Energy & Environmental Research Center
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

September 16, 2019

Ms. Karlene Fine
North Dakota Industrial Commission
ATTN: Oil and Gas Research Program
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2020-0038 Entitled "Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions" in Response to the North Dakota Industrial Commission Oil and Gas Research Program Solicitation

The Energy & Environmental Research Center (EERC) is pleased to submit an original and one copy of the subject proposal. Also enclosed is the $100 application fee. The EERC, a research organization within the University of North Dakota, an institution of higher education within the state of North Dakota, is not a taxable entity; therefore, it has no tax liability.

This transmittal letter represents a binding commitment by the EERC to complete the project described in this proposal. If you have any questions, please contact me by telephone at (701) 777-5120, by fax at (701) 777-5181, or by e-mail at nazzolina@undeerc.org.

Sincerely,

Nicholas A. Azzolina

Dr. Nicholas A. Azzolina
Principal Hydrogeologist and Statistician

Charles D. Gorecki, CEO
Energy & Environmental Research Center

NAA/rlo

Enclosures

c/enc: Brent Brannan, OGRC

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Project Title: Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions

Applicant: Energy & Environmental Research Center

Principal Investigator: Dr. Nicholas A. Azzolina

Date of Application: September 16, 2019

Amount of Request: $500,000

Total Amount of Proposed Project: $10,000,000

Duration of Project: 5 years

Point of Contact (POC): Dr. Nicholas A. Azzolina

POC Telephone: (701) 777-5120

POC E-Mail Address: nazzolina@undeerc.org

POC Address:

15 North 23rd Street, Stop 9018

Grand Forks, ND 58202-9018

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ABSTRACT

Objective: The Energy & Environmental Research Center (EERC) was selected by the U.S. Department of Energy (DOE) to field-test controllable completions (interval control valves [ICVs]) for active (smart) well control during CO_2 enhanced oil recovery (EOR) (Award DE-FE0031790). The goals of this field test are to 1) implement controllable completions in horizontal wells through a rigorously monitored field test in a reservoir undergoing new tertiary recovery, 2) apply data analytics and machine learning to evaluate the test performance and develop a semiautonomous active control system, and 3) assess various business case scenarios to accelerate the development and application for commercial EOR.

Expected Results: The outcomes of this project will be to 1) evaluate perceived risks of deploying semiautonomous controllable completions technology in horizontal wells; 2) quantify the lowered net CO_2 utilization and increased oil recovery with fewer wells, which lower infrastructure costs and improve overall EOR project economics; and 3) develop economic (business) cases for implementation of this approach applicable to a wider range of reservoirs and fields, including potential application for conformance control for Bakken EOR. These outcomes will reduce the uncertainty in CO_2 EOR performance for a range of reservoir types, accelerating adoption of the approach across existing operations and expansion of CO_2 EOR into other locations where current marginal economic outlook or conformance control issues deter investment.

Total Project Cost and Duration: The total value of the project is $10,000,000, with $8,000,000 committed by DOE and a combined 1,500,000 of in-kind cost share from Computer Modelling Group (CMG) and Schlumberger. This proposal requests $500,000 from the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP).

Participants: In addition to OGRP and DOE, the EERC is partnering with Denbury Onshore LLC (Denbury), NCS Multistage LLC (NCS), North Dakota Geologic Survey (NDGS), Schlumberger, and CMG.

PROJECT DESCRIPTION

The EERC, in partnership with the project participants, will field-test integrating controllable completions (ICVs) to enable active (smart) well control during CO_2 EOR. The concepts to be tested are that 1) ICVs can reliably be used to direct fluids into selected zones of horizontal wells, mitigate CO_2 breakthrough, and maximize CO_2 sweep efficiency and 2) real-time monitoring data can be integrated in a machine learning approach to develop a "human-in-the-loop" (semiautonomous) active control system for both injection and production wells. The active control concept will be evaluated through the design and execution of a pilot CO_2 EOR test in the carbonates of the Red River Formation of the Cedar Hills South Unit (CHSU) in southwestern North Dakota. Denbury will begin a new CO_2 EOR project in the field in early 2021. CHSU is a marginal conventional field being developed with horizontal injection and production wells. The successful application of the proposed concept could spur development by providing a cornerstone technology to provide conformance control and allow for EOR application in unconventional plays (e.g., the Bakken).

A pilot test well pattern will be identified in the earliest stages of the project. The pilot area will be screened and selected using core, log, and completion data. The pilot test will use one horizontal CO_2 injection well and one horizontal production well completed with ICVs (Figure 1). Fast-flow pathways in the reservoir will be identified using a combination of monitoring technologies. An active control system will be developed that uses machine learning to analyze real-time data sets generated from these monitoring technologies and manage ICV operation. Geologic model construction and numerical simulation will be conducted using industry standard software to predict key EOR performance metrics (e.g., incremental production and CO_2 utilization). Sensitivity studies will be conducted to investigate potential performance improvements in a range of scenarios, including ranges of permeability, heterogeneity, injection/production well ICV combinations, and operational schedule. These results will inform high-level techno-economic assessments based on a range of potential commercial scenarios.

