources
Biorecro AB	Missouri Department of Natural Resources	SaskPower
Blue Source, LLC	Missouri River Energy Services	Schlumberger
BNI Coal, Ltd.	Montana–Dakota Utilities Co.	Sejong University
British Columbia Ministry of Energy, Mines, and Petroleum Resources	Montana Department of Environmental Quality	Shell Canada Limited
British Columbia Oil and Gas Commission	National Commission on Energy Policy	Spectra Energy
C12 Energy, Inc.	Natural Resources Canada	Suncor Energy Inc.
Computer Modelling Group Ltd.	Nebraska Public Power District	TAQA North, Ltd.
Continental Resources, Inc.	North American Coal Corporation	TGS Geological Products and Services
Dakota Gasification Company	North Dakota Department of Commerce Division of Community Services	University of Alberta
Denbury Onshore LLC	North Dakota Department of Health	University of Regina
Eagle Operating, Inc.	North Dakota Geological Survey	WBI Energy, Inc.
Eastern Iowa Community College District	North Dakota Industrial Commission Department of Mineral Resources, Oil and Gas Division	Weatherford Advanced Geotechnology
Enbridge Inc.	North Dakota Industrial Commission Lignite Research, Development and Marketing Program	Western Governors' Association
Encore Acquisition Company	North Dakota Industrial Commission Oil and Gas Research Council	Westmoreland Coal Company
Energy Resources Conservation Board/ Alberta Geological Survey		Wisconsin Department of Agriculture, Trade and Consumer Protection
Environment Canada		Wyoming Office of State Lands and Investments
Excelsior Energy Inc.		Xcel Energy
Great Northern Project Development, LP		

The PCOR Partnership was established in the fall of 2003. Phase I was focused on characterizing sequestration opportunities in the region. In the fall of 2005, the PCOR Partnership launched its 4-year Phase II program focused on carbon storage field validation projects. These Phase II projects were designed to build core local technical expertise and experience needed to facilitate future large-scale CO_2 storage efforts in the region's subsurface and terrestrial settings. In the fall of 2007, the PCOR Partnership initiated its 10-year Phase III program focused on implementing two commercial-scale geologic carbon storage demonstration projects in the region.

Phase III is divided into three budget periods (BPs), running from October 1, 2007, to September 30, 2017:

BP3: October 1, 2007 – September 30, 2009
BP4: October 1, 2009 – September 30, 2015

BP5: October 1, 2015 – September 30, 2017
BP1 and BP2 were effective in Phase II.

The overall mission of the Phase III program is to 1) gather characterization data to verify the ability of the target formations to store CO_2, 2) facilitate the development of the infrastructure required to transport CO_2 from sources to the injection sites, 3) facilitate development of the rapidly evolving North American regulatory and permitting framework, 4) develop opportunities for PCOR Partnership partners to capture and store CO_2, 5) establish a technical framework by which carbon credits can be monetized for CO_2 stored in geologic formations, 6) continue collaboration with other RCSPs, and 7) provide outreach and education for CO_2 capture and storage stakeholders and the general public.

In Phase III, the PCOR Partnership is building on the information generated in its characterization (Phase I) and validation (Phase II) phases. The PCOR Partnership plans to fully utilize the infrastructure of its region to maximize CO_2 injection volumes. A programmatic development phase (Phase III) goal is implementation of large-scale field testing involving at approximately 1 million metric tons of CO_2 per project. Each of the RCSP's large-volume injection tests is designed to demonstrate that the CO_2 storage sites have the potential to store regional CO_2 emissions safely, permanently, and economically for hundreds of years.

The PCOR Partnership has established two large-scale demonstration projects. The sites are located 1) in Denbury Resources Inc.'s (Denbury's) Bell Creek oil field in Powder River County, southeastern Montana, and 2) near Spectra Energy's (Spectra's) Fort Nelson gas-processing facility, situated near Fort Nelson, British Columbia, Canada (Figure 1).

In Program Year (PY) 7, CO_2 injection continued at the Bell Creek test site, and over 1 million metric tons was injected. Efforts were focused on completing the first 3-D vertical seismic profile (VSP) repeat survey, the first full-repeat pulsed-neutron logging (PNL) campaign, and a third-round risk assessement, as well as continued collection of groundwater- and soil gas-sampling data. The first annual operational (injection-phase) sampling event was completed throughout the Bell Creek Field in November 2013, and September 2014 marked collection of the complete data set for the annual full-repeat near-surface operational monitoring survey. Petrophysical and geochemical analyses were performed on various core samples, and 81 core samples of the Muddy and Mowry Formations from 21 wells were selected from the U.S. Geological Survey (USGS) Core Research Center (CRC) in Denver, Colorado, and analyzed by the EERC's Applied Geology Laboratory (AGL).

In collaboration with Spectra, the PCOR Partnership is supporting the evaluation of the feasibility of a large-scale, integrated carbon capture and storage (CCS) project near Spectra's existing Fort Nelson natural gas-processing facility in northeast British Columbia, Canada. The Fort Nelson facility is one of the largest sour gas-processing plants in North America. The PCOR Partnership's monitoring, verification, and accounting (MVA) efforts will help Spectra determine whether deep underground saline reservoirs and associated infrastructure in the Fort Nelson area are appropriate for CCS. Although the Fort Nelson demonstration project was placed on hold until Spectra can establish a business case for the project, the PCOR Partnership has prepared a comprehensive summary of its characterization, modeling and simulation, and risk

Figure 1. Location of large-scale sites with PCOR Partnership Phase III participation.

assessment activities into a best practices manual (BPM), and the information acquired and analyzed suggests that the Fort Nelson area has sink and seal conditions that make it an exceptional candidate location for large-scale CCS.

The PCOR Partnership's objectives for the demonstration projects are as follows: 1) conduct a successful Bell Creek demonstration to verify that the region's large number of oil fields have the potential to store significant quantities of CO_2 in a safe, economical, and environmentally responsible manner and 2) support Spectra's feasibility study of a Fort Nelson demonstration to verify the economic feasibility of using the region's carbonate saline formations for safe, long-term CO_2 storage. During Phase III, the PCOR Partnership will continue to refine storage resource estimates and evaluate other factors relevant to regional storage goals.

APPROACH

The PCOR Partnership is identifying practical CO_2 storage options for the PCOR Partnership region, characterizing the technical issues, enhancing the public's understanding of

CO_2 storage, identifying the most promising opportunities for storage in the region, and detailing an action plan for the demonstration of regional CO_2 storage opportunities.

The PCOR Partnership is achieving its Phase III mission through a series of 16 tasks, as shown in Figure 2. These tasks include 1) Regional Characterization; 2) Public Outreach and Education; 3) Permitting and National Environmental Policy Act (NEPA) Compliance; 4) Site Characterization and Modeling; 5) Well Drilling and Completion; 6) Infrastructure Development; 7) CO_2 Procurement; 8) Transportation and Injection Operations; 9) Operational Monitoring and Modeling; 10) Site Closure; 11) Postinjection Monitoring and Modeling; 12) Project Assessment; 13) Project Management; 14) RCSP Water Working Group (WWG) Coordination; 15) Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project; and 16) Characterization of the Basal Cambrian System. Table 2 contains the responsibility matrix for these 16 tasks.

The EERC entered into a cooperative agreement with DOE NETL for Phase III activities in late September 2007. Phase III is a 10-year project, in three BPs, running from October 1, 2007, to September 30, 2017. This Annual Assessment Report summarizes the activities for PY7 (October 1, 2013 – September 30, 2014) of Phase III.

ASSESSMENT SUMMARY

In BP3, the focus of the program was to select two distinct and regionally significant geologic formations for large-volume (approximately 1 Mt of CO_2 a project) commercial tests designed to demonstrate that CO_2 storage sites have the potential to store regional CO_2 emissions safely, permanently, and economically for hundreds of years. The Fort Nelson test site was selected in December 2007 and involves MVA and risk management support for the injection of up to 2 million metric tons/year CO_2 captured from one of the largest gas-processing plants in North America into a Devonian-aged carbonate formation in British Columbia, Canada. The Bell Creek test site was selected in September 2009 and involves injection of CO_2 into a Cretaceous-aged sandstone formation in the Powder River Basin (PRB) in southeastern Montana for the dual purpose of CO_2 storage and enhanced oil recovery (EOR).

Strong project management is crucial to the success of any project. The PCOR Partnership project management team focuses on providing timely completion of milestones, quality deliverables, and accurate and timely project reports as directed in the Federal Assistance Reporting Checklist and effective communication between the PCOR Partnership and DOE NETL management. All required deliverables, milestones, and project reports were completed on schedule during PY7. These included 18 required reports, achievement of mandatory milestones, and four quarterly progress reports.

In August and September 2013, respectively, the PCOR Partnership participated in the RCSP annual project review meetings in Pittsburgh, Pennsylvania, and hosted the 2014 annual membership meeting in Denver, Colorado. The EERC program manager presented an overview and update of Phase III PCOR Partnership activities in November 2013 before the IEA

Figure 2. Phase III tasks.

Table 2. Phase III Responsibility Matrix

Phase III Task Title	Task Leader
Task 1 – Regional Characterization	Wesley D. Peck
Task 2 – Public Outreach and Education	Daniel J. Daly
Task 3 – Permitting and NEPA Compliance	Lisa S. Botnen
Task 4 – Site Characterization and Modeling	James A. Sorensen
Task 5 – Well Drilling and Completion (completed)	John A. Hamling
Task 6 – Infrastructure Development	Melanie D. Jensen
Task 7 – CO_2 Procurement (completed)	John A. Harju
Task 8 – Transportation and Injection Operations	Melanie D. Jensen
Task 9 – Operational Monitoring and Modeling	Charles D. Gorecki
Task 10 – Site Closure	TBA
Task 11 – Postinjection Monitoring and Modeling	TBA
Task 12 – Project Assessment	Katherine K. Anagnost
Task 13 – Project Management	Charles D. Gorecki
Task 14 – RCSP WWG Coordination	Ryan J. Klapperich
Task 15 – Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project (completed)	Charles D. Gorecki
Task 16 – Characterization of the Basal Cambrian System (completed)	Wesley D. Peck

Greenhouse Gas R&D Programme (IEAGHG) expert panel review of the RCSPs to ensure that program goals are being met. Results of the review indicated that there was a unanimous view from the panel that the Bell Creek project has excellent scientific and technical merit combined with a comprehensive test program. It was also evident from the review that the project team covered each technical area comprehensively and was able to address all the technical points raised. Since the last peer review in 2011, the PCOR Partnership established a Technical Advisory Board (TAB) to provide scientific and operational guidance which has aided the project. This was the only partnership that implemented this recommendation of the previous IEAGHG RCSP review. Other notable positive features were the wide-ranging public outreach program, a proven relationship with the operator, and an impressive reservoir characterization.

Throughout PY7, the PCOR Partnership was represented at over 90 meetings/ conferences/workshops and submitted over 30 abstracts. The PCOR Partnership also prepared nearly 20 (deliverable) technical reports, achieved 17 program milestones, and gave nearly 90 presentations (oral and poster combined).

The PCOR Partnership continued to post technical information about its program on its public Web site, which received over 10,000 site visits from 143 countries in PY7. The PCOR Partnership distributed nearly 1100 documentary DVDs and 370 atlases in PY7. In addition, there were nearly 20 telecasts of the documentaries on public television, and over 160 teachers heard the PCOR Partnership message and learned about CCUS. Through these efforts, the CO_2 storage community is kept informed of the PCOR Partnership's accomplishments and activities.

Project management cannot be considered complete without identification of technical and nontechnical risks that may threaten successful project implementation. Accordingly, the PCOR Partnership developed a programmatic risk management plan (RMP) in April 2011 to document individual project risks, consequences, and impacts and updated the plan in August 2014. During PY4, the EERC worked closely with the Fort Nelson demonstration site owners/operators to prepare a 2011 update to the 2010 first-round risk assessment. In PY5, an internal risk register was developed for the Bell Creek demonstration project, and in PY7, a third-round risk assessment was completed. The Bell Creek Round 3 risk assessment process involved a thorough, integrated approach to obtain input from the PCOR Partnership technical staff and to quantify risk scores such that each of the 95 risks on the final technical risk register could be mapped and evaluated for their relative ranking.

In BP4, the focus of the program is to inject CO_2 at commercial scale at the two demonstration sites. For each site, the critical steps/decision points are 1) securing a CO_2 source, 2) permitting for pipelines and injection, 3) infrastructure development, 4) CO_2 injection, and 5) MVA implementation. Several years of injection and monitoring will be required in BP4 to move into the BP5 site closure and project wrap-up activities.

The CO_2 source has been secured for both the Fort Nelson and Bell Creek sites. In both cases, the CO_2 source is a natural gas-processing facility. Spectra owns the gas-processing facility near the Fort Nelson site. CO_2 for the Bell Creek site comes from the ConocoPhillips Lost Cabin Natural Gas-Processing Facility and LaBarge Field, and Denbury has secured the CO_2 from that facility until 2024, as well as the LaBarge Field.

Permitting of the sites required that the EERC complete DOE environmental questionnaires for both the Fort Nelson and Bell Creek demonstration projects. The Fort Nelson demonstration project received a categorical exclusion in 2010, and a categorical exclusion for the Bell Creek demonstration project was granted in 2011. A permitting action plan was prepared for the Bell Creek project in August 2011 and described the regulatory and permitting steps taken by the EERC and Denbury to conduct the project.

The PCOR Partnership continues to establish and maintain excellent relationships with regional regulatory authorities. EERC staff participates fully in Interstate Oil and Gas Compact Commission (IOGCC) efforts. Through the efforts of the IOGCC Carbon Geologic Storage (CGS) Task Force, the PCOR Partnership addressed issues relating to liability (operational and postoperational) that remain as barriers to the establishment of state and federal legal and regulatory frameworks for CCUS. Draft findings, recommendations, and guidance were developed in August 2013, and published online in September 2014. The PCOR Partnership also hosted its sixth annual regulatory workshop in June 2014, where oil and gas and pipeline regulators met informally to develop strategies to work past state/provincial boundaries and to establish rules and regulations outside of federal mandate. These relationships will prove invaluable as the demonstration projects progress.

For the Fort Nelson CCS project, the potential pipeline route is under development. For the Bell Creek demonstration project, construction of the 232-mile Greencore CO_2 pipeline to the Bell Creek oil field was completed in late November 2012. Denbury began injecting CO_2 in the

Bell Creek oil field in May 2013, and by September 2014, over 1,361,551 cumulative metric tons was injected, thereby surpassing a major RCSP Phase III metric of injection of 1 million metric tons of CO_2 per project.

The success of the PCOR Partnership Program will be evidenced by a region that has a supportive population, an accommodating regulatory environment, and, ultimately, a vibrant commercial CCUS industry. Through its outreach and education activities, its rapport with regional regulators and federal decision makers, and its ongoing collaborative MVA activities with supportive partners, the PCOR Partnership is well on its way to achieving its goals.

This Annual Assessment Report provides information about the foregoing activities in more detail and is organized as set forth below:

- Progress update and budget status of the 13 tasks (Tasks 1–9 and 12–16) that were active in BP4, PY7 (October 1, 2013 – September 30, 2014)
- Accomplishments achieved during BP4, PY7 (October 1, 2013 – September 30, 2014)
- Description of planned BP4, PY8 (October 1, 2014 – September 30, 2015) activities

It should be noted that Tasks 10 and 11 will be initiated in BP5.

BP4, PY7 ACTIVITIES (2013–2014)

Progress Report

BP3 included the first 2 years of Phase III, with activities initiated October 1, 2007. Thirteen tasks were originally scheduled for Phase III. A new task, Task 14, was added during PY2 of BP3. Out of the 14 tasks, 12 tasks were active during BP4, PY3. In February 2011, DOE approved moving former Subtask 1.4 to a newly created Task 15 and added a new task, Task 16, as shown in Figure 2. Out of the 16 tasks, 13 tasks were active during BP4, PY6 (Task 7 concluded at the end of PY6, and Tasks 10 and 11 will not begin until BP5). The progress update for the active tasks is presented within this section. This Annual Assessment Report (Deliverable [D] 57) details activities beginning October 1, 2013, through the end of BP4, PY7, or September 30, 2014.

Charles D. Gorecki is the overall EERC program manager and principal investigator (PI) and provides leadership in fully coordinating and integrating the activities of the PCOR Partnership. To facilitate the management of this project, task leaders were designated, as shown in Table 2.

Task 1 – Regional Characterization

The PCOR Partnership continues to refine the characterization of sources, geologic sinks, and infrastructure within its region. The goal is to further refine the assessment of the region's

CO_2 production and storage potential in an effort to optimize source–sink opportunities within the region. This continued regional characterization will be used to refine capacity estimates for DOE NETL's national atlas and to provide context for extrapolating the results of the large-scale demonstrations.

Activities and Results

Phase III regional characterization efforts for BP4, PY7 (October 1, 2013 – September 30, 2014) are addressed as follows.

Review and Update Attribute Data for CO_2 Source Locations Within the Region

The PCOR Partnership maintains a database of regional sources of CO_2 emissions and evaluates it on an annual basis. The database is an important part of assessing potential CO_2 capture–transportation–storage scenarios that could reduce GHG in the PCOR Partnership region. The emission measurements compiled in this database are typically acquired through online databases of the U.S. Environmental Protection Agency (EPA) and Environment Canada. The updated database shows that there are 911 significant (greater than 13,600 metric tons or 15,000 short tons) CO_2 emission sources that emit 562 million metric tons (619 million short tons) on an annual basis. Occasionally, the name of a source is found to have changed in an emission data set. The PCOR Partnership database was modified to reflect the name change of five sources since July 31, 2013. Sources that no longer exist or that were found to be duplicate entries in the database were eliminated. There were a total of 26 such point sources in the PCOR Partnership database. Figure 3 shows the locations of 39 new facilities that were found to be missing from the data set and were, therefore, added to it (1).

Third Target Area Characterization Completed

In this subsubtask, the EERC is to perform detailed characterization of several target areas similar to the demonstration area to develop methodologies for refined capacity estimations. In PY2, the PCOR Partnership completed a detailed geologic site characterization for its first target area, the Dickinson Lodgepole Mounds (including the Eland oil field) near Dickinson, North Dakota. In PY5, work characterizing the Rival oil field, located in northwestern North Dakota, was completed. Several potential target areas and/or formations were considered for the PY7 third target area characterization; however, after consideration, it was determined that a different path would be taken.

Through its close involvement with DOE and the international community with respect to the development and use of storage efficiency factors, the PCOR Partnership has accrued valuable insight into the methodologies for CO_2 storage resource and capacity estimations for deep saline formations. This insight has resulted in the development of a workflow that introduces intermediate storage efficiency factors that take into account increased levels of geologic reconnaissance (e.g., the geographic distribution of salinity and depth values) to generate refined CO_2 storage resource values for saline formations. While this investigation does not focus on a site-specific characterization activity, the advancement in the understanding and

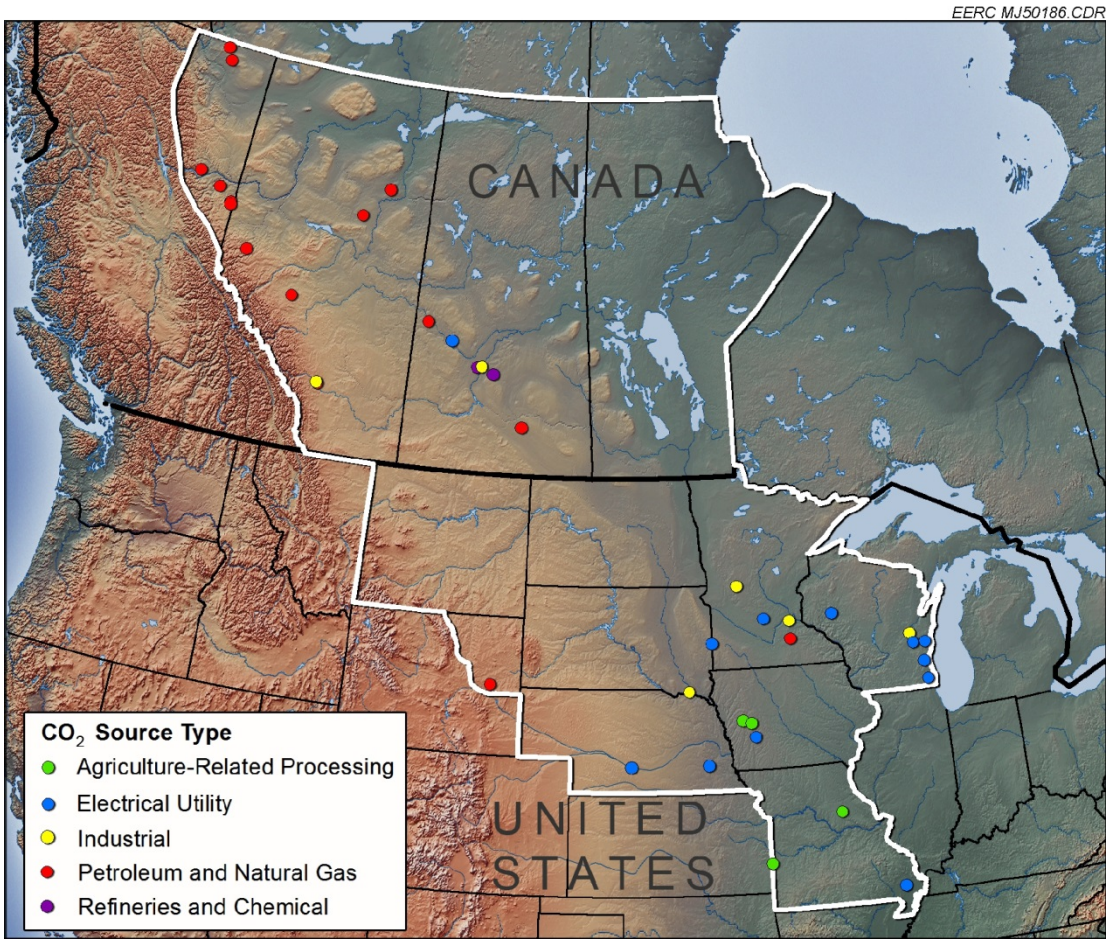


Figure 3. Location of the new facilities identified during the 2014 database update.

application of what has become the standard DOE methodology for saline formation CO_2 storage assessment is notable. Improvements in the application of the DOE saline storage methodology are founded on the premise that simply applying the formula to the gross characteristic values of a saline formation will produce results that are frequently misinterpreted. To avoid these misinterpretations, a formation should not be considered for CO_2 resource evaluation if there is no indication of what geographic extent is deep enough to sustain supercritical CO_2 and what portion of the reservoir extent has water salinities greater than 10,000 ppm total dissolved solids (TDS). In cases where that information (depth and salinity) is known, then a refined level of storage efficiency factors should be applied (2).

Plans are under way to submit a journal article tentatively entitled "Improvements in the Application of CO_2 Storage Efficiency Values for Deep Saline Formations" to the *International Journal of Greenhouse Gas Control* in PY8.

Refine Storage Analogs for Specific Geologic Horizons Within the Regional Basins

There are eight depositional basins lying fully or partially within the PCOR Partnership region. Efforts are under way to expand the number of assessed target formations in these basins. The largest of these efforts is aimed at characterizing the Basal Cambrian saline system lying across the Alberta and Williston Basins. This effort was reassigned its own task (Task 16) in 2011 and is anticipated to run through March 2014.

A value-added report on the geologic characterization and CO_2 storage potential of the state of Nebraska, including the Cedar Hills sandstone and Amazon dolomite, continued in PY7 and should be finalized in PY8.

Work with Geological Surveys/Oil and Gas Divisions

In PY7, regional characterization staff continued to work closely with the Montana Board of Oil and Gas (MBOG), the Nebraska Oil and Gas Conservation Commission, and the Wyoming Oil and Gas Conservation Commission to acquire updated cumulative oil production numbers for the fields and pools in the U.S. portion of the PCOR Partnership region.

PCOR Partnership Atlas

The *PCOR Partnership Atlas* provides an introduction to the concept of global climate change and CCUS as well as a regional profile of CO_2 sources and potential sinks across the nearly 1.4 million square miles of the PCOR Partnership region of central North America. Efforts to reinvent the *PCOR Partnership Atlas, 4th Edition*, were undertaken in PY4, and after the appropriate approvals were received, 1200 atlases were printed in June 2012. A new printing of 1250 copies of the *PCOR Partnership Atlas, 4th Edition, Revised*, was received in June 2013.

The atlas continues to serve as an excellent resource as well as a valuable outreach tool. It is distributed to partners, visitors, educators, libraries, and conference attendees and is available upon request, including via the public PCOR Partnership Web site. Approximately 370 atlases were distributed in PY7 (compared to 684 distributed in PY6). Overall, since its first printing in 2005, over 5200 atlases have been distributed.

The *PCOR Partnership Atlas, 5th Edition*, is anticipated to be complete in PY8 (August 31, 2015).

Updating the Decision Support System (DSS) Web Site (www2.undeerc.org/website/PCORP)

Modifications and refinement to the partners-only DSS are continually undertaken to ensure the timely dissemination of data and information as well as to help improve the quality and efficacy for our partners for their carbon management decisions.

The current DSS has been updated with CO_2 sources as well as oil fields, including previously abandoned fields in Montana. Improvements worked on in a PY7 “test phase” (but

not yet moved to the "live" DSS) include an advanced search tool, housing an identification and selection tool, and an exporting, printing, and reporting system. The reporting system is available to show the most in-depth information for the sources and oil fields.

This advanced search tool was implemented to better serve the needs of the partners and to improve the ability to search using different attributes. With respect to sources, this tool will allow the user to search by the source type, source name, and source CO_2 amounts, including use of these same attributes to remove sources that do not fit certain criteria. For example, one can search for all ethanol plants and, from that search, eliminate any sources with a CO_2 output of less than 25,000 metric tons. There is also an option of exporting the remaining results. Searching the oil fields has now been broken down into oil fields and unitized oil fields and allows the user to search the oil fields by name.

In addition, the following activities continued in PY7.

- The various databases (oil fields, wells, gas plants) that ultimately feed the DSS were updated as well as the current GIS (geographic information system) well files.

- New PCOR Partnership products are regularly added to the database once they are approved for release to partners. Currently, the database contains 1120 products (an increase by 220 over PY6 [900]) produced by the PCOR Partnership since its inception in 2003.

- The Partner Directory is a database-driven page that is continuously updated to include the partners' most recent contact information. As new partners join the PCOR Partnership, their company name and URL are updated.

It should be noted that the requirements for updated DSS reports (D9) in September 2013 and 2015 were deleted in September 2012. In PY7, updates to the DSS were reported in the quarterly technical progress reports rather than in stand-alone reports.

Development of a Demonstration Project Reporting System (DPRS)

Collection of information specific to the demonstration sites is ongoing in an effort to populate a Web-based interface to house the data and facilitate communication and interpretation of the data. A DPRS was created to provide structured access to data from the PCOR Partnership Phase III demonstration projects at Bell Creek and Fort Nelson. Each project has its own section and is updated upon receipt of approval from the commercial site owner/operator.

It should be noted that the requirements for DPRS updates (D10) in September 2014 and 2016 were deleted in September 2012. In PY7, updates to the DPRS will continue to be reported in the quarterly technical progress reports rather than in stand-alone reports.

Collaboration with Petroleum Technology Research Centre's (PTRC's) Aquistore Project

PTRC at the University of Regina is in the process of conducting a CCUS project in southeastern Saskatchewan, Canada, to demonstrate the feasibility of CO_2 storage in a deep saline formation. The formal name for this project is Aquistore.

The PCOR Partnership is collaborating with PTRC, assisting in the site characterization, acting as advisor in the risk assessment and MVA activities, and directly performing aspects of the modeling and simulation activities. The PCOR Partnership will utilize site characterization data collected by PTRC to update the geologic model and perform predictive simulations. The period of performance for this subtask was July 2012 – June 2013, subsequently extended to March 31, 2014. Based upon positive feedback received from the PTRC SERC (Science and Engineering Research Council), an extension to September 30, 2015 was requested, along with a continuation of modeling and simulation efforts and completion of a new deliverable (D93, Update 2, due July 30, 2015).

The Aquistore project is part of the world's first commercial postcombustion CCUS project from a coal-fired power-generating facility, the SaskPower Boundary Dam, located in Saskatchewan, Canada, and will be acting as a storage site for a portion of the captured CO_2 from the Boundary Dam power plant. The Aquistore site includes one injection well and a 152-meter offset observation well. Both wells were drilled and completed in the Deadwood and Black Island Formations.

Aquistore Geologic Modeling and Simulation Activities

To better understand the storage implications of injecting at the Aquistore site, the EERC developed a geocellular model of the basal saline system for the dual purposes of determining the static CO_2 storage capacity and as a basis to run detailed reservoir simulation to determine injectivity, dynamic storage capacity, and breakthrough time at the observation well. To compensate for a lack of well control locally, a regional-scale model was first constructed to determine the regional stratigraphic reservoir and nonreservoir zones. From this regional model, a fine-scale model was confined to the extent of the 13.1-square-mile PTRC 3-D seismic survey area, with higher structural resolution. Integration of the data derived from the regional model and the data from the 3-D seismic survey helped create a robust and heterogeneous model around the Aquistore injection well and the observation well.

As a first pass, the detailed 13.1-square-mile model was used to estimate a static storage capacity employing the DOE methodology and resulted in a range of static storage resource of approximately 8.4 to 27.1 million metric tons for the P_{10} to P_{90} confidence intervals, respectively. This result indicated that our model was probably big enough to model a short- to medium-duration injection of perhaps 5–30 years at 1 million metric tons/yr; however, it may be too small to adequately simulate a 50-year injection period.

To further evaluate the targeted saline system and, thus, its viability as a potential storage horizon for CO_2, the geocellular model was used as the framework for an assessment of the dynamic storage capacity of the system. Two scenarios were designed based on the static

geologic model. The first investigated the injectivity of the system and the timing of CO_2 breakthrough at the observation well in a 13.1-mi^2 area. The second scenario, which will be detailed in a subsequent report, encompasses a 3670-mi^2 area. As part of this investigation, core plug analysis and relative permeability studies were also conducted on samples provided from the injection well core. Information from these analyses was integrated into the construction of the geocelluar model and the dynamic simulations and will be provided in a subsequent report.

A total of nine simulation cases were run to investigate factors such as boundary conditions, injection rates, and time length. The injection duration for these scenarios was set at 1, 5, and 50 years, and the injection rates were set at 1 million metric tons/yr and 0.3 million metric tons/yr. Although the maximum injection rate in the model was set as 1 million metric tons/yr, the maximum attained in the model was 0.73 million metric tons/yr because of bottomhole pressure (BHP) limitations. The total mass of CO_2 injected in the 50-year cases ranged from 1.5 to 33.6 million metric tons, with the large range in values a result of changing the boundary conditions from closed to open. CO_2 storage values for the 5-year cases range from 1.5 to 3.6 million metric tons, and those for the 1-year cases range from 0.3 to 0.7 million metric tons.

An important aspect of this investigation with regard to potential monitoring efforts is the timing of CO_2 breakthrough at the observation well. The earliest breakthrough occurred between 10 and 15 days at the higher injection rate (0.73 million metric tons/yr), and the projected CO_2 path follows the top reservoir zone of the Deadwood Formation. At the lower injection rate (0.3 million metric tons/yr), breakthrough happens between 25 and 30 days after injection and follows the same path. Overall, CO_2 breakthrough in most of the reservoir zones happens in about 3 months for the low injection rate; this time is reduced to 45 days at the higher rate. Based on the information derived from the various simulation cases, the CO_2 breakthrough will most likely happen in the first month of injection regardless of the injection rate and assumptions of relative permeability.

Based on the simulation results, the storage of CO_2 in the study area using the existing two-well configuration is feasible, depending on the volume of CO_2 that need to be injected and stored from the neighboring Boundary Dam power plant. Generally, the maximum injectivity for the current injection well could reach 0.73 million metric tons/yr based on the geological characterization of the study area. However, this could be improved through optimization operations such as adding additional injection wells, utilizing formation water extraction wells, and/or the use of horizontal injection wells. All of these additional optimization techniques will be investigated in the next phase of work and reported on in a subsequent report. In addition, the larger regional-sized model will be utilized to provide better insights with respect to a commercial-scale injection rate over a long period of time. Finally, future work will also include geomechanical, geochemical, and geothermal behaviors and integrate them throughout the entire modeling and simulation process to investigate the role these variables may play in CO_2 storage at the Aquistore site (3).

To better understand the storage implications of injecting CO_2 at the Aquistore site, the EERC has constructed P_{10}, P_{50}, and P_{90} geologic model realizations and run three new predictive simulation scenarios on each realization. These models and simulations were constructed to

better understand both operational and geologic uncertainties that may exist at the Aquistore site. In this update, the same fine-scale model extent of the 34-square-kilometer PTRC 3-D seismic survey area, with higher structural resolution, was continually used for the uncertainty analysis. A low (P_{10}), mid (P_{50}), and high volumetric (P_{90}) case for the amount of pore volume accessible to store the potential injected CO_2 was ranked based on certain deviation variations of model-building parameters, including effective porosity and net-to-gross reservoir, in six sand units of the study area. Three cases with various injection rate and period schemes were simulated based on uncertainty models P_{10}, P_{50}, and P_{90}.

The first CO_2 breakthrough time, pressure change, CO_2 plume extent, and CO_2 movement probability distribution for three cases over all uncertainty realizations were monitored and calculated. The first CO_2 breakthrough for the high injection rate cases (Cases 1 and 3, 1000-metric ton/day injection rate) most likely happened within the first injection month. With the various heterogeneities of the realizations, the breakthrough time may be earlier, between 14 to 19 days (Table 3). For the low injection rate Case 2 (1000-metric ton/day injection rate), the first CO_2 breakthrough may be postponed to the end of the second month (~59 days) of when the injection started. This time was even extended to the middle of the third month, which is about 73 days for the first breakthrough (Table 3).

Table 3. Simulation Results Summary for All Cases

	Injection Rate, metric tons/day	Injection Period, days	Injection Pattern	First Breakthrough Time, days		
				P_{10}	P_{50}	P_{90}
Case 1	1000	30	Continuous	~19	~19	~30
Case 2	301	1095	Continuous	~59	~59	~73
Case 3	1000	933	Start–stop–start	~19	~19	~30

The pressure monitoring on the observation well was always lower than 37,250 kPa based on the injection BHP constraint, 42,750 kPa, imposed on the injection well. The maximum reservoir pressure increasing because of CO_2 injection is around 4800 kPa within the first breakthrough time, as compared to the initial pressure of the reservoir.

The times of CO_2 breakthrough, pressure change, CO_2 movement, plume extent, and probability distribution were changed in Cases 2 and 3 because of the different injection rates and periods, especially in the individual time intervals. The differences may decrease after the same total amount of CO_2 is injected in Cases 2 and 3.

Uncertainty over geologic realizations is significant to influence CO_2 injection behavior and CO_2 movement underground. The first breakthrough time, pressure front, reservoir pressure buildup, CO_2 plume, and CO_2 probability distribution were significantly varied over such geologic realizations. Uncertainty analysis of the results by calculating the probability distribution could provide insights on CO_2 movement that ultimately assist with the decision on leakage monitoring, risk assessment, and the MVA plan (4).

Aquistore Petrophysical Activities

The EERC, in collaboration with PTRC, analyzed rock samples from a well near Estevan, Saskatchewan (Figure 4) as part of the ongoing efforts to characterize the subsurface for potential CO_2 injection and long-term storage. These samples were characterized to accomplish two key goals. The first goal was to provide PTRC with insight into the lithology, porosity, and permeability of a proposed injection target for a small-scale demonstration project. The second goal was the utilization of the data by the EERC in the development of static geologic models to be used for dynamic simulation of CO_2 injection and storage scenarios. This report details the core analysis conducted and provides a summary of key petrographic and petrophysical properties obtained.

Figure 4. Location map of PTRC_INJ_5-6-2-8 W2M well.

In late August 2012, core was collected from a wellbore that penetrated the basal Deadwood Formation currently being evaluated for CO_2 storage as part of the PTRC Aquistore Project. The EERC was invited to view and provide geologic descriptions of the 19.2 m (63 feet) of core collected from the lowermost section of the Deadwood Formation (Figure 5). Following the macroscopic description, 20 samples were collected spanning the 63-foot length and representative of the heterogeneities thought to exist through the injection target.

The EERC conducted several analyses on the well samples to determine mineralogy, porosity, and permeability. Specific tests included gas porosimetry and petrographic analysis via thin sections and gas porosimetry on all samples; scanning electron microscopy (SEM), x-ray diffraction (XRD), and permeability to gas and liquid on a select subset of samples and CO_2–brine relative permeability testing on one sample.

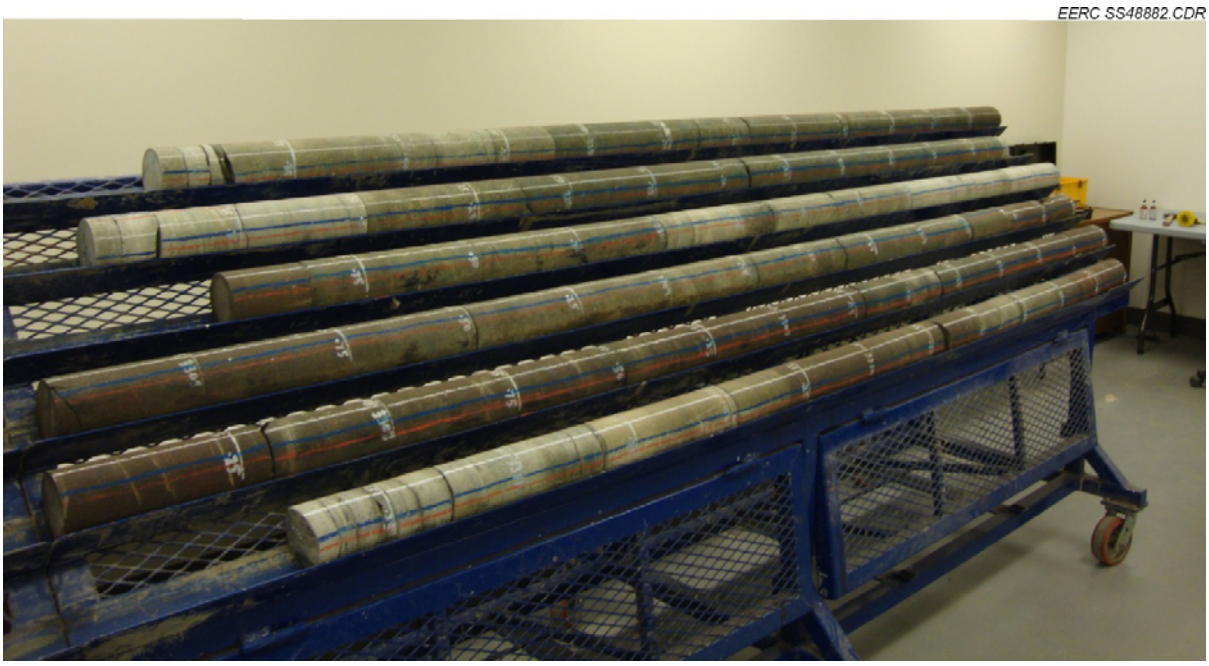


Figure 5. Initial view of Aquistore core.

The samples evaluated from the lower Deadwood Formation are sandstones dominated by well-compacted quartz sand with glauconite clay in varying stages of dissolution. Sample porosities ranged from 2.7% to as high as 15.9%, and permeability to air values ranged from 0.002 to 137 mD. Of the 20 samples tested, six had less than 9% porosity. In each of these cases, the corresponding permeability value was less than 2 mD, implying that where porosity exists, it is likely not well connected.

Results of the thin-section and SEM analyses showed that the interval sampled is predominantly quartz and glauconite-rich sandstone with dolomite cementing. Evidence of Compaction and solution weathering were evidenced by highly sutured grain boundaries. Intraparticle porosity exists as a result of mineral crushing and mineral dissolution, including glauconite dissolution. Quartz overgrowths and mineral dissolution were observed as well as occasional clay and iron oxide pore linings. SEM analysis showed evidence of dissolution or weathering of glauconite in varying stages. In some cases, this dissolution led to the formation of clays and a residual iron-rich phase, and in other cases, the iron released by the glauconite dissolution was incorporated into pore-filling dolomite.

Based on the general stages of glauconite dissolution, only three samples were selected for semiquantitative XRD analysis to identify/verify the major phases present in the samples. An additional sample was analyzed to support the modeling effort. All four samples consisted primarily of quartz. Other mineral phases identified included dolomite, glauconite, montmorillonite, K-feldspar, and chlorite.

The steady-state relative permeability testing conducted at the EERC used simulated formation brine (300,000 ppm) and pure CO_2. The steady-state method entails running various

mixtures of CO_2 and brine through the sample, from 100% brine and 0% CO_2 to 100% CO_2 and 0% brine. The permeability of the core to 100% brine was measured as 4.9 mD; however, CO_2 permeability was virtually nonexistent, except to 100% CO_2 with the presence of irreducible water saturation (44%). The permeability of CO_2 relative to the brine permeability is approximately 20% (or roughly 1 mD). Following the relative permeability testing, the plug was cleaned and dried and then retested for porosity. No changes in porosity were observed following relative permeability testing.

While the characterization work described was thorough and effective with respect to the resources allocated, the Aquistore Project team may benefit by performing additional tests. Specifically, geochemical, mineralogical, and flow-through experimentation would provide additional insight into the injection and long-term distribution of CO_2 in this reservoir. Threshold intrusion pressures should be determined to understand and evaluate the quality of the sealing formation. Finally, mercury injection capillary entry pressure data will provide adequate estimates of pore throat size and distribution, ultimately providing a better understanding of the storage potential of this site (5).

In mid-2012, PTRC drilled and completed the PTRC_INJ_5-6-2-8 W2M well in southwestern Saskatchewan near Estevan. During the drilling of the well, a decision was made by PTRC to core the Bakken Formation interval to gain insight regarding its resource potential and/or viability as an alternate CO_2 storage sink. In March 2014, representatives of the EERC were invited to collect samples from this well in support of both PTRC's and the EERC's CO_2 storage research programs.

One of the goals of the PCOR Partnership is to develop a first-order, reconnaissance-level estimate of the potential CO_2 storage capacity of a wide variety of geologic formations in the region. To date, research efforts to better understand and estimate CO_2 storage capacity in geologic formations have been largely focused on relatively permeable targets, such as saline formations and conventional oil reservoirs. However, as development of unconventional oil and gas reservoirs throughout North America continues to expand, there is increasing interest from stakeholders regarding the feasibility of CO_2 storage and/or simultaneous CO_2 storage and EOR within these types of formations. In particular, there are questions as to whether tight, organic-rich oil- and gas-producing formations (e.g., "tight oil" formations) can serve as CO_2 sinks or seals. One example is the Bakken petroleum system (Bakken), a tight (<10-mD), fractured oil and gas reservoir in the Williston Basin. The Bakken Formation contains geology that represents a fractured reservoir or storage system that contains brine and hydrocarbons (Middle Bakken), which is sandwiched between tight, organic-rich, oil-wet black shales (Upper and Lower Bakken) that may be representative of sealing formations. Laboratory-based activities have been conducted by the EERC to determine the viability of the Bakken to incidentally store CO_2 during EOR operations.

To determine the role that a tight oil formation, such as the Bakken, may play in CCS, it is critical to understand the petrophysical characteristics of that formation relative to its likely interactions with CO_2. Collected samples were extensively characterized and tested to examine their interactions with CO_2. Laboratory activities included petrographic analysis, pore throat size

determination, total organic content analysis, porosity, and relative permeability analyses. The findings of these activities will be reported in PY8.

DOE NETL Carbon Sequestration Atlas of the United States and Canada (Atlas V)

The primary purpose of Atlas V is to update U.S.–Canada CO_2 storage potential and provide updated information on DOE's Carbon Storage Program and international CCS collaborations, as well as on the activities of DOE's seven RCSPs. Atlas V will include a feature spread on each partnership's large-scale field project. In order to support Atlas V efforts, the PCOR Partnership participated in multiple conference calls to discuss progress of the data compilation and provided data via NATCARB (DOE NETL's distributed NATional CARBon Sequestration Database and Geographic Information System), including photos and text focused on the Bell Creek project. Atlas V is planned to be released in PY8.

RCSP GIS Working Group

The task lead participated in the RCSP GIS Working Group conference calls, as scheduled. There were no working group meetings held in PY7.

Task 2 – Public Outreach and Education

This task provides outreach and education mechanisms to raise awareness regarding CO_2 storage opportunities in the region as well as outreach to select target audiences concerned with the demonstration activities.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) are addressed as follows.

Meetings and Conferences

EERC employees attended 93 meetings/conferences/workshops at the regional, national, and international level. As a result, numerous external individuals and groups were exposed to the PCOR Partnership name, messaging, and informational materials, and numerous participants within the RCSP Initiative were updated on PCOR Partnership activities. The meetings/ conferences featured audiences ranging from the general public, to educators, to scientists and researchers, to regulators and partners. Specifically, the PCOR Partnership peer and public outreach activities included 27 poster and 60 oral presentations as well as seven exhibit booths. Compared to PY6, PCOR Partnership personnel's meeting/conference/workshop attendance increased during PY7, and personnel gave 15 more oral presentations. However, in PY7, there were slightly fewer poster presentations given (27 poster presentations versus 31 in PY6).

Outreach Material Distribution

The standard PCOR Partnership outreach packet contains some combination of the five documentary DVDs, the regional atlas, fact sheets, and other program materials. The materials are provided as part of presentations in select venues (e.g., teacher workshops), as part of acquainting new contacts with the PCOR Partnership Program, and by request through the PCOR Partnership public Web site or other pathways (e.g., telephone or e-mail). During PY6, the PCOR Partnership distributed over 1630 documentary DVDs and over 680 atlases. During PY7, the PCOR Partnership distributed nearly 1100 documentary DVDs and 370 atlases, as follows:

- PCOR Partnership documentary entitled "Nature in the Balance: CO_2 Sequestration" – 102
- PCOR Partnership documentary entitled "Reducing Our Carbon Footprint: The Role of Markets" – 101
- PCOR Partnership documentary entitled "Out of the Air: Into the Soil" – 188
- PCOR Partnership documentary entitled "Managing Carbon Dioxide: The Geologic Solution" – 339
- PCOR Partnership documentary entitled "Global Energy and Carbon: Tracking Our Footprint" – 340
- PCOR Partnership documentary entitled "Installing a Casing-Conveyed Permanent Downhole Monitoring System" – 21
- *PCOR Partnership Atlas, 4th Edition, Revised* – 370

Throughout the course of the program, the PCOR Partnership has distributed a total of 5228 copies of the various regional atlas editions and 9643 copies of the five different documentary DVDs and the technical training video.

Outreach Planning

An update to the PCOR Partnership outreach action plan (D11) was prepared in March 2010. This plan describes the activities undertaken and products developed to help raise awareness of both the practice of CO_2 storage in general and the PCOR Partnership specifically. The next version of the plan is scheduled for March 2016.

Data Acquisition and Management

The outreach data management system is envisioned as an addition to the DSS to consist of GIS-compatible databases. When completed, these databases will contain information needed to plan, track, and aid in assessment actions as well as to produce thematic maps and other products to aid in outreach activities, including the Web site, PowerPoint presentations, fact sheets, and documentary products both at the regional level and for the areas of the demonstration projects. During PY7, efforts continued to populate, test, and refine the outreach tracking database.

Public Web Site (www.undeerc.org/pcor)

Web Site Updates

The PCOR Partnership public Web site has been online since June 2004. This Web site will be updated and expanded as appropriate, with major updates on a biennial basis.

An update (D13) was submitted July 29, 2014, for the period of July 1, 2012, through June 30, 2014. The central focus of this update was the implementation and documentation of a comprehensive Web-tracking and research effort based on Google Analytics (GA). This tracking work included an inventory of Web pages and other trackable elements (PDFs, documentaries, and video clips). A time line for the work is presented in Figure 6. The development and implementation of a standard operating procedure for tracking was included as an appendix to the Web update report. Other modifications included a video player upgrade that improved functionality for video streaming and made the tracking of video clip access possible. In addition, several pages were revised including the Home page, Atlas page, About the Partnership page, Carbon Capture and Storage page, Fact Sheets page, and several project pages in the CO_2 Sequestration Projects section. A Final Reports page was also added. The PCOR Partnership public Web site has been online since early 2004, and the next contractual update is due in July 2016.

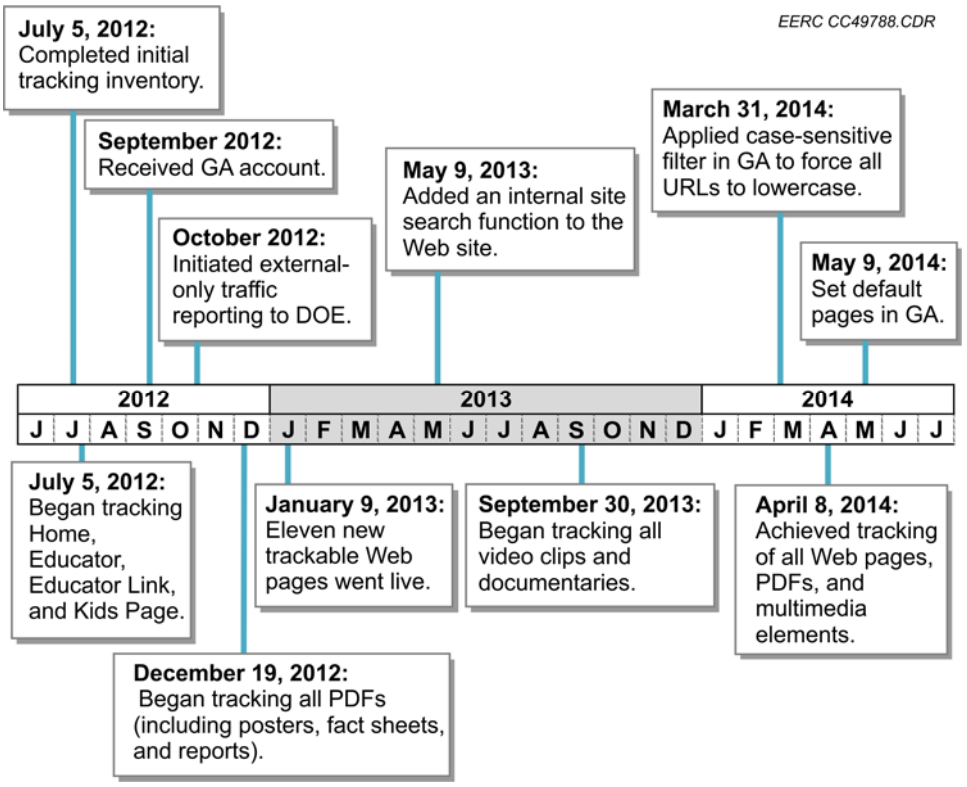


Figure 6. Tracking time line for the period July 1, 2012 – June 30, 2014.

Web Site Activity Tracking

The PCOR Partnership has used GA to track activity for the PCOR Partnership public Web site since April 2010. During PY7, Google recently upgraded tracking capability and moved all users with a "classic" analytics account to Universal Analytics (UA). The new UA will move away from session-based tracking to user-based tracking, facilitating user behavior tracking across all devices (e.g., Web, mobile, tablet). Although the PCOR Partnership public Web site is now in UA mode, all Web pages still have the "classic ga:gs" cookie tag. The PCOR Partnership has 2 years to update all ga:gs tracking codes to UA.

Although data collection and process are currently unchanged, the UA upgrade does contain noticeable differences regarding the naming of two key metrics: 1) visits are now shown as sessions and 2) visitors are now referred to as users. Because of the renaming of these metrics, visits and visitors will be used along with sessions and users, respectively, in reporting.

As instituted in the beginning of PY6, the Advanced Segments feature in GA is used to exclude internal Web site traffic (project personnel and Web site maintenance visits), thus providing a reasonable starting point to gauge public activity. The results reported below are for public (external) traffic only.

Web Site Traffic

During the PY7 reporting period there were 10,102 sessions/visits to the public Web site. Traffic to the Web site increased 50% from PY6 (5026 sessions/visits). In PY7, approximately 16% of the visitors came to the site using a mobile device or tablet.

There were 8593 unique visitors to the public Web site in PY7, representing a 53% increase from PY6 (4039 visitors). 83% of these visitors (8441visitors) were new to the Web site during PY7.

The PCOR Partnership public Web site received traffic from 143 countries from October 1, 2013, to September 30, 2014, as illustrated in Figure 7. Of the 10,102 sessions/visits, 45% of the Web traffic was domestic and 55% international. Table 4 lists the ten countries with the highest number of sessions/visits to the PCOR Partnership Web site. These included the United States, India, Canada, United Kingdom, Australia, Philippines, South Africa, Pakistan, Malaysia, and Nigeria.

There were 1246 visits from within the PCOR Partnership region. Approximately 73% of regional visits originated from the United States and 27% from Canada. Figure 8 illustrates Web visits to states and provinces within the region.

Sessions/visits from the PCOR Partnership region represent 12% of the total traffic to the public Web site (It should be noted that the totals may overestimate regional traffic to some degree because the visit location data were aggregated at the state and province level even though the PCOR Partnership region formally includes only portions of British Columbia, Montana, and Wyoming).

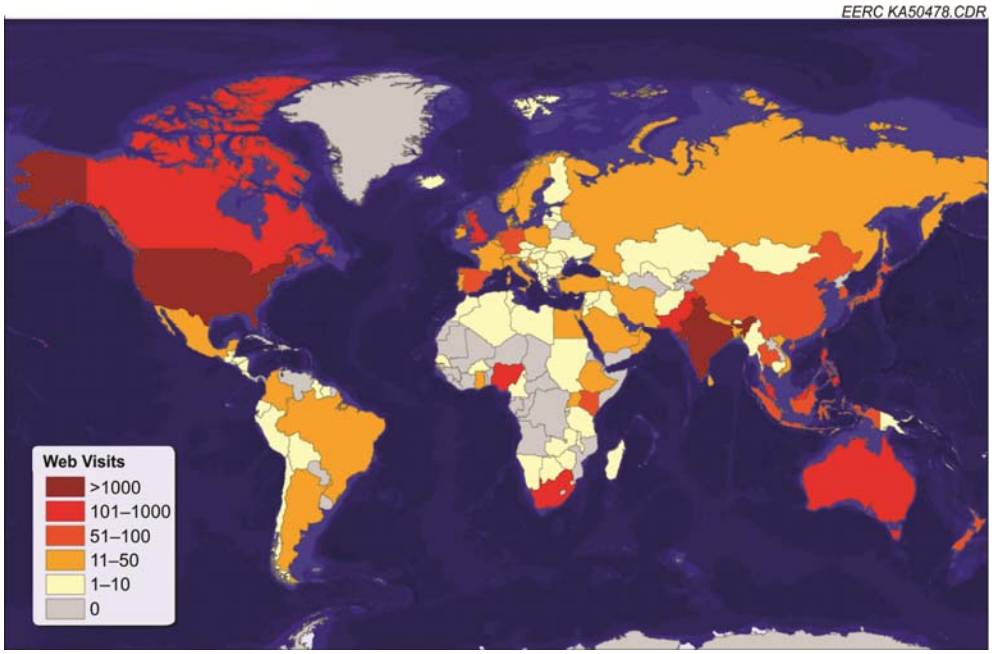


Figure 7. Map of PCOR Partnership global Web traffic for PY7 (source: GA).

Table 4. Visit Activity from the Top Ten Countries and the PCOR Partnership Region

	Country	Visits*	PCOR Partnership State/Province	Visits*
1.	United States	4512		
			North Dakota	324
			Minnesota	191
			Wyoming	99
			Wisconsin	78
			Montana	76
			Missouri	51
			Nebraska	49
			South Dakota	20
			Iowa	19
2.	India	1325		
3.	Canada	591		
			Alberta	154
			British Columbia	91
			Saskatchewan	72
			Manitoba	22
4.	United Kingdom	546		
5.	Australia	411		
6.	Philippines	220		
7.	South Africa	174		
8.	Pakistan	118		
9.	Malaysia	113		
10.	Nigeria	102		
	Other 143 countries	1990		
	Total Visits	**10,102**	**Total PCOR Partnership Visits**	**1246**

*Arranged by the number of visits to the site.

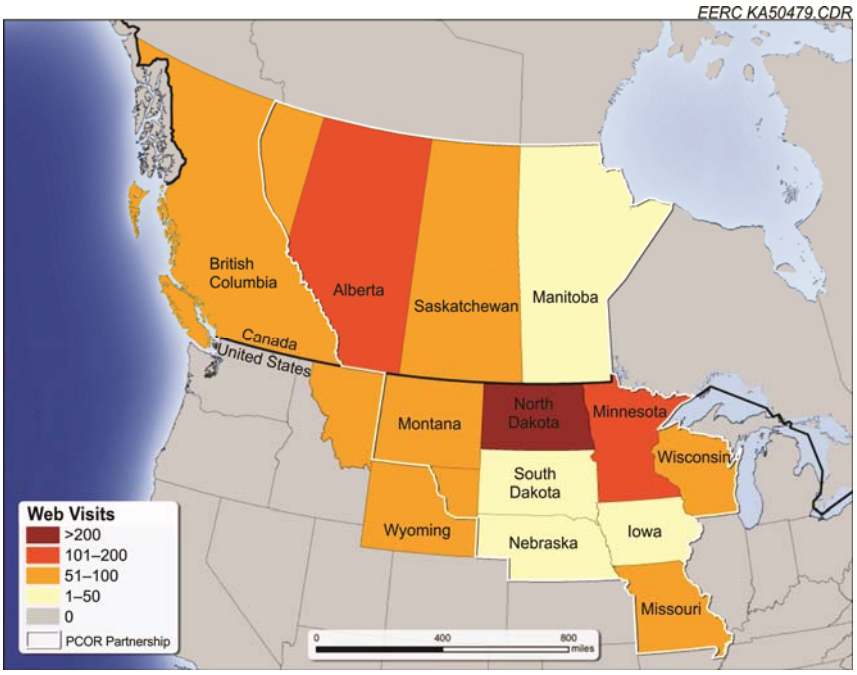


Figure 8. Map of PCOR Partnership regional Web site sessions/visits for PY7 (source: GA).

Web Site Traffic Sources

Traffic sources indicate how visitors came to the PCOR Partnership Web site. The three general categories of traffic sources include search, direct, and referral sites. Lesser traffic sources are acquired from social media and campaigns. These categories and their percentage of the total traffic sources are presented in Figure 9.

Search traffic refers to the use of search engines such as Google, Bing, and Yahoo. Search traffic accounted for more than 82% of the overall traffic that came to the public Web site. GA provides keywords visitors used to find the public Web site. The top three keywords and phrases used include "carbon sequestration," "what is CO_2," and "CO_2 sequestration."

Direct traffic consists of those visitors who bookmark or type a specific PCOR Partnership URL, e.g., www.undeerc.org/pcor, into a Web address bar. Direct traffic accounted for 12% of the overall traffic.

Referral traffic is traffic to the PCOR Partnership Web site from other sites via links. About 5% of external traffic resulted from referral sites. The top three referring Web sites were those from energy.gov, mybigcampus.com, and sequestration.mit.edu.

Less than 1% came from teacher campaigns and social interactions, such as e-mail or from social media sources like Facebook or YouTube.

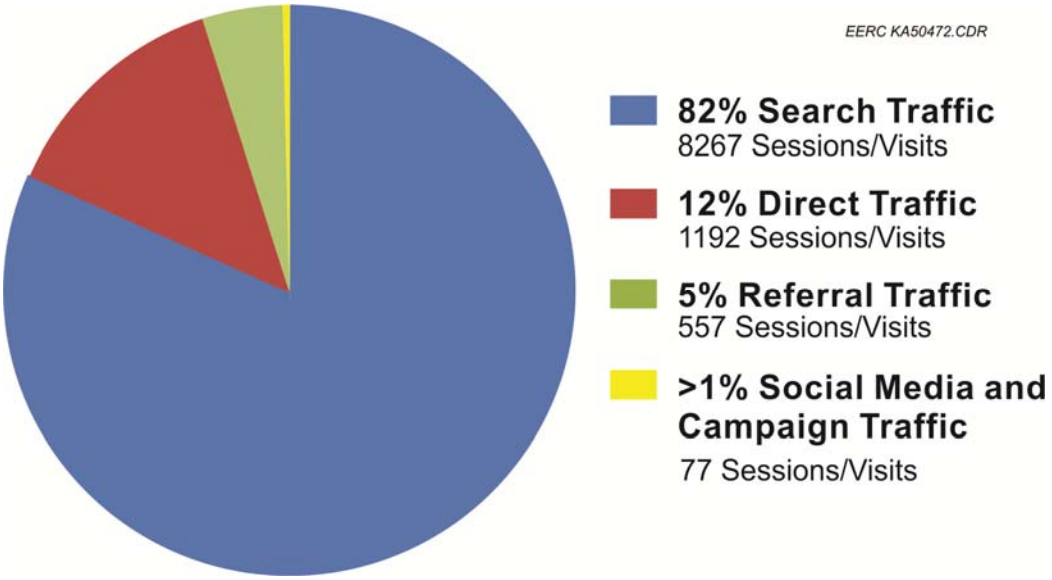


Figure 9. PCOR Partnership public Web site traffic in PY7 (source: GA).

Nature of Visits

A total of 18,120 page views (a 40% increase from PY6) resulted from the 10,102 sessions/visits to the PCOR Partnership public Web site in PY7. The top five viewed Web pages comprised about 54% of page views overall. The "What Is CO_2 Sequestration?" and "Home Page" pages accounted together for 39% of the total page views (Table 5).

Table 5. Top Pages for "Page Views" on the PCOR Partnership Public Web Site

Page Title	Page Views	% Page Views	Page URL
What Is CO_2 Sequestration?	5307	29%	www.undeerc.org/pcor/sequestration/whatissequestration.aspx
Home Page	1885	10%	www.undeerc.org/pcor/default.aspx
Video Clip Library	1366	7.5%	www.undeerc.org/pcor/video-clip-library/default.aspx
CO_2 Sequestration Projects	843	4.7%	www.undeerc.org/pcor/co2sequestrationprojects/default.aspx
What Is CO_2?	575	3.2%	www.undeerc.org/pcor/sequestration/whatisco2.aspx

Fact Sheets

Fact sheets have been created with general background information on the PCOR Partnership Phase III program and a profile on each of the demonstration projects. These fact sheets, along with the ones developed in previous phases, will be updated as needed. Other fact sheets may be developed as needed.

The Bell Creek fact sheet was revised November 20, 2013, including the information about the commencement of incidental CO_2 storage (spring 2013), updating the number of natural gas processing plants worldwide, and using the term "incidental CO_2 storage" throughout.

On January 14, 2014, the incremental oil recovery information for Bell Creek was updated from 30 million barrels to 40–50 million barrels, and the fact sheet was revised.

In June 2014, the Bell Creek fact sheet was revised to include that the CO_2 also comes from LaBarge Field and to change "incidental" was changed to "associated" (www.undeerc.org/PCOR/co2sequestrationprojects/Downloads/Factsheet17.pdf).

Approval of the Aquistore project fact sheet (D94), prepared in collaboration with PTRC, was given in February 2014 (www.undeerc.org/PCOR/co2sequestrationprojects/Downloads/Factsheet18.pdf).

Revisions to the DOE Plains CO_2 Reduction Partnership—Development Phase – Large-Scale Field Tests fact sheet for distribution to the Peer Review panel were sent October 18, 2013 (www.netl.doe.gov/publications/factsheets/project/NT42592.pdf).

The Lignite fact sheet entitled "CO_2 Sequestration Test in a Deep, Unminable Lignite Seam" was submitted for approval on May 30, 2014 (www.undeerc.org/PCOR/newsandpubs/pdf/FactSheet10B.pdf).

A revised version of the Exclusive Documentary Series flyer was made in July 2014 to highlight upcoming documentaries, including the tentatively titled "Coal and the Modern Age" and "The Bell Creek Story." It also announced the release of the permanent downhole monitoring (PDM) technical training video and continued to highlight the five completed documentaries and the various awards they have received (cover page excerpt in Figure 10).

PowerPoint Presentations

PowerPoint presentations have been developed for Phase III general activities as well as for each of the demonstration projects and for targeted outreach to specific audiences (e.g., educators). In September 2012, DOE NETL approved that future updates to D18 (Bell Creek) and D19 (Fort Nelson) are no longer required as separate stand-alone presentations. Instead, we will continue to give a variety of presentations related to these projects and will report upon the presentations, including any updates, in the technology transfer section. As indicated above, 60 oral presentations were given in PY7, and the majority included information on the Bell Creek project as well as updates on the Fort Nelson project and other PCOR Partnership activities.

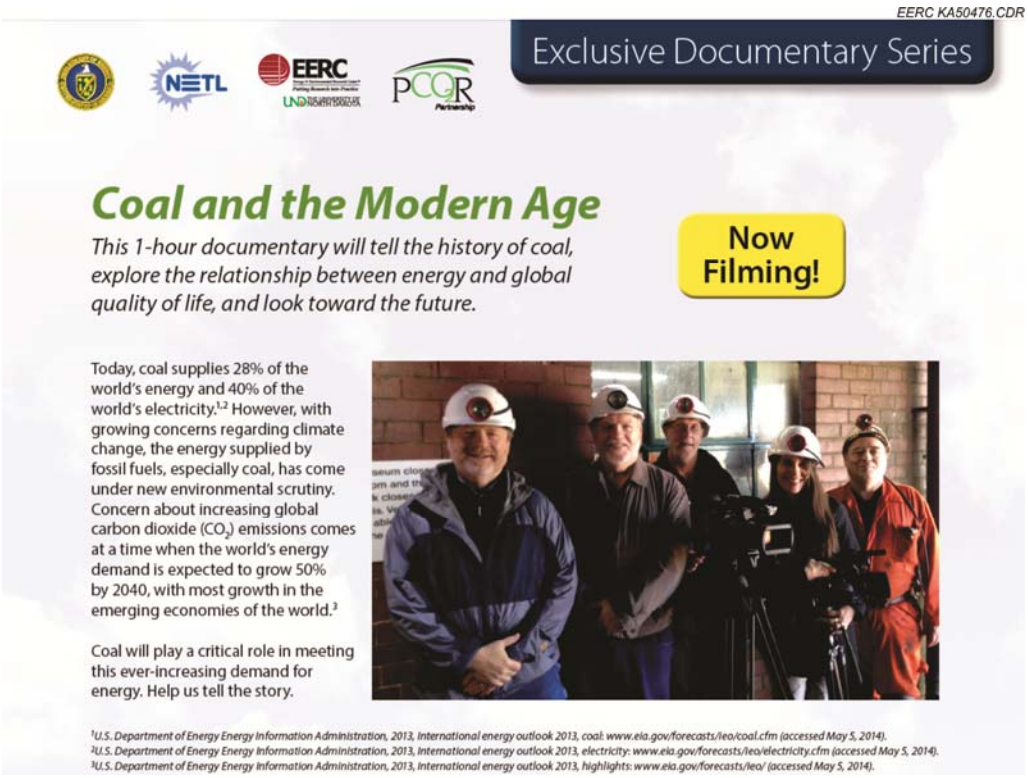


Figure 10. Cover-page excerpt from the updated Exclusive Documentary Series flyer used to highlight documentaries "in progress" and encourage participation.

The general Phase III information PowerPoint presentation (D17) was updated for general use in May 2014. This update included a new section related to energy, with 29 new slides, and 29 new slides covering a variety of CCS-related topics, e.g., the Bell Creek project, Aquistore, Zama, Basal Cambrian, wellbore integrity, and carbon management plans. This slide show serves as the basis for many of the general outreach presentations, including those given at teacher seminars.

Project-Related Outreach Activities

During PY7, outreach at Bell Creek included periodic telephone and personal contact with the eight landowners controlling access to the water wells and ponds in the water-monitoring program. In addition, written reports of sampling results were provided to each of these landowners after each of the two monitoring events (the report for the second event is currently in preparation).

Outreach Working Group

The RCSP Outreach Working Group (OWG), comprising representatives from each of the seven regional partnerships as well as ad hoc representatives from DOE, recognizes the importance of conducting public outreach in tandem with successful field tests. Its members pool their experiences and resources in an effort to provide a foundation for future commercialization

efforts and even more extensive outreach efforts. Based on contributions by the outreach leads of the seven regional partnerships, DOE NETL's outreach BPM entitled "Public Outreach and Education for Carbon Storage Projects" was released in December 2009.

Examples of the PCOR Partnership's participation in the OWG during PY7 include the following:

- Participated in eight (October 17, November 21, and December 19, 2013, and February 20, March 22, May 22, August 21, and September 18, 2014) monthly OWG conference calls and an in-person meeting held in conjunction with the 13th Annual Carbon Capture, Utilization, and Sequestration Conference (CCUS-13) in May. Topics discussed included Web-tracking protocols, the PDM video, and various conference presentations, posters, and papers.

- Participated in preparation of presentation materials for CCUS-13 held April 28 – May 1, 2014, in Pittsburgh, Pennsylvania. The RCSP OWG presented a session entitled "Discussion on CCS Education" held April 29, 2014.

- Participated in preparation of a paper and presentation for the 12th Greenhouse Gas Control Technologies Conference (GHGT-12) entitled "Digital Communications: Status and Potential Applications for CCUS Public Outreach" for the "Perceptions in CCS" session scheduled for October 9, 2014.

Posters

A general outreach poster (D24) was approved in March 2009. A complete redesign of this product was created in March 2014. This redesigned D24 poster features a general representation of the geologic columns associated with CO_2 injection into a saline reservoir and CO_2 injection for use in EOR and ultimate geologic storage underground. The poster is considered a valuable tool and was used as a booth backdrop at the 2014 PCOR Partnership Annual Membership Meeting in September 2014 in Denver, Colorado.

Documentaries and Video Products

A spectrum of video products is developed to meet the needs of general and site-level outreach. Broadcast-quality documentaries are produced in partnership with Prairie Public Broadcasting (PPB), are broadcast in the PPB market area, are made available to other public broadcasting markets for possible broadcast, are placed on the public Web site, and are available as DVDs. In January 2014, DOE NETL approved the creation of a new deliverable with the working title "Coal and the Modern Age," a 60-minute documentary that will be due January 2016. This documentary will replace the former D22 (Domestic Energy and Carbon 30-minute documentary, due May 2015) and D23 (Storage in Carbon Management 30-minute documentary, due April 2017). Changes to the SOPO (statement of project objectives) were approved via an award modification. Video segments and products are intended for stand-alone use in meetings, in PowerPoint presentations, and on public Web pages.

Bell Creek Project-Related Filming

The Bell Creek (D21) demonstration site documentary is due April 2016. Interviews with Denbury personnel and minor location filming remain to complete the production phase of the documentary. This work was deferred until adequate experience was gained at the site. As a result, no additional filming activities were conducted in PY7. However, a storyboard was prepared in PowerPoint outlining the proposed documentary, and this was presented to Denbury.

Coal in the Modern Age 60-minute Documentary Filming

As stated above, PY7 saw the authorization of a new 60-minute documentary by DOE NETL, and two overseas filming trips (Great Britain and Europe) were authorized and completed. On June 3–14, 2014, PCOR Partnership personnel and a PPB film crew traveled to Great Britain and captured 12 hours of footage; the schedule included visits to the National Mining Museum – Scotland; National Mining Museum – England; National Railway Museum; Bit Pit Coal Mine; Forncett Industrial Steam Museum; Bressingham Steam and Gardens; and interviews with Dr. Stuart Haszeldine (University of Edinburgh), John Gale (IEAGHG), and others.

On September 19–30, 2014, PCOR Partnership personnel and a PPB film crew traveled to France, Germany, the Netherlands, and Sweden and captured approximately 7.5 hours of footage; the schedule included footage of Rhine River traffic in Baden-Baden, Germany; general scenery; historic, working windmills in Schiedam and Kinderdjik (near Rotterdam), the Netherlands; a CO_2 geyser in Wallenborn, Germany; natural CO_2 springs at the Laakersee in Germany; equipment and restored facilities at the Zollverein Coal Mining Museum in Essen, Germany; open-pit coal mines and coal-fired power plants, Koln, Germany; solar and wind turbine sites; and interviews with Juho Lipponen (International Energy Agency), Christoph Oboton (Zollverein Coal Mining Museum), and Astrid Kandor (University of Lund, Sweden).

Plans are under way to coordinate another filming trip to China in spring 2015. Discussions have been held with personnel from the World Resources Institute to aid in scheduling and travel arrangements.

Aquistore Project-Related Filming

In response to an offer by the EERC as part of the Aquistore Project Communications Advisory Group, PTRC agreed to filming activities by PPB at the Aquistore site near Estevan, Saskatchewan, Canada, as well as interviews of project staff. As a result, several days (October 29 – November 1, 2012) were spent filming on location, capturing the installation of CO_2 soil gas samplers, water sampling, water well drilling, and completion of the second Aquistore well as well as interviews with personnel at PTRC, the International Test Center for CO_2 Capture, and the Saskatchewan Geological Survey.

A similar offer was made to SaskPower with respect to the Boundary Dam project. On March 28, 2013, PPB signed an agreement with SaskPower granting permission for PPB to film at the Boundary Dam site and conduct interviews as part of Aquistore outreach activities. On

October 23, 2013, a film crew traveled to the Boundary Dam power plant near Estevan, Saskatchewan, Canada, to film interviews and location footage of the plant and its CO_2 capture facility.

Educator-Related Video Production

In PY7, production continued on a four-part Carbon and Energy video series for use by educators. This video series combines multimedia, including PowerPoint presentations, filmed excerpts, and narration. Parts 1 and 2 were approved by management at the EERC, and Parts 3 and 4 will be completed in PY8.

YouTube Exposure

In an effort to expand the PCOR Partnership outreach initiative, 50 video clips and five full-length documentaries (currently available on the public Web site) were uploaded to the EERC's YouTube channel on April 1, 2014 (www.youtube.com/user/undeerc/videos?sort=dd&shelf_id=1&view=0). Table 6 provides a summary of the top five viewed video items.

Table 6. Top Five PCOR Partnership-Related YouTube Channel Videos Accessed

Video	Views	Est. Minutes Watched	Avg. View Duration
Reservoir Geology 101: Fluid in the Rocks	220	271	1.13
The Phases of Oil Recovery – So Far	178	400	2.14
Reforestation in Brazil	159	369	2.19
An Emerging Economy: Household Energy in India	158	410	2.35
Household Electricity and Carbon Footprint	130	274	2.06

Broadcast of Documentaries

In PY7, the PCOR Partnership received public television exposure from documentaries which were broadcast in four states and one Canadian province as listed in Table 7. A total of 50 broadcasts were aired, which is significantly higher than the 18 broadcasts in PY6 (however, it is lower than in PY5 [66], and PY4 [221]). The number of telecasts by documentary is as follows: "Out of the Air: Into the Soil" (10), Managing Carbon Dioxide: The Geological Solution (13) and "Global Energy and Carbon: Tracking our Footprint" (27). All three documentaries were aired in the PCOR Partnership region.

Table 7. State/Province Broadcasts

State/Province	Broadcasts
North Dakota	40
Manitoba[1]	40
Alaska	7
North Carolina	2
Texas	1

[1] The Canadian province of Manitoba is part of the same broadcast area as North Dakota.

Outreach to Teachers and Librarians

In PY7, the PCOR Partnership participated in four teacher training workshops and education conferences. These activities included introducing PCOR Partnership materials (DVDs, atlas, Web site awareness) to educators in K–12 schools as well as the dissemination of the materials to librarians in school, university, government, and public libraries. They included:

1. A 2-day science teacher conference presented by the North Dakota Science Teachers Association (presentation given, materials disseminated) held February 20–21, 2014, in Bismarck, North Dakota.

2. A 4-day coal-focused workshop presented by the North Dakota Lignite Energy Council (presentation given, materials disseminated) held June 17–20, 2014, in Bismarck, North Dakota.

3. A 2-day CCUS-focused teacher training institute (presentation given, materials disseminated) held June 24–25, 2014, in Moorhead, Minnesota.

4. A 2-day CCUS-focused workshop (presentation given, materials disseminated) held July 30–31, 2014, in Decatur, Illinois.

These activities reached a total of 168 teachers representing 81 different school districts in six states in the PCOR Partnership region. Compared to PY6, there were fewer teachers reached (168 versus 206 teachers), but more school districts (81 versus 75 districts). Thirteen of the PY7 teachers had previously heard a PCOR Partnership outreach presentation at a different workshop. Based on informal discussion during the workshops, teachers voiced interest in utilizing PCOR Partnership materials in their classroom. Figure 11 shows the geographic distribution of school districts having teachers who received materials.

Librarian contact took place at the North Dakota Library Association (NDLA) annual meeting. Materials were provided to 130 librarians from four states in the PCOR Partnership region. Figure 12 illustrates the library type and location of the participants. Potential audiences ranged from primary and secondary teachers and students, to university faculty, staff, and students, to public library patrons.

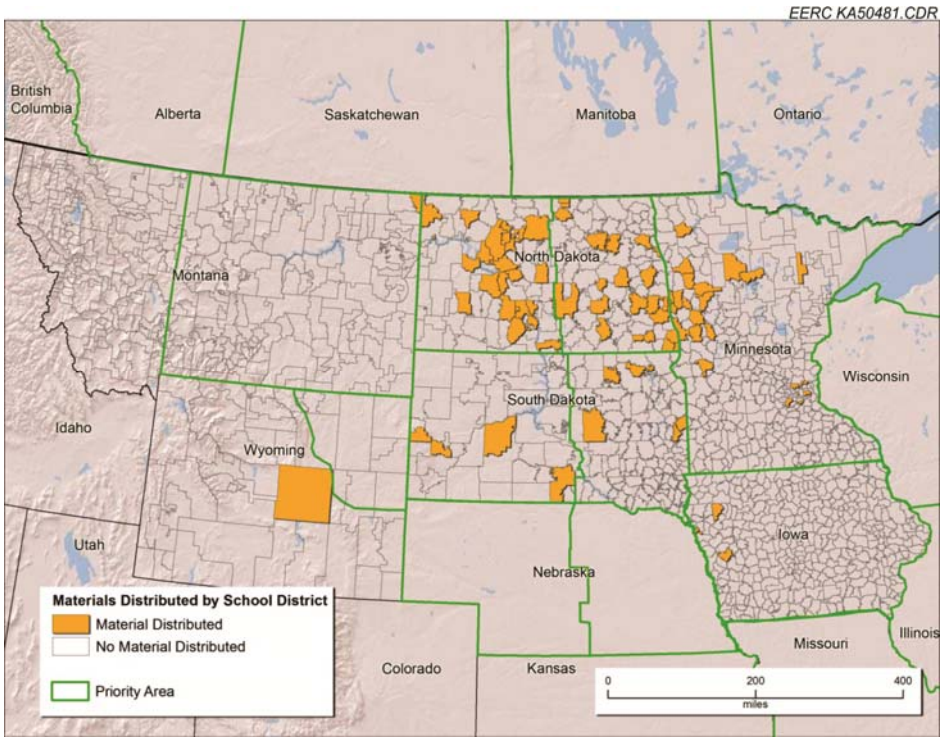


Figure 11. Distribution by school district of teachers who received outreach materials in PY7.

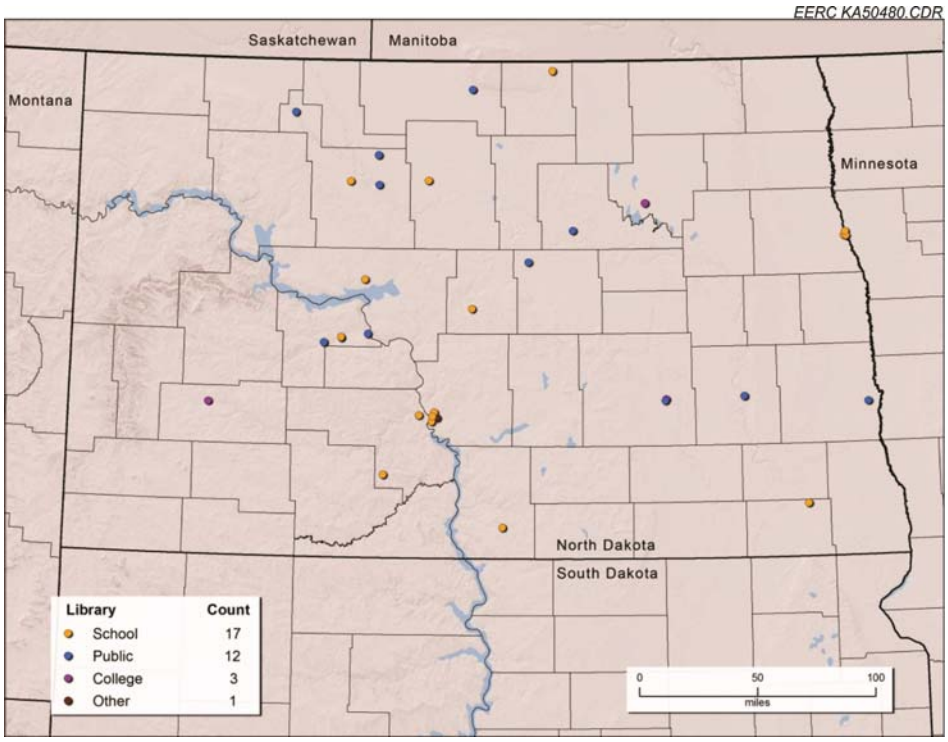


Figure 12. Distribution of public libraries, university libraries, school libraries, and other libraries that received PCOR Partnership materials in PY7.

Media Coverage

Media coverage is defined as articles related to the PCOR Partnership on television or radio networks or in newspapers and magazines, including both print and online news sources. The EERC tracks media coverage internationally utilizing a variety of clipping and news-gathering services. In addition, Google Alerts is used, which e-mails PCOR Partnership-related news retrieved from the Internet.

During PY7, no coverage on the PCOR Partnership was reported online, in newspaper articles, or by television or radio.

Task 3 – Permitting and NEPA Compliance

The overall goal of Task 3 is to advance the regulatory and permitting framework for CO_2 storage projects in North America as well as to assist the demonstration site owners as necessary in obtaining the permits and approvals needed for the projects to comply with state, provincial, and federal requirements.

Activities and Results

The PCOR Partnership continues to stay abreast of federal legislative actions occurring in the United States and Canada and follows the developments of various state, provincial, and regional initiatives. Internal documents that outline the activities of these groups are updated on a regular basis. Reviews continue of publications relating to the regulation of CO_2 sequestration, MVA issues, and carbon market developments. Updates are provided to task leaders with regard to federal, state, and provincial actions. In addition, the regulatory section on the DSS is updated regularly.

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) are detailed as follows.

General Permitting Assistance

The EERC interfaces with relevant regulatory agencies within the PCOR Partnership region as well as with federal regulatory agencies (United States and Canada) to understand the regulatory framework for project implementation. The EERC determines anticipated permitting activities for potential projects in all states and provinces of the PCOR Partnership region.

In PY7, the following regulatory-related items were reviewed:

- EPA's "Geologic Sequestration of Carbon Dioxide: Draft Underground Injection Control (UIC) Program Guidance on Transitioning Class II Wells to Class VI Wells." This document provides information regarding how Class II operations should be evaluated to determine if repermitting as Class VI wells is necessary and also discusses the Class VI requirements that apply to transitioning wells (http://water.epa.gov/type/groundwater/uic/class6/upload/epa816p13004.pdf).

- EPA's final rule conditionally excluding CO_2 streams in geologic sequestration activities from the Resource Conservation and Recovery Act (RCRA) requirements.

- Proposals by western U.S. states and Canadian provinces to align their GHG reduction targets.

- EPA's proposed rule for carbon emissions from existing stationary sources.

- DOE's FutureGen 2.0 Project Class VI permit applications.

- Activities and presentations related to the proposed International Organization for Standardization (ISO)/Technical Committee (TC) 265 Carbon Dioxide Capture, Transportation, and Geological Storage (www.iso.org/iso/iso_technical_committee?commid=648607).

Canadian Standards Association

In October 2012, the Canadian Standards Association (CSA) released a standard for geological storage of CO_2 entitled "Standard Z741-12 Geological Storage of Carbon Dioxide." The standard was developed by the CSA Technical Committee on Geological Storage of Carbon Dioxide, which was a joint Canada–U.S. technical committee. This committee included 38 individuals with a broad range of experience in government, academia, and the oil and gas industry.

The CSA standard can be considered to be comprehensive in that it provides detailed descriptions of practices and procedures for essentially all aspects of a CCS project. Specifically, the CSA standard provides guidance for what it considers to be the six key elements of a CCS project: 1) management systems; 2) site screening, selection, and characterization; 3) risk management; 4) well infrastructure development; 5) monitoring and verification; and 6) closure.

This standard, by itself, does not have the force of law unless it is officially adopted by a regulatory authority (6). However, it is possible that the CSA standard, in total or in part, could be adopted or referred to by regulatory authorities. With this in mind, the Fort Nelson CCS Feasibility project was compared to the CSA standard.

The EERC evaluation compared preinjection work completed by the EERC and Spectra for the Fort Nelson project to select required specifications presented in Sections 5.3, 5.4, 5.5, 8.3, and 8.4 of the CSA standard. Each required specification was highlighted according to a color code that indicates where the Fort Nelson project clearly complies with the draft standard, where it clearly does not comply, where it may comply after clarification or moderate expansion, and where it is out of the scope of the preinjection program. (7)

Sixth Annual PCOR Partnership Regulatory Meeting

The 2009 regulatory meeting looked at the regulatory regime associated with subsurface injection of CO_2. At the meeting held in 2010, there was an effort to embrace a larger community

by also addressing pipelines and focusing on the efficient movement of CO_2 throughout the region. A continuing goal of the meetings in 2011–2014 was to continue to develop strategies to work past state/provincial boundaries.

Eleven people attended the 2014 meeting, including regulators from North Dakota, Alberta, Canada, and five representatives from the EERC. Also present were representatives of IOGCC; Melzer Consulting; The CETER Group; and Premier Oil Recovery, LLC (Figure 13).

Figure 13. Attendees at the 6th Annual Regulatory Roundup held June 24 and 25, 2014, in Deadwood, South Dakota (not pictured: Kevin Connors, North Dakota Industrial Commission [NDIC]).

Presentations were given on the following topics:

- PCOR Partnership Update
- RCSP Water Working Group Overview
- IOGCC and PCOR Partnership Phase III Project
- IOGCC Update
- Provincial/State CCS Updates
- National EOR Initiative Update
- Federal Update – Status/Potential Concerns

Interstate Oil and Gas Compact Commission

IOGCC is a multistate government agency that promotes the conservation and efficient recovery of domestic oil and natural gas resources while protecting health, safety, and the environment. The PCOR Partnership participates in IOGCC activities. In fact, John Harju is a past chair of IOGCC's Energy Resources, Research, and Technology Committee and serves on the CGS Task Force.

EERC staff members participated in the following IOGCC meetings in PY7:

- Attended the IOGCC Annual Meeting held November 4–6, 2013, in Long Beach, California, where the chair of the CGS Task Force presented "CO_2 Phase III: Guidelines for States & Provinces on Operational and Postoperational Liabilities."

- Attended the IOGCC Midyear Meeting held May 18–20, 2014, in Biloxi, Mississippi, at the request of the state of North Dakota, and provided an update on the NDIC Department of Mineral Resources (DMR) Oil and Gas Division's (OGD's) Class VI primacy application to the EPA–IOGCC Memorandum of Understanding (MOU) Committee.

IOGCC CGS Task Force Activities

Through the efforts of the IOGCC CGS Task Force, the PCOR Partnership addressed issues relating to liability (operational and postoperational) that remain as barriers to the establishment of state and federal legal and regulatory frameworks for CCUS. Clarification of attendant liability issues will remove significant barriers to CCUS deployment and thus provide prospective CCUS project developers with greater regulatory certainty, a necessary prerequisite for CCUS project development to move forward. Findings, recommendations, and guidance were developed. IOGCC will communicate the CGS Task Force output to the public, along with state and local elected and administrative officials, industry representatives, prospective CCUS project operators and financiers, and other stakeholders through an outreach and awareness effort. The period of performance for this subtask is July 1, 2012 – March 30, 2014.

- Prepared an abstract entitled "Guidance for States and Provinces on Operational and Postoperational Liability in the Regulation of Carbon Geologic Storage" for submittal to GHGT-12.

- Worked with IOGCC on the development of a fact sheet based on the joint report entitled "Guidance for States and Provinces on Operational and Regulation of Carbon Geologic Storage."

- Held discussions with IOGCC and NDIC personnel regarding publication of and fact sheets associated with the operational and postoperational liability report.

Guidance for States and Provinces on Operational and Postoperational Liability

This report (Figure 14), published in September 2014, is the product of the IOGCC CGS Task Force. It represents the work product of the IOGCC CGS Task Force in its fourth iteration since formation in 2002. With this writing, the Task Force now has produced reports in each of the three phases of DOE's RCSP Program. Taken together, all of the reports in 2005, 2007, 2010, and now 2013 constitute IOGCC guidance to U.S. states and Canadian provinces on the formation of legal and regulatory frameworks for the storage of CO_2 in non-hydrocarbon-bearing geologic formations.

This Phase III effort of the Task Force, of which this report is the primary component, began in July 2012. Under the terms of the agreement with DOE and its NETL through the PCOR Partnership, the IOGCC Task Force focuses upon issues of liability in all of the phases of a CGS project related to CGS in non-hydrocarbon-bearing formations. It does not, except cursorily, address CGS in the context of EOR.

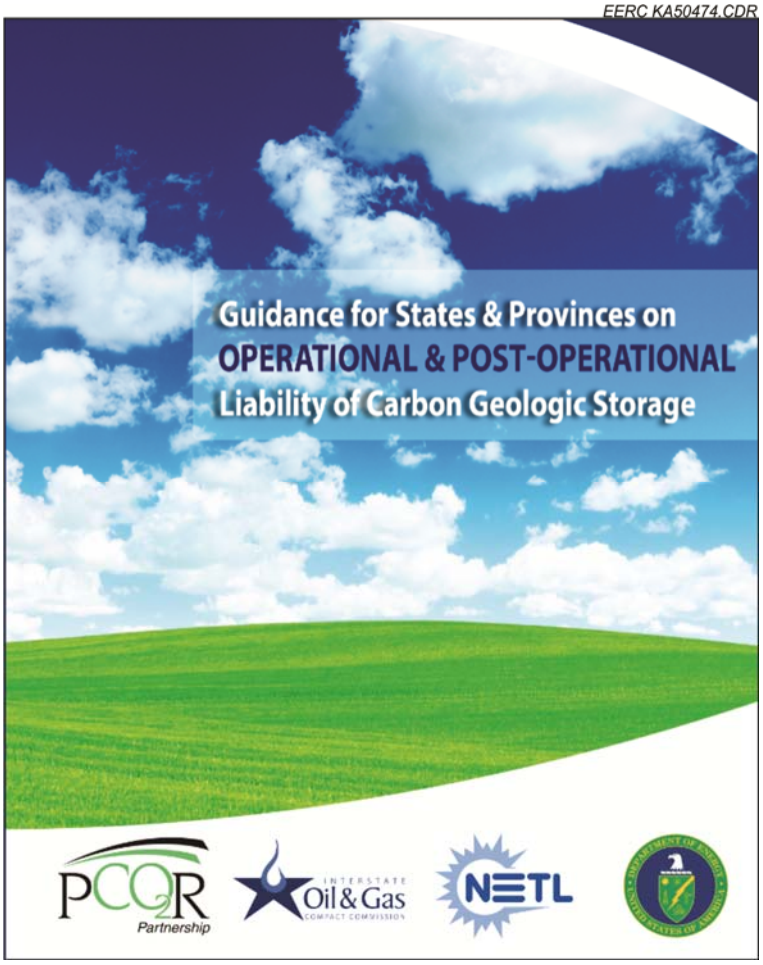


Figure 14. The final report prepared by the IOGCC Task Force on Carbon Geologic Storage is available free of charge online at http://iogcc.ok.gov/Websites/iogcc/images/CO2_phase_III_guidelines_FINAL.pdf (accessed December 2014).

In this report, the Task Force discusses liability broadly under federal, state or provincial, and common law, from the perspective of the state or provincial regulator of CGS. The most relevant of these liability concerns likely are to be those liabilities that arise out of the state or provincial and, in the United States, federal laws that deal directly with CGS.

Since the last IOGCC guidance in 2010, EPA promulgated regulations (Class VI) under the Safe Drinking Water Act (SDWA) and its UIC Program to govern CGS. Addressed in detail in the body of this report, the new EPA regulations address many but not all aspects of a CGS project.

To better illustrate the divisions in federal/state regulation and jurisdiction within a CGS project, the Task Force did two things in this report. First, it posited a CGS project as being comprised of five phases: (I) exploratory; (II) permitting (prestorage); (III) storage (operational); (IV) closure; and (V) postclosure. Five phases rather than the four identified in previous IOGCC Task Force guidance better capture the limited federal jurisdiction under SDWA.

Second, the Task Force produced a CGS Project Framework and Risk Analysis. The analysis, by activity over the five phases of a CGS project, identifies the risks posed by each activity, the regulatory jurisdiction (federal or state) over the activity, and the recommended financial assurance (FA) to cover the regulatory risks of the activity. In the report, the Task Force discusses FA and the various mechanisms available to the states to protect their interests related to a CGS project.

One of the major conclusions of this report is that in the United States, states must play a significant, leading role in the regulation of CGS. EPA jurisdiction does not cover all of the states' regulatory interests in a CGS project (This conclusion is not relevant to Canadian provinces as there is no comparable provincial–federal regulatory overlap in Canada). The EPA regulatory mandate under SDWA begins and ends with the protection of underground sources of drinking water. The report will discuss how state interests extend well beyond this important but limited mandate. Those state interests include protecting the state from associated liability from what would otherwise be nonregulated CGS-related activity under the UIC Class VI rule.

In addition to the recommendation that states play a regulatory role alongside EPA in regulation of CGS, the Task Force encourages states to secure Class VI "primacy" jurisdiction from EPA. By securing Class VI primacy, a state concurrently will exercise both its regulatory jurisdiction and the federal SDWA regulatory jurisdiction (SDWA allows a state to be granted primacy if it meets certain conditions set forth in the act).

The Task Force concluded that in order to facilitate the orderly development of CO_2 storage projects within state and provincial boundaries, a state or province should embrace two basic principles enumerated in previous Task Force efforts: 1) that it is in the public interest to promote the geologic storage of CO_2 in order to reduce anthropogenic CO_2 emissions and 2) that the pore space of the state or province should be regulated and managed as a resource under a resource management framework. This should be done by the state or province prior to storage occurring within the state or province.

In this report, the Task Force once again recommends, as it did in 2007 and 2010, that states and provinces are best situated to assume responsibility for the "caretaking" (monitoring and maintenance) responsibility in the final postclosure (long-term storage) phase of a CGS project when that project has been deemed to have stabilized (8).

Development of a Permitting Action Plan – Bell Creek Test Site

The EERC is required to develop a permitting action plan in conjunction with the site owner in accordance with relevant local, state, and federal regulatory requirements for the Bell Creek project. D29, permitting action plan, was completed in August 2011. Because permitting for the Bell Creek project has been secured by the site owner and operator, Denbury, there is no need for the EERC to prepare an update to the permitting action plan. Accordingly, in September 2014, DOE NETL approved a request to adjust the scope of D76, BPM – Permitting, due September 2017. Instead, D76 will now be called "Regional Regulatory Perspective" and will be due August 2017.

Fort Nelson Test Site

Legislative and regulatory actions by the province of British Columbia are continually followed for the effect they may have on the Fort Nelson demonstration project. For example, in PY7, British Columbia's proposal to update its Water Act with the new Water Sustainability Act was reviewed.

Plug and Abandon Wells and Land Reclamation of Lignite Project Site

Reclamation of the lignite site is nearly complete. The five wells on the site were plugged and abandoned in September of 2011, and the site reclamation commenced and an electric fence was erected around the site 2 months later in November 2011. By May 2012, grass and other vegetation started to take root, and by September of that year, while some small areas were still bare, much of the lignite site saw grass and other vegetation up to 3 feet in height. By June 2013, with the electric fence removed, it was difficult to determine where the surrounding pasture began, and the reclamation site should be completed in spring 2015.

Site reclamation activities, with weed spraying and fence maintenance responsibilities, continued during this reporting period. Eight site visits occurred during PY7 (compared to 17 in PY6) on the following dates:

- October 12 and November 29, 2013.
- January 23, February 26, March 24, May 20, June 16, and July 16, 2014.

Lignite Field Validation Test Site Closure Report

In October 2013, the finishing touches were put on a value-added report that details the procedures used to close a carbon storage pilot field test that was conducted in 2009–2011 in Burke County, North Dakota, and included the injection of CO_2 into a 10-foot-thick seam of lignite at a depth of 1100 ft. The report is intended to provide an understanding of industrial

procedures that are conducive to securing an environmentally sound project conclusion. The EERC coordinated the plugging and abandonment (P&A) of five wells on a quarter section of land owned by the North Dakota State Land Department (NDSLD). The procedure was conducted according to rules administered by DMR. Requirements for reclamation of the land also include a combination of rules set forth by both DMR and NDSLD. The conclusion of site closure is the reclamation of the land to its original contour, cementing of the wells, and reseeding of native vegetation.

Various aspects of site closure are paramount. Notable highlights include the following:

- Communication of state requirements to service companies during bidding, contracting, and job execution.

- Coordination with inspectors during job execution.

- Coordination with surface owners regarding appropriate reclamation.

Additional Conference/Meeting Participation

- Participated on October 8, 2013, in a North America 2050 Sequestration Working Group Webinar – Demonstrating Carbon Storage.

- Attended the NDIC hearing held November 13, 2013, in Grand Forks, where the petition of an energy company for unitized management, operation, and further development was heard.

- Attended the SECARB (Southeast Regional Carbon Sequestration Partnership) 9th Annual Stakeholders' Briefing March 4 and 5, 2014, in Atlanta, Georgia. A link to the agenda is at www.secarbon.org/wp-content/uploads/2011/05/2014_030414_ Agenda4.pdf.

- Participated on January 29, 2014, in the Enhanced Oil Recovery Institute's Webinar entitled "Avoid Air-rors! Discuss the Air Regulations That Impact Oil and Gas Development."

- On April 30, 2014, participated in the EPA UIC Financial Responsibility Implementation Training Webinar.

- On May 8, 2014, participated in the C2ES (Center for Climate and Energy Solutions) Webinar series entitled "Water for Energy and Energy for Water: An Overview of Water/Energy Issues from National and Federal Perspectives" (www.c2es.org/science-impacts/adaptation/water-energy-webinar-series).

Task 4 – Site Characterization and Modeling

This task involves selecting the two field-based large-scale demonstration sites and developing baseline characterization data and petrophysical models for such sites. The Bell Creek demonstration site work is continuing, but the Fort Nelson demonstration site work under Task 4 has been completed.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) are described as follows.

Fort Nelson Demonstration Site

The primary objective of the Fort Nelson project is to verify and validate the concept of utilizing one of North America's numerous saline formations for large-scale CO_2 injection, proposed to be up to 2 million metric tons a year of anthropogenic CO_2 for permanent storage. In September 2014, this subtask was completed. Activities completed in PY7 are listed below.

Fort Nelson Test Site – Site Characterization Report

Key findings of the characterization activities to date include the following:

- The Sulphur Point and Keg River Formations appear to have adequate storage- and injectivity-related properties to serve as primary sinks.
- The Fort Simpson and Muskwa Formations appear to have the tightness, competency, thickness, and lateral continuity necessary to be the primary seals.
- Evidence suggests the Slave Point, Sulphur Point, and Keg River Formations are in hydraulic communication (laterally and vertically) with each other.
- Surface, shallow subsurface, and deep subsurface characterization data are limited because of the remote, inaccessible nature of the Fort Nelson area and because of the lack of producer wells in the area being considered for CO_2 storage.
- The storage capacity of the Presqu'ile reef complex in the Fort Nelson area has been estimated to range from 100 to over 240 million metric tons of CO_2.

It was anticipated that future characterization activities would include drilling and testing of a new exploratory well, collecting new seismic survey data, and conducting laboratory-based geochemical and geomechanical investigations. However, because Spectra decided not to pursue these events, no additional characterization activities occurred in PY7. This report was finalized in PY7 (9).

Fort Nelson – Preliminary Geochemical Observations

A screening-level geochemical laboratory test program was conducted (2009–2011) at the EERC to investigate the theorized and potential effects of the injection of 100% CO_2 and sour CO_2 (i.e., a mixture of CO_2 and H_2S ranging from 86.5% CO_2 and 13.5% H_2S to 95% CO_2 and 5% H_2S) on the cap rock, transition-zone rock, and reservoir rock from Spectra's Fort Nelson CCS Project in northeastern British Columbia, Canada. The primary goals of this program were as follows:

- Identify the predominant mineral phases of the potential sink and seal formations.

- Determine possible interactions and mineralogical changes within the cap rock, transition-zone rock, and reservoir rock when exposed to CO_2 and sour CO_2 at near- and far-from-wellbore reservoir conditions.

- Determine the mineral dissolution and precipitation potential resulting from the exposure of the cap rock, transition-zone rock, and reservoir rock to CO_2 and sour CO_2.

- Determine potential changes in reservoir fluid properties as a result of CO_2 and sour CO_2 injection into the geologic storage reservoir(s).

Baseline and postexposure mineralogical and petrophysical characterization data were obtained using XRD, x-ray fluorescence, SEM, and inductively coupled plasma–mass spectrometry techniques. Exposure tests using CO_2, sour CO_2, and brine were conducted under three sets of pressure and temperature conditions to represent the conditions of the reservoir from the near wellbore to the edge of the CO_2 plume.

Interpretation of the results may be limited by the uncertainty of provenance associated with drill cuttings, the potential for cuttings to be contaminated with drill-related impurities and cuttings from above formations, and the difficulty in applying results from static batch experiments to dynamic reservoir systems. With these caveats in mind, the following data trends and observations can be made:

- No significant changes in mineralogy were observed in the cap rock, transition-zone rock, or reservoir rock during exposure to either pure CO_2 or sour CO_2 at any of the reservoir conditions that were investigated. However, minor shifts in chemical composition were observed that suggest dolomite dissolution and calcite and sulfur precipitation may occur at both the near-wellbore and far-from-wellbore conditions.

- Although counterintuitive, in the Fort Simpson shale, the sour CO_2 mixture is likely less reactive geochemically than pure CO_2, as the dissolution of pyrite is enhanced by the presence of CO_2, and the presence of H_2S possibly inhibits the dissolution of pyrite.

- Exposure of carbonate formation rock to pure CO_2, as compared to sour CO_2, may result in a higher probability of dissolving natural cementing material (e.g., calcite, gypsum, and pyrite) and mobilizing iron from the clay and carbonate mineral matrix.

- Based on the samples available for this study, potential for calcite and calcium chloride precipitation appears to be minimal and on the order of less than 1 wt%. The significance of these precipitation reactions on reservoir injectivity for other formations should be investigated further.

- The chemistry of the reservoir fluid is important. Analysis of the synthesized brine showed little-to-no effect when exposed to high-pressure CO_2, whereas the synthetic brine showed increased calcium and magnesium concentrations.

Overall, the results of this screening geochemical study suggest that adequately understanding dissolution and precipitation reactions will require further investigation through a series of more detailed, targeted geochemical and geomechanical investigations (10). This report was finalized in PY7, and this subtask is now complete.

Bell Creek Demonstration Site

The Bell Creek oil field in southeastern Montana has been identified as a PCOR Partnership Phase III demonstration site. Detailed subsurface mapping and characterization are being conducted in advance of a large-scale study of CO_2 storage associated with CO_2 injection for EOR. Site characterization activities will be conducted to develop predictive models that address three critical issues to determine the ultimate effectiveness of the target formation: 1) the capacity of the target formation, in this case, an oil reservoir within an established oil field; 2) the mobility and fate of the CO_2 at near-, intermediate-, and long-term time frames; and 3) the potential for out-of-zone migration of the injected CO_2 outside of the field or into overlying formations and/or the surface environment. Key site characterization parameters that are being addressed include properties of the reservoir and seal rocks, properties of the fluids in the reservoir and overlying fluid-bearing formations, and the production and operational history of the target oil reservoir.

In-House Project Update Meetings

In an effort to keep the EERC project management team updated and coordinate activities, in-house meetings were scheduled on the following dates: December 4, 2013, and January 30, March 20, and May 7, 2014. At these meetings, action items were reviewed, deliverables and reports were discussed, and project updates were given.

Bell Creek Test Site Baseline Geology Determination

3-D Seismic Acquisition and Characterization Report

A technical team that includes Denbury, the EERC, and others are conducting activities to determine the baseline reservoir characteristics for development of a geologic model for predictive simulations and to serve as a comparison to time-lapse data as they are acquired. One of the activities was the acquisition and interpretation of a baseline 3-D surface seismic survey acquired over a major portion of the field, which is the subject of this report. The interpretation will be used to advance the field characterization effort. The geophysical data will be integrated

with the EERC's geologic model to improve its accuracy. In the future, when paired with at least one subsequent 3-D surface seismic survey, the data difference will provide a direct indication of where the CO_2 has migrated within the reservoir and aid in MVA goals.

The EERC has been involved with every stage of the seismic source testing, data acquisition, and data processing to date. A seismic source configuration consisting of two heavy vibrators operated in tandem was chosen after a series of tests conducted in August and December 2011. The data acquisition for the main survey occurred in August and September 2012. The data were processed by a contractor in Houston and delivered to Denbury early in 2013. The EERC received a stacked data set in April, with redactions where Denbury did not have mineral rights or leases.

Seismic interpretation efforts began with making well ties to the data and identifying the Bell Creek reservoir reflector. The polarity of the data set was established to be such that an increase in acoustic impedance (AI) would cause a negative deflection on the data. The reservoir is thin and of higher AI than the encasing shale layers, so with this polarity, it presents on the seismic data as a trough–peak combination representing the entering and exiting reflections at a two-way time of ~1150 msec at the 05-06 OW monitoring well location.

The origin of the reservoir reflection is due to a large increase in AI at the top of the Springen Ranch and a similar decrease in AI at the top of the Skull Creek. The measured thickness of the Springen Ranch-to-Skull Creek interval in the field varies from about 50 to 75 feet. Spectral analysis of data in the zone of interest reveals a bandwidth of 10–48 Hz, which together with the average interval velocity mathematically limits the vertical resolution of the seismic data at reservoir depth to just under 60 feet. Therefore, the reservoir is a thin-bed reflector with thickness near or below the limit of resolution. A reflector of this type would be expected to exhibit possible tuning effects, but they are not evident.

Tuning is an effect that occurs on thin beds when the top and bottom reflections interact to partially add in a phase, resulting in high reflection amplitudes. An important assumption is that the interval is lithologically homogeneous. The tuning thickness for these data's bandwidth is 6 feet, so high amplitudes would be expected in thicker Springen Ranch-to-Skull Creek sections and lower amplitudes expected where the interval is thinner. The data exhibit the opposite character. This implies a nonhomogeneous interval where internal interactions due to lithology affect the composite reflection amplitude. The character of the Bell Creek sand meaningfully contributes to this effect.

The Bell Creek reservoir sand is a subset of the reflection interval. Typically 20 to 30 feet thick, its top and bottom cannot be directly resolved on the seismic data set as delivered. When the sand is thick and clean and juxtaposed against the harder, fine-grained components of the Springen Ranch at the top and the Rozet below, these impedance contrasts internal to the overall composite reflection appear to cause interference effects which result in a low-amplitude reflection. When the sand is thinner or fines upward with less AI contrast, less internal interference results, and the composite reflection maintains a higher amplitude. Because of this, a map of seismic amplitudes generated from the reservoir reflection differentiates between areas of 1) thick, clean sand and 2) thinner, clean sand or sand with a fine-grained component or shaley

matrix. The effect is illustrated in cross sections paired with well logs and also by overlaying the map on existing isopach maps of sand, with good agreement.

Several geologic features are visible on the amplitude map and are briefly examined in cross section with the seismic data and well logs:

1. A fluvial channel feature in the northern part of the field, trending roughly north–south, has a higher amplitude than surrounding areas and is shown to be shale-filled and acts as a flow boundary.

2. A flow boundary between Phases 1 and 2 is also shown to be shale-filled and is a possible extension of the fluvial channel feature to the north.

3. A linear erosional valley trending northwest–southeast which predates the fluvial channel feature and serves as a flow boundary between Phases 1 and 3 and between Phases 2 and 4. The fill at the erosional surface is characterized by coal and bentonitic shales.

4. An erosional valley on the south end of the field which exhibits a dendritic outline. The fill at the erosional surface is characterized by coal and bentonitic shales.

Three structural aspects of the field were briefly explored:

1. Thinning of the Bell Creek sand which forms the updip boundary and trap to the southeast is not directly discernible on the seismic data.

2. Polygonal faulting is shown to be prevalent within the overlying Belle Fourche Formation. The faults are thought to originate from dewatering of thick bentonite layers at the bottom of the Belle Fourche and top of the Mowry. Faults do not extend below the top of the Mowry or above the Belle Fourche and likely do not impact the containment integrity of the reservoir.

3. A possible basement faulting system thought to control the southwest to northeast trend of the reservoir paleo-high was identified and is shown on a section.

Future work will include integrating the 3-D data and interpretation with the geocellular model and 3-D VSP data acquired in 2013 and 2014. Geomechanical properties will be computed across the field, guided by the seismic data. Future time-lapse surface seismic data will use the baseline survey to generate difference displays to image and verify the progress of CO_2 that has been injected into the reservoir. Modeling performed by Denbury has shown that injected CO_2 will induce a detectable amplitude reduction on the reservoir reflection at the current bandwidth (11). This report is currently under review by Denbury and has not yet been finalized.

First 3-D VSP Repeat Surveys Completed

The first 3-D VSP repeat survey at the Bell Creek oil field was conducted from Saturday, March 1, 2014, through Tuesday, March 4, 2014. Data were collected from 83 shot points utilizing a 60-level retrievable geophone array deployed in the 05-06 OW well and a 50-level permanent geophone array installed in the 04-03 OW well.

The first repeat VSP acquisition was conducted to demonstrate that CO_2 is visible at the reservoir reflector in order to guide future monitoring efforts, including a potential subsequent repeat VSP survey and a repeat 3-D surface seismic survey.

Because of an unexpected incident that occurred during the first day of acquisition, the first full-repeat VSP survey was suspended indefinitely pending the results of seismic processing. In total, 83 of the anticipated 930 shot points were recorded. Should processing demonstrate the ability to image and or detect CO_2 at the reservoir level, a subsequent VSP acquisition (at either the 04-03 OW well or both wells) would be evaluated. Timing of a subsequent survey is contingent on local landowner access, weather conditions, permit restrictions, and budget constraints, with July 2014 being a likely target. Evolving reservoir conditions due to active large-scale CO_2 injection necessitate that any additional VSP work be considered, acquired, and processed as a subsequent VSP repeat (12).

Subsequent processing of the 83 repeat VSP shots indicated a high probability of identifying the presence of CO_2 in the reservoir. Based on the positive results, subsequent planning meetings and discussions with Denbury and the PCOR Partnership's DOE project manager began to determine the scope and budget for any subsequent repeat VSP efforts.

First Full-Repeat of PNL Campaign Completed

The first full repeat of the PNL logging campaign, run from August 2013 to January 2014, covers seven wells which also have a baseline set of logs for comparison before and after the CO_2 injection has commenced. The seven wells comprise one monitoring well (05-06 OW), three active production wells (04-04, 33-12, 56-08), and three active injection wells (05-01, 05-05, 05-07) all within the Phase 1 development area (Figure 15).

Because of the nature of how the sigma curve is measured, sigma values should generally decrease in the presence of increasing amounts of CO_2 near the wellbore. Initially, the injection wells will show more of a change than the production wells as the near-wellbore environment will be heavily saturated with CO_2 as it begins to penetrate the reservoir through wellbore perforations. Breakthrough of CO_2 will eventually occur at nearby production wells, at first through zones of high transmissibility, then through zones of lesser transmissibility. The results will show decreasing sigma values over the reservoir zone with the presence of CO_2 when the repeat logs are directly compared to the baseline logs.

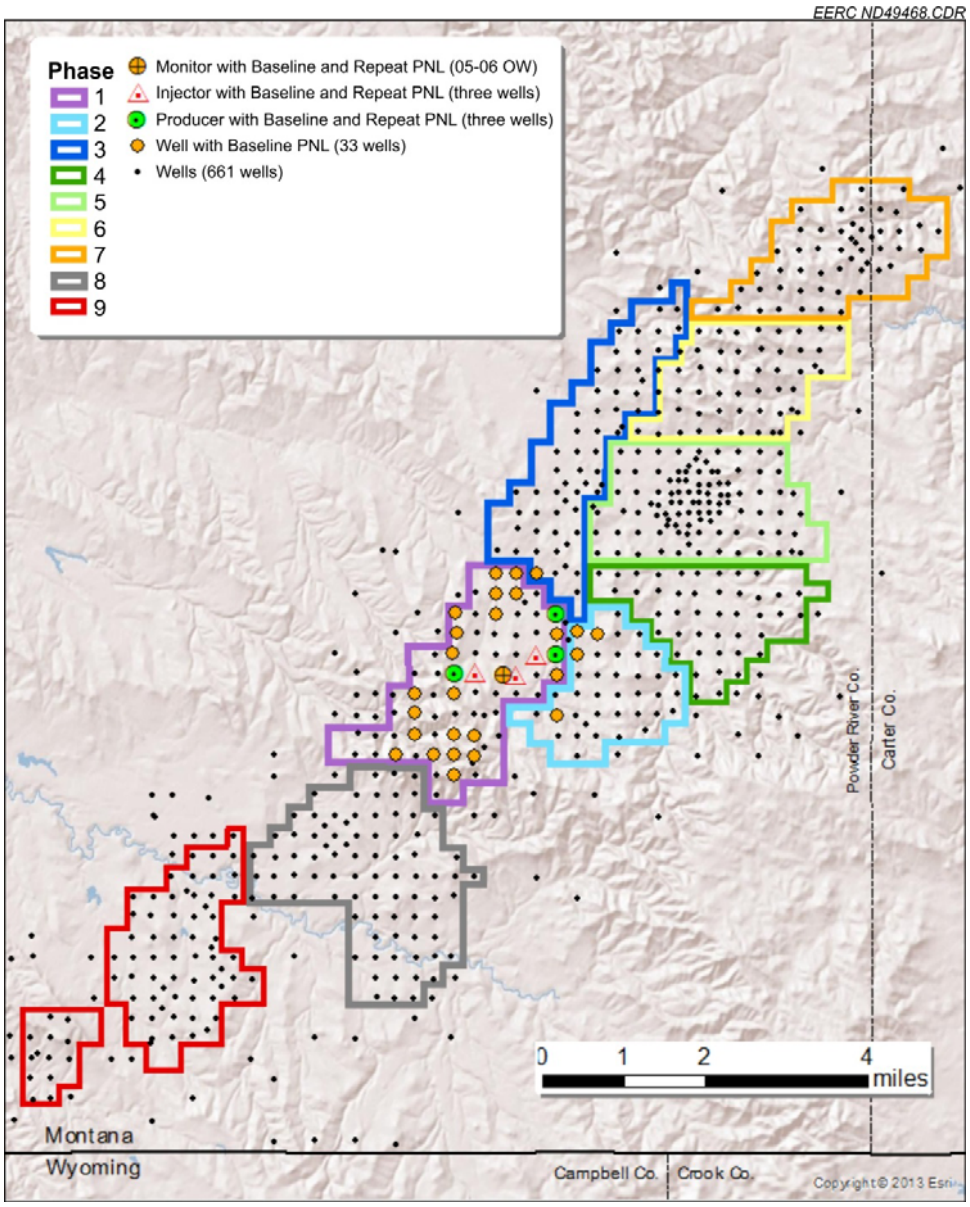


Figure 15. Map of wells showing where baseline and repeat PNLs were collected in relation to the Bell Creek oil field.

With the exception of the monitoring well, which has not yet come into contact with injected CO_2, repeat sigma values are indeed lower than their respective baseline measurements. For the injection wells, sigma values in the repeat logs are 6 to 9 units less than what is measured in the baseline logs, indicating the presence of CO_2. The production wells show a slight decrease 1 to 4 units less than the baseline measurements, indicating initial breakthrough in the high-transmissibility zones but overall lower CO_2 saturations than the injection wells, as is expected. These zones correlate with the cleanest sand in the Muddy Formation (according to the gamma ray curve).

The EERC is currently reviewing the steps used to post-process PNLs on all three types of wells (monitoring, injection, and production) in order to better understand fluid saturation changes in the reservoir. Efforts are being made to understand whether or not these trends will be seen in other wells and how PNL data can be correlated to other MVA-derived data such as 3-D seismic surveys and history-matched 3-D geocellular models. Once a full review of the baseline and first full-repeat logs is satisfied, a decision will be made on continuing the PNL campaign (13).

Best Practices Manual – Site Characterization

A BPM for characterizing oil fields for CO_2 storage (D35) was scheduled for completion by September 30, 2014. However, upon discussion with the DOE NETL project manager, it was decided to expand the number of technical BPMs that would be prepared and establish and/or adjust due dates. As such, the BPM for Bell Creek site characterization has been delayed until August 31, 2015. Accordingly, Subtask 2.3 of the SOPO will be extended to the end of BP4 or September 30, 2015.

Petrophysical Evaluations for the Bell Creek Test Site

Full-diameter core was collected from 05-06 OW starting on December 21, 2011. Standard core analysis and special core analysis (SCAL) are being performed and utilized to supplement and update modeling efforts.

In March 2013, the EERC provided on-site technical advice during the collection of horizontal sidewall cores at the 56-14R well. Samples were cut (for thin-section preparation) from the 23 sidewall cores collected, and the EERC photographed, weighed, and measured the core plugs. In April 2013, the EERC provided on-site technical advice during the collection of full-diameter core at the 33-14R well. Additional petrophysical activities were performed for both sets of core in PY7 and are anticipated to be completed in PY8.

Petrophysical Assessment of USGS Core Samples

As part of the characterization efforts for the Bell Creek oil field, 81 core samples of the Muddy and Mowry Formations from 21 wells were selected from the USGS CRC in Denver, Colorado, and analyzed by the EERC's AGL. The samples consist of core pieces and plugs. The samples were characterized in detail for several rock properties, such as compositional mineralogy, bulk mineralogy, grain size, porosity, permeability, pore volume, clay type, bulk chemistry, diagenetic features, and biological characteristics. The goal of this characterization activity is to achieve a better understanding of the petrographic and petrophysical properties of the Mowry and Muddy Formations in and around the Bell Creek oil field.

Samples have been classified into five informal sequences of the Muddy and Mowry Formations according to the current field operator's designation: the Shell Creek and Springen Ranch sequences of the Mowry Formation and the Coastal Plain, Bell Creek sand, and Rozet sequences of the Muddy Formation. High-porosity sand predominates the majority of the Bell Creek sand samples; however, varying amounts of clay and/or siderite pore lining/filling were observed in several samples. In addition, a low-porosity, calcite-rich zone was consistently

identified in several wells. The samples from the Springen Ranch and Coastal Plain sequences are predominantly siltstone units with high concentrations of clay, siderite, pyrite, and/or microcrystalline quartz. Coastal Plain samples tended to be more varied, with cross-bedded and interfingering layers of low-porosity siltstone and higher-porosity sands. Siderite and pyrite are both important diagenetic features of the Bell Creek samples reported. However, their implications, fluid flow, and geochemical stability within the reservoir during the CO_2 flood have not been assessed for this report. Further characterization work may be necessary to understand the impact to flow throughout the field within these lower-porosity facies as well as zones of restricted porosity in the Muddy Formation (14). A value-added report was finalized in November 2013.

CO_2 Exposure Studies

The EERC conducted a complementary laboratory study to investigate potential CO_2–rock interactions. The goal of that effort was to provide geochemical and mineralogical data sets and develop an understanding of mineral dissolution/precipitation trends as well as groundwater chemistry changes as a result of interaction of CO_2 with the groundwater zone overlying the Bell Creek oil and gas reservoir.

The laboratory experiments were designed to expose Hell Creek groundwater to CO_2 at relevant temperatures and pressures. The results of the batch experiment testing provided information and semiquantitative data on potential mineralogical dissolution and/or precipitation reactions in the formation rock following exposure to CO_2. Groundwater samples were collected during the June 2012 sampling event. Drill cuttings from the 05-06 OW observation well and groundwater samples collected from wells drilled at depths approximately corresponding to the drill cuttings were utilized for testing. Three distinct groundwater locations along with six different drill cutting samples collected at depths ranging from 120 to 520 feet below ground surface were subjected to continuous CO_2 exposure at 25°C and 200 psig for a 30-day period.

The results will be included in a value-added report anticipated to be completed in PY7, but delayed until PY8.

Geomechanical Rock Properties and Stress Regime Determination

The geomechanical properties of the reservoir and cap rock and stress regime in the area will be examined to assess the mechanical integrity of the system and potential for rock fracturing. An in-depth review of available information on the stress regime and structural features in the area of the reservoir will be conducted to identify structures such as faults or dissolution areas. This information will help to elucidate the geologic history of the reservoir and identify possible natural leakage paths. The results of the geomechanical evaluations will be presented in a preinjection geomechanical report (D32) and updated as appropriate. An update to D32 is anticipated in PY8.

As reported in D32, Bell Creek Test Site geomechanical report (submitted January 31, 2013, and revised in October 2013), a 1-D mechanical earth model (MEM) was constructed based on existing data as well as field and laboratory data from a monitoring well (05-06 OW) drilled in December 2011. Preliminary analyses using the 1-D MEM include estimation of

predrilling wellbore stability and stress polygons for determining the faulting regimes within the reservoir.

In PY7, geomechanical work continued, as follows. A 3-D MEM, which incorporates the entire Bell Creek Field, has been constructed with additional synthetic well logs and 3-D seismic data. Synthetic well logs using the neutral network technique in Techlog were constructed in selected wells from every phase of the field. 3-D seismic data have been processed with time-depth conversion, depth shifting, and inversion. Several additional formation tops were picked for the formations below the reservoir to include the surrounding rock deep and far enough to avoid influence of boundary conditions on modeling and simulation results. A proper modeling area was selected to cover the field, and 3-D geomechanical gridding was built with the constructed mechanical stratigraphy. Finally, the 3-D rock mechanical properties have been populated into the whole modeling area through the genetic inversion process of the 3-D seismic volume attributes.

Following the completion of the 3-D MEM, a comprehensive geomechanical analysis will be performed to identify, anticipate, and evaluate predrilling wellbore stability, cap rock integrity, the potential for induced fracturing of faulting, and the potential risk for out-of-zone fluid migration. It could also be used to match, monitor, and predict the geomechanical response from the reservoir, overlying formations, and the surface. Additionally, predictive geomechanical simulations will be designed and performed that will help guide and update the MVA plan, evaluate potential risk scenarios, and ensure injected CO_2 remains stored within the reservoir.

Assessment of Wellbore Integrity and Leakage Potential

It is not possible to determine the exact state of all wellbores within an oil field; consequently, both real field data and analytical or numerical simulations will be combined to quantify processes associated with the hydraulic integrity of the wells. The results of this assessment were presented in a wellbore leakage draft final report prepared in March 2014. This report is currently under review by Denbury and has not yet been finalized.

A wellbore integrity evaluation was performed to rank the relative potential for degradation of wellbore integrity as part of a larger associated CO_2 storage study being conducted at the Bell Creek oil field. The results of such a screening-level assessment do not provide conclusive information that a well will or will not experience a degradation or failure of wellbore integrity but, rather, provide a means to prioritize detailed well evaluations, target additional data collection, identify wells requiring modifications prior to CO_2 injection, and guide monitoring efforts. The PCOR Partnership's methods were employed to demonstrate how such an assessment could be performed utilizing the legacy data sets commonly available when preparing a site for CO_2 injection.

An evaluation of Bell Creek wellbore integrity was conducted for over 600 wells throughout and surrounding the Bell Creek Field. A modification of the method of Bachu and others (15) was implemented to determine a ranking system by which to suggest wellbore integrity. The leakage potential was divided into two scores based on depth and deep and shallow leakage potential. Other factors affecting wellbore integrity were not used in this study because

of the lack of data to support a correlation with decreased wellbore integrity or the ability to assign a representative ranking impact. The scores derived in this study indicate relative wellbore integrity and do not suggest whether a wellbore will fail or otherwise lose integrity. They only serve to identify points or areas that may require additional analysis. Ultimately, the results of this study are being used to help strategically guide monitoring activates within the field.

The overall wellbore integrity scores indicate sound wellbore integrity throughout the study area, despite the Bell Creek Field being an actively producing oil field. The study's methods provide a good screening-level assessment to rank wells that may require further investigation as part of a CCS project. Finally, the ranking of the relative integrity factors provides a mechanism to screen wells for detailed evaluation in areas being targeted for CO_2 injection (16).

Training

EERC modeling staff attended the following training sessions:

- Participated in Schlumberger's NExT (Network for Excellence in Training) PetroMod Fundamentals training in Houston, Texas, March 23–28, 2014.

- Attended the 48th U.S. Rock Mechanics–Geomechanics Symposium in Minneapolis, Minnesota, May 30 – June 5, 2014, including workshops on petroleum geomechanics testing and the role of geomechanics in geothermal reservoir engineering.

- Traveled to Denver, Colorado, to attend COMSOL Multiphysics Intensive Training, July 21–24, 2014.

Task 5 – Well Drilling and Completion

The PCOR Partnership worked with Denbury, the operator of the Bell Creek oil field, to develop engineering designs for the installation of a dedicated monitoring and characterization well in the Bell Creek oil field. The feasibility of reentry into existing wells within the field which could provide additional downhole monitoring points was also evaluated.

The development of operational plans for the injection and recycling of CO_2 over the duration of the project was conducted. As the host site for the Bell Creek large-volume CO_2 injection test is an operational oil field already undergoing large-volume water injection activities, existing wells will be utilized for CO_2 injection, oil production, and monitoring. These wells are currently being reworked to accommodate long-term injection of supercritical CO_2. The EERC provided technical support for these activities; however, the actual drilling, completion, and/or reconditioning of injection and production wells was conducted by Denbury, while the EERC was responsible for the drilling of a new monitoring well in the field, with support provided by Denbury. Activities under this task commenced October 1, 2010, and concluded in June 2014.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – June 30, 2014) included the following.

Injection Scheme Design

The injection scheme will include the minimum number of wells needed to achieve the injection goal and the optimal location of wells. Material needs and costs will be determined for the Bell Creek test. A draft injection experimental design package (D42) was prepared in October 2013 but continues to be reviewed by Denbury and has not been finalized yet.

Denbury is carrying out the injection and production operations as part of a commercial EOR project, while the EERC is providing support for the site characterization, modeling and predictive simulation, assurance monitoring, and development of a MVA plan to study the interrelationship of CO_2 EOR and CO_2 storage associated with EOR activities. The PCOR Partnership is using an iterative approach to evaluate the impacts of Denbury's injection and production scheme on reservoir performance and the array of MVA, site characterization, and modeling and simulation techniques used for the Bell Creek study.

Beginning in May 2013, the ongoing activities at Bell Creek are injecting approximately 1 million metric tons of CO_2 a year for a commercial CO_2 EOR operation. CO_2 is injected into an oil-bearing sandstone reservoir in the Lower Cretaceous Muddy (Newcastle) Formation at a depth of approximately 4500 feet (1372 meters). Produced water and CO_2 are being processed at a recycling facility, comingled with the incoming CO_2 stream, and reinjected into the formation as part of the CO_2 EOR project. Continuous CO_2 injection is expected to be followed by CO_2 water alternating gas (WAG) in Phase 1 at a target rate of 2 million cubic feet a day for each injector well.

The injection program being developed throughout the Bell Creek oil field, with current injection activities occurring in Phase 1, is dictated by the commercial EOR project. The injection-monitoring program at the Bell Creek oil field will capitalize on planned variances in the injection scheme to study (WAG cycle) flood conformance and incidental CO_2 storage specific to the Bell Creek CO_2 EOR activities which, in turn, provide direct benefit to other CCS sites throughout the PCOR Partnership region and beyond. Additionally, insights gained during EOR operations from injection pattern performance will allow enhancement of the other key Bell Creek study components (site characterization, MVA, and modeling and simulation) through the PCOR Partnership's iterative research philosophy (17).

Monitoring Scheme Design

A monitoring experimental design package (D43) for the Bell Creek test site was prepared in May 2013.

MVA Work Plan

A work plan was prepared (and approved by Denbury) for the surface and near-surface MVA plan.

Baseline MVA Activities

In March 2011, the baseline MVA was initiated to aid in evaluating site security, accounting, and location of the lateral and vertical extent of CO_2 in the Bell Creek oil field and surrounding area. These activities can be broken into two main groups (surface and near-surface, and deep MVA). Collection of relevant baseline MVA data was completed in May 2013.

Baseline Surface and Near-Surface MVA Program

A near-surface soil gas and water chemistry baseline monitoring program was conducted in order to provide scientifically defensible data sets that can be used in context with operational monitoring data to demonstrate safe, permanent storage of CO_2 association with commercial EOR. The data sets acquired and the methodology developed at Bell Creek will allow future CCUS operators to make informed decisions regarding site-specific monitoring programs at commercial-scale injection sites throughout the region.

The purpose of the near-surface baseline monitoring program is to establish baseline preinjection concentrations and seasonal variations in soil gas and water chemistries that can be used in conjunction with operational monitoring data to 1) demonstrate that the near-surface environments remain unaffected by fluid or gas migration associated with CO_2 injection and 2) identify and characterize any deviation from baseline conditions during operational and postinjection monitoring.

Baseline monitoring was performed over a 1½-year period at the Bell Creek Field. Sample collection and physical and chemical analyses of surface waters, groundwaters, and shallow-vadose-zone soil gas were conducted during six quarterly fieldwide sampling events from November 2011 to April 2013. The preinjection baseline data set was statistically analyzed to establish standard error ranges valid for the sampled interval. Data collected during continued monitoring of the operational phase of the project will be compared to this baseline data set to identify any results that fall outside of the estimated standard error range of previously observed analyses. As baseline results only cover a 1½-year preinjection sampling period, interannual variations or the magnitude of potential changes that may occur during drought conditions or wet cycles may not be fully represented. Therefore, anomalies identified during operational monitoring may not necessarily be indicative of a CO_2 migration but, rather, that site conditions have changed and warrant further investigation. The baseline monitoring program has demonstrated that the analysis techniques being employed are capable of accurately detecting variability in the near-surface environments as well as provide a means to identify and characterize the source of the observed variability.

The results of the baseline monitoring program have allowed the PCOR Partnership to quantify and define a full cycle of seasonal variability that naturally occurs in each of the surface and near-surface environments present throughout the Bell Creek Field.

A value-added report covering the baseline surface and shallow subsurface MVA activities is under development and anticipated to be completed in early PY8.

Baseline Deep MVA Program

The spud date for the deep monitoring well was December 15, 2011. Drilling, coring, logging, and PDM equipment installation at the Bell Creek observation well, 05-06 OW, was completed on January 10, 2012. The specialty wellhead installed permits PDM technologies to be utilized in conjunction with other wireline-deployed downhole-monitoring technologies such as pulsed-neutron well logs and borehole seismic tools. Activities used to gather additional baseline data and a point in the field to monitor CO_2 as it moves between injectors and producers were reported in last year's assessment report.

Drilling and Completion Activities Report (D44)

A draft final report describing the key aspects associated with the drilling and completion of injection and monitoring wells was prepared in June 2014. The issues related to the installation and operation of downhole instrumentation with respect to oil field operations and storage activities was also addressed. This report is currently undergoing review by Denbury and has not been finalized; however, an overview is presented below.

Six new wells were successfully drilled between December 2011 and April 2013 as part of the PCOR Partnership's study to demonstrate CO_2 storage potential in clastic formations in association with CO_2 EOR. The name and intended purpose of each well is as follows: 05-06 OW and 04-03 OW, monitoring; 56-14R and 33-14R, characterization; and MW0504 (Fox Hills) and MW3312 (Fox Hills), shallow groundwater monitoring.

The wells were successfully drilled and completed using proven techniques and materials common to the oil and gas industry. Each newly drilled well has provided key characterization and operational monitoring data as part of the PCOR Partnership Bell Creek study. Advanced wireline log suites acquired during the drilling of the wells have aided in the creation of geologic models to be used in the dynamic simulation of the reservoir. Simulations will ultimately serve as a key tool for fine-tuning injection and reservoir performance, correlating with monitoring data, and estimating CO_2 storage associated with commercial EOR activities. Core samples have been analyzed from the 05-06 OW well, and at the time of this report, analyses are ongoing for the 33-14R and 56-14R wells. Results of analysis from the 05-06 OW core have provided additional porosity, permeability, and mineralogy (including advanced clay typing) data, as well as confirmation of lithofacies within the reservoir. Continuously collected pressure and temperature data have been retrieved from the site and are proving to be a valuable means of monitoring CO_2 injection and confirming its containment within the reservoir. Seismic data have been collected from 04-03 OW and are in the process of being analyzed and incorporated into geomodeling efforts. Finally, the groundwater-monitoring wells have been sampled on multiple

occasions and are providing a physical, time-sensitive confirmation that CO_2 is not migrating into the source of drinking water.

The wells have provided an opportunity to conduct operational monitoring activities to 1) demonstrate that associated CO_2 storage can be safely and permanently achieved on a commercial scale in conjunction with an EOR operation; 2) demonstrate that oil-bearing sandstone formations are viable CO_2 sinks, 3) develop and demonstrate MVA methods that can be used to effectively monitor commercial-scale CO_2 injection projects and provide a technical framework for the accounting of injected CO_2; and 4) acquire data, information, and knowledge needed to inform commercial-scale CO_2 storage and EOR projects throughout the region (18).

Task 6 – Infrastructure Development

This task facilitates the infrastructure planning required for CCS to be implemented on a wide-scale regional basis as well as the development of the specific infrastructure associated with the capture, dehydration, compression, and pipeline transportation of CO_2 from its source to the Bell Creek oil field for EOR. The infrastructure development for the Bell Creek test site will be performed by Denbury. EERC personnel will document the activities, interfacing with source facility engineers and vendors, and providing assistance as requested.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) included the following.

It should be noted that on March 25, 2013, DOE NETL waived the requirement for an update to D85, "Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCUS Activities," due March 31, 2013. A journal article (see below) is under preparation in lieu of the report.

Regional Infrastructure Planning

Efficient and cost-effective implementation of CCS on a wide scale will require a complete understanding of the PCOR Partnership region's infrastructure needs. It will also necessitate the development of a regional pipeline vision connecting various CO_2 sources with the most likely geologic storage opportunities. Activities include the following.

Regional CO_2 Emission Source Characterization

In September 2014, the annual update and quality assurance/quality control (QA/QC) of the CO_2 emission source master data spreadsheet were completed (performed in conjunction with Task 1).

Capture Technology "Tree"

A value-added report entitled "Current Status of CO_2 Capture Technology Development and Application" was finalized in January 2011. This report provided a comprehensive overview of the status of carbon capture technology development and application at that time. The overview covered technologies that apply to the three combustion platforms: precombustion, during combustion (oxycombustion and chemical-looping combustion), and postcombustion. The technologies included fall into the categories of physical and chemical absorption; physical and chemical adsorption; mixed absorption and adsorption; oxygen-, hydrogen-, and CO_2-permeable membrane processes; cryogenic processes; mineralization; and photosynthesis and chemical and biochemical reduction processes as well as alternative mass transfer techniques. The document provided an overview of the technical basis for each separation method and information on nearly 100 technologies and/or research efforts. A summary table of the capture technologies was included in the report as an appendix.

The capture technologies table (from the appendix) was adapted into a technology "tree" and made available to partners via the DSS in PY6. The PCOR Partnership capture technology tree was maintained, and an update was initiated during PY7 as a service to the PCOR Partnership partners. The tree provides basic technical information about various capture technologies as well as development status, source type applicability, and economic information (when available).

CO_2 Compression Activities

The majority of research on CCS has been on capture, injection, and subsequent monitoring of the CO_2 plume in a secure geologic setting, with little attention paid to compression or pipeline transport. In March 2011, a report entitled "Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCS Activities" was finalized. In lieu of an update to this report in 2013, a journal article entitled "Assessing Temporary Storage Options to Attenuate Variable-Rate CO_2 Emissions for Use During Enhanced Oil Recovery" was proposed and approved. A draft article was written, and a short list of appropriate peer-reviewed journals was reviewed. *Energy & Environmental Science* is the journal that has been targeted for publication. Work on refining the manuscript continued throughout PY7.

In addition, a database of existing and emerging CO_2 compression technologies is under development and will ultimately be incorporated into the partners-only Web site.

Bell Creek Test Site Infrastructure Development

An infrastructure development report (D45) will be prepared in PY8 describing the key elements of infrastructure that are required to cost-effectively distribute and inject CO_2 within an operating oil field as part of a simultaneous CCUS and EOR project. The report will contain some of the lessons learned from the Bell Creek demonstration project with respect to the capture efficiency and cost as well as all aspects of CO_2 compression and pipeline transport of the CO_2 to the injection site.

Ramgen Compression Technology Slipstream Test

The applicability of the Ramgen Power Systems compressor technology to CO_2 streams during CCUS was evaluated. The EERC partnered with Ramgen Power Systems, LLC, to perform these activities. Initial subcontracted activities with Ramgen ended on September 30, 2009, with the submittal of a topical report on the preliminary design of advanced compression technology (D47). This report summarized Ramgen Power Systems activities relative to integration of the Ramgen compression technology with a power plant.

Since June 2011, and continuing through January 2014, efforts concentrated on gathering information about the well depth, diameter, downhole pressure, downhole temperature, etc., that are required in order to develop Bell Creek in-field compression specifications. A compressor must be able to meet these specifications to be considered for implementation at the Bell Creek site. Discussions with the Rampressor technology team and Denbury personnel were held. Two opportunities for implementation of the Ramgen compression technology into the Bell Creek project were identified: compression of the CO_2 (or a portion of the CO_2) leaving the Lost Cabin gas-processing facility and recompression of the recycle CO_2 stream at the Bell Creek Field. The first opportunity, compression at the Lost Cabin fenceline, was not feasible because a compressor had already been installed at that location that had the capability to compress all of the CO_2 produced by the plant. The second opportunity appeared to be the better option and was briefly explored.

Dresser-Rand invested in the development of the Rampressor. Discussions with Dresser-Rand managers indicated that the prototype single-stage compressor (now called the SuperCompressor) was too large to use for recompression of the recycle CO_2 stream at the Bell Creek Field. Because the technology cannot be reasonably implemented during the Bell Creek project prior to the end of PCOR Partnership Phase III, it was determined that incorporation of the Ramgen compression technology into the Bell Creek demonstration project is premature. It is possible that the technology could be demonstrated at other EOR project sites in the future.

Following this decision point, work continued with Ramgen and/or Dresser–Rand on establishing a list of possible sites for a field demonstration of the SuperCompressor (as the Rampressor is now called).

Conferences and Meetings

- Attended the 2014 CO_2 Capture Technology Meeting held July 29 – August 1, 2014, in Pittsburgh, Pennsylvania.

- Presented a PCOR Partnership Program update at the 9th Annual Power Summit cohosted by Nebraska Public Power District and the Nebraska Department of Environmental Quality in Lincoln, Nebraska, on November 5, 2013.

- Attended the PCOR Partnership Annual Membership Meeting held September 16 and 17, 2014, in Denver, Colorado.

Task 7 – CO_2 Procurement

This task documented CO_2 procurement procedures for CCS and EOR activities in the PCOR Partnership region. This task provided for EERC personnel to interface with commercial partners with respect to CO_2 procurement in the region as a means of documenting critical pathways for future projects.

Activities and Results

This task concluded in BP4, PY6 (September 30, 2013).

Task 8 – Transportation and Injection Operations

This task consists of monitoring and documenting commercial partner activities related to compression and transport of CO_2 via pipeline to the Bell Creek site, particularly as they relate to on-site injection. This task does not cover activities for the Fort Nelson site.

Activities and Results

CO_2 transport and injection will be conducted by Denbury as part of the commercial EOR project. The EERC will monitor and assess these operations. The results of the CO_2 transport and injection operations will be summarized in a report (D49) now due in July 2015 (instead of February 2016).

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) included the following activities.

Participation in the in-house Bell Creek project update meetings ensures keeping abreast of transportation and injection operations.

Monitoring and Assessment of Commercial Operations

A cursory literature review was conducted regarding injection-related documents. In particular, potential methods of measurement or estimation of fugitive CO_2 emissions during activities at injection sites are under investigation. The accuracy and application of the techniques as they apply to surface facilities as well as wellbores and the subsurface are being studied. The results of the study will be discussed in a value-added report that was anticipated to be completed in PY7, but will continue into PY8. In addition, planned approaches for a report about the surface facilities at Bell Creek continue to be under discussion.

In PY7, the effects of different impurities in CO_2 from anthropogenic sources on pipeline operation during start-up, shutdown, and at transient conditions were researched. The effects of impurities on operability of injection site infrastructure were also reviewed, and the effects of CO_2 stream mass-flow variability on pipeline and injection field infrastructure were also studied. These findings will be documented in a short report during PY8.

Task 9 – Operational Monitoring and Modeling

This task develops data sets for the large-volume CO_2 injection tests that 1) verify that injection operations do not adversely impact human health or the environment and 2) validate the storage of CO_2 for the purpose of developing an understanding of the process for monetizing carbon credits.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) include the following.

Bell Creek Test Site

CO_2 Injection Began

1 Year of Injection Completed

Denbury is developing the Bell Creek oil field in a phased approach, with each project phase corresponding to approximately 12 months of injection before the next development phase is brought online. Continuous CO_2 injection has been occurring at the Bell Creek oil field since May 2013, primarily in the Phase 1 development area. In summer 2014, active injection was being expanded into the Phase 2 development area. The mass of injected CO_2 is reported to the MBOG by Denbury on a monthly basis. There is approximately a 2-month (or more) delay between when data are supplied to MBOG and when they are made publicly available.

Cumulative CO_2 injection is 1,361,551 metric tons through September 30, 2014 (Table 8, Figure 16). In the month of July 2014, Denbury surpassed a cumulative injection total of 1 million metric tons of CO_2 at the Bell Creek site. This is a significant achievement not only for Denbury, but also for the PCOR Partnership Program. The primary objective of the RCSP Program Phase III (Development Phase) is the implementation of large-scale field testing

Table 8. Bell Creek CO_2 Injection Totals May 2013 – September 2014

	May 2013 Injection	September 2014 Injection
Total, Mscf	187,073	2,202,088
Total, U.S. tons*	10,700	125,956
Total, metric tons*	9717	114,376
Cumulative Total, Mscf[+]	187,073	26,213,934
Cumulative Total, U.S. tons*[+]	10,700	1,499,396
Cumulative Total, metric tons*[+]	9717	1,361,551

Source: MBOG Database.

* There is an approximately 2–3-month lag in posting of injection/production volumes to the MBOG database. This was calculated utilizing a conversion of 17.483 Mscf/U.S.ton and 19.253 Mscf/metric ton.

[+]Cumulative totals are for the period from May 2013 to the month(s) listed.

Figure 16. Booth backdrop showcasing the milestone achievement of 1 million tons of CO_2 injected at the Bell Creek test site, presented at the 2014 PCOR Partnership Annual Membership Meeting in Denver, Colorado.

injecting approximately 1 million metric tons of CO_2 per project to confirm that CO_2 injection and storage can be achieved safely, permanently, and economically. As of July 2014, the PCOR Partnership has successfully met this objective and is now exceeding it with the cooperation and support from the commercial operator of the Bell Creek site, Denbury.

Implementation of Monitoring Plan

First Full-Repeat Sampling of the Groundwater- and Soil Gas-Monitoring Program Completed

The baseline water- and soil gas-monitoring program, which comprised six full-field quarterly events and five targeted monthly events, was carried out by the PCOR Partnership between November 2011 and April 2013. The majority of the sites sampled during the baseline monitoring program (Figure 17) were also targeted for the first full-field operational-phase sampling event (after injection, May 2013). Collection of groundwater and soil gas data was completed throughout the Bell Creek Field November 15, 2013, for the first annual operational sampling event. The following locations were sampled for water or soil gas monitoring:

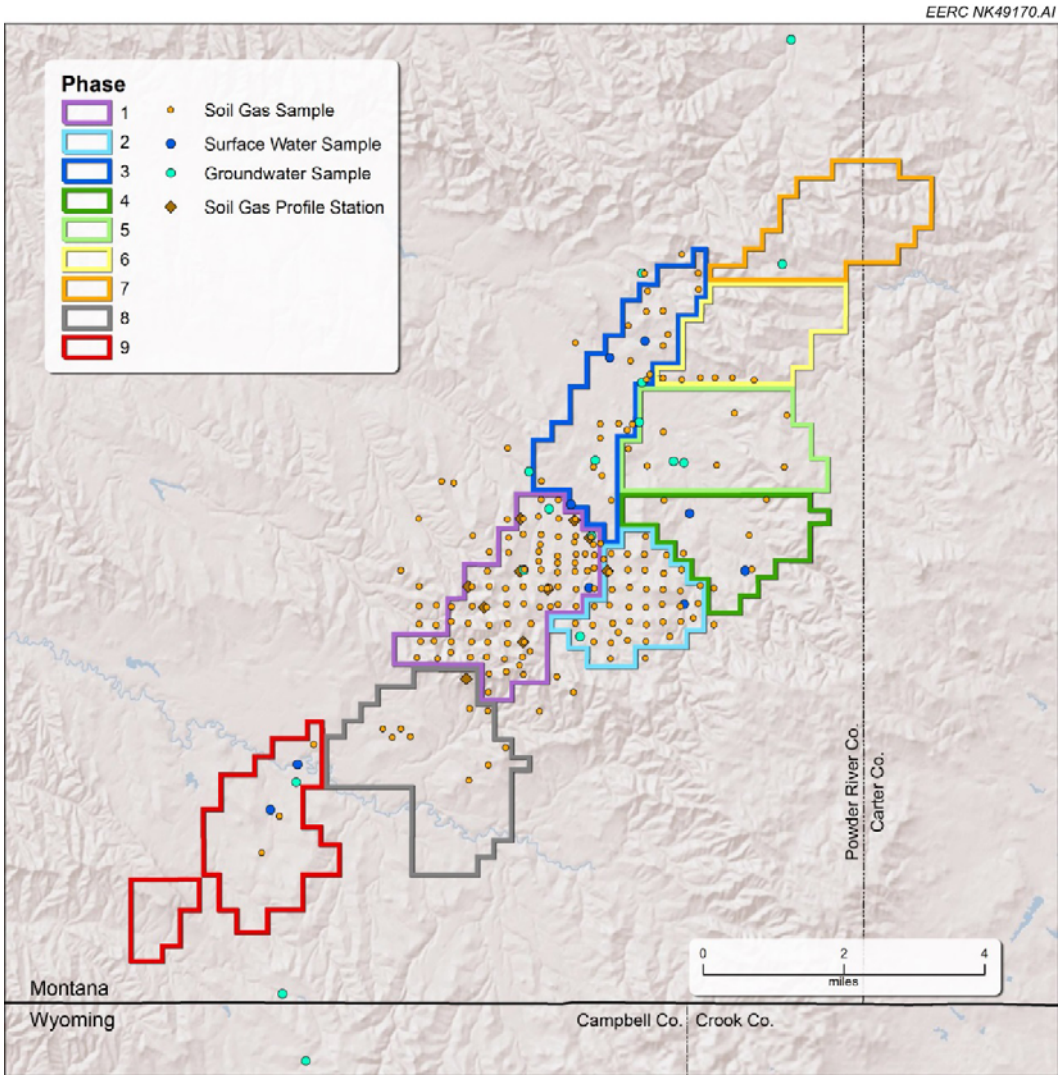


Figure 17. Soil gas- and groundwater-sampling locations collected for baseline monitoring activities between November 2011 and April 2013.

- Water monitoring
  - Fieldwide water chemistry analysis was established at:
    - Sixteen existing shallow groundwater wells.
    - Eight surface water locations.
    - Two purpose-built groundwater-monitoring wells screened in the Fox Hills Formation (the deepest regional underground source of drinking water).

- Soil gas monitoring
  - Fieldwide soil gas concentrations established near:
    - One hundred twenty-four active (injection/production) well locations.
    - Ten interspaced (between active well) locations.
    - Forty-nine P&A well locations (sampled in a three-directional spot pattern at each location).
    - Five redrilled wells that were previously P&A well locations during baseline sampling (sampled in a three-directional spot pattern).
    - Ten purpose-built fixed-location soil gas profile stations (SGPSs) (sampled at depths of 3.5, 9, and 14 feet).

The newly acquired operational data sets will 1) provide a scientifically defensible data set to evaluate any deviation from baseline conditions, 2) assess variances in water chemistry and soil gas concentrations when compared to the baseline results, and 3) provide a means to identify and characterize the significance and source of anomalies (if present) when compared to baseline conditions. Select sites will be sampled monthly and as a full-field repeat annually during the operational monitoring phase of the project. Acquired data sets and the methodology developed at Bell Creek will allow future CCUS operators to make informed decisions regarding site-specific monitoring programs at other commercial-scale injection sites throughout the region (19). Because of a severe winter storm ("Atlas") during the September–October 2013 sampling event (Figure 18), reported during last year's annual report, a second trip was conducted on November 11–15, 2013, to collect the remaining soil gas and water samples. This effort was coordinated concurrently with the monthly November event for sampling soil gas at selected well locations, SGPSs, and water at the Fox Hills groundwater-monitoring wells, including:

- Over 330 soil gas samples.
- Nine water samples.

Additional Sampling of the Groundwater- and Soil Gas-Monitoring Activities

Also in PY7, monthly soil gas sampling was conducted at select well locations, SGPSs, and water field parameter recordings at Fox Hills monitoring wells, including:

- Over 130 soil gas samples and two Fox Hills groundwater-monitoring well samples (December 10–12, 2013).
- Approximately 130 soil gas samples and two Fox Hills groundwater-monitoring well samples (January 13–15, 2014).

Figure 18. Photos after Winter Storm “Atlas” near Hulett, Wyoming (top) and in Rapid City South Dakota (bottom). Top photo courtesy of Craig Seidel, and bottom photo from online Rapid City Journal, http://rapidcityjournal.com/photos/winter-storm-atlas/collection_82a122aa-6e17-55c6-afl a-d9931e65b578.html#4 (accessed November 6, 2013).

- Thirty-five soil gas samples and two Fox Hills groundwater-monitoring well samples (February 10–12, 2014). No Phase 1 or interspaced locations were sampled during this event because of frost-related issues affecting soil gas probe sampling. The Fox Hills Formation wells were also sampled for a full suite of laboratory analyses such as major anions and cations, metals, nonmetals, organics, isotopes, etc.

- Forty-four soil gas samples at the SGPSs (Figure 19) and two Fox Hills groundwater-monitoring well samples (March 10, 2014). Collecting Phase 1 and interspaced location samples was limited during this event because of frost-related issues affecting soil gas probe sampling.

Figure 19. EERC field personnel monitor soil gas concentrations at a SGPS in the Bell Creek Field (March 2014).

- Approximately 130 soil gas samples and two Fox Hills groundwater-monitoring well samples (April 14–16, 2014).

A near-surface monitoring sampling protocol was revised and established in May 2014 to augment soil gas- and water-sampling strategies and make better use of available resources based on first-year, near-surface monitoring results. The revised strategy included collecting additional samples and analyses, i.e., Phase 2 soil gas samples. It also involved the field parameters for select groundwater locations adjacent to the injection phases:

- Over 210 soil gas samples and two Fox Hills groundwater monitoring well samples (June 16 –20, 2014). The Fox Hills Formation wells were also sampled for a full suite of laboratory analyses such as major anions and cations, metals, nonmetals, organics, isotopes, etc. (Figure 20).

- Field parameters for seven additional groundwater samples were recorded July 31, 2014.

Figure 20. EERC field personnel record water table elevation data and purge a minimum of three well casing volumes during groundwater monitoring at the MW33-12 monitoring well (Fox Hills) (February 2014).

September 19–25, 2014, marked collection of the complete data set for the annual full-repeat near-surface operational monitoring survey, including:

- Approximately 400 soil gas samples.
- Two Fox-Hills Formation groundwater well samples.
- Twenty-five additional fieldwide water samples.

In PY7, the team planned and developed an internal, interactive database-driven map product capable of querying, displaying, and enhancing rapid targeted comparison and interpretation of the large analytical data sets from near-surface monitoring data from both the baseline and operational monitoring periods to improve data accessibility and efficiency of analysis between project team members and stakeholders.

Additional injection-phase near-surface monitoring activities included collection and analysis from the incoming purchase supply as well as the recycled CO_2 streams. Specific collection dates of these samples are summarized below:

- A CO_2 purchase gas sample was collected for chemical composition and isotope content analysis on March 19, 2014.

- A CO_2 purchase gas sample was collected for chemical composition and isotope content analysis on May 7, 2014.

- A CO_2 purchase and recycle gas sample was collected for chemical composition and isotope content analysis on June 18, 2014.

- A CO_2 purchase and recycle gas sample was collected for chemical composition and isotope content analysis on July 30, 2014.

Deep MVA Program Activities

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 that may require remediation; 2) identification of potential injectivity issues; and 3) the ability to monitor and account for injected CO_2 to monetize carbon credits, potentially offsetting project costs.

The PCOR Partnership deep subsurface MVA program utilizes a combination of wellbore technologies, such as pulsed neutron tools, PDM, 3-D VSP acquisition, passive seismic acquisition, and production/injection data to measure reservoir changes during injection, track the vertical and lateral extent of fluid and CO_2 movements during the injection process, and account for injected CO_2. In PY7, the following activities were used to gather operational data for comparing to baseline data acquisitions and provide references in the field to monitor CO_2 as it moves between injectors and producers.

Injection-Phase PNL Activities

PNLs are acquired via wireline conveyance in conjunction with a crane truck. Tool specifications allow for acquisition through 2⅞-inch tubing and are run with wellhead pressure control equipment (wireline blowout preventer [BOP], lubricator, and grease injection). Logging operations require each well be sequentially taken off-line (production or injection) and take approximately 8 hours per well from rig up to rig down. Scheduling and acquisition is coordinated between Denbury, the EERC, and the logging service provider to allow for minimal impact to commercial CO_2 EOR operation (20).

PNLs provide a quantitative assessment of water, oil, and CO_2 saturations in the near-wellbore environment. PNL repeats were completed within and surrounding the Phase 1 development area to compare against baseline logs and monitor for vertical CO_2 migration in the near-wellbore environment and changes in water, oil, and gas saturations to evaluate conformance and storage efficiency as follows:

- Liquid–gas saturation from reservoir depth up to 200 ft of surface
- Water, oil, and CO_2 saturation over the Muddy Formation (storage reservoir)

1. October 2013

   - Acquired three repeat test wells (05-01, 05-05, and 05-07) and an injection spinner log in the 05-01 well, and processing is complete.

2. January 2014

   - Acquired four repeat test wells (04-04, 33-12, 56-08, and 05-06 OW), and processing is complete.

3. July–August 2014

   - For the summer 2014 repeat PNL campaign, finalized evaluation and selection of wells for repeat PNLs, and initiated logging acquisition on July 21, 2014.

   - Acquired an additional 19 repeat operational wells, and completed initial QC and quick analysis of sigma logs in comparison to baseline logs of the 19 wells; detailed analysis and processing are in progress.

Pressure and Temperature PDM Injection-Phase Activities

Real-time wellhead pressure, temperature, flow, and well test data (surface casing pressure, production casing pressure, flow-line pressure, tubing pressure, mass flow, recycling volumes, and production volumes) were collected periodically for all active injection and production wells fieldwide. These measurements were accessed with permission from Denbury and will continue to be collected during the operational phase of the project at the same frequency (20). The following activities were performed in PY7:

- Acquired and processed near-continuous data (5-minute intervals) since October 1, 2013, from three casing-conveyed downhole pressure and temperature gauges (05-06 OW):

  - Lower facies of the Muddy Sandstone
  - Upper facies of the Muddy Sandstone
  - Niobrara (thin sand lense within the primary seal)

- Acquired and processed near-continuous data (4-hour intervals) since October 1, 2013, from a fiber optic distributed-temperature system (05-06 OW):

  - 1-meter intervals from ~4700 ft to surface

- Specific PDM data acquisition dates and interpretations are summarized below:

  - Traveled to Bell Creek to download PDM (MOREVision and Qorex units) data through January 24, 2014, as well as through March 25, 2014.

  - Observed an upper zone pressure anomaly from the PROMORE data acquisition unit for 05-06 OW for the March 20–25, 2014, data acquisitions.

  - Installed a backup data interrogator and data acquisition unit on the 05-06 OW well on April 4, 2014, and sent the primary interrogator to PROMORE for repair and refurbishment.

  - Traveled to Bell Creek to download PDM data through May 21, 2014.

  - Conducted review and analysis of pressure gauge response from the 05-06 OW well of Bell Creek AZMI (above-zone-monitoring interval) pressure gauge analysis, which concluded that the AZMI is competently sealed and isolated from zones directly overlying the top of cement which are in contact with the annular space in offset wellbores, including:

    - Analysis of casing pressure testing of the 05-06 OW well.
    - Pressure differential transient analysis.
    - Pressure–temperature correlation analysis.
    - Hydrostatic pressure gradient and subnormal pressure analysis of the AZMI.
    - Temperature gradient profile analysis.
    - Seismic and microseismic analysis.

  - Worked on developing a methodology to allocate pressure response from the PDM system to individual production/injection wells.

  - Constructed stratigraphic columns for the 05-06 OW well and surrounding wells to help with interpretation of upper pressure gauge response in the 05-06 OW well.

- Traveled to Bell Creek to download PDM data through July 21, 2014, and replace the PROMORE data acquisition unit at the 05-06 OW well.

- Traveled to Bell Creek to download PDM data through September 22, 2014.

- Processing of all PDM data sets is complete through July 21, 2014, for this reporting period.

Injection-Phase Seismic Efforts

Baseline and repeat 3-D VSPs were conducted with a downhole geophone array deployed into the 05-06 OW and 04-03 OW wells. A baseline survey was collected in each of these wells during May 2013, with at least one time-lapse repeat 2014. The VSP equipment consisted of a 60-level retrievable geophone array in the 05-06 OW well and a permanently installed 50-level geophone array cemented into the 04-03 OW well. The VSP data will allow for calibration and enhanced processing of the time-lapse 3-D surface seismic data, seismic characterization of subsurface structure, and for time-lapse seismic images of CO_2 saturation changes. The permanently installed geophone array may also be used for passive seismic monitoring of the field. Timing and quantity of additional repeat surveys are still under consideration and will be guided by reservoir response to CO_2 injection and coincide with time-lapse surface seismic and PNL activities (20). The following activities were performed in PY7:

- Conducted the first 3-D VSP repeat survey at the Bell Creek oil field March 1–4, 2014. The first repeat VSP acquisition was conducted to demonstrate that CO_2 is visible at the reservoir reflector in order to guide future monitoring efforts, including a potential subsequent repeat VSP survey and a repeat 3-D surface seismic survey.

  - An unexpected incident occurred during the first day of acquisition which suspended the full-repeat VSP survey pending the results of seismic processing.

  - Data were collected from 83 of the anticipated 930 shot points utilizing a 60-level retrievable geophone array deployed in the 05-06 OW well and a 50-level permanent geophone array installed in the 04-03 OW well.

  - An attempt was made to glean useful information from the data that were acquired, but only 12 of the acquired shot points proved suitable for further analysis. The results, while encouraging, were ultimately inconclusive.

  - Plans of an additional repeat VSP survey centered on the 05-06 OW and 04-03 OW wells were discussed.

- Worked on passive seismic monitoring, including the borehole array recording system provided by SIGMA^3—daily operational checks are now performed by the EERC—and found/tested a utility application to view SEG-D field records (SegDSee) that will allow a verification check of data records after loading to the server.

- Used predictive simulation results to create a cross section for Denbury to help personnel select shot points for repeat 2-D seismic lines and selected shot points around the 04-03 OW monitoring well that have a high probability of detecting CO_2.

- Continued building the updated facies model by incorporating new data, including seismic, to create a more accurate model of the field for better prediction of CO_2 movement.

- Worked on picking horizons for the underburden formations of the reservoir using seismic data.

- Picked horizons for the Version 3 geologic model from the 3-D seismic.

- Discussed planning for a potential repeat 3-D surface seismic survey.

- Worked on the 3-D surface seismic baseline survey, including the geomechanical model, maps (including creating maps of the 11.5-square-mile monitor survey), and interpretations.

Injection and Production Data Acquisitions

Injection and production data are acquired and supplied from Denbury utilizing oil field manager (OFM) database software. Injection and production data are also made publically available through the online MBOG database. The MBOG data are compiled, QA/QC-checked, and used to report CO_2 injection totals regularly to DOE. CO_2 injection and production data acquired from the OFM database, are used for data processing/interpretation for MVA-related activities and are integrated into Bell Creek simulation activities.

Bell Creek Risk Management Activities for the Bell Creek Test Site

Two preliminary screening-level risk assessments were completed for the Bell Creek Project in April (Round 1) and June (Round 2)[a] 2012. A third-round risk assessment was completed in April 2014 to update these prior risk assessments by incorporating additional project knowledge that had been gained since their completion. All of these risk assessments were performed in accordance with the risk management framework that was utilized for the PCOR Partnership Program and the Fort Nelson Project. The outputs of these risk assessments were reviewed by an EERC work group prior to the implementation of the baseline MVA program. The results of the Round 2 and Round 3 risk assessments, as well as some initial observations from a recently initiated MVA program, are presented in the remainder of this programmatic risk update.

[a] The preliminary Bell Creek Round 2 risk assessment updated the Bell Creek Round 1 risk assessment in two ways: 1) The scoring of the individual risks in the risk register engaged more of the senior PCOR Partnership staff, who were intimately involved in the Bell Creek Phase III Demonstration project and 2) the lower end of the probability classification, which ranged from 1% to 24%, was parsed into additional categories (i.e., <1%, 1% to 5%, 6% to 10%, 11% to 15%, and 16% to 24%) to increase the resolution of the scoring. The results of the Bell Creek Round 2 risk assessment are discussed in this document.

Bell Creek Round 3 Risk Assessment

A third-round risk assessment was completed in April 2014 to update the previous risk assessments by incorporating additional project knowledge that was gained between April/ June 2012 and February 2014 (approximately 20 to 22 months). Additional project knowledge was acquired during this period as a result of the following project activities:

- Installation of two groundwater-monitoring wells (0504 FH and 3312 FH)
- Conduct of two VSPs
- Conduct of MVA baseline and operational sampling
- 3-D seismic data collection and processing
- Installation of one dedicated geophone/passive seismic
- Characterization of collected core
- Reservoir fluid testing, including minimum miscibility pressure (MMP)
- 33 baseline PNLs
- Pressure monitoring and BHP measurements
- Additional reservoir static geocellular modeling and dynamic simulations
- CO_2 injection initiated at the site in May 2013
- Monitoring of production and injection rates

Bell Creek Round 3 Risk Register

Based on these site activities, several modifications were made to the previous risk register. The primary change was the addition of a new risk category, "Executing Field Work," which contains ten additional individual risks related to field activities. In spite of this addition of ten risks, the net result of the Round 3 risk assessment update was a net reduction of the total number of individual technical risks in the risk register from 120 to 95.

In summary, the 95 individual risks were categorized into seven groupings as follows:

1. Group 1 – Capacity, Injectivity, and Retention

2. Group 2 – Containment (lateral migration – CO_2/formation water)

3. Group 3 – Containment (vertical migration via P&A wells – CO_2/formation water/oil)

4. Group 4 – Containment (vertical migration via injection wells – CO_2/formation water/oil)

5. Group 5 – Containment (vertical migration via producing wells – CO_2/formation water/oil)

6. Group 6 – Containment (other)/Seismic

7. Group 7 – Executing Fieldwork/Other

Bell Creek Round 3 Risk Maps

Probability and impact scores were assigned to each risk by the PCOR Partnership task leaders. Four risk maps were created for each of the 95 risks, one each for the impacts of cost, time/schedule, scope, and quality. The probability score was unchanged across all four risk maps (i.e., the probability that the risk could occur was unaffected by the impact of interest); however, the impacts of these events on the cost, time/schedule, scope, and quality varied based upon the impact of interest. Two types of risk maps were created, most likely values and 90th percentile estimate:

- *Most likely values*. The most likely values were the mode (the most frequently reported score) of the group assessment. These risk maps represent the most likely assessment of each individual risk probability and impact or the best estimate given the project team's current technical knowledge of the Bell Creek project.

- *90th percentile estimate*. Rather than use the maximum score value, which commonly reflects the input of only a single individual and is the worst-case estimate, the high-end estimate on the risk maps displays the 90th percentile value of a triangular distribution. The triangular distribution is a continuous probability distribution with a lower limit, a (best-case estimate); an upper limit b (worst-case estimate); and a mode c (most likely estimate), where a $< b$ and $a \leq c \leq b$. The triangular distribution is commonly used in risk assessment when not much is known about the distribution of an outcome besides its smallest and largest values and the most likely outcome (21).

Bell Creek Round 3 Risk Assessment Results

The Bell Creek Round 3 risk assessment process involved a thorough, integrated approach to obtain input from the PCOR Partnership technical staff and to quantify risk scores such that each of the 95 risks on the final technical risk register could be mapped and evaluated for their relative ranking.

Under the most likely scenario, which represents the best estimate given the PCOR Partnership's current technical knowledge of the Bell Creek Project, all 95 risks mapped within either the low or transition risk map fields. None of the 95 risks was determined to be either a moderate or high risk.

Under the 90th percentile assessment, into which a significant conservative level was used to capture the maximum scores of the group responses, most of the risks still mapped within the low or transition categories. However, the increased probability and/or impact scores for this upper estimate placed several risks into the moderate category. None of the risks mapped into the high category, indicating that even under the conservative assumptions embedded in the 90th percentile estimate, there were no immediate risks requiring further analysis and/or short-term risk treatment (22).

Reservoir Modeling

Attributes such as injectivity, fluid production, and reservoir dynamics will be modeled using relevant software packages. The ultimate fate of the CO_2 over short-, intermediate-, long-, and extremely long term time frames will be predicted. A report on the specific results of the Bell Creek oil field simulations was prepared in August 2011, updated in August 2012, August 2013, and again in August 2014 (D66). The updated reports remain under review by Denbury and have not yet been finalized.

The modeling and simulation program includes 1) characterizing and modeling the study area using advanced geologic modeling workflows; 2) developing a robust pressure, volume, and temperature (PVT) model to predict the miscibility behavior of the CO_2–Bell Creek crude system and to aid in compositional simulation; 3) history-matching the constructed dynamic reservoir models; and 4) running predictive simulations to aid in monitoring long-term behavior of injected CO_2.

This report encompasses the modeling and simulation work completed since the August 2013 Bell Creek simulation report and includes 1) the incorporation of 33 baseline and seven repeat PNLs to improve the static and dynamic geocellular models, 2) history-matching and predictive simulations of the Phase 2 area of the Bell Creek Field, and 3) additional predictive simulations of the Phase 1 area of the Bell Creek Field.

In order to better evaluate different injection scenarios, five simulation cases for both Phases 1 and 2 (ten cases total) were performed to evaluate WAG and continuous CO_2 injection (CCI) at two injection BHP constraints and varying WAG cycle lengths. The results indicate that WAG is more effective at yielding a faster oil recovery and better sweep efficiency than CCI in Phase 1 and Phase 2, while CCI results in more CO_2 being stored.

The estimated associated CO_2 storage potential varied from 3.06 million metric tons of CO_2 with 6 hydrocarbon pore volumes (HCPVs) of CCI to 1524 metric tons of CO_2 with 6 HCPV (3 HCPV of CO_2) of WAG injection in Phase 1. In Phase 2, the estimated associated CO_2 storage potential varied from 2912 metric tons of CO_2 with CCI to 1914 metric tons for WAG injection. The CO_2 utilization factor ranged from 73.6 to 247.7 (scm)bbl in Phase 1 and varies from 137.3 to 213.1 scm/bbl in Phase 2, depending on the scenario.

For the Phase 1 area, the earliest CO_2 breakthrough at a production well during simulation occurred 2 months after the start of CO_2 injection for the continuous CO_2 flooding scenario, while the earliest CO_2 breakthrough for WAG occurred after 2.5 months. The simulation results also indicated that the injected CO_2 in this phase is expected to reach Observation Well 05-06 OW about 6 months after injection for both scenarios. In Phase 2, the earliest CO_2 breakthrough at a production well occurred after about 4 months following the start of CO_2 injection for the continuous CO_2 flooding scenario, increasing to 5 months for WAG cases.

Ongoing modeling and simulation work in the Bell Creek oil field includes refining the Version 3 geocellular model using newly acquired 3-D seismic data, additional repeat PNLs, and log and core data. The Version 3 model will be integrated with a comprehensive reference model

for geomechanical modeling, as well as Phases 1 and 2 combined simulations, to improve the understanding of long-term storage of CO_2 associated with EOR in the Bell Creek Field. Moreover, relative permeability curves are being revised using SCAL conducted by Core Labs. These results will be incorporated into the next iteration of the simulation activities to finely tune CO_2 EOR efficiency. Finally, recent data recorded from the ongoing CO_2 flooding in the Bell Creek oil field will be matched to the dynamic simulation results (23).

Fort Nelson Test Site

In September 2012 (end of PY5), an e-mail was received from Spectra management indicating that it would not be conducting 2012–2013 winter field activities, i.e., exploratory well-drilling or 3-D seismic activities. This will result in further delaying CO_2 injection at the Fort Nelson test site until Spectra develops a business case for the project. To date, Spectra has not developed a business case for the project. The following activities were performed in PY7.

Injection Zone Modeling

Attributes such as injectivity, fluid production, and reservoir dynamics were modeled using relevant software packages. The ultimate capacity of the injection zone and the fate of the CO_2 over short-, intermediate-, and extremely long term time frames was predicted. Key findings are presented below.

The static geologic model was updated based on commercially available well data, acquisition of existing 2-D and 3-D seismic surveys, well log analysis, review and testing of available core, pressure transient analyses from well testing, and interpretation of the facies for the barrier reef complex that is the target for the Fort Nelson CCS project. It has resulted in a more realistic static geologic model (Version 3) of the test site.

A dynamic model based on the completed Version 3 geologic model was constructed for the purpose of matching the historical gas and water production, water disposal data, and scattered BHPs in the gas pools. This, in turn, re-creates the pressure sink in the model that exists in the project area as a result of significant gas production from nearby gas pools since the 1960s. Through the history-matching process, the geologic model was validated and improved by decreasing the realistic range of several key geologic properties, including permeability, fault transmissibility, vertical to horizontal permeability ratio (k_v/k_h), and others. In addition, with the pressure sink from gas production now included in the model, via the history match process, the injection simulation cases will now be more realistic by including the effects of the offset production on CO_2 plume development and pressure effects from the injection.

Both injection locations (c-47-E and c-61-E) appear to have sufficient storage capacities to accommodate target injection volumes.

In both injection scenarios, the injected sour CO_2 showed migration structurally upward (buoyancy effects), and plumes developed at the contact between the reservoir (reef) and the cap rock (shale) in structural highs. The plume was contained within the reservoir (reef) in all scenarios over the 100 years.

Both injection site scenarios showed the required injectivity for the life of the injection periods while ensuring that the maximum injection sand face pressures at each of the injection wells did not exceed 80% of the fracture gradient – an anticipated regulatory restriction. The BHPs of each of the injection wells in the c-47-E location were predicted to be 1000 to 3000 kPa lower than the BHPs at the c-61-E location.

The c-61-E showed higher reservoir pressures at the end of the injection life than the c-47-E site as the pressure in the c-61-E area was not able to dissipate as easily as the c-47-E site because of the presence of a nearby low-permeability barrier that was identified during the history match process.

The injection site around c-47-E is a better option compared to the c-61-E area because the injected sour CO_2 plume did not contact the adjacent gas pools during the 100-year simulation period, and the resulting reservoir pressures were lower, which is a better situation as regards the cap rock integrity.

The low-permeability cases applied to the c-47-E injection area before the history match process suggest that the CO_2 plume area will be larger and may result in migration of the CO_2 plume into the c-61-E area and a small gas-producing pool; this risk can be managed through application of the first recommendation noted below to further understand the likelihood of this scenario. The impact is likely past the operational life of this small gas pool and potential acquisition of the small gas pool in the c-61-E area.

The history match process and simulations show that the c-47-E injection area has had some pressure reduction since the 1960s because of the pressure sink in the model area from the gas production and also because the reef is naturally subhydrostatic. The simulation scenarios indicate that, while there are pressure increases in the reservoir from the injection around c-47-E, the maximum reservoir pressure increase basically returns to its 1960 reservoir pressure.

To further confirm the evaluations presented in the study, the following recommendations are suggested to be included in any future modeling and simulation studies:

- Collection of more geologic information in the c-47-E area by means of drilling, testing, coring, and logging of a new well and acquisition of a new 3-D seismic survey over the predicted CO_2 plume footprint.

- Integration of various physical phenomena such as geochemical reactions, geomechanical behaviors, and thermal effects into the dynamic model to comprehensively understand the sink–seal system for more reliable predictions.

The foregoing information was finalized and approved in March 2014 (24).

A BPM for Storage in a Deep Carbonate Saline Formation

A BPM summarizing activities performed in conjunction with the CCS feasibility study for the Fort Nelson test site (D100) was completed September 2014. This comprehensive manual also included a) a comparison of site activities with the CSA Guidelines for Geological Storage of CO_2 and b) a hypothetical MVA plan that combines the shallow-surface and deep-subsurface MVA plans into a CSA-compliant MVA plan.

Since 2009, Spectra and the PCOR Partnership have conducted substantial efforts to collect baseline characterization data on potential sink and sealing formations in the Fort Nelson area. Those data were used to create static petrophysical models of potential CO_2 storage reservoirs and to conduct dynamic simulation modeling of potential injection scenarios. The baseline characterization data and modeling results were, in turn, applied to a risk assessment of potential operational scenarios. While a final injection strategy has not yet been determined for the Fort Nelson gas-processing facility, a draft MVA plan for a hypothetical injection scheme has been developed using assumptions that are based on the feasibility study efforts. The risk-based draft MVA plan covers the surface, near-surface, and deep subsurface environments in the Fort Nelson facility area and includes specific technologies, spatial locations of measurements, and baseline data necessary to address critical project risk and regulatory requirements and identify any deviations from expected conditions in a timely manner. Although specific techniques and procedures may change as the project proceeds, the project's philosophy of integrated, iterative geologic characterization, modeling, and RA will ensure that MVA strategies remain fit for purpose and cost-effective and have the greatest potential for success throughout the project's lifetime.

The results of characterization, modeling, and risk assessment efforts suggest that the Fort Nelson area has sink and seal conditions that make it an exceptional candidate location for large-scale CCS. The potential sink formations include areas with excellent injectivity characteristics. The storage capacity of the Devonian carbonate formations in the area has been estimated to range from 140 million to 240 million metric tons, sufficient to support the full anticipated formation CO_2 emissions of the Fort Nelson facility for several decades. The extremely low permeability, high geomechanical competence, and tremendous thickness (>500 m) of the overlying Muskwa and Fort Simpson shale formations mean that they will serve as excellent seals. Climate and terrain will hamper the deployment of some MVA technologies, but implementation of an effective MVA plan for both surface and subsurface environments can be achieved by the application of proven approaches used by the oil and gas industry in the area. Acknowledging the need for longer lead times for planning and elevated levels of coordination between different technical teams and service providers will also be keys to successful MVA deployment and operation at Fort Nelson.

The key elements for the Fort Nelson efforts and a hypothetical draft MVA plan were examined in the context of how they address the guidelines enumerated in the CSA Standard CSA Z741-12 Geological Storage of Carbon Dioxide. The Fort Nelson efforts to date meet or exceed a majority of the CSA standard specifications. Most of the deficiencies are in topic areas that would not typically be addressed in the feasibility study phase of a project but, rather, are more appropriately addressed after a "go" decision has been made, during the design phase of a project.

With respect to broadly applicable best practice elements that were identified over the course of the Fort Nelson project, several key observations and recommendations are offered.

Deep carbonate saline formations may serve as effective, high-capacity locations for the large-scale geological storage of CO_2. However, carbonate formations are inherently heterogeneous and anisotropic with respect to rock properties, including porosity and permeability distribution. This makes characterization of carbonates challenging and can lead to a high degree of uncertainty in the interpretation of results, especially with respect to predicting the injectivity and storage capacity of a formation. Therefore, detailed rock characterization from multiple wells and the correlation and integration of the data with other data sets (e.g., seismic surveys, hydrogeological studies) are critical to reducing that uncertainty.

The injection of CO_2 and its mobility in a deep carbonate saline formation is closely analogous to conventional oil and gas production operations. Therefore, site characterization and modeling exercises should follow standard practices, protocols, and workflows that are commonly applied in the oil and gas industry. Those approaches are also generally well accepted and understood by the regulatory community.

Oil and gas industy activities have been conducted in challenging climates and terrains for decades. Over that time, industry has developed proven, cost-effective, and environmentally sustainable approaches to installing, operating, and maintaining production and injection projects that serve as excellent analogs for how to conduct CCS projects in extreme environments.

Robust risk assessment efforts can provide a technically defensible basis for a cost-effective MVA strategy that addresses the concerns of multiple stakeholders. MVA technologies should be deployed at locations selected according to their surface accessibility and spatial relationship to the predicted plume. The MVA technology matrix should include monitoring of the surface and near-subsurface environment (e.g., surface water, groundwater, and soil gas), geophysical logs, wellbore integrity monitoring, and a variety of downhole instruments (e.g., pressure and temperature sensors) and remote sensing tools. While traditional 3-D seismic surveys should be considered and deployed where cost-effective and appropriate, areas with accessibility issues and/or geologic conditions that are not conducive to seismic data collection should not be precluded from being candidates for hosting a CCS project. As long as there are means of delineating the geometry of the plume in a technically defensible manner that are acceptable to the regulator, then the site should be considered for CCS (7).

Modeling Training Courses

- Modeling staff attended the Society of Petroleum Engineers (SPE) ATCE (Annual Technical Conference and Exhibition) held September 30 – October 2, 2013, in New Orleans, Louisiana.

- Staff participated in a Webinar entitled “Simulating Geological Sequestration of CO_2 with COMSOL Multiphysics” on November 12, 2013, to determine the software’s applicability to Bell Creek modeling activities.

- Modeling staff attended Schlumberger PetroMod Fundamentals modeling software training March 23–29, 2014, in Houston, Texas (www.nexttraining.net/Sessions/Details/17103/PetroMod-Fundamentals-%28previously-Introduction-to-PetroMod%29.aspx).

- Staff prepared materials and templates from PCOR Partnership data (these templates can be used for actual simulation and history-matching projects) for the Computer Modelling Group Ltd. (CMG) and CMOST™ in-house training. This training consisted of two half-days (May 7–8, 2014). Approximately ten EERC geologists and reservoir engineers attended this training.

- Staff attended the 2014 CMG Technical Symposium held June 3 and 4, 2014, in The Woodlands, Texas, and presented "Implementation of Detailed Reservoir Simulation to Demonstrate CO_2 EOR and Storage in the Bell Creek Field" and "Tools for Interfacing and Integrating CMG Software with Other Software Packages."

- Staff attended a 2-day training workshop (September 22–23, 2014) at the EERC held by Outsource Petrophysics, covering the basics of petrophysical analysis (used in both modeling and laboratory activities).

- Staff attended a 2-day COMSOL training session. This software is advanced physics simulation software that has diverse applications. It is being investigated for its applicability to the Bell Creek project for potential modeling of the near-surface environment.

- Staff participated in the National Ground Water Association Webinar Environmental Isotopes in Groundwater Studies: Groundwater, Environmental Isotopes, and Salinity.

Task 10 – Site Closure

This task was not active in BP4, PY7.

Task 11 – Postinjection Monitoring and Modeling

This task was not active in BP4, PY7.

Task 12 – Project Assessment

This task communicates and disseminates all Phase III activities detailed in annual progress reports. Reports summarize program progress, accomplishments, program recognition, travel, planned activities, and goals.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) include the following.

Assessment was conducted for the tasks during the period October 1, 2012 – September 30, 2013. A project assessment annual report (D57) was submitted on January 31, 2014.

Task 13 – Project Management

This task focuses on ensuring the overall success of the entire program by providing experienced management and leadership to each of the individual tasks and to the program as a whole. The PI and task leaders meet regularly to report the progress of their tasks and discuss any issues and corrective actions necessary. Task leaders are also responsible to provide the PI with written weekly updates. These updates include highlights (including trip reports), issues (i.e., budget, staffing, technical issues, etc.), opportunities, and travel plans. The monthly, quarterly, and yearly updates can be found on the PCOR Partnership DSS.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) include the following.

Progress Reports

Quarterly progress reports (D58), each including a milestone report (D59), were submitted to DOE and the PCOR Partnership partners 1 month after the end of each calendar quarter. In addition, monthly progress reports are submitted to the DOE NETL project manager shortly after month end and are also posted on the partners-only Web site. Informal weekly updates are e-mailed to the DOE NETL project manager.

DOE Contract (DE-FC26-05NT42592) Modifications

During PY7, four modifications to the contract were issued.

The EERC received DOE Cooperative Agreement Amendment 27 effective January 22, 2014. The amendment authorized the following:

- Increased the total estimated amount of the award by $3,927,791 (and increased EERC cost share to a minimum of 36.1%) because of a cost overrun and increased cost share for field injection preparation on an increased number of wells.

- Modified the SOPO to update subtask activity reporting frequency, including a new requirement for a BPM for permitting to be submitted and to add Subtask 14.1.3 for the creation of fact sheets on the "Nexus of CCS and Water."

- Incorporated a revised project budget.

The EERC received DOE Cooperative Agreement Amendment 28 effective February 11, 2014. This amendment changed the DOE project officer from Andrea McNemar to Andrea Dunn.

The EERC received DOE Cooperative Agreement Amendment 29 effective April 11, 2014. The purpose of this amendment was to revise the SOPO as follows:

- Revise Subtask 2.6 to add a new deliverable (D22).
- Revise Subtask 6.3.3 to add a note.
- Add Subtask 14.1.4, which also adds a new deliverable (D101).
- Delete Subtask 14.4 in its entirety.

The EERC received DOE Cooperative Agreement Amendment 30 effective August 7, 2014. The amendment authorized the following:

- Obligated DOE funds in the amount of $13,611,895, bringing the total DOE obligation to $90,454,435, and fully funds the award for all budget periods.

- Modified the SOPO as follows:

  - Delete and replace D22.
  - Delete D23 in its entirety.
  - Add a new Subsubtask 14.1.4, to include a new deliverable (D101).
  - Eliminate D83 (at Subtask 6.3.3), and include a note that the compression technology will not be implemented.
  - Correct other administrative errors from prior SOPO changes.

IEAGHG Expert Review of the RCSPs

DOE requires that an independent technical review of the Phase III program be periodically conducted. In October 2010, the PCOR Partnership provided an update as to the current status of recommendations detailed by the 2008 expert review panel. DOE selected IEAGHG to undertake the expert review held in March 2011. On August 12, 2011, responses to the expert review panel's comments and recommendations were submitted. An outcome of note stemming from the expert panel's review was the recommendation to create a TAB to provide scientific and/or operational guidance to the PCOR Partnership Program, including both demonstration sites (Modification 21 to the PCOR Partnership award provided funding and authorization for such an advisory board).

DOE again selected IEAGHG to undertake the expert review scheduled for November 15, 2013. IEAGHG has extensive experience with CO_2 injection projects worldwide and has organized a number of independent technical reviews. In order to review the Phase III activities, IEAGHG appointed an independent international panel of experts drawn from onshore CO_2 injection projects under way in Canada, Europe, and Australia. The PCOR Partnership submitted a project information form (PIF) for the "Bell Creek CO_2 CCS, and EOR Demonstration" on September 13, 2013, with revisions sent October 1 and 11, 2013. The required PowerPoint

presentation was submitted September 27, 2013, with revisions on October 11 and 31, 2013. The 45-minute presentation was given before the expert panel on November 15, 2013. A call was held with DOE NETL and the regional partnerships to review the peer review results on January 21, 2014.

The review panel's general comments are presented below.

There was a unanimous view from the panel that this project has excellent scientific and technical merit combined with a comprehensive test program. It was evident from the review that the team covered each technical area comprehensively and was able to address all the technical points raised. The team has kept and presented a record of milestones that have been comprehensively tracked. The panel agreed that the project has made effective use of government resources given the quality of the technical work and the program objectives. They also thought that the technical approach had been tackled in a robust and constructive style. The team's risk assessment, especially the approach to technical risks, for example, wellbore integrity and mitigation, was regarded as exceptional. The presentation showed in some detail how data from MVA methods were used and interpreted and how they were clearly linked to risks and risk reduction measures. Since the last peer review, the PCOR Partnership has established a TAB to provide scientific and operational guidance, which has aided the project. This is the only partnership that has implemented this recommendation of the previous IEAGHG RCSP review in 2011.

Other notable positive features were the wide-ranging public outreach program, a proven relationship with the operator, and an impressive reservoir characterization. The team's comprehensive modeling and baseline monitoring program included 1960s background data. The project has analyzed a large number of wells (C. 700), compiled a new lidar data set over the project area, and completed 3-D seismic and 3-D VSP. The team also applied a unique suite of PNLs in 33 wells. In addition to this comprehensive data set, the project team was able to combine input from different models to address the technical challenges.

The panel raised only limited reservations on this project. The thinness of the reservoir zone (~30 ft [9.2 m]) could present a monitoring challenge. Although there is a strong relationship with the operator, there is a risk that a change of ownership or management could have an impact on the project. Some panelists thought that the thickness of the reservoir could limit its potential for regional storage.

The review panel acknowledged that this project demonstrated a thoroughly comprehensive and integrated technical program. The proactive public outreach component of the project was also notable.

Draft responses to the recommendations made by the review panel were due to DOE NETL by February 21, 2014, with final review and approval due by March 7, 2014. For each Recommendation, the PI and NETL project manager developed a consensus response. The response had four parts to be addressed:

- Develop a consensus narrative response.

- Identify if there is a scope, cost, or schedule impact.

- Indicate whether the recommendation will or will not be incorporated into the project's SOPO or statement of work by placing an "X" on the appropriate line.

- If incorporated, designate a planned completion date for the recommendation by marking a 3-month range and calendar year.

The review panel recommendations were as follows:

1. Knowledge dissemination must follow on from the excellent technical work (completion due March 2014).

2. Consideration of the storage implications needs to be studied in more depth and there needs to be a push for opportunities to maximize the storage potential (completion due September 2016).

3. The improvements in reducing uncertainty from different methods as the project progresses should be quantified (completion due September 2016).

4. The team should continue to apply a cost-benefit analysis from multiple monitoring techniques (completion due September 2016).

5. The team should estimate the detection limits of CO_2 within the formation and the formation fluid leakage induced by CO_2 injection (completion due September 2016).

6. The strong team on this project should be maintained and keep focused (completion due March 2014).

7. The project should push for opportunities to maximize CO_2 storage while recognizing the operator's overall interest in optimizing oil production (completion due March 2014).

On May 29, 2014, a description was submitted of how the review panel's recommendations (see 1, 6, and 7 above) were addressed.

Project Management Plan

Revisions to the plan are under way and will be submitted in PY8.

Annual Meetings

Regular project meetings (annual or as otherwise directed) will be held to ensure that project management and PCOR Partnership partner goals are being met. During PY7, the 12th partner meeting (the 11th meeting that included project results) was held.

The 2014 PCOR Partnership Annual Membership Meeting was held September 16 and 17, 2014, in Denver, Colorado, and attracted 86 attendees representing 52 organizations from 14 states, the District of Columbia, and three Canadian provinces and provided an overview of CO_2 management on a regional level in the upper Great Plains of North America, including recent program accomplishments, storage strategies and technologies, regulatory developments, and carbon storage infrastructure (Figure 21). The meeting also provided summaries of the PCOR Partnership's completed and ongoing activities. The presentations from the meeting and workshop are now available in the Products Database of the Partners-Only Web site.

As shown in Table 9, the PCOR Partnership still garners significant interest from its varied members. In 2014, the number of attendees at the annual meeting was greater than the six-year average, and the number of organizations sending representatives was the highest.

Figure 21. Attendees at the PCOR Partnership 2014 Annual Membership Meeting held September 16 and 17, 2014, in Denver, Colorado.

Table 9. Participation Numbers, Including the Average, from the Past Six Annual Meetings

Year	2009	2010	2011	2012	2013	2014	Average
Attendees	84	74	83	84	88	86	83
Organizations	50	45	42	51	46	52	48
U.S. States	14	15	12	15	15	14	14
District of Columbia	Y	Y	Y	Y	Y	Y	Y
Canadian Provinces	5	4	4	4	3	3	4
Other Foreign Countries	Sweden			England			

RCSP Support

- The PCOR Partnership was asked to coordinate the RCSP WWG. This task began in January 2009 and is ongoing through 2017.

- Members of the GIS Working Group, OWG, and WWG took part in scheduled conference calls.

- PCOR Partnership personnel attended several regional partnership annual meetings, including the Midwest Regional Carbon Sequestration Partnership meeting hosted by Battelle and Core Energy in Traverse City, Michigan, October 2 and 3, 2013; the 2013 Midwest Carbon Sequestration Science Conference in Champaign, Illinois, October 7–9, 2013, including participating in a tour of the Illinois Basin – Decatur Project at the Archer Daniels Midland Company in Decatur, Illinois, on October 9, 2013; and the SECARB annual membership meeting in Atlanta, Georgia, March 3–5, 2014.

- An EERC staff member served as Chairman of North American Energy Working Group's (NAEWG's) Subcommittee on CO_2 Storage Capacity Estimation, also known as the Methodology Subcommittee. This subcommittee discussed geologic storage capacity coefficients and the methodology for estimations. The data sharing of this group led to a solid foundation in the area of CO_2 capture and sequestration mapping and estimations in North America. This subcommittee coordinates its activities closely with NAEWG–NACAP (North American Carbon Atlas Partnership). Natural Resources Canada (NRCan), the Mexican Ministry of Energy (SENER), and DOE released the North American Carbon Storage Atlas (NACSA) in 2012, which was produced under the leadership of NACAP. In PY7, no meetings were held, but EERC staff attended and presented at the Advanced Workshop for CO_2 Storage in Mexico City, Mexico, on August 26–27, 2014.

- CCS is one of the topics that both the United States and Canada have expressed interest in to continue discussions. The U.S.–Canada Clean Energy Dialogue is led on the U.S. side by the DOE Office of Policy and International Affairs. In PY7, the PCOR Partnership program manager attended the U.S.–Canada Clean Energy Dialogue Third CCS Binational Conference in Edmonton, Alberta, Canada, May 5–8, 2014.

National Risk Assessment Partnership

The National Risk Assessment Partnership (NRAP)—an initiative within DOE's Office of Fossil Energy and led by NETL—applies DOE's core competency in science-based prediction for engineered–natural systems to the long-term storage of CO_2. The science-based prediction of engineered–natural systems is a core competency that crosscuts many of today's energy challenges. Over decades, DOE has built a unique set of resources for predicting how these complex and heterogeneous systems behave under extreme conditions and over large ranges in time. NRAP has joined international efforts to develop the risk assessment tools needed for safe, permanent geologic CO_2 storage. NRAP members include five national DOE laboratories that have been conducting collaborative research for the Office of Fossil Energy's Carbon Sequestration Program for many years. The NRAP Program receives input from industry,

government, nongovernment organizations, and academia regarding research needs for large-scale CO_2 storage deployment. The NRAP collaborative also keeps abreast of international developments by participating in collaborations like the IEAGHG Risk Assessment Network (25).

In PY7, the PCOR Partnership provided input to NRAP as follows:

- Participated in a conference call led by DOE NETL on October 3, 2013, to continue the conversation that was started at the August 2013 annual review meeting and expand on the activities between the RCSPs and NRAP.

- Participated in a WebEx meeting with DOE NETL and the other regional partnerships to discuss NRAP on January 16, 2014.

- Presented at an NRAP stakeholders meeting held February 4 and 5, 2014, in Washington, D.C.

- Attended the NRAP Stakeholders Meeting on August 14–15, 2014, in Pittsburgh, Pennsylvania, and presented in an impromptu panel session discussing the MVA activities that are under way at Bell Creek.

Annual Carbon Capture and Sequestration Conference

Six staff members attended CCUS-13, sponsored by ExchangeMonitor Publications & Forums, held April 28 – May 1, 2014, in Pittsburgh, Pennsylvania. The following presentations were given.

- "Carbon Dioxide Storage Potential of the Basal Saline System in the Alberta and Williston Basins of North America"

- "The Plains CO_2 Reduction Partnership's Adaptive Management Strategy for CO_2 Storage"

- "Development of a Monitoring, Verification, and Accounting Plan for a Potential CCS Project at Fort Nelson, British Columbia, Canada"

- "Modeling of Acid Gas Injection for Enhanced Oil Recovery and Long-Term Storage in Devonian-Aged Pinnacle Reefs"

Annual Review Meeting

Five staff members attended and presented at the DOE Carbon Storage Project Review Meeting held August 12–14, 2014, in Pittsburgh, Pennsylvania. One oral presentation in the plenary session focused on Bell Creek was given plus four poster presentations covering the work performed by the PCOR Partnership for the Aquistore project, Zama project, Basal Cambrian characterization, and the Fort Nelson CCS Feasibility Study.

GHGT-12

The GHGT conference series was formed in 1997 following the merger of the earlier series of the International Conference on Carbon Dioxide Removal and the Greenhouse Gas: Mitigation Options Conference. IEAGHG is the guardian of the conference series. The GHGT conferences are held every two years in IEAGHG's member countries. The conference series rotates between North America, Europe, and Asia.

The GHGT conference series has established itself as the principal international conference on GHG mitigation technologies especially on CCS. Each conference is a forum for technical discussions related to the field of GHG control technology. This field can be defined, broadly, as technologies that allow us to continue using our large fossil energy reserves while reducing their associated GHG emissions.

The PCOR Partnership agreed to present ten of the accepted abstracts, comprising six oral presentations and four poster presentations. The deadline for receipt of abstracts was January 10, 2014, and final papers were due September 12, 2014. The conference is scheduled for October 5–9, 2014, in Austin, Texas. The following presentations will be given:

- Oral presentations:
  - "A Rapid Method for Determining CO_2–Oil MMP (minimum miscibility pressure) and Visual Observations of CO_2–Oil Interactions at Reservoir Conditions"
  - "Application of Canadian Standards Association Guidelines for Geologic Storage of CO_2 Toward the Development of a Monitoring, Verification, and Accounting Plan for a Potential CCS Project at Fort Nelson, British Columbia, Canada"
  - "A Workflow to Determine CO_2 Storage in Deep Saline Formations"
  - "The Rising Tide of Digital Communications: Implications for CCUS Outreach" (via OWG)
  - "Guidance for States and Provinces on Operational and Postoperational Liability in the Regulation of Carbon Geologic Storage"
  - "The Nexus of Water and CCS: A Regional Carbon Sequestration Partnership Perspective"
- Poster presentations:
  - "Evaluation of Large-Scale Carbon Dioxide Storage Potential in the Basal Saline System in the Alberta and Williston Basins in North America"
  - "Characterization and Time-Lapse Monitoring Utilizing Pulsed-Neutron Well Logging at an Incidental CO_2 Storage Demonstration"

– "A Regional Wellbore Evaluation of the Basal Cambrian System"

– "Model Development of the Aquistore CO_2 Storage Project"

In addition, the PCOR Partnership program manager agreed to chair several sessions at the conference, including Session 8E, CCS and Water Use, and Session 9B, Geomechanics.

PCOR Partnership Partners

The PCOR Partnership has significant support and participation from its partners. As of September 30, 2014, over 90 partners are supporting Phase III activities. Peabody Energy was added as a new partner on December 2, 2013. Sejong University (Seoul, South Korea) joined on April 30, 2014, and Outsource Petrophysics, Inc., joined on May 13, 2014. On August 18, 2014, MBI Energy Services joined the PCOR Partnership.

Task Leader Meetings

Approximately once a month, internal EERC meetings are held with all the task leaders, the PI/program manager, budget personnel, and support staff. These meetings are convened in order to share information, create time lines for the completion of products, and disseminate data.

Carbon Sequestration Leadership Forum

The Carbon Sequestration Leadership Forum (CSLF) promotes collaborative research, development, and demonstration projects that reflect member priorities. CSLF may recognize collaborative projects that 1) facilitate the development of improved cost-effective technologies for the separation and capture of CO_2 for transport and long-term safe storage, 2) make these technologies broadly available internationally, and 3) identify and address wider issues relating to CCS. The RCSP project, comprising the seven regional partnerships including the PCOR Partnership, was recognized by CSLF at its Berlin meeting in September 2005.

The PCOR Partnership's Fort Nelson CCS project was granted CSLF recognition in October 2009 and is one of 43 such projects formally recognized. The PCOR Partnership has received project recognition for not only one project, but two projects. The Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project also received recognition in 2007.

In March 2014, PCOR Partnership management staff attended the CSLF Technical Group Meeting and Technology Workshop in Seoul, South Korea (Figure 22).

In September 2014, DOE, on behalf of CSLF, requested updated information to track progress in the development of technologies that will assist in CCS development for the CSLF Technology Roadmap. A response is under preparation and will be sent at the beginning of PY8.

Also in PY8, efforts will continue to encourage Denbury to seek recognition of the Bell Creek project.

Figure 22. Ed Steadman, EERC Deputy Associate Director for Research, presented and served on a panel regarding cost reduction strategies for CO_2 capture (www.cslforum.org/meetings/workshops/technical_seoul2014.html).

Advisory Board Meetings

In September 2011, DOE issued a contract modification, No. 21, authorizing the creation of an advisory board under SOPO Task 13 – Project Management. DOE also agreed to fund meetings and associated expenses through September 30, 2015.

The inaugural TAB meeting was held in February 2012 in San Diego, California. The first TAB includes the following CCUS and EOR experts:

- Bill Jackson, BillyJack Consulting, Inc. (Chair)
- Stefan Bachu, Alberta Innovates – Technology Futures (AITF)
- Ray Hattenbach, Blue Strategies
- Lynn Helms, NDIC
- Mike Jones, Lignite Energy Council
- Steve Melzer, Melzer Consulting
- Tom Olle, Texas International Energy Partners
- Steve Whittaker, Global CCS Institute
- Neil Wildgust, PTRC

The third annual TAB meeting was scheduled and held March 4–5, 2014, in Austin, Texas. Although only five board members are required for a quorum, six of the nine appointed TAB members were able to attend. Several presentations were given to update the TAB on the most recent status of the PCOR Partnership's projects. Topics covered included manuscript publication, outreach activities, regulatory developments in CCS, MVA, and the Bell Creek project. The TAB provided feedback in each of these areas and encouraged the PCOR Partnership to continue to disseminate the results of its work. Additionally, the TAB reminded the PCOR Partnership to continue to implement novel monitoring techniques to ensure a research component is maintained in its work.

In addition, several technical WebEx meetings were held in PY7. This format was preferable to the TAB members to accommodate their busy travel schedules, and this meeting was held in lieu of a face-to-face meeting at the EERC. In November 2013, five TAB members

participated in a review of the PCOR Partnership presentation for the 2013 RCSP Expert Panel Review (three of the four members who did not participate were a part of the IEAGHG review panel and were unable to participate in this WebEx because of conflict of interest). In June 2014, eight of the nine TAB members participated in a WebEx discussion on "Laboratory Investigations Related to CCS and EOR."

Brief TAB updates are also held in conjunction with the PCOR Partnership Annual Membership Meetings, and as such, a meeting was held on September 15, 2014, in Denver, Colorado.

Programmatic Risk Management Plan

A value-added RMP update (22) presented the latest formal update of the PCOR Partnership Program risk assessment (i.e., PCOR Partnership Round 2 risk assessment) in August 2014. Specifically, it presented an updated PCOR Partnership risk register, a subsequent reassessment of the probability and impact scores of the individual risks on four impact categories (i.e., cost, scope, time/schedule, and quality), and the preparation of revised risk maps. The risk register of the interim update risk assessment, which had been created in September 2013, was updated during the conduct of the Round 2 risk assessment. The results of this effort yielded a net increase of the risk register from 42 to 45 individual risks when two external risks were combined into a single risk and four new risks were identified (three external risks and one project management risk). With these changes, the Round 2 risk register of the PCOR Partnership consists of 45 individual risks that are distributed across the four risk categories as follows:

- External – 21 individual risks
- Technical – ten individual risks
- Organizational – ten individual risks
- Project management – four individual risks

This updated risk register provided the basis for generating the updated PCOR Partnership Round 2 risk assessment.

The risk trend analysis showed that the PCOR Partnership integrated strategy for CCUS project implementation is working. The programmatic risk assessments (RAs), RA1 (April 2011), RA2 (September 2013), and RA3 (August 2014), were implemented as part of that strategy, and as demonstrated in the update of the programmatic RMP, have resulted in the effective identification and management of risks over the course of the PCOR Partnership Program plan being executed. During that time, individual risks have been identified; other risks have been added or deleted over time, reflecting the dynamic nature of the program; and mitigation strategies have been put in place for those risks which demonstrated elevated risk criticality numbers. This implementation strategy will be continued until the PCOR Partnership Program is complete and has achieved its objectives.

Task 14 – RCSP WWG Coordination

In order to investigate the relationship between water and CCS, members of the RCSPs have formed the WWG. Each RCSP has its own unique set of challenges related to water utilization and the implementation of CCS activity, and the WWG will help to address those concerns. The PCOR Partnership leads the RCSP WWG comprising appropriate stakeholders. The RCSP WWG was initiated in January 2009. The purpose of the WWG is to address the wide variety of concerns and opportunities at the nexus of carbon storage and water resources. Development of documents under this task is led by the EERC, with input from all WWG participants.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – September 30, 2014) include the following.

Monthly Conference Calls

A total of 54 monthly conference calls (Milestone [M] 23) have taken place since the inception of this task, ten of which were completed in PY7, as follows: October 31, 2013; November 21, 2013; January 28, 2014; February 27, 2014; March 25, 2014; April 24, 2014; May 21, 2014; June 26, 2014; July 17, 2014 (WebEx meeting); and September 30, 2014. DOE NETL waived the requirement for conference calls during the months of December 2013, 2014, 2015, and 2016, in addition to August 2013. Minutes of the calls are submitted to the WWG the subsequent month following a call.

Status of the WWG

The WWG has completed the following items:

- Produced a white paper that identified a wide variety of nexus of water and CCS, provided a comprehensive review of related processes and concepts, and began identifying the various challenges and opportunities.

- Created a mission statement:

  "The mission of the RSCP WWG is 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."

- Developed a water and CCS fact sheet (Fact Sheet No. 1; 2011) and general PowerPoint presentation that summarized work in the white paper. In March 2013, Fact Sheet No. 2 entitled "Carbon Capture and Storage: Protecting Freshwater Resources" was finalized. Fact Sheet No. 3, "Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide" was finalized October 31, 2013. Development of Fact Sheet No. 4 (due October 31, 2014) is under

way. These products provide public outreach for the WWG and are distributed/presented at several conferences throughout the year.

- Developed a technologies gap assessment document (2011).

Annual Meetings

The sixth annual WWG meeting (M24) was held on August 11, 2014, in Pittsburgh, Pennsylvania, prior to the DOE Carbon Storage R&D Project Review Meeting. This meeting was held in conjunction with the OWG. There were ten attendees from four partnerships. The meeting agenda related to a discussion of potential synergies between the WWG and OWG and a discussion of the future direction of the WWG.

The OWG will review the WWG Web site and key deliverables to provide an outreach-focused approach. Additionally, the OWG will attempt to identify water and CCS-related issues that may have arisen during outreach-related conferences, workshops, and focus groups. The OWG will also assist the WWG in identifying new audiences for CCS–water-related research and work to refine the needs and interests of existing CCS stakeholders.

Methodology Document

A methodology document (D79) to estimate the resource that might be available in different reservoirs will be generated as storage projects are developed. Because of the lack of water produced in current RCSP storage projects, on December 15, 2009, DOE waived the requirement for water resource estimation methodology documents originally due February 2010 and May 2011. The fact sheet submitted April 30, 2010, replaced the former. The technology gaps assessment document replaced the latter. In September 2012, DOE waived the requirement for the methodology documents originally due November 30, 2012, and November 30, 2015. New fact sheets were created to replace these requirements (see section below). In February 2014, DOE eliminated the requirement for methodology documents due May 2014 and May 2017. Instead, the use of publicly accessible Web site content was decided upon as a means to share information on the nexus of water and CCS, and D101, WWG Web Site Content Update, was created with due dates in May 2014 and May 2016. Interim updates will be performed and reported during WWG conference calls and/or meetings.

Fact Sheet Development

In December 2011, the WWG distributed a Stakeholder Group Outreach Survey. The results of the survey were compiled into a WWG interest inventory. The primary vehicle to address the WWG survey results is through the development of fact sheets. In September 2012, a new deliverable, D99 – water–CCS nexus-related fact sheet, was created. The WWG then determined the topics for three fact sheets due March 31, 2013; October 31, 2013; and October 31, 2014, respectively.

In October 2013, a fact sheet entitled “Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide” was finalized.

This 4-page fact sheet provides an overview of the monitoring technologies that are being investigated for the protection of water resources. It is available on the PCOR Partnership public Web site at http://undeerc.org/pcor/pdfs/WWG_Fact_Sheet_3.pdf.

In PY7, work commenced on development of Fact Sheet No. 4. The working title of this fact sheet is "Long-Term Protection of Freshwater Resources Following CO_2 Storage," and it is due in PY8.

Web Site Content Development

In order to more effectively engage stakeholder groups and address stakeholder concerns, the WWG has prepared the content for a Web site that will be hosted on NETL's existing Web site as one of the programs described within the set of Web pages which describe the Carbon Dioxide Storage Program. NETL's current Web page will dictate specific content formatting, but the content itself has been generated by the WWG. This content generated in May 2014, will be periodically updated and formally reported as part of the scheduled update due the end of May 2016 (PY9).

The Web site content is broken into six individual "pages" which outline the WWG program and goals, provide links to WWG-produced content and other related sources of information, and provide contact information for Web site users to request additional information from the group. These six pages consist of:

- An introduction page.
- A page describing the basic principles of CCS.
- A page highlighting the interrelationships, the nexus, of water and CCS.
- A page highlighting the challenges and opportunities provided by CCS.
- A page of WWG products.
- A page of relevant program links.
- A page formally describing the goals of the WWG and appropriate contact information.

The Web site content is designed to be self-contained and informative but also succinct and streamlined. Users are given brief topical discussions and encouraged to explore additional linked resources (26).

Best Practices Manual

A BPM on the nexus of water and carbon storage activities will be assembled (D80) in BP5. This report will highlight the findings of the WWG and identify opportunities for water resource optimization in CCUS and topic areas where additional research could be conducted.

Task 15 – Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project

The Zama oil field in Alberta, Canada, was one of the geologic storage validation test sites during Phase II of the program. This project focused on the injection of acid gas into a partially

depleted oil field for the simultaneous purpose of acid gas disposal, CO_2 storage, and EOR. Because of the useful results and positive outcomes developed throughout the Phase II project, the site owner, Apache Canada Ltd. (Apache), was amenable to participation in follow-on characterization efforts at the Zama site. Accordingly, in June 2010, DOE NETL approved furtherance of the work that was performed in the Zama oil field during Phase II. A new deliverable was added for this new work (D86), an updated regional technology implementation plan for the Zama project, which was completed in February 2014. This task is now complete.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – February 28, 2014) include the following.

Updated Regional Technology Implementation Plan for Zama

Since December 2006, the Zama oil field in northwestern Alberta, Canada, has been the site of acid gas (approximately 70% CO_2 and 30% hydrogen sulfide [H_2S]) injection for the simultaneous purpose of EOR, acid gas disposal, and CO_2 storage. PCOR Partnership Phase III activities were designed and conducted to build upon knowledge gained in Phase II, including laboratory studies of the effects of acid gas on storage integrity and modeling efforts to develop improved predictions of both oil recovery and CO_2 storage capacity at Zama.

Previous geochemical modeling work conducted under Phase II indicated that reactions between Zama-type acid gas and typical Zama reservoir rocks can lead to varying degrees of both dissolution and precipitation. The Phase III program included laboratory experimental activities to directly examine geochemical interactions between Zama reservoir rocks, brine, pure CO_2, and CO_2–H_2S under Zama reservoir pressure and temperature conditions. No clear differences were observed between the preexposure and postexposure mineralogy. However, the applicability of these results may be limited because the rock samples that were available for these efforts were all limestones, and there can be significant quantities of dolomite in the Zama pinnacle reefs. Also, the experiments were of a short duration (28 days) and static. Longer-duration experiments that incorporate more variables may be more appropriate for assessing the interactions between acid gas and a carbonate reservoir.

While the rock analysis data may have limited applicability, some insight may be gained from the evaluation of changes in the composition of the fluids in which the rocks were immersed during the experiments. A clear decrease in the reactivity of both calcium and sulfate was observed in the samples exposed to the H_2S-rich gas stream. Also, measurements of TDS data indicate that CO_2–H_2S dissolved a lesser quantity of total mineral content. From the perspective of storage integrity, this lower mineral loss will presumably correspond to minimal loss of structural integrity of the formation. These results suggest that the presence of H_2S may actually reduce the reactivity of some carbonate rocks, thereby possibly serving to maintain reservoir and wellbore integrity rather than degrade it.

The effects that acid gas streams may have on wellbore cement were examined by exposing cement cores to pure CO_2 and CO_2–H_2S mixtures under Zama reservoir conditions. The

studies used Class H portland cement, which is typically used on acid gas injection/production wells. The addition of H_2S to the CO_2 storage system resulted in the formation of ettringite throughout the cement and precipitation of pyrite in the carbonated rim. Both phenomena can potentially lead to degradation of cement integrity. However, the experimental results also indicated that CO_2 in the system may dissolve the ettringite and reprecipitate calcium carbonates that may help improve the overall cement integrity.

The effects of corrosion on seven well casing steels, when exposed to CO_2 and acid gas under typical Zama reservoir conditions, were evaluated. The highest level of corrosion was observed in steels that were submerged in high-TDS water and exposed to pure CO_2. Corrosion rates from tests that included H_2S were consistently lower than those that included pure CO_2, with higher corrosive mass loss appearing in all samples reacted with pure CO_2. However, a significant amount of sulfur was found on the surfaces of samples exposed to CO_2–H_2S mixtures. While pitting was observed in all of the samples, it was more severe in cases of pure CO_2 exposure as compared to CO_2–H_2S. As with the rock studies, these results appear to suggest that, in some circumstances, the presence of H_2S may actually serve to counteract the effects of CO_2, helping to maintain wellbore integrity rather than contributing to its degradation.

PVT modeling work was performed to investigate the effect of H_2S and varying gas–oil ratios (GORs) on MMP. The results indicate that MMP decreased nearly linearly with increasing levels of H_2S in the injection gas dropping from 2660 psi with pure CO_2 to 2020 psi with 20 mol% H_2S in the G2G pool. Likewise, when the GOR was reduced from 414 to 200 scf/bbl, the simulated MMP dropped from 2660 to 1950 psi. These results indicate that it is important to consider both the components of the injected gas and the GOR of the current oil when estimating the MMP.

Modeling-based investigations of different operational scenarios yielded insight regarding the CO_2 sweep efficiency, possible injection and production schemes, EOR potential, and CO_2 storage capacity for Zama pinnacles. Static models of three of the six additional pinnacles were used to conduct dynamic simulations of various combinations of acid gas injection, EOR, and water extraction. The predicted storage capacity from simulation of the three individual pinnacles ranged from 0.16 to 1.11 million metric tons of CO_2, with the average storage capacity of the three pinnacles being nearly 0.36 million metric tons. Assuming the 840 other pinnacle reefs in the Zama Field have similar storage capacity, the CO_2 storage capacity may be nearly 303 million metric tons. With respect to EOR potential, results indicate acid gas EOR may yield an additional 6.2% to 15.6% of the original oil in place. The simulated CO_2 utilization factor results for the modeled Zama pools averaged approximately 0.56 metric tons/bbl or 11 Mscf/bbl.

Overall, the laboratory results indicate that the injection of a CO_2–H_2S mixed-gas stream into a carbonate formation for EOR and CO_2 storage is not likely to be more deleterious to wellbore integrity than the injection of pure CO_2. In fact, it appears that under some circumstances, the presence of H_2S may actually help maintain wellbore integrity against degradation from CO_2. These observations are supported by the fact that industrial-scale acid gas injection projects have been conducted in Alberta for over 20 years with no reported breaches in the wellbore integrity of acid gas injection wells. The modeling results confirm that miscible flooding with sour acid gas is an excellent means of storing large volumes of CO_2 while improving oil recovery. There are hundreds of pinnacle reefs throughout the world that hold in

excess of 1 million barrels of oil each. The results of the PCOR Partnership research activities at Zama indicate that, globally, pinnacle reef structures represent an excellent opportunity to recover millions of barrels of incremental oil through CO_2-based EOR and also have a great potential to perhaps store billions of metric tons of CO_2. The results also indicate that CO_2 streams do not have to be "pure" to be considered for use in CCUS projects and that some impurities may even be desirable under certain circumstances (27).

Task 16 – Basal Cambrian System Characterization

As part of the ongoing effort to characterize the northern Great Plains region of North America, a multiyear project was performed, with a goal of determining the potential for geologic storage of CO_2 in rock formations of the Basal Cambrian system. This sequence of saline formations is continuous throughout much of the PCOR Partnership region and underlies many of the area's large point sources of CO_2. The Basal Cambrian system represents a regionally significant target for CCS but is an area that had not previously been systematically evaluated with respect to CO_2 storage resource.

Because the Basal Cambrian system occurs in large parts of both the United States and Canada, this project was conducted by the EERC in cooperation with AITF as a binational effort. The EERC worked closely with key partners in the United States to evaluate the American portion of the Basal Cambrian system. AITF led a multiprovince team to conduct a similar evaluation for the Canadian portion of this system.

Members of the steering and technical committees include the following:

United States
- DOE NETL
- EERC
- Lawrence Berkeley National Laboratory (LBNL)
- Princeton University

Canada
- AITF
- Alberta Innovates – Energy & Environmental Solutions
- CANMETenergy
- Manitoba Innovation, Energy, and Mines
- Manitoba Water Stewardship
- NRCan
- PTRC
- Saskatchewan Energy & Resources
- TOTAL E&P Ltd.

This task was completed in March 2014.

Activities and Results

Accomplishments during BP4, PY7 (October 1, 2013 – March 31, 2014) include the following.

Storage Capacity Evaluation

This 3-year project was conducted with the goal of determining the potential for geologic storage of CO_2 in rock formations of the 517,000-square-mile Cambro-Ordovician Saline System (COSS). The project characterized the COSS using well log and core data from three states and three provinces, determined its storage potential by creating a heterogeneous 3-D model, and determined the effects of CO_2 storage in this system using dynamic simulation. The area underlain by the COSS includes several large CO_2 sources that each emits more than 0.9 million metric tons CO_2/year. Assuming that each of these sources will target the COSS for the storage of their CO_2, the primary questions addressed by this study are 1) what is the CO_2 storage resource of the COSS, 2) how many years of current CO_2 emissions will it be capable of storing, and 3) what will be required and what will be the effect of injecting 94 million metric tons/yr of CO_2 into the COSS?

A 3-D geocellular model was created and used to determine the static CO_2 storage resource and the dynamic storage capacity. The complexity of the reservoir was characterized from numerous sources of data, including the online databases of North Dakota, South Dakota, and Montana and a wealth of data provided by project partners in Canada. Multimineral petrophysical analysis was conducted to determine the system's gross lithology and key petrophysical characteristics. Information derived from these analyses was used to create a facies model that captures the heterogeneity of the COSS at this broad scale. The completed geocellular model contains information on temperature, pressure, porosity, permeability, and salinity (Figure 23). These variables were distilled to produce components needed to compute the CO_2 storage resource of the COSS following the E_{saline} formula detailed by the DOE Office of Fossil Energy Atlas III (201) and IV (2012) (28, 29). The resulting effective static CO_2 storage resource is 198, 373, and 640 billion metric tons at the P_{10}, P_{50}, and P_{90} percentiles, respectively. This resource potential represents more than 2100 years of storage for the current 94 million metric tons/yr point source emissions.

To further evaluate this extensive system and thus its viability as a potential sink, the geocellular model was used as the framework for an assessment of the system's dynamic CO_2 storage capacity. In the area above the COSS, there are 25 large stationary sources that were grouped into 16 geographic areas that have a combined annual emission of 94 million metric tons. With this in mind, the first injection scenario considered seven cases where the target was to inject this total mass of CO_2 for 36 or 50 years in the 16 injection areas using a total of 210 wells. Results from these cases show a total mass of CO_2 injected ranging from 74 to 1281 million metric tons across the injection period of 36 and 50 years. These values represent between 2.2% and 27.2% of the available CO_2 emitted from the 16 source locations. In the second scenario, eight new cases where the original 16 injection locations were disaggregated and moved (pipelined) to areas defined by the model as having good reservoir volume connection (geobodies) based on permeabilities greater than 50 mD. Injection amounts in the second scenario range from 1768 to 2823 million metric tons of CO_2. These values represent 37.5% to 59.8% of the CO_2 emitted from the source locations. Based on the results of both scenarios, the selection of areas with better permeability and connected volume had a large impact on increasing the total amount of CO_2 stored and the per well injection rates. However,

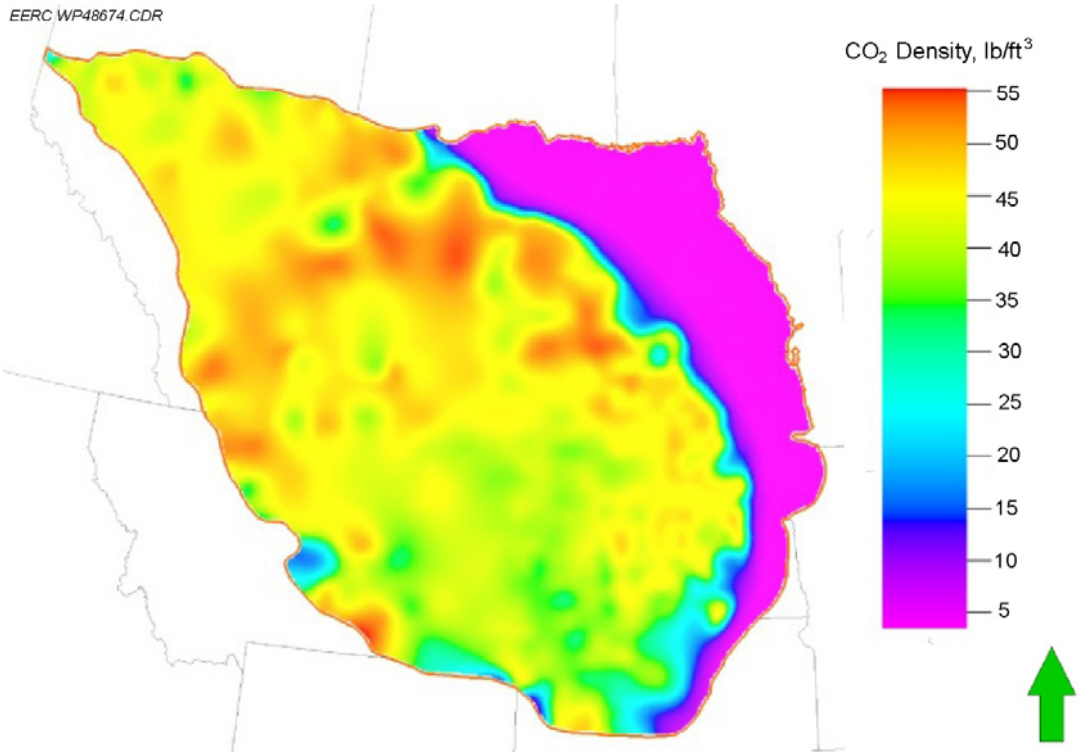


Figure 23. Modeled CO_2 density of the basal saline system and outline of the injectable area for sequestration (lb/ft^3).

even in the better area, the COSS was not able to support 211 injection wells with an average injection rate of 0.45 million metric tons/yr. In the second scenario, the average annual per well injection rate was between 168,000 and 249,500 metric tons/yr. At these injection rates, a total of 378 to 563 wells would have been required to meet the injection target. Pressure differences monitored in the second scenario show small changes in the 50-year injection time period. These minimal pressure differences indicate small risks of leakage from the reservoir and integrity of the sealing cap rock due to CO_2 injection in the COSS.

The results of the static CO_2 storage resource estimate indicate that the COSS has thousands of years of storage potential at the current point source CO_2 emission levels. However, the actual task of injecting the annual emissions is more difficult. Results from simulation indicate that injecting all the point source CO_2 in an area directly beneath the sources using 210 wells did not result in meeting the storage target. With that in mind, the COSS model and simulations were run on limited data, and just because these simulation cases indicated that the injection volumes, as a whole, could not be reached does not mean that the geology around a particular CO_2 source is poor. These results indicate that there is sufficient storage potential in the COSS to store all of the current point source CO_2 emissions for at least the next 50 years; however, more wells will likely be needed and spread out over more of the COSS to achieve this goal (30).

Petrophysical Evaluation of Core

The reader should refer to the Task 1 report entitled "Petrophysical Evaluation of Core from the Aquistore CO_2 Injection Site" that was submitted on March 26, 2014 (5) as a companion document to the "Geologic Modeling and Simulation Report for The Aquistore Project." The core analyzed was collected during PTRC's Aquistore project drilling operations. Because the Aquistore project lies within the Basal Cambrian system, the analyses were beneficial to work performed in Tasks 1 and 16.

Presentations

- Presented "Wellbore Evaluation of the Basal Cambrian System in the U.S. Portion of the Williston Basin" at the North American Wellbore Integrity Workshop on October 16, 2013, in Denver, Colorado.

- Presented "Carbon Dioxide Storage Potential of the Basal Saline System in the Alberta and Williston Basins of North America at CCUS-13.

- Submitted abstracts and papers for GHGT-12, including the following:

  – "Evaluation of Large-Scale Carbon Dioxide Storage Potential in the Basal Saline System in the Alberta and Williston Basins in North America"

  – "A Regional Wellbore Evaluation of the Basal Cambrian System"

- Submitted an abstract entitled "Case Study of Large-Scale Carbon Dioxide Storage in the Basal Saline System Utilizing a High-Performance Parallel Computing Cluster" for the High-Performance Computing Conference at Rice University in March 2014.

- Presented "Carbon Sequestration Case Study: Large-Scale Exploration in a Basal Saline System in Canada and the United States" at Carbon Management Technology Conference in Alexandria, Virginia.

- Compiled data for a manuscript using Bayesian classifiers and Bayesian networks to assess CO_2 leakage risk from wells in the Basal Cambrian.

- Prepared an abstract for the Society of Exploration Geophysicists Summer Research Workshop August 3–8, 2014, in San Diego, California (www.seg.org/events/upcoming-seg-meetings/sd14).

COST STATUS

The currently approved budget for Phase III is shown in Table 10.

On September 30, 2014, the PCOR Partnership completed its seventh year of BP4 activities (PY7, October 1, 2013 – September 30, 2014). Actual cash expenditures of DOE and nonfederal sources, as well as noncash cost share reported through September 30, 2014, are listed in Table 11.

Table 10. PCOR Partnership Phase III Budget as of Modification 30

	BP3 Year 1 – Year 2 10/1/07 – 9/30/09		BP4 Year 3 – Year 8 10/1/09 – 9/30/15		BP5 Year 9 – Year 10 10/1/15 – 9/30/17		Total	
DOE Share	$4,209,149	54.59%	$60,124,121	62.62%	$9,668,307	80.00%	$74,001,577	63.90%
Nonfederal Cost Share								
Cash*	$887,428		$2,411,971		$0		$3,299,399	
In-Kind	$2,613,890		$33,483,776		$2,417,076		$38,514,742	
Total Nonfederal Cost Share	$3,501,318	45.41%	$35,895,747	37.38%	$2,417,076	20.00%	$41,814,141	36.10%
Total	**$7,710,467**	**100.00%**	**$96,019,868**	**100.00%**	**$12,085,383**	**100.00%**	**$115,815,718**	**100.00%**

* Cash as recognized by DOE.

Table 11. BP4 Funding and Actual Costs as of September 30, 2014

Organization	Approved Budget*, $	Actual Costs Incurred, $
DOE Share – Cash	60,124,121	47,569,205
Nonfederal Share – Cash	2,411,971	2,868,827
Nonfederal Share – In-Kind	33,483,776	33,339,053
Total	96,019,868	83,777,085

*As of Modification 30.

SCHEDULE STATUS

Table 12 contains all of the Phase III deliverables, milestones, and submission dates for the reporting period. Tables 13–15 provide Gantt charts for BP4, including the reporting period (BP4, PY7) and the next program year.

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 1 – Quarter 1 (October–December 2007)		
D37: Task 4 – Fort Nelson Test Site – Geological Characterization Experimental Design Package	12/31/07	12/28/07
D63: Task 13 – Project Management Plan	12/31/07	12/28/07
M17: Task 4 – Fort Nelson Test Site Selected	12/31/07	12/28/07
Year 1 – Quarter 2 (January–March 2008)		
D38: Task 4 – Fort Nelson Test Site – Geomechanical Experimental Design Package	1/31/08	1/31/08
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/08	1/31/08
D11: Task 2 – Outreach Plan	3/31/08	3/31/08
D27: Task 3 – Environmental Questionnaire – Fort Nelson Test Site	3/31/08	4/02/08
D30: Task 4 – Williston Basin Test Site – Geomechanical Experimental Design Package	3/31/08	3/31/08
M1: Task 1 – Three Target Areas Selected for Detailed Characterization	3/31/08	3/20/08
M18: Task 4 – Fort Nelson Test Site Geochemical Work Initiated	3/31/08	3/19/08
Year 1 – Quarter 3 (April–June 2008)		
D14: Task 2 – General Phase III Fact Sheet	4/30/08	4/30/08
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/08	4/30/08
D17: Task 2 – General Phase III Information PowerPoint Presentation	5/30/08	5/30/08
M3: Task 3 – Start Environmental Questionnaire for Williston Basin Test Site	6/30/08	6/27/08
M6: Task 4 – Williston Basin Test Site Geochemical Work Initiated	6/30/08	6/30/08
M7: Task 4 – Williston Basin Test Site Geological Characterization Data Collection Initiated	6/30/08	6/30/08
Year 1 – Quarter 4 (July–September 2008)		
D12: Task 2 – Demonstration Web Pages on the Public Site	7/31/08	7/31/08
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/08	7/31/08
D1: Task 1 – Review of Source Attributes	9/30/08	9/26/08
M2: Task 1 – Demonstration Project Reporting System (DPRS) Prototype Completed	9/30/08	9/26/08
Year 2 – Quarter 1 (October–December 2008)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/31/08	10/31/08
D20: Task 2 – Documentary Support to PowerPoint and Web Site	12/31/08	12/31/08
D57: Task 12 – Project Assessment Annual Report	12/31/08	12/31/08

Continued…

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 2 – Quarter 2 (January–March 2009)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/09	1/30/09
M21: Task 14 – Outline of White Paper on Nexus of CO_2 Capture and Sequestration (CCS) and Water, Part Subtask 14.2 – White Paper on Nexus of CCS and Water	2/28/09	2/27/09
D24: Task 2 – PCOR Partnership Region CO_2 Storage General Poster	3/31/09	3/31/09
Year 2 – Quarter 3 (April–June 2009)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/09	4/30/09
M23: Task 14 – Monthly WWG Conference Call Held	4/30/09	4/15/09
D2: Task 1 – First Target Area Completed	5/29/09	5/29/09
M23: Task 14 – Monthly WWG Conference Call Held	5/29/09	5/29/09
D16: Task 2 – Fort Nelson Test Site Fact Sheet	5/29/09	5/29/09
M24: Task 14 – WWG Annual Meeting Held	5/31/09	5/07/09
M23: Task 14 – Monthly WWG Conference Call Held	6/30/09	6/25/09
Year 2 – Quarter 4 (July–September 2009)		
M23: Task 14 – Monthly WWG Conference Call Held	N/A	Not required
D19: Task 2 – Fort Nelson Test Site PowerPoint Presentation	7/31/09	7/31/09
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/09	7/31/09
M22: Task 14 – Draft White Paper – Nexus of CCS and Water Available for Comments	8/17/09	8/18/09 (DOE) 8/21/09 (WWG)
M23: Task 14 – Monthly WWG Conference Call Held	8/31/09	8/25/09
D1: Task 1 – Review of Source Attributes (Update)	9/30/09	9/25/09
D3: Task 1 – Permitting Review – One State and One Province	9/30/09	9/30/09
D9: Task 1 – Updated DSS	9/30/09	9/29/09
D47: Task 6 – Report on the Preliminary Design of Advanced Compression Technology	9/30/09	9/30/09
D77: Task 13 – RMP Outline	9/30/09	9/18/09
M4: Task 4 – Bell Creek Test Site Selected	9/30/09	9/30/09
M5: Task 4 – Bell Creek Test Site – Data Collection Initiated	9/30/09	9/30/09
M23: Task 14 – Monthly WWG Conference Call Held	9/30/09	9/22/09

Continued . . .

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 3 – Quarter 1 (October–December 2009)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/30/09	11/02/09
D78: Task 14 – Final White Paper on the Nexus of CCS and Water	10/30/09	10/28/09
M23: Task 14 – Monthly WWG Conference Call Held	10/31/09	10/26/09
M23: Task 14 – Monthly WWG Conference Call Held	11/30/09	11/16/09
D57: Task 12 – Project Assessment Annual Report	12/31/09	12/31/09
M23: Task 14 – Monthly WWG Conference Call Held	12/31/09	Waived by DOE
Year 3 – Quarter 2 (January–March 2010)		
D13: Task 2 – Public Site Updates	1/15/10	1/15/10
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/10	1/29/10
M23: Task 14 – Monthly WWG Conference Call Held	1/31/10	1/6/10
D79: Task 14 – Water Resource Estimation Methodology Document	2/28/10	Waived by DOE
M23: Task 14 – Monthly WWG Conference Call Held	2/28/10	2/25/10
D11: Task 2 – Outreach Plan	3/31/10	3/31/10
M23: Task 14 – Monthly WWG Conference Call Held	3/31/10	3/23/10
Year 3 – Quarter 3 (April–June 2010)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/10	4/30/10
M23: Task 14 – Monthly WWG Conference Call Held	4/30/10	4/28/10
M23: Task 14 – Monthly WWG Conference Call Held	5/31/10	5/13/10
D17: Task 2 – General Phase III Information PowerPoint Presentation (Update)	6/30/10	6/30/10
D19: Task 2 – Fort Nelson Test Site PowerPoint Presentation (Update)	6/30/10	6/29/10
M23: Task 14 – Monthly WWG Conference Call Held	6/30/10	6/23/10
M24: Task 14 – WWG Annual Meeting Held	6/30/10	5/13/10
Year 3 – Quarter 4 (July–September 2010)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/10	7/29/10
M23: Task 14 – Monthly WWG Conference Call Held	7/31/10	7/28/10
M23: Task 14 – Monthly WWG Conference Call Held	8/31/10	8/31/10
D1: Task 1 – Review of Source Attributes – (Update)	9/30/10	9/20/10
D52: Task 9 – Fort Nelson Test Site – Site Characterization, Modeling, and Monitoring Plan	9/30/10	9/30/10
M9: Task 4 – Bell Creek Test Site Geological Model Development Initiated	9/30/10	9/30/10
M23: Task 14 – Monthly WWG Conference Call Held	9/30/10	Waived by DOE

Continued…

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 4 – Quarter 1 (October–December 2010)		
D87: Task 4 – Bell Creek Test Site – Geomechanical Experimental Design Package	10/30/10	10/29/10
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/31/10	10/29/10
M23: Task 14 – Monthly WWG Conference Call Held	10/31/10	10/26/10
M23: Task 14 – Monthly WWG Conference Call Held	11/30/10	Waived by DOE
D57: Task 12 – Project Assessment Annual Report	12/31/10	12/23/10
M23: Task 14 – Monthly WWG Conference Call Held	12/31/10	12/23/10
Year 4 – Quarter 2 (January–March 2011)		
M8: Task 4 – Bell Creek Test Site Wellbore Leakage Data Collection Initiated	1/15/11	1/14/11
D31: Task 4 – Bell Creek Test Site – Geological Characterization Experimental Design Package	1/31/11	1/27/11
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/11	1/31/11
M23: Task 14 – Monthly WWG Conference Call Held	1/31/11	1/19/11
M28: Task 4 – Bell Creek Geological Experimental Design Package Completed	1/31/11	1/27/11
D15: Task 2 – Bell Creek Test Site Fact Sheet	2/28/11	2/28/11
M23: Task 14 – Monthly WWG Conference Call Held	2/28/11	Waived by DOE
D10: Task 1 – Demonstration Project Reporting System Update	3/31/11	3/25/11
D18: Task 2 – Bell Creek Test Site PowerPoint Presentation	3/31/11	3/31/11
D26: Task 2 – Fort Nelson Test Site Poster	3/31/11	3/31/11
D28 : Task 3 – Environmental Questionnaire – Bell Creek Test Site	3/31/11	3/30/11
D85: Task 6 – Report – Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCUS Activities	3/31/11	3/31/11
M23: Task 14 – Monthly WWG Conference Call Held	3/31/11	3/22/11
Year 4 – Quarter 3 (April–June 2011)		
M30: Task 5 – Bell Creek Test Site Baseline MVA will be initiated	4/01/11	3/24/11
M23: Task 14 – Monthly WWG Conference Call Held	4/30/11	4/21/11
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/11	4/29/11
D88: Task 13 – Programmatic RMP	4/30/11	4/29/11
D17: Task 2 – General Phase III Information PowerPoint Presentation (Update)	5/31/11	5/31/11
D34: Task 4 – Bell Creek Test Site – Baseline Hydrogeological Experimental Design Package	5/31/11	5/31/11
M23: Task 14 – Monthly WWG Conference Call Held	5/31/11	5/5/11

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Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 4 – Quarter 3 (April–June 2011) (continued)		
D19: Task 2 – Fort Nelson Test Site PowerPoint Presentation (Update)	6/30/11	6/30/11
M23: Task 14 – Monthly WWG Conference Call Held	6/30/11	6/23/11
M24: Task 14 – WWG Annual Meeting Held	6/30/11	5/5/11
Year 4 – Quarter 4 (July–September 2011)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/11	7/28/11
M23: Task 14 – Monthly WWG Conference Call Held	7/31/11	7/26/11
D29: Task 3 – Permitting Action Plan	8/31/11	8/31/11
D66: Task 9 – Bell Creek Test Site – Simulation Report	8/31/11	8/31/11
D67: Task 9 – Fort Nelson Test Site – Simulation Report	8/31/11	8/31/11
M23: Task 14 – Monthly WWG Conference Call Held	8/31/11	8/24/11
D1: Task 1 – Review of Source Attributes (Update)	9/30/11	9/21/11
D4: Task 3 – Permitting Review – Basic EPA Requirements	9/30/11	9/30/11
D9: Task 1 – Updated DSS	9/30/11	9/23/11
D25: Task 2 – Bell Creek Test Site Poster	9/30/11	9/30/11
D50: Task 9 – Bell Creek Test Site – Site Characterization, Modeling, and Monitoring Plan	9/30/11	9/30/11
M23: Task 14 – Monthly WWG Conference Call Held	9/30/11	Waived by DOE
M31: Task 9 – Bell Creek Test Site – Site Characterization, Modeling, and Monitoring Plan Completed	9/30/11	9/30/11
M33: Task 16 – Basal Cambrian Baseline Geological Characterization Completed	9/30/11	9/29/11
Year 5 – Quarter 1 (October–December 2011)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/31/11	10/31/11
M23: Task 14 – Monthly WWG Conference Call Held	10/31/11	10/26/11
M23: Task 14 – Monthly WWG Conference Call Held	11/30/11	11/30/11
D57: Task 12 – Project Assessment Annual Report	12/31/11	12/30/11
M23: Task 14 – Monthly WWG Conference Call Held	12/31/11	Waived by DOE
M34: Task 16 – Basal Cambrian Static Geological Model Completed	12/31/11	12/21/11

Continued . . .

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 5 – Quarter 2 (January–March 2012)		
M16: Task 4 – Bell Creek Test Site – Initiation of Production and Injection Simulation	1/13/12	12/29/11
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/12	1/31/12
D65: Task 4 – Fort Nelson Test Site – Site Characterization Report	1/31/12	1/31/12
D81: Task 1 – Regional Carbon Sequestration Atlas (Update)	1/31/12	1/31/12
M29: Task 4 – Fort Nelson Site Characterization Report Completed	1/31/12	1/31/12
M23: Task 14 – Monthly WWG Conference Call Held	1/31/12	1/19/12
D91: Task 16 – Report – Geological Characterization of the Basal Cambrian System in the Williston Basin	2/29/12	2/29/12
M23: Task 14 – Monthly WWG Conference Call Held	2/29/12	2/28/12
D5: Task 1 – Second Target Area Completed	3/31/12	3/30/12
D18: Task 2 – Bell Creek Test Site PowerPoint Presentation (Update)	3/31/12	3/30/12
M10: Task 4 – Bell Creek Test Site Wellbore Leakage Data Collection Completed	3/31/12	3/12/12
M23: Task 14 – Monthly WWG Conference Call Held	3/31/12	3/27/12
M36: Annual Advisory Board Meeting Scheduled	3/31/12	3/28/12
Year 5 – Quarter 3 (April–June 2012)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/12	4/30/12
M23: Task 14 – Monthly WWG Conference Call Held	4/30/12	Waived by DOE
D17: Task 2 – General Phase III Information PowerPoint Presentation (Update)	5/31/12	5/31/12
M23: Task 14 – Monthly WWG Conference Call Held	5/31/12	5/31/12
D19: Task 2 – Fort Nelson Test Site PowerPoint Presentation (Update)	6/30/12	6/29/12
D41: Task 4 – Fort Nelson Test Site – Geochemical Report (extension from 12/15/11 % 4/30/12)	6/30/12	6/29/12
D84: Task 6 – Report – A Phased Approach to Building Pipeline Network for CO_2 Transportation During CCUS	6/30/12	6/29/12
M23: Task 14 – Monthly WWG Conference Call Held	6/30/12	6/28/12
M24: Task 14 – WWG Annual Meeting Held	6/30/12	5/3/12
M32: Task 4 – Fort Nelson Geochemical Report Completed (extension from 12/15/11 and 4/30/12)	6/30/12	6/29/12
Year 5 – Quarter 4 (July–September 2012)		
D13: Task 2 – Public Site Updates	7/31/12	7/31/12
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/12	7/31/12
D67: Task 9 – Fort Nelson Test Site – Simulation Report	7/31/12	7/31/12
M23: Task 14 – Monthly WWG Conference Call Held	7/31/12	7/24/12

Continued . . .

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 5 – Quarter 4 (July–September 2012) (continued)		
D66: Task 9 – Bell Creek Test Site – Simulation Report	8/31/12	8/31/12
M23: Task 14 – Monthly WWG Conference Call Held	8/31/12	8/30/12
D1: Task 1 – Review of Source Attributes (Update)	9/30/12	9/28/12
D10: Task 1 – DPRS Update	9/30/12	9/28/12
M23: Task 14 – Monthly WWG Conference Call Held	9/30/12	9/27/12
Year 6 – Quarter 1 (October–December 2012)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/31/12	10/31/12
M23: Task 14 – Monthly WWG Conference Call Held	10/31/12	10/25/12
M23: Task 14 – Monthly WWG Conference Call Held	11/30/12	11/28/12
D41: Fort Nelson Test Site – Geochemical Report (Update 1)	12/15/12	12/15/12
D57: Task 12 – Project Assessment Annual Report	12/31/12	12/28/12
M23: Task 14 – Monthly WWG Conference Call Held	12/31/12	Waived by DOE
M37: Task 3 – IOGCC Task Force Subgroup Meeting 1 Held	12/31/12	12/21/12
Year 6 – Quarter 2 (January–March 2013)		
D32: Task 4 – Bell Creek Test Site – Geomechanical Report	1/31/13*	1/31/13
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/13	1/31/13
M23: Task 14 – Monthly WWG Conference Call Held	1/31/13	1/16/13
D14: Task 2 – General Phase III Fact Sheet (Update)	2/28/13	2/28/13
M23: Task 14 – Monthly WWG Conference Call Held	2/28/13	2/26/13
D85: Task 6 – Report – Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCS Activities	3/31/13	Waived by DOE
D89: Task 16 – Report – Geochemical Evaluation of the Basal Cambrian System	3/31/13	3/28/13
D99: Task 14 – Water–CCS Nexus-Related Fact Sheet	3/31/13	3/22/13
M23: Task 14 – Monthly WWG Conference Call Held	3/31/13	3/26/13
M36: Task 13 – Annual Advisory Board Meeting Scheduled	3/31/13	3/27/13

Continued . . .

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 6 – Quarter 3 (April–June 2013)		
D15: Task 2 – Bell Creek Test Site Fact Sheet (Update)	4/15/13	3/25/13
D16: Task 2 – Fort Nelson Test Site Fact Sheet (Update)	4/30/13	Waived by DOE
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/13	4/30/13
M14: Task 4 – Bell Creek Test Site Geological Characterization Data Collection Completed	4/30/13	4/30/13
M23: Task 14 – Monthly WWG Conference Call Held	4/30/13	4/25/13
M35: Task 16 – Basal Cambrian Dynamic Capacity Estimation Completed	4/30/13	4/30/13
D17: Task 2 – General Phase III Information PowerPoint Presentation (Update)	5/31/13	5/31/13
D43: Task 5 – Bell Creek Test Site – Monitoring Experimental Design Package	5/31/13	5/31/13
M23: Task 14 – Monthly WWG Conference Call Held	5/31/13	5/30/13
M27: Task 5 – Bell Creek Test Site – MVA Equipment Installation and Baseline MVA Activities Completed	5/31/13	5/31/13
M42: Task 3 –Findings and Recommendations of the Operational and Postoperational Subgroups Presented to the CGS Task Force	6/30/13	6/28/13
M23: Task 14 – Monthly WWG Conference Call Held	6/30/13	6/27/13
M26: Task 8 – Bell Creek Test Site – CO2 Injection Initiated	6/30/13	May 2013
M37: Task 3 – IOGCC Task Force Subgroup Meeting 2 Held	6/30/13	5/9/13 sent 5/29/13
Year 6 – Quarter 4 (July–September 2013)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/13	7/31/13
D33: Task 4 – Bell Creek Test Site – Preinjection Geochemical Report	7/31/13*	7/31/13
M12: Task 4 – Bell Creek Test Site – Preinjection Geochemical Work Completed	7/31/13*	7/31/13
M23: Task 14 – Monthly WWG Conference Call Held	7/31/13	7/25/13
D64: Task 4 – Bell Creek Test Site – Site Characterization Report	8/31/13*	8/29/13
D66: Task 9 – Bell Creek Test Site – Simulation Report	8/31/13*	8/30/13
D81: Task 1 – Regional Carbon Sequestration Atlas (Update)	8/31/13	5/1/13
M23: Task 14 – Monthly WWG Conference Call Held	8/31/13	Waived by DOE

Continued . . .

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 6 – Quarter 4 (July–September 2013) (continued)		
D1: Task 1 – Review of Source Attributes (Update)	9/30/13	9/5/13
D6: Task 3 – Permitting Review – Update 1	9/30/13	9/24/13
D48: Task 7 – Bell Creek Test Site – Procurement Plan and Agreement Report	9/30/13	9/24/13
D90: Task 16 – Report – Wellbore Evaluation of the Basal Cambrian System	9/30/13	9/5/13
D94:Task 2 – Aquistore Project Fact Sheet	9/30/13	9/30/13
D95: Task 2 – Aquistore Project Poster	9/30/13	9/30/13
D98: Task 3 – Report – Findings, Recommendations, and Guidance of the CGS Task Force on Operational and Postoperational Liability	9/30/13	8/30/13
M23: Task 14 – Monthly WWG Conference Call Held	9/30/13	9/30/13
M38: Task 3 – IOGCC Task Force Wrap-Up Meeting Held	9/30/13	8/16/13 & 9/5/13
M39: Task 3 – IOGCC Task Force Editing Subgroup Meeting Held	9/30/13	6/3/13 & 9/5/13
M40: Task 15 – Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project Completed	9/30/13	9/24/13
Year 7 – Quarter 1 (October–December 2013)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/31/13	10/31/13
D42: Task 5 – Bell Creek Test Site – Injection Experimental Design Package	10/31/13	10/30/13
D99: Task 14 – Water/CCS Nexus-Related Fact Sheet	10/31/13	10/31/13
M23: Task 14 – Monthly WWG Conference Call Held	10/31/13	10/31/13
M23: Task 14 – Monthly WWG Conference Call Held	11/30/13	11/21/13
M23: Task 14 – Monthly WWG Conference Call Held	12/31/13	Waived by DOE
M24: Task 14 – WWG Annual Meeting Held	12/31/13	8/19/13
M43: Task 9 – Bell Creek Test Site – First Full-Repeat Sampling of the Groundwater- and Soil Gas-Monitoring Program Completed	12/31/13	11/15/13 & 12/13/13
Year 7 – Quarter 2 (January–March 2014)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/14	1/31/14
D57: Task 12 – Project Assessment Annual Report	1/31/14	1/31/14
M23: Task 14 – Monthly WWG Conference Call Held	1/31/14	1/28/14
M41: Task 6 – Decision to Incorporate Ramgen Compression Technology into Bell Creek Project	1/31/14	1/29/14
D86: Task 15 – Updated Regional Implementation Plan for Zama (extension from 4/30/12)	2/28/14	2/28/14
M23: Task 14 – Monthly WWG Conference Call Held	2/28/14	2/27/14

Continued . . .

Table 12. PCOR Partnership Phase III, BP3 and BP4 (through 9/30/2014) Deliverables and Milestones

Title/Description	Due Date	Actual Completion Date
Year 7 – Quarter 2 (January–March 2014) (continued)		
D24: Task 2 – PCOR Partnership Region CO_2 Storage General Poster (Update)	3/31/14	3/27/14
D36: Task 4 – Bell Creek Test Site – Wellbore Leakage Final Report	3/31/14	3/19/14
D92: Task 16 – Report – Storage Capacity and Regional Implications for Large-Scale Storage in the Basal Cambrian System	3/31/14	3/27/14
D93: Task 1 – Geological Modeling and Simulation Report for the Aquistore Project	3/31/14	3/25/14
D96: Task 4 – Bell Creek Test Site – 3-D Seismic Acquisition and Characterization Report	3/31/14	3/27/14
M23: Task 14 – Monthly WWG Conference Call Held	3/31/14	3/25/14
M36: Task 13 – Annual Advisory Board Meeting Scheduled	3/31/14	3/4/14 – sent 3/25/14
M44: Task 4 – Bell Creek Test Site – First 3-D VSP Repeat Surveys Completed	3/31/14	3/1/14 – sent 3/25/14
Year 7 – Quarter 3 (April–June 2014)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/14	4/30/14
M23: Task 14 – Monthly WWG Conference Call Held	4/30/14	4/24/14
D17: Task 2 – General Phase III Information PowerPoint Presentation (Update)	5/31/14	5/30/14
D101: Task 14 – WWG Web Site Content	5/31/14	5/30/14
M23: Task 14 – Monthly WWG Conference Call Held	5/31/14	5/21/14
D44: Task 5 – Bell Creek Test Site – Drilling and Completion Activities Report	6/30/14	5/30/14
M23: Task 14 – Monthly WWG Conference Call Held	6/30/14	6/26/14
M45: Task 4 – Bell Creek Test Site – First full-repeat of pulsed-neutron logging campaign completed	6/30/14	6/9/14
M46: Task 9 – Bell Creek Test Site – 1 year of Injection Completed	6/30/14	6/26/14
Year 7 – Quarter 4 (July–September 2014)		
D13: Task 2 – Public Site Updates	7/31/14	7/29/14
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/14	7/31/14
M23: Task 14 – Monthly WWG Conference Call Held	7/31/14	WebEx
D66: Task 9 – Bell Creek Test Site – Simulation Report	8/31/14	8/27/14 (exec sum only)
M23: Task 14 – Monthly WWG Conference Call Held	8/31/14	Waived
D1: Task 1 – Review of Source Attributes (Update)	9/30/14	9/24/14
D7: Task 1 – Third Target Area Completed	9/30/14	9/26/14
D93: Task 1 – Geological Modeling and Simulation Report for the Aquistore Project (Update)	9/30/14	9/30/14
D100: Task 9 – Fort Nelson Test Site – Best Practices Manual – Feasibility Study	9/30/14	9/30/14
M23: Task 14 – Monthly WWG Conference Call Held	9/30/14	9/30/14

Table 13. PCOR Partnership Phase III Gantt Chart (BP4, PY3–PY4)

Continued…

Table 13. PCOR Partnership Phase III Gantt Chart (BP4, PY3–PY4) (continued)

Continued…

Table 13. PCOR Partnership Phase III Gantt Chart (BP4, PY3–PY4) (continued)

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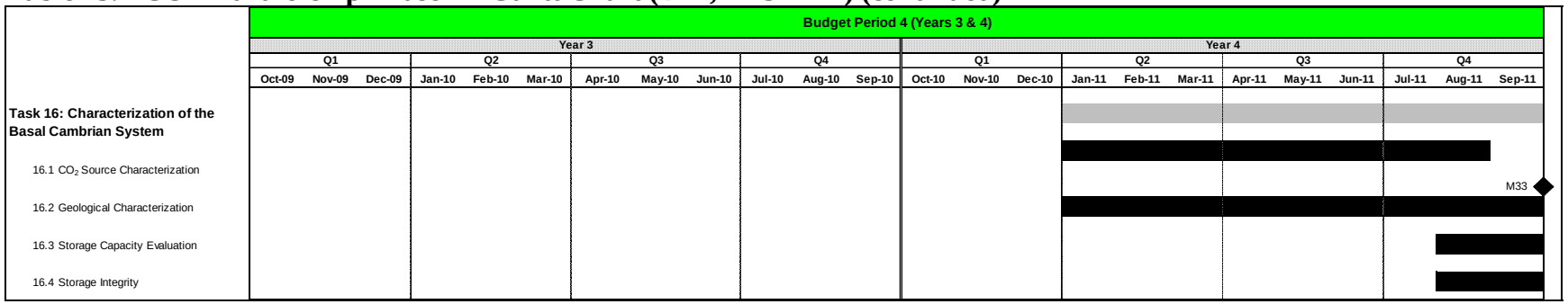
Table 13. PCOR Partnership Phase III Gantt Chart (BP4, PY3–PY4) (continued)



Summary Task | Activity Bar | Progress Activity Bar | Time Now | Deliverable | Milestone

Key for Deliverables (D)			
D1	Review of Source Attributes	D29	Permitting Action Plan
D4	Permitting Review – Basic EPA Requirements	D31	BC Test Site – Geological Characterization Experimental Design Package
D9	Updated DSS	D34	BC Test Site – Baseline Hydrogeological Experimental Design Package
D10	DPRS Update	D50	BC Test Site – Site Characterization, Modeling, and Monitoring Plan
D11	Outreach Plan	D52	FN Test Site – Site Characterization, Modeling, and Monitoring Plan
D13	Public Site Updates	D57	Project Assessment Annual Report
D15	Bell Creek (BC) Test Site Fact Sheet	D58	Quarterly Progress Report
D16	Fort Nelson (FN) Test Site Fact Sheet	D59	Milestone Quarterly Report
D17	General Phase III Information PowerPoint Presentation	D66	BC Test Site – Simulation Report
D18	BC Test Site PowerPoint Presentation	D67	FN Test Site – Simulation Report
D19	FN Test Site PowerPoint Presentation	D78	White Paper – Nexus of CCS and Water
D20	Video Support to PowerPoint and Web Site	D81	Regional Carbon Sequestration Atlas (update)
D24	PCOR Partnership Region CO_2 Storage General Poster	D85	Report – Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCS Activities
D25	BC Test Site Poster		
D26	FN Test Site Poster	D87	BC Test Site – Geomechanical Experimental Design Package
D28	BC Test Site – Environmental Questionnaire	D88	Programmatic Risk Management Plan

Key for Milestones (M)	
M8	BC Test Site – Wellbore Leakage Data Collection Initiated
M9	BC Test Site – Geological Model Development Initiated
M23	Monthly WWG Conference Call Held
M24	WWG Annual Meeting Held
M28	BC Test Site – Geological Characterization Experimental Design Package Completed
M30	BC Test Site – Baseline MVA Activities Initiated
M31	BC Test Site – Site Characterization, Modeling, and Monitoring Plan Completed
M33	Basal Cambrian Baseline Geological Characterization Completed

Table 14. PCOR Partnership Phase III Gantt Chart (BP4, PY5–PY6)

Continued…

Table 14. PCOR Partnership Phase III Gantt Chart (BP4, PY5–PY6) (continued)

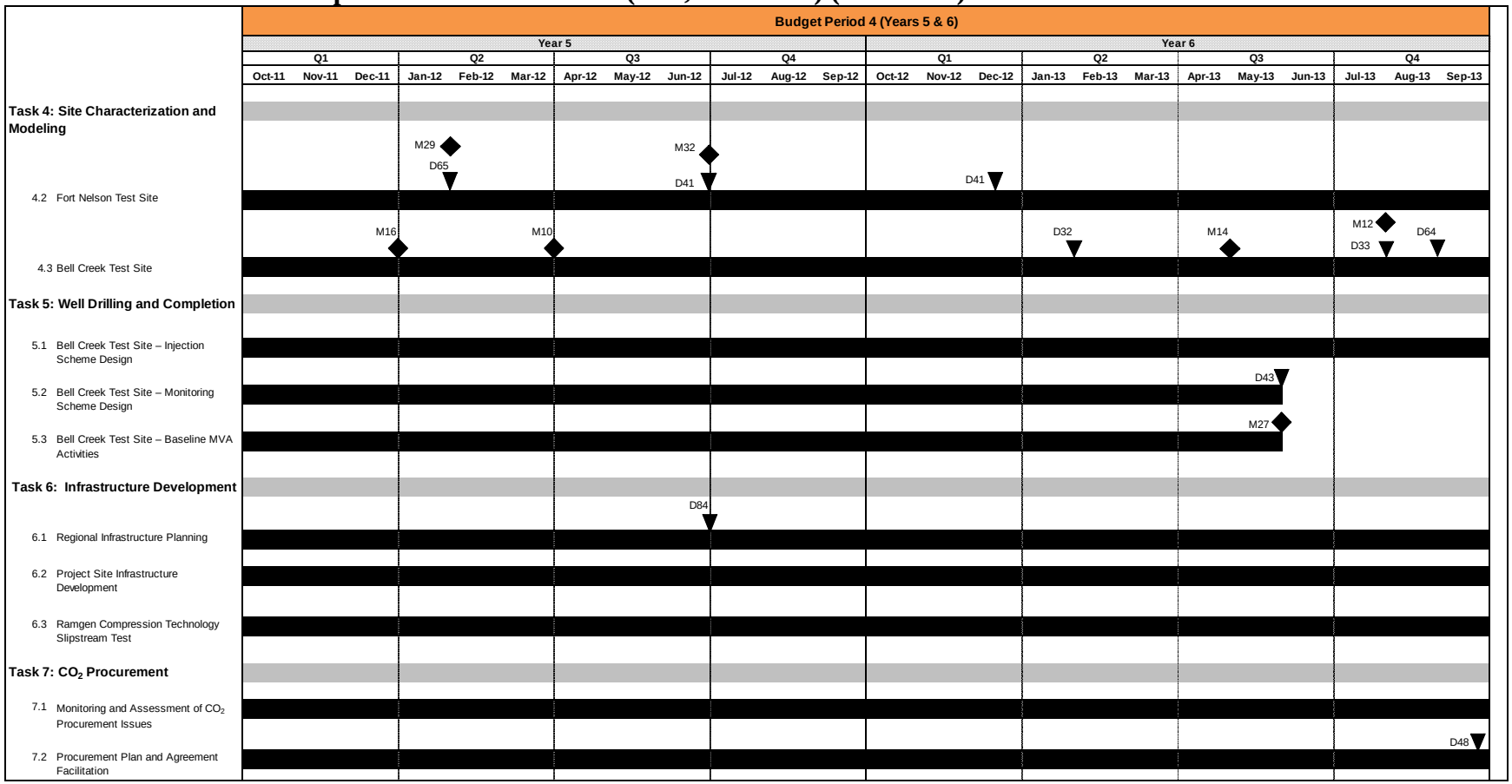


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Table 14. PCOR Partnership Phase III Gantt Chart (BP4, PY5–PY6) (continued)

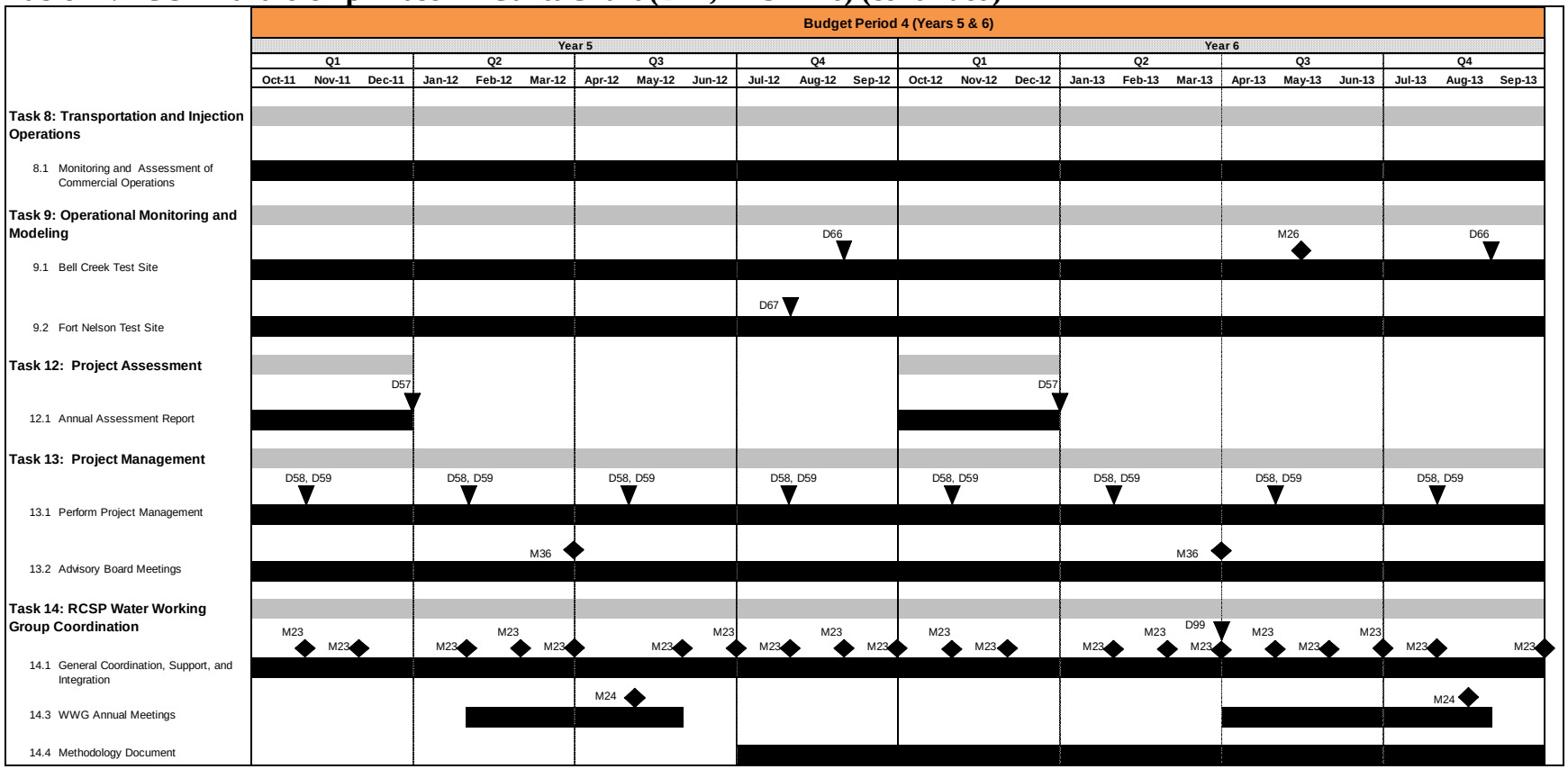

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Table 14. PCOR Partnership Phase III Gantt Chart (BP4, PY5–PY6) (continued)

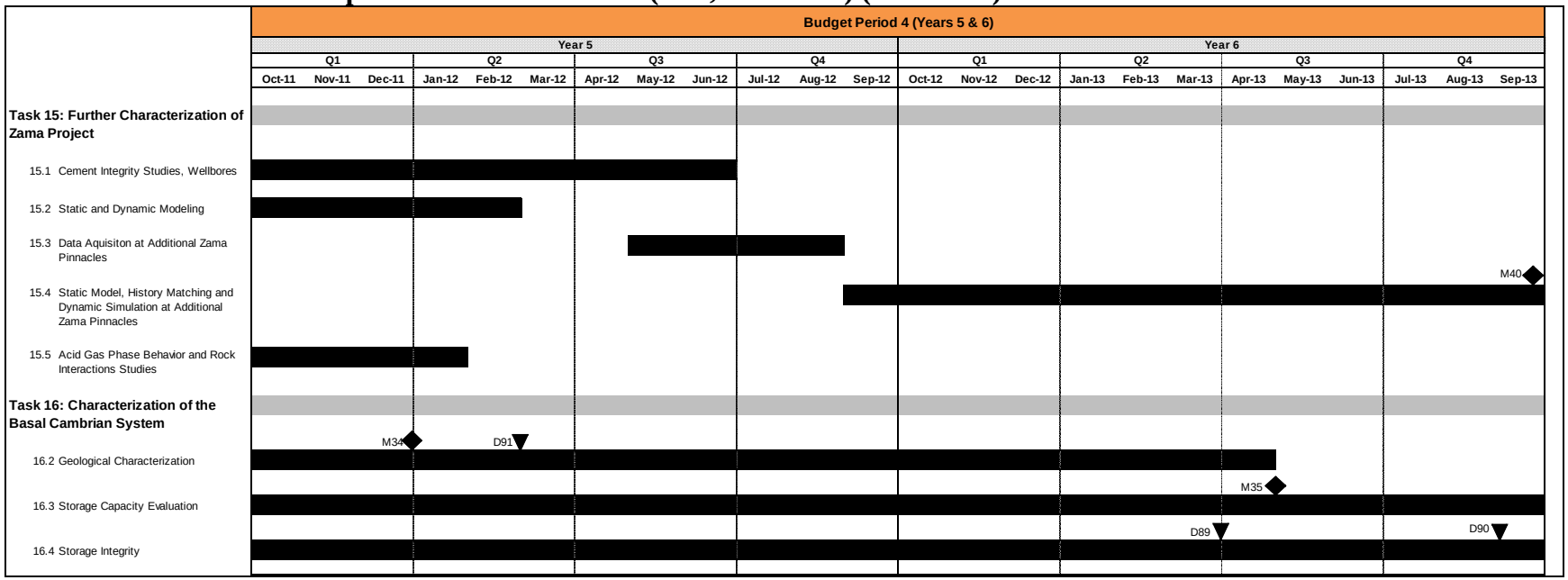

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Table 14. PCOR Partnership Phase III Gantt Chart (BP4, PY5–PY6) (continued)

Key for Deliverables (D) ▼		Key for Milestones (M) ◆
D1 Review of Source Attributes	D52 FN Test Site – Site Characterization, Modeling, and Monitoring Plan	M8 BC Test Site – Wellbore Leakage Data Collection Initiated
D4 Permitting Review – Basic EPA Requirements	D57 Project Assessment Annual Report	M9 BC Test Site – Geological Model Development Initiated
D5 Second Target Area Completed	D58 Quarterly Progress Report	M10 BC Test Site – Wellbore Leakage Data Collection Completed
D6 Permitting Review – Update 1	D59 Milestone Quarterly Report	M12 BC Test Site – Preinjection Geochemical Work Completed
D9 Updated DSS	D64 BC Test Site – Site Characterization Report	M14 BC Test Site – Geological Characterization Data Collection Completed
D10 DPRS Update	D65 FN Test Site – Site Characterization Report	M16 BC Test Site – Initiation of Production and Injection Simulations
D11 Outreach Plan	D66 BC Test Site – Simulation Report	M23 Monthly WWG Conference Call Held
D13 Public Site Updates	D67 FN Test Site – Simulation Report	M24 WWG Annual Meeting Held
D14 General Phase III Fact Sheet	D78 White Paper – Nexus of CCS and Water	M26 BC Test Site – CO_2 Injection Initiated
D15 BC Test Site Fact Sheet	D81 Regional Carbon Sequestration Atlas	M27 BC Test Site – MVA Equipment Installation and Baseline MVA Activities Completed
D17 General Phase III Information PowerPoint Presentation	D84 Report – A Phased Approach to Building Pipeline Network for CO_2 Transportation During CCUS	M28 BC Test Site – Geological Characterization Experimental Design Package Completed
D18 BC Test Site PowerPoint Presentation		M29 FN Test Site – Site Characterization Report Completed
D19 FN Test Site PowerPoint Presentation	D85 Report – Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCUS Activities	M30 BC Test Site – Baseline MVA Activities Initiated
D20 Video Support to PowerPoint and Web Site		M31 BC Test Site – Site Characterization, Modeling, and Monitoring Plan Completed
D24 PCOR Partnership Region CO_2 Storage General Poster	D87 BC Test Site – Geomechanical Experimental Design Package	M32 FN Test Site – Geochemical Report Completed
D25 BC Test Site Poster	D88 Programmatic Risk Assessment	M33 Basal Cambrian Baseline Geological Characterization Completed
D26 FN Test Site Poster	D89 Report – Geochemical Evaluation of the Basal Cambrian System	M34 Basal Cambrian Static Geological Model Completed
D28 BC Test Site – Environmental Questionnaire	D90 Report – Wellbore Evaluation of the Basal Cambrian System	M35 Basal Cambrian Dynamic Capacity Estimation Completed
D29 Permitting Action Plan	D91 Report – Geological Characterization of the Basal Cambrian System in the Williston Basin	M36 Annual Advisory Board Meeting Scheduled
D31 BC Test Site – Geological Characterization Experimental Design Package		M37 Subgroup Meetings Held
D32 BC Test Site – Geomechanical Report	D93 Report – Geological Modeling and Simulation for the Aquistore Project	M38 Task Force Wrap-Up Meeting Held
D33 BC Test Site – Preinjection Geochemical Report	D94 Aquistore Project Fact Sheet	M39 Editing Subgroup Meeting Held
D34 BC Test Site – Baseline Hydrogeological Experimental Design Package	D95 Aquistore Project Poster	M40 Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project Completed
D41 FN Test Site – Geochemical Report	D98 Report – Findings, Recommendations and Guidance of the GCS Task Force on Operational and Postoperational Liability	
D43 BC Test Site – Monitoring Experimental Design Package		M42 Findings and Recommendations of the Operational and Postoperational Liability Subgroups Presented to the GCS Task Force
D48 BC Test Site – Procurement Plan and Agreement Report	D99 Water/CCS Nexus Related Fact Sheet	
D50 BC Test Site – Site Characterization, Modeling, and Monitoring Plan		

Table 15. PCOR Partnership Phase III Gantt Chart (BP4, PY7–PY8)

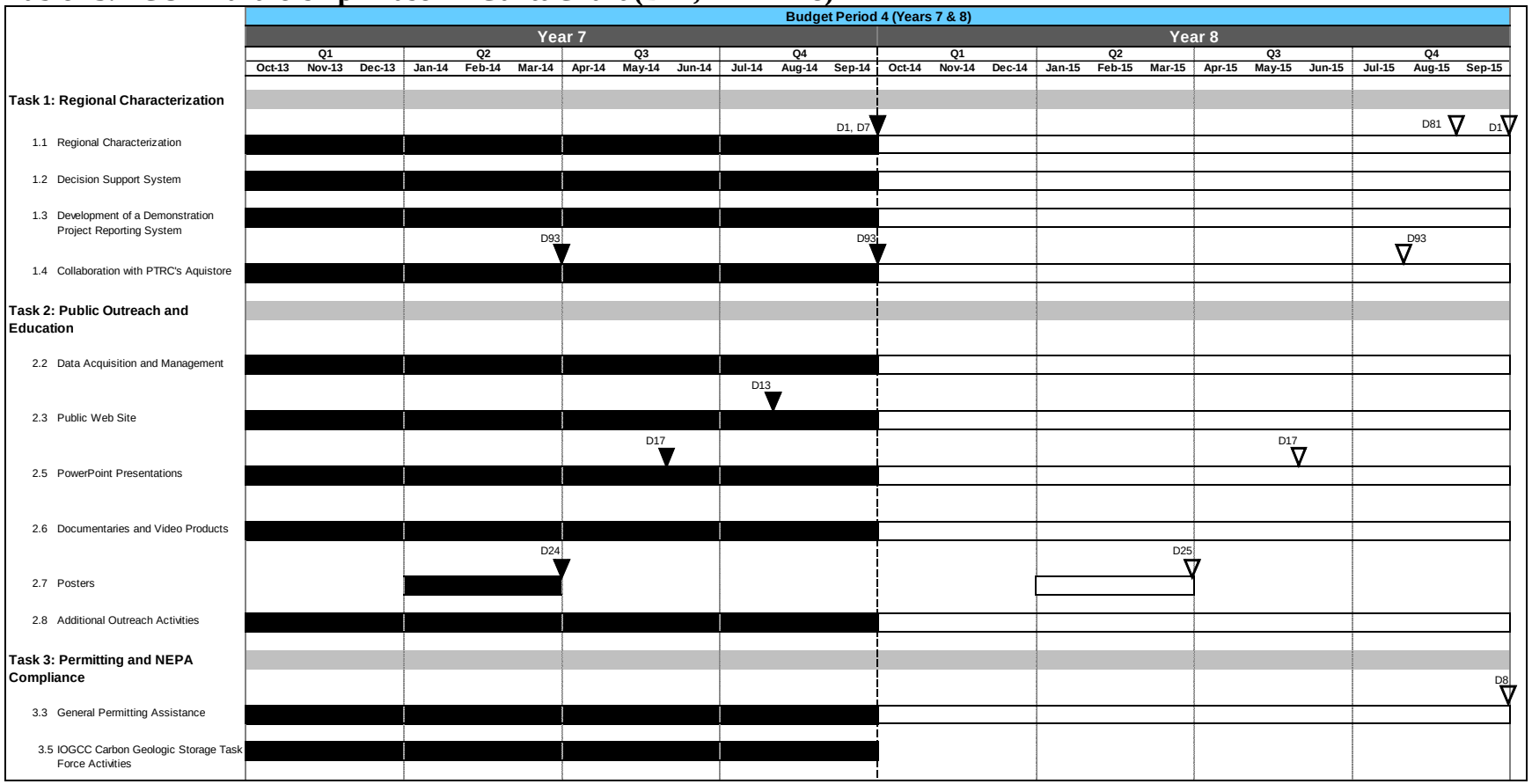

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Table 15. PCOR Partnership Phase III Gantt Chart (BP4, PY7–PY8) (continued)

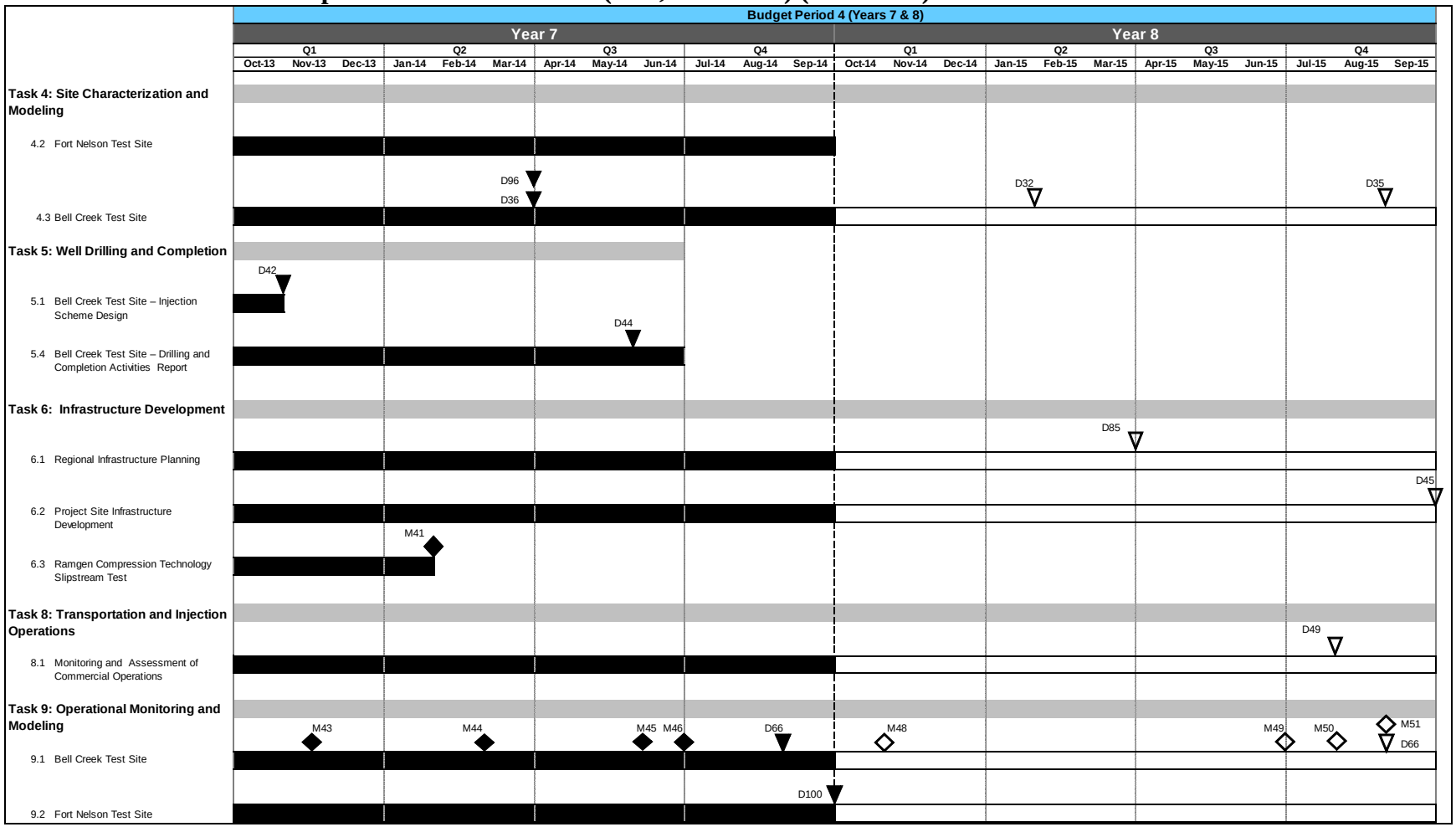

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Table 15. PCOR Partnership Phase III Gantt Chart (BP4, PY7–PY8) (continued)

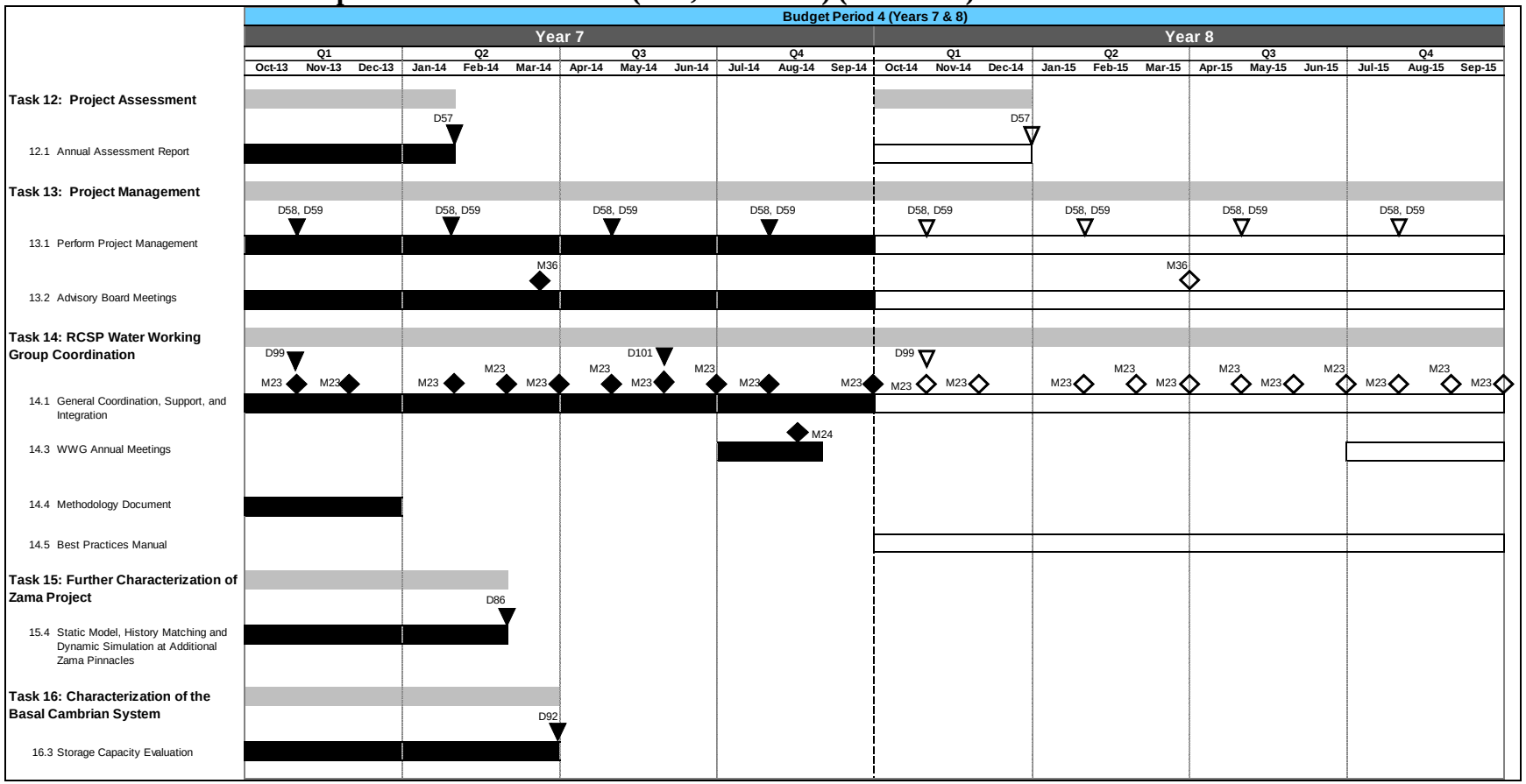

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Table 15. PCOR Partnership Phase III Gantt Chart (BP4, PY7–PY8) (continued)

Key for Deliverables ▼				Key for Milestones ◆	
D1	Review of Source Attributes	D58	Quarterly Progress Report	M23	Monthly WWG Conference Call Held
D7	Third Target Area Completed	D57	Project Assessment Annual Report	M24	WWG Annual Meeting Held
D8	Permitting Review – Update 2	D59	Milestone Quarterly Report	M36	Annual Advisory Board Meeting Scheduled
D13	Public Site Updates	D66	BC Test Site – Simulation Report	M41	Decision to Incorporate Ramgen Compression Technology into BC Project
D17	General Phase III Information PowerPoint Presentation	D81	Regional Carbon Sequestration Atlas	M43	BC Test Site – First Full-Repeat Sampling of the Groundwater- and Soil Gas- Monitoring Program Completed
D22	Energy from Coal 60-Minute Documentary	D85	Report – Opportunities and Challenges Associated with CO_2 Compression and Transportation During CCUS Activities	M44	BC Test Site – First 3-D VSP Repeat Surveys Completed
D24	PCOR Partnership Region CO_2 Storage General Poster	D86	Updated Regional Technology Implementation Plan for Zama	M45	BC Test Site – First Full-Repeat of Pulsed-Neutron Logging Campaign Completed
D25	BC Test Site Poster (Update)	D92	Report – Storage Capacity and Regional Implications for Large-Scale Storage in the Basal Cambrian System	M46	BC Test Site – 1 Year of Injection Completed
D32	BC Test Site – Geomechanical Report	D93	Report – Geological Modeling and Simulation for the Aquistore Project	M48	BC Test Site – 1 Million Metric Tons of CO_2 Injected
D35	BC Test Site – Best Practices Manual – Site Characterization	D96	BC Test Site – 3-D Seismic Acquisition and Characterization Report	M49	BC Test Site – 1.5 Million Metric Tons of CO_2 Injected
D36	BC Test Site – Wellbore Leakage Final Report	D99	Nexus of Water and CCS Fact Sheet	M50	BC Test Site – 2 Years of Near-Surface Assurance Monitoring Completed
D42	BC Test Site – Injection Experimental Design Package	D100	FN Test Site – Best Practices Manual– Feasibility Study	M51	Initial Analysis for First Large-Scale Repeat Pulsed-Neutron Logging Campaign Post-Significant CO_2 Injection Completed
D44	BC Test Site – Drilling and Completion Activities Report	D101	WWG Web Site Content Update		
D45	Report – Infrastructure Development				
D49	BC Test Site – Transportation and Injection Operations Report				

10/30/2014

PLANNED ACTIVITIES

Task 1 – Regional Characterization

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Review and update attribute data for existing sources. Add additional attributes as necessary for characterization. Incorporate new sources as they come online (D1).

- Continue to work with the geological surveys/oil and gas divisions of the states and provinces to develop greater detail of the field and reservoir data.

- Continue to update the DSS and DPRS, and report changes in the quarterly progress reports.

- Finalize a value-added white paper on the characterization of relevant oil fields located in the Cedar Creek Anticline.

- Prepare the next edition of the PCOR Partnership Atlas (D86), by August 31, 2015; however, ideally in time to distribute at the 2015 annual membership meeting.

Task 2 – Public Outreach and Education

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Continue to review and improve the public PCOR Partnership Web site (D13).

- Update the PowerPoint presentation for Phase III general activities (D17). Other PowerPoint presentations may be developed as needed.

- Prepare an update to the Bell Creek Test Site outreach poster (D25) for use explaining CO_2 storage and PCOR Partnership efforts to educators and general public.

- Continue to develop video products to meet the needs of general and site-level outreach.

- Continue preproduction activities with regard to the Bell Creek Test Site 30-minute documentary.

- Continue filming interviews and B-roll for the tentatively entitled “Coal and the Modern Age” 60-minute documentary, including a filming trip with PPB to China.

- Continue to collaborate with PTRC on outreach activities related to the Aquistore project. These activities may include assisting in assembling material for public presentations, assisting in collection of information about public perception,

participating in meetings with PTRC about public outreach activities, and collecting video of the activities at the project site.

- Continue to update project-related fact sheets, and develop new fact sheets as needed.

- Continue to act on opportunities to provide outreach both at the regional level and in the vicinity of the demonstrations, and address needs with respect to general information on CO_2 storage as well as information on the specific demonstration projects. Activities may include public presentations; assembly of materials for the press and for specific audiences, including middle and high school students; conducting focus groups and undertaking other means of gaining audience feedback to gauge the knowledge of target audiences as well as the effectiveness of outreach materials; and working with outreach and education professionals in an effort to improve the effectiveness of outreach and education activities.

- Continue participation in the RCSP OWG, the Weyburn–Midale Outreach Advisory Panel, and the Aquistore Project Communications Advisory Group.

Task 3 – Permitting and NEPA Compliance

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Continue to gather information on current and planned CO_2 storage-related regulations at the state, province, and federal levels.

- Continue to facilitate the Regulatory Roundup meeting with regulators in the PCOR Partnership region.

- Interface with relevant regulatory agencies within the PCOR Partnership region as well as with federal regulatory agencies (United States and Canada) to understand the regulatory framework for project implementation.

- Continue participation in IOGCC activities as well as in the North Dakota CO_2 Storage Workgroup.

- Prepare a second permitting review update (D8) by September 30, 2015.

Task 4 – Site Characterization and Modeling

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Bell Creek Test Site

  – Complete Version 3 of the geologic model.

- Prepare an update to the geomechanical report (D32) by January 31, 2015.
- Complete the BPM on site characterization (D35) by August 31, 2015.

Task 5 – Well Drilling and Completion

This task ended June 30, 2014. No further activity is anticipated.

Task 6 – Infrastructure Development

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Prepare an infrastructure development report (D45) by September 30, 2015.
- Prepare an update to the report on opportunities and challenges associated with CO_2 compression and transportation during CCUS activities (D85) by March 31, 2015.
- Publish a journal article on the topic of assessing temporary storage options to attenuate variable-rate CO_2 emissions for use during EOR.
- Update the interactive capture technologies table on the DSS.
- Complete an interactive table of compression technologies for the DSS.
- Continue to investigate regional infrastructure needs. Information will be made available for possible inclusion in the DSS.
- Continue to assist commercial partners with the activities required to develop the infrastructure to deliver CO_2 to the EOR site for the Bell Creek demonstration.

Task 7 – CO_2 Procurement

This task ended September 30, 2013. No further activity is anticipated.

Task 8 – Transportation and Injection Operations

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Monitor and assess the CO_2 transport and injection operations conducted by the site owner/operator of the Bell Creek test site.
- Prepare a report on transportation and injection operations (D49) by July 31, 2015.

Task 9 – Operational Monitoring and Modeling

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Bell Creek test site
  - Complete the initial analysis for the first large-scale repeat PNL campaign post-significant CO_2 injection (M51) by August 31, 2015.
  - Complete 2 years of near-surface assurance monitoring (M50) by July 31, 2015.
  - Continue to provide a quarterly summary of injection operations in the quarterly technical progress reports.
  - Achieve 1.5 million metric tons of CO_2 injected (M49) by June 30, 2015.
  - Update the simulation report (D66) by August 31, 2015.
- Fort Nelson test site
  - Continue interaction with Spectra to determine whether a business case for CCS at its site has been made.
  - Continue to monitor for site-related CCS activities or opportunities.

Task 10 – Site Closure

No activity is anticipated during the next program year.

Task 11 – Postinjection Monitoring and Modeling

No activity is anticipated during the next program year.

Task 12 – Project Assessment

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Prepare the Annual Project Assessment Report (D57).

Task 13 – Project Management

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Continue to ensure timely production of deliverables and overall project management.

- Continue to expand the PCOR Partnership's membership base.

- Continue to update the TAB, and execute at least one meeting prior to the next annual meeting.

- Plan the next annual meeting.

- Continue to participate in and support RCSP efforts.

- Update the project management plan as necessary.

- Update the RMP as necessary.

Task 14 – RCSP WWG Coordination

During the next program year (October 1, 2014 – September 30, 2015), the following activities will be undertaken:

- Continue to conduct monthly WWG conference calls.

- Plan and conduct the seventh annual meeting of the WWG.

- Prepare a fact sheet on the long-term protection of freshwater resources following CO_2 storage (D99-3) by October 31, 2014.

- Begin working on the BPM on the nexus of water and carbon storage activities.

Task 15 – Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project

This task ended February 28, 2014. No further activity is anticipated.

Task 16 – Basal Cambrian System Characterization

This task ended March 31, 2014. No further activity is anticipated.

PLANNED SCHEDULE

Table 16 contains all of the Phase III deliverables, milestones, and submission dates for PY8 (October 1, 2014 – September 30, 2015).

Table 16. Phase III Milestones and Deliverables

Title/Description	Due Date	Actual Completion Date
Year 7 – Quarter 1 (October–December 2013)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	10/31/13	10/31/13
D42: Task 5 – Bell Creek Test Site – Injection Experimental Design Package	10/31/13	10/30/13
D99: Task 14 – Water/CCS Nexus-Related Fact Sheet	10/31/13	10/31/13
M23: Task 14 – Monthly WWG Conference Call Held	10/31/13	10/31/13
M23: Task 14 – Monthly WWG Conference Call Held	11/30/13	11/21/13
M23: Task 14 – Monthly WWG Conference Call Held	12/31/13	Waived by DOE
M24: Task 14 – WWG Annual Meeting Held	12/31/13	8/19/13
M43: Task 9 – Bell Creek Test Site – First Full-Repeat Sampling of the Groundwater- and Soil Gas-Monitoring Program Completed	12/31/13	11/15/13 and 12/13/13
Year 7 – Quarter 2 (January–March 2014)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	1/31/14	1/31/14
D57: Task 12 – Project Assessment Annual Report	1/31/14	1/31/14
M23: Task 14 – Monthly WWG Conference Call Held	1/31/14	1/28/14
M41: Task 6 – Decision to Incorporate Ramgen Compression Technology into Bell Creek Project	1/31/14	1/29/14
D86: Task 15 – Updated Regional Implementation Plan for Zama	2/28/14	2/28/14
M23: Task 14 – Monthly WWG Conference Call Held	2/28/14	2/27/14
D24: Task 2 – PCOR Partnership Region CO_2 Storage General Poster (update)	3/31/14	3/27/14
D36: Task 4 – Bell Creek Test Site – Wellbore Leakage Final Report	3/31/14	3/19/14
D92: Task 16 – Report – Storage Capacity and Regional Implications for Large-Scale Storage in the Basal Cambrian System	3/31/14	3/27/14
D93: Task 1 – Geological Modeling and Simulation Report for the Aquistore Project	3/31/14	3/25/14
D96: Task 4 – Bell Creek Test Site – 3-D Seismic Acquisition and Characterization Report	3/31/14	3/27/14
M23: Task 14 – Monthly WWG Conference Call Held	3/31/14	3/25/14
M36: Task 13 – Annual Advisory Board Meeting Scheduled	3/31/14	3/4/14 – sent 3/25/14
M44: Task 4 – Bell Creek Test Site – First 3-D VSP Repeat Surveys Completed	3/31/14	3/1/14 – sent 3/25/14

Continued . . .

Table 16. Phase III Milestones and Deliverables (continued)

Title/Description	Due Date	Actual Completion Date
Year 7 – Quarter 3 (April–June 2014)		
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	4/30/14	4/30/14
M23: Task 14 – Monthly WWG Conference Call Held	4/30/14	4/24/14
D17: Task 2 – General Phase III Information PowerPoint Presentation (update)	5/31/14	5/30/14
D101: Task 14 – WWG Web Site Content	5/31/14	5/30/14
M23: Task 14 – Monthly WWG Conference Call Held	5/31/14	5/21/14
Year 7 – Quarter 3 (April–June 2014) (continued)		
D44: Task 5 – Bell Creek Test Site – Drilling and Completion Activities Report	6/30/14	5/30/14
M23: Task 14 – Monthly WWG Conference Call Held	6/30/14	6/26/14
M45: Task 4 – Bell Creek Test Site – First full-repeat of pulsed-neutron logging campaign completed	6/30/14	6/9/14
M46: Task 9 – Bell Creek Test Site – 1 Year of Injection Completed	6/30/14	6/26/14
Year 7 – Quarter 4 (July–September 2014)		
D13: Task 2 – Public Site Updates	7/31/14	7/29/14
D58/D59: Task 13 – Quarterly Progress Report/Milestone Quarterly Report	7/31/14	7/31/14
M23: Task 14 – Monthly WWG Conference Call Held	7/31/14	WebEx
D66: Task 9 – Bell Creek Test Site – Simulation Report	8/31/14	8/27/14 (ex. summary only)
M23: Task 14 – Monthly WWG Conference Call Held	8/31/14	Waived
D1: Task 1 – Review of Source Attributes (update)	9/30/14	9/24/14
D7: Task 1 – Third Target Area Completed	9/30/14	9/26/14
D93: Task 1 – Geological Modeling and Simulation Report for the Aquistore Project (update)	9/30/14	9/30/14
D100: Task 9 – Fort Nelson Test Site – Best Practices Manual – Feasibility Study	9/30/14	9/30/14
M23: Task 14 – Monthly WWG Conference Call Held	9/30/14	9/30/14

TRAVEL

Representatives from the PCOR Partnership attended and/or participated in the following 57 meetings/conferences plus nine workshops, three training opportunities, and 32 project management site trips in this reporting period. As the Phase III program nears the end of BP4, travel decreased in PY7 compared to PY6. There were fewer meetings/conferences/workshops (66 compared to 75 in PY6), fewer training opportunities (three versus nine), and significantly fewer site trips were made during the operational monitoring phase (32 versus 53).

1. September 27 – October 3, 2013: Attended SPE ATCE in New Orleans, Louisiana.
2. September 29 – October 6, 2013: Visited landowners and performed soil gas and water sampling at the Bell Creek site.
3. October 1–3, 2013: Attended the Midwest Regional Carbon Sequestration Partnership meeting in Traverse City, Michigan.
4. October 7–9, 2013: Attended the 2013 Midwest Carbon Sequestration Science Conference in Champaign, Illinois, and toured the Illinois Basin – Decatur Project at the Archer Daniels Midland Company in Decatur, Illinois.
5. October 10, 2014: Inspected the Phase II Lignite Field Validation Test site near Kenmare, North Dakota.
6. October 15–17, 2013: Presented at the North American Wellbore Integrity Workshop on Denver, Colorado.
7. October 20–23, 2013: Presented at CMTC in Alexandria, Virginia.
8. October 20–23, 2013: Presented at Air Quality IX in Arlington, Virginia.
9. November 2–7, 2013: Attended the 2013 IOGCC Annual Meeting in Long Beach, California.
10. November 4–5, 2013: Presented at the 9th Annual Power Summit in Lincoln, Nebraska.
11. November 10–16, 2013: Traveled to the Bell Creek area for sampling activities.
12. November 13–15, 2013: Presented at the Fiscal Year 14 RCSP Expert Review in Washington, D.C.
13. November 13–15, 2013: Participated in a PTRC outreach workshop in Regina, Saskatchewan, Canada.
14. November 13–16, 2013: Visited Stanford University and Core Test Inc. in San Francisco and Santa Cruz, California, respectively.
15. November 19, 2013: Attended a meeting with PPB at its offices in Fargo, North Dakota.
16. November 19, 2013: Attended the North Dakota Lignite Research Council meeting in Bismarck, North Dakota.

17. November 29, 2013: Inspected the Phase II Lignite Field Validation Test site near Kenmare, North Dakota.
18. December 6, 2013: Attended a teacher focus group meeting at PPB offices in Fargo, North Dakota.
19. December 8–12, 2013: Presented at the AGU (American Geophysical Union) Fall Meeting held in San Francisco, California.
20. December 8–13, 2013: Participated in CO_2 Conference Week in Midland, Texas.
21. December 9–14, 2013: Traveled to the Bell Creek oil field for monthly sampling efforts.
22. December 10–11, 2013: Visited the hotel venue for the 2014 annual membership meeting in Denver, Colorado.
23. January 12–17, 2014: Traveled to the Bell Creek area for sampling activities.
24. January 12–18, 2014: Remotely located staff participated in project-related meetings in Grand Forks, North Dakota.
25. January 14–15, 2014: Attended the SPE Williston Basin Section annual meeting in Dickinson, North Dakota.
26. January 18–23, 2014: Presented at the International Petroleum Technology Conference in Doha, Qatar.
27. January 21–23, 2014: Attended meetings with the North Dakota Public Service Commission and NDIC Oil and Gas Research Council in Bismarck, North Dakota.
28. January 23, 2014: Attended a meeting with PPB at its offices in Fargo, North Dakota.
29. January 23–25, 2014: Inspected the Phase II Lignite Field Validation Test site near Kenmare, North Dakota, and visited the Bell Creek site for data download.
30. January 28–31, 2014: Traveled to the Bell Creek area for landowner visits.
31. February 2–7, 2014: Presented at the Energy, Utility, and Environment Conference (EUEC) in Phoenix, Arizona.
32. February 2–5, 2014: Presented at the NRAP Stakeholders Group meeting in Washington, D.C.
33. February 6–7, 2014: Discussed project-related activities with Denbury at its headquarters in Plano, Texas.
34. February 9–14, 2014: Traveled to the Bell Creek area for sampling activities.
35. February 10–14, 2014: Remotely located staff participated in project-related meetings in Grand Forks, North Dakota.
36. February 11–14, 2014: Viewed core samples at USGS CRC and the Colorado School of Mines (CSM) in Denver, Colorado.
37. February 23–26, 2014: Met with various DOE NETL staff members in Pittsburgh, Pennsylvania.

38. February 25–28, 2014: Presented at the 3rd Annual America's Forum in Washington, D.C.
39. February 26, 2014: Inspected the Phase II Lignite Field Validation Test site near Kenmare, North Dakota.
40. February 27–28, 2014: Attended the SPE Williston Basin Section meeting in Williston, North Dakota.
41. March 3–5, 2014: Hosted the third annual TAB meeting in Austin, Texas.
42. March 3–5, 2014: Attended the SECARB annual membership meeting in Atlanta, Georgia.
43. March 3–5, 2014: Traveled to the Bell Creek Field to observe 3-D seismic activities.
44. March 9–13, 2014: Traveled to the Bell Creek area for sampling activities.
45. March 17–20, 2014: Traveled to the Bell Creek Field to visit with area landowners.
46. March 22–29, 2014: Participated in the CSLF Technical Group Meeting in Seoul, South Korea.
47. March 23–28, 2014: Participated in Schlumberger NEXT PetroMod Fundamentals training in Houston, Texas.
48. March 24–27, 2014: Inspected the Phase II Lignite Field Validation Test site near Kenmare, North Dakota, and also the Bell Creek Field to download PDM data.
49. March 25–27, 2014: Viewed and retrieved Aquistore core in Regina, Saskatchewan, Canada.
50. March 31 – April 4, 2014: Traveled to the Bell Creek Field to download data.
51. April 13–17, 2014: Traveled to the Bell Creek area for sampling activities.
52. April 14, 2014: Attended a meeting with Sigma^3 in Denver, Colorado.
53. April 16, 2014: Attended a meeting with PPB in Fargo, North Dakota.
54. April 21–25, 2014: Chaired a workshop at the 4th European Association of Geoscientists and Engineers (EAGE) CO_2 Workshop in Stavenger, Norway.
55. April 28 – May 1, 2014: Presented at the 13th CCUS Conference in Pittsburgh, Pennsylvania.
56. May 5–8, 2014: Attended the U.S.–Canada Clean Energy Dialogue Third CCS Binational Conference in Edmonton, Alberta, Canada.
57. May 5–9, 2014: Traveled to the Bell Creek area for sampling activities.
58. May 14–16, 2014: Attended a meeting with the North Dakota Petroleum Council (NDPC) in Bismarck, North Dakota.
59. May 18–21, 2014: Attended the IOGCC Midyear Meeting in Biloxi, Mississippi.
60. May 18–26, 2014: Traveled to the Bell Creek area for sampling activities.

61. May 19–23, 2014: Presented at Williston Basin Petroleum Conference (WBPC) in Bismarck, North Dakota.
62. May 20–23, 2014: Traveled to the Bell Creek area for sampling activities.
63. May 30 – June 5, 2014: Attended the 48th Annual U.S. Rock Mechanics–Geomechanics Symposium in Minneapolis, Minnesota.
64. June 1–4, 2014: Traveled to Minneapolis, Minnesota, to attend the American Rock Mechanics Association 48th U.S. Rock Mechanics/Geomechanics Symposium.
65. June 1–5, 2014: Attended the Enhanced Oil Recovery Institute Minnelusa field trip and workshops in Gillette, Wyoming.
66. June 1–10, 2014: Attended the Research Experience in Carbon Sequestration (RECS) Program in Birmingham, Alabama.
67. June 2–5, 2014: Attended the British Columbia Natural Gas Symposium in Vancouver, British Columbia, Canada.
68. June 2–5, 2014: Presented at the CMG 2014 Technical Symposium in The Woodlands, Texas.
69. June 3–14, 2014: Traveled to Edinburgh, Scotland, with a PPB film crew to conduct interviews for an upcoming documentary.
70. June 8–16, 2014: Traveled to the Bell Creek area for sampling activities.
71. June 16–19, 2014: Presented at the Lignite Energy Council Teacher Workshop in Bismarck, North Dakota.
72. June 17–18, 2014: Presented at the North Dakota–Minnesota Geographic Alliance in Moorhead, Minnesota.
73. June 17–22, 2014: Traveled to the Bell Creek area for sampling activities.
74. June 22–23, 2014: Traveled to Miles City, Montana, for a Bell Creek site visit.
75. June 23–25, 2014: Presented at the PCOR Partnership Regulatory Roundup in Deadwood, South Dakota.
76. June 24, 2014: Presented at the Prairie Region Teacher Training Institute in Moorhead, Minnesota.
77. July 7–11, 2014: Traveled to Casper, Wyoming, to attend the 8th Annual Wyoming CO_2 Conference.
78. July 16, 2014: Traveled to Kenmare, North Dakota, to inspect the lignite site.
79. July 18–22, 2014: Traveled to Denver, Colorado, to present at the American Association of Petroleum Geologists (AAPG) Rocky Mountain Section Meeting and attend the short course.
80. July 20–24, 2014: Traveled to Gillette, Wyoming, for sampling work at the Bell Creek Field.
81. July 21–24, 2014: Traveled to Denver, Colorado, to attend COMSOL Multiphysics Intensive Training.

82. July 24–27, 2014: Traveled to Plano, Texas, to attend project meetings with Denbury.
83. July 28 – August 1, 2014: Traveled to Pittsburgh, Pennsylvania, for the DOE NETL 2014 CO_2 Capture Technology Meeting.
84. July 29–31, 2014: Traveled to Decatur, Illinois, to present at the National Sequestration Education Workshop on Public Education, Training, and Community Outreach for Carbon Capture, Utilization, and Storage.
85. July 29 – August 2, 2014: Traveled to Gillette, Wyoming, for site sampling work at the Bell Creek Station.
86. August 3–8, 2014: Traveled to San Diego, California, to present at the 2014 SEG/SPE/AAPG/SPWLA/EAGE (Scientific Ecology Group, Inc.–Society of Petroleum Engineers—AAPG–Society of Petrophysicists and Well Log Analysts–European Association of Geoscientists and Engineers) Summer Research Workshop.
87. August 3–9, 2014: Traveled to Gillette, Wyoming, for site work at Bell Creek.
88. August 4–7, 2014: Traveled to Morgantown, West Virginia, to present at the IEAGHG Combined Monitoring and Modelling Network Meeting.
89. August 9–16, 2014: Traveled to Gillette, Wyoming, for site sampling work at the Bell Creek Station.
90. August 10–17, 2014: Traveled to Pittsburgh, Pennsylvania, to present at the 2014 Carbon Storage R&D Project Review Meeting, host the WWG Annual Meeting, and attend the NRAP Stakeholder's Meeting.
91. August 25–28, 2014: Traveled to Mexico City, Mexico, to present at the Advanced Workshop for CO_2 Storage.
92. September 9–12, 2014: Traveled to Columbia, South Carolina, to present at the University of South Carolina Energy Leadership Institute's Cradle to Grave: CO_2 Opportunities and Challenges.
93. September 14–18, 2014: Traveled to Denver, Colorado, to host the PCOR Partnership Annual Membership Meeting and two premeeting side meetings.
94. September 17–19, 2014: Traveled to Bismarck, North Dakota, to attend the NDLA Annual Meeting and Exhibit.
95. September 17–28, 2014: Traveled to Gillette, Wyoming, for sampling and site work at Bell Creek oil field.
96. September 23–26, 2014: Traveled to Dickinson, North Dakota, to attend the NDPC Annual Meeting.

Materials presented at these meetings are available to partners on the PCOR Partnership DSS Web site (www2.undeerc.org/website/pcorp/).

PHASE III PRODUCTS/PUBLICATIONS

During PY7, the PCOR Partnership submitted 30 abstracts, all but three of which were accepted, and the author declined three. The PCOR Partnership had nine conference papers prepared and gave 87 presentations (oral and poster combined). In addition, it completed 27 deliverable/milestone reports (33 were finalized), six value-added products (five were finalized), and 12 progress reports (monthlies and quarterlies combined) and prepared several conference call and meeting minutes.

Abstracts

Submitted, Accepted, and Declined by Author (3)

Gao, P., Gorecki, C.D., Braunberger, J.R., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2014, Demonstrating acid gas EOR and CO_2 storage technologies in Devonian-aged pinnacle reefs [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Gorecki, C.D., Ayash, S.C., Klapperich, R.J., Sorensen, J.A., Hamling, J.A., Steadman, E.N., and Harju, J.A., 2013, An adaptive management approach to CO_2 storage projects [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Hamling, J.A., Gorecki, C.D., Klapperich, R.J., Kalenze, N.S., Stepan, D.J., Steadman, E.N., Harju, J.A., Miller, H., Rawson, J., Welch, R., and Walsh, F., 2013, Monitoring one year's worth of CO_2 injection and incidental storage at the Bell Creek oil field [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Submitted and Accepted for Presentation (10)

Botnen, L.S., Harju, J.A., Connors, K.C., Bliss, K.J., and Bengal, L.E., 2013, Guidance for states and provinces on operational and postoperational liability in the regulation of carbon geologic storage [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Braunberger, J.R., Bosshart, N.W., Klenner, R.C.L., Liu, G., Peck, W.D., and Gorecki, C.D., 2014, Characterization and 3-D modeling of Devonian pinnacle reefs for CO_2 storage and enhanced oil recovery [abs.]: 2014 Rocky Mountain Section AAPG Annual Meeting, Denver, Colorado, July 20–22, 2014.

Dotzenrod, N.W., Braunberger, J.R., Klenner, R.C.L., Liu, G., and Gorecki, C.D., 2014, Workflow optimization using Python programming,—a tool kit for every geoscientist [abs.]: 2014 Rocky Mountain Section AAPG Annual Meeting, Denver, Colorado, July 20–22, 2014.

Gao, P., Gorecki, C.D., Braunberger, J.R., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2014, Modeling of acid gas injection for enhanced oil recovery and long-term storage in Devonian-aged pinnacle reefs [abs.]: 13th Annual Carbon Capture, Utilization & Storage Conference, Pittsburgh, Pennsylvania, April 28 – May 1, 2014.

Gorecki, C.D., Ayash, S.C., Klapperich, R.J., Sorensen, J.A., Hamling, J.A., Steadman, E.N., and Harju, J.A., 2014, The Plains CO_2 Reduction Partnership's adaptive management strategy for CO_2 storage [abs.]: 13th Annual Carbon Capture, Utilization & Storage Conference, Pittsburgh, Pennsylvania, April 28 – May 1, 2014.

Hawthorne, S.B., Miller, D.J., Gorecki, C.D., Sorensen, J.A., Hamling, J.A., Roen, T.D., Steadman, E.N., Harju, J.A., and Melzer, L.S., 2014, A rapid method for determining CO_2/oil MMP and visual observations of CO_2/oil interactions at reservoir conditions [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Klenner, R.C.L., Peck, W.D., Ayash, S.C., Gorecki, C.D., Braunberger, J.R., Liu, G., and Dotzenrod, N.W., 2014, A workflow to determine CO_2 storage potential in deep saline formations [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Klenner, R.C.L., Braunberger, J.R., Dotzenrod, N.W., Bosshart, N.W., Peck, W.D., and Gorecki, C.D., 2014, Training image characterization and multipoint statistical modeling of clastic and carbonate formations [abs.]: 2014 Rocky Mountain Section AAPG Annual Meeting, Denver, Colorado, July 20–22, 2014.

Liu, G., Peck, W.D., Braunberger, J.R., Klenner, R.C.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Carbon dioxide storage potential of the basal saline system in the Alberta and Williston Basins of North America [abs.]: 13th Annual Carbon Capture, Utilization & Storage Conference, Pittsburgh, Pennsylvania, April 28 – May 1, 2014.

Sorensen, J.A., Smith, S.A., Gorecki, C.D., Botnen, L.A., Steadman, E.N, and Harju, J.A., 2013, Application of Canadian Standards Association guidelines for geologic storage of CO_2 toward the development of a monitoring, verification, and accounting plan for a potential CCS project at Fort Nelson, British Columbia, Canada [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Submitted and Accepted for Poster (15)

Braunberger, J.R., Hamling, J.A., Gorecki, C.D., Steadman, E.N., Harju, J.A., Miller, H., Rawson, J., Walsh, F., Pasternack, E., Rowe, W., and Butsch, R., 2013, Characterization and time-lapse monitoring utilizing pulsed-neutron well logging at an incidental CO_2 storage demonstration [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Gao, P., Gorecki, C.D., Braunberger, J.R., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2014, Modeling and simulation of acid gas injection for enhanced oil recovery and long-term storage in Zama pinnacle reefs [abs.]: Carbon Storage R&D Project Review Meeting: Developing the Technologies and Infrastructure for CCS, Pittsburgh, Pennsylvania, August 12–14, 2014.

Gao, P., Gorecki, C.D., Braunberger, J.R., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2014, Modeling and simulation of acid gas injection for enhanced oil recovery and long-term storage in Zama pinnacle reefs [abs.]: IEAGHG Combined Monitoring & Modelling Network Meeting, Morgantown, West Virginia, August 4–8, 2014.

Glazewski, K.A., Hamling, J.A., Peck, W.D., Doll, T.E., Laumb, J.D., Gorecki, C.D., Azzolina, N.A., Nakles, D.V., Steadman, E.N., and Harju, J.A., 2013, A regional wellbore evaluation of the Basal Cambrian system [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Gorecki, C.D., Hamling, J.A., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2013, The Plains CO_2 Reduction (PCOR) Partnership Program—addressing CO_2 storage through enhanced oil recovery [abs.]: 4th European Association of Geoscientists & Engineers (EAGE) CO_2 Geological Storage Workshop, Stavanger, Norway, April 23–25, 2014.

Klapperich, R.J., Stepan, D.J., Jensen, M.D., Gorecki, C.D., Steadman, E.N., Harju, J.A., Nakles, D.V., and McNemar, A.T., 2014, The nexus of water and CCS—a regional carbon sequestration partnership perspective [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Liu, G., Peck, W.D., Klenner, R.C.L., Braunberger, J.R., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Carbon dioxide storage potential of the basal saline system in the Alberta and Williston Basins of North America [abs.]: IEAGHG Combined Monitoring & Modelling Network Meeting, Morgantown, West Virginia, August 4–8, 2014.

Liu, G., Braunberger, J.R., Gorecki, C.D., Gao, P., Peck, W.D., Steadman, E.N., and Harju, J.A., 2014, Integrated modeling and simulation for CO_2 EOR and CO_2 storage in the Zama pinnacle reefs of Alberta Basin, Canada [abs.]: 2014 SEG/SPE/AAPG/SPWLA/EAGE Summer Research Workshop, San Diego, California, August 3–8, 2014.

Liu, G., Peck, W.D., Braunberger, J.R., Klenner, R.C.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Evaluation of large-scale carbon dioxide storage potential in the basal saline system in the Alberta and Williston Basins in North America [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Peck, W.D., Klenner, R.C.L., Liu, G., Gorecki, C.D., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2014, Model development of the Aquistore CO_2 storage project [abs.]: Carbon Storage R&D Project Review Meeting: Developing the Technologies and Infrastructure for CCS, Pittsburgh, Pennsylvania, August 12–14, 2014.

Peck, W.D., Liu, G., Braunberger, J.R., Klenner, R.C.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Carbon dioxide storage potential of the basal saline system in the Alberta and Williston Basins of North America [abs.]: Carbon Storage R&D Project Review Meeting: Developing the Technologies and Infrastructure for CCS, Pittsburgh, Pennsylvania, August 12–14, 2014.

Peck, W.D., Klenner, R.C.L., Liu, G., Gorecki, C.D., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2013, Model development of the Aquistore CO_2 storage project [abs.]: International Conference on Greenhouse Gas Technologies (GHGT-12), Austin, Texas, October 5–9, 2014.

Peck, W.D., Bailey, T.P., Klenner, R.C.L., Liu, G., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Model development of the Aquistore CO_2 storage project [abs.]: IEAGHG

Combined Monitoring & Modelling Network Meeting, Morgantown, West Virginia, August 4–8, 2014.

Sorensen, J.A., Smith, S.A., Gorecki, C.D., Botnen, L.A., Steadman, E.N., and Harju, J.A., 2014, Development of a monitoring, verification, and accounting plan for a potential CCS project at Fort Nelson, British Columbia, Canada [abs.]: 13th Annual Carbon Capture, Utilization & Storage Conference, Pittsburgh, Pennsylvania, April 28 – May 1, 2014.

Sorensen, J.A., Smith, S.A., Gorecki, C.D., Botnen, L.S., Steadman, E.N., and Harju, J.A., 2014, Development of a monitoring, verification, and accounting plan for a potential CCS project at Fort Nelson, British Columbia, Canada [abs.]: Carbon Storage R&D Project Review Meeting: Developing the Technologies and Infrastructure for CCS, Pittsburgh, Pennsylvania, August 12–14, 2014.

Submitted and Rejected for Presentation (2)

Braunberger, J.R., Klenner, R.C.L., Peck, W.D., Liu, G., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Integrated modeling and simulation for geologic carbon dioxide storage in the basal saline system of Central North America [abs.]: 2014 SEG/SPE/AAPG/SPWLA/EAGE Summer Research Workshop, San Diego, California, August 3–8, 2014.

Liu, G., Peck, W.D., Braunberger, J.R., Klenner, R.C.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2013, A case study of large-scale carbon dioxide storage in the basal saline system utilizing a high-performance parallel computing cluster [abs.]: Rice University Oil and Gas High Performance Computing (HPC) Workshop, Houston, Texas, March 6, 2014.

Rejected for Presentation (1)

Bosshart, N.W., Braunberger, J.D., Gorecki, C.D., and Steadman, E.N., 2013, Using multiple-point statistics in the modeling of a Winnipegosis Formation pinnacle reef for enhanced oil recovery and CO_2 storage applications [abs.]: American Association of Petroleum Geologists Annual Convention and Exhibition 2014, Houston, Texas, April 6–9, 2014.

Presentations (60)

Botnen, L.S., 2014, IOGCC Carbon Storage Task Force operational and postoperational liability: Presented at the Plains CO_2 Reduction (PCOR) Partnership Regulatory Roundup, Deadwood, South Dakota, June 24–25, 2014.

Braunberger, J.R., Bosshart, N.W., Klenner, R.C.L., Liu, G., Peck, W.D., and Gorecki, C.D., 2014, Characterization and 3-D modeling of Devonian pinnacle reefs for CO_2 storage and enhanced oil recovery: Presented at the 2014 Rocky Mountain Section AAPG Annual Meeting, Denver, Colorado, July 20–22, 2014.

Braunberger, J.R., 2013, A geospatial overview in the Plains CO_2 Reduction (PCOR) Partnership: Lecture for Introduction to GIS presented at North Dakota State University, Fargo, North Dakota, December 11, 2013.

Burnison, S.A., and Gorecki, C.G., 2014, Geophysics at the Energy & Environmental Research Center: Presented to Denbury Resources Inc. personnel, Plano, Texas, July 25, 2014.

Burnison, S.A., Ditty, P., Gorecki, C.D., Hamling, J.A., Steadman, E.N., and Harju, J.A., 2013, Integrated geophysical monitoring program to study flood performance and incidental CO_2 storage associated with a CO_2 EOR project in the Bell Creek oil field: Presented at the American Geophysical Union Fall Meeting, San Francisco, California, December 9–13, 2013.

Daly, D.J., 2014, Energy, carbon, and CO_2 management—geologic CO_2 sequestration: Presented to the Lions Club, Grand Forks, North Dakota, August 20, 2014.

Daly, D.J., Crocker, C.R., Dambach, B., Pearson, B., and Anderson, D., 2014, A collaboration among Prairie Public Broadcasting, classroom teachers, and the PCOR Partnership to produce classroom-ready CCS lessons: Presented at the International Workshop on Public Education, Training, and Community Outreach for Carbon Capture, Utilization, and Storage, Decatur, Illinois, July 30, 2014.

Daly, D.J., 2014, Energy and CO_2 management—carbon capture and storage: Presented at the 2014 Lignite Education Seminar, Bismarck, North Dakota, June 16–19, 2014.

Daly, D.J., 2014, The PCOR Partnership Program: Presented at the Prairie Region Teacher Training Institute – Integrating Regional History, Culture, Science and the Arts, Moorhead, Minnesota, June 24–25, 2014.

Daly, D.J., and Crocker, C.R., 2014, Energy and carbon—the big picture: Presented at Cultivating Geographic Connections in the Red River Valley: A Crossroads of Agriculture, Reinvention, and Innovation – Minnesota Alliance for Geographic Education and the North Dakota Geography Alliance, Moorhead, Minnesota, June 18, 2014.

Dotzenrod, N.W., Braunberger, J.R., Klenner, R.C.L., Liu, G., and Gorecki, C.D., 2014, Workflow optimization using Python programming, a tool kit for every geoscientist: Presented at the 2014 Rocky Mountain Section AAPG Annual Meeting, Denver, Colorado, July 20–22, 2014.

Gao, P., Gorecki, C.D., Braunberger, J.R., Ayash, S.C., Steadman, E.N., and Harju, J.A., 2014, Modeling of acid gas injection for enhanced oil recovery and long-term storage in Devonian-aged pinnacle reefs: Presented at the 13th Annual Carbon Capture, Utilization & Storage Conference, Pittsburgh, Pennsylvania, April 28 – May 1, 2014.

Glazewski, K.A., Hamling, J.A., Peck, W.D., Doll, T.E., Laumb, J.D., Gorecki, C.D., Azzolina, N., Nakles, D.V., Steadman, E.N., and Harju, J.A., 2014, Development of an MVA plan for a potential CCS project at Fort Nelson, British Columbia, Canada: Presented at the Carbon Storage R&D Project Review Meeting: Developing the Technologies and Infrastructure for CCS, Pittsburgh, Pennsylvania, August 12–14, 2014.

Gorecki, C.D., 2014, PCOR Partnership Technical Advisory Board (TAB) side meeting: Presentation for the PCOR Partnership Technical Advisory Board Meeting, Denver, Colorado, September 15, 2014.

Gorecki, C.D., 2014, Plains CO_2 Reduction (PCOR) Partnership Program highlights: Presented at the PCOR Partnership Annual Membership Meeting, Denver, Colorado, September 16–17, 2014.

Gorecki, C.D., Hamling, J.A., Pu, H., Braunberger, J.R., Gao, P., Liu, G., Steadman, E.N., and Harju, J.A., 2014, Modeling and monitoring associated CO_2 storage at the Bell Creek Field: Presented at the IEAGHG Combined Monitoring & Modelling Network Meeting, Morgantown, West Virginia, August 4–8, 2014.

Gorecki, C.D., and Jensen, M.D., 2014, Overview of carbon management, storage, and EOR: Presented to Japan Coal Energy Center (JCOAL) personnel, Grand Forks, North Dakota, August 25, 2014.

Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Plains CO_2 Reduction (PCOR) Partnership – Phase III: Presented at the Carbon Storage R&D Project Review Meeting: Developing the Technologies and Infrastructure for CCS, Pittsburgh, Pennsylvania, August 12–14, 2014.

Gorecki, C.D., 2014, Bell Creek modeling and simulation: Presentation for the Denbury Resources Inc. Webinar, April 2, 2014.

Gorecki, C.D., 2014, Plains CO_2 Reduction (PCOR) Partnership update: Presented at the Plains CO_2 Reduction (PCOR) Partnership Regulatory Roundup, Deadwood, South Dakota, June 24–25, 2014.

Gorecki, C.D., Ayash, S.C., Klapperich, R.J., Sorensen, J.A., Hamling, J.A., Steadman, E.N., and Harju, J.A., 2014, The Plains CO_2 Reduction (PCOR) Partnership adaptive management strategy for CO_2 storage: Presented at the 13th Annual Carbon Capture, Utilization & Storage Conference, Pittsburgh, Pennsylvania, April 28 – May 1, 2014.

Gorecki, C.D., Dotzenrod, N.W., Liu, G., and Braunberger, J.R., 2014, Tools for interfacing and integrating CMG software with other software packages: Presented at the Computer Modelling Group 2014 Technical Symposium, The Woodlands, Texas, June 3–4, 2014.

Gorecki, C.D., Pu, H., Gao, P., and Liu, G., 2014, Implementation of detailed reservoir simulation to demonstrate CO_2 EOR and storage in the Bell Creek Field: Presented at the Computer Modelling Group 2014 Technical Symposium, The Woodlands, Texas, June 3–4, 2014.

Gorecki, C.D., 2014, CO_2 enhanced oil recovery—the Plains CO_2 Reduction Partnership's approach to carbon capture and storage: ePoster presented at IPTC International Petroleum Technology Conference, Doha, Qatar, January 20–22, 2014, no. 1574.

Gorecki, C.D., 2014, PCOR Partnership Program—accomplishments and path forward: Presented to Konkuk University and Sejong University personnel, Grand Forks, North Dakota, February 20, 2014.

Gorecki, C.D., Sorensen, J.A., Nakles, D., and Jackson, B., 2014, PCOR Partnership Technical Advisory Board Meeting: Presentation for the PCOR Partnership Technical Advisory Board Meeting, Austin, Texas, March 4–5, 2014.

Gorecki, C.D., 2013, Plains CO_2 Reduction (PCOR) Partnership—demonstrating CO_2 storage solutions: Presented to Omaha Public Power District personnel, Grand Forks, North Dakota, October 18, 2013.

Gorecki, C.D., 2013, Plains CO_2 Reduction (PCOR) Partnership—demonstrating CO_2 storage solutions: Presented via WebEx for the Scalable, Automated, Semipermanent Seismic Array (SASSA) Project Kickoff, Grand Forks, North Dakota, October 29, 2013.

Gorecki, C.D., 2013, Plains CO_2 Reduction (PCOR) Partnership – Phase III—DE-FC26-05NT42592: Presented at the U.S. Department of Energy National Energy Technology Laboratory Strategic Center for Coal FY14 Regional Carbon Sequestration Partnerships Expert Review, Arlington, Virginia, November 11–14, 2013.

Gorecki, C.D., 2013, RCSP Water Working Group (WWG)—the nexus of water and carbon capture and storage: Presented at the Carbon Management Technology Conference, Alexandria, Virginia, October 21–23, 2013.

Gorecki, C.D., and Hamling, J.A., 2013, PCOR Partnership data sources: Presented via WebEx for the Scalable, Automated, Semipermanent Seismic Array (SASSA) Project Kickoff, Grand Forks, North Dakota, October 29, 2013.

Hamling, J.A., and Braunberger, J.R., 2014, Bell Creek update – 2014 Plains CO_2 Reduction (PCOR) Partnership Program activities: Presented at the PCOR Partnership Annual Membership Meeting, Denver, Colorado, September 16–17, 2014.

Hamling, J.A., Gorecki, C.D., and Braunberger, J.R., 2014, PNL acquisition summer 2014: Presentation for the Denbury Resources Inc. Webinar, June 26, 2014.

Hamling, J.A., Kalenze, N.S., Klapperich, R.J., and Azzolina, N., 2014, Bell Creek Data Management standard operating procedure (SOP): Presented at the Data Management Group Kickoff Meeting, Grand Forks, North Dakota, May 15, 2014.

Hamling, J.A., 2013, Evaluation of pulsed-neutron well logging for time-lapse monitoring: Presented at the Midland CO_2 Conference Week Short Course on Surveillance and Monitoring of CO_2 Injection Projects, a Part of the 19th Annual CO_2 Flooding Conference, Midland, Texas, December 9–13, 2013.

Hamling, J.A., and Gorecki, C.D., 2013, Pulsed-neutron well logging for characterization and time-lapse monitoring of a combined CO_2 EOR and CO_2 incidental storage project: Presented at the Carbon Management Technology Conference, Alexandria, Virginia, October 21–23, 2013.

Harju, J.A., and Steadman, E.N., 2014, The Energy & Environmental Research Center's economic case for CCUS—reducing capture costs and increasing demand for commodity CO_2: Presented at the Carbon Sequestration Leadership Forum 2014 CSLF Technology Workshop, Seoul, Korea, March 26, 2014.

Harju, J.A., and Steadman, E.N., 2014, The Plains CO_2 Reduction (PCOR) Partnership: Presented to U.S. Department of Energy National Energy Technology Laboratory personnel, Pittsburgh, Pennsylvania, February 25–26, 2014.

Hawthorne, S.B., 2014, Laboratory investigations related to CCS and EOR—rocks, fluids, and video tape: Presentation for the Plains CO_2 Reduction (PCOR) Technical Advisory Board Webinar, June 27, 2014.

Hawthorne, S.B., 2013, Non-traditional (naïve?) thoughts on CO_2 EOR from the lab (down the miscibility rabbit hole): Presentation for the Denbury Oil Phase Behavior (Bell Creek) Webinar, Grand Forks, North Dakota, November 13, 2013.

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Value-Added Products

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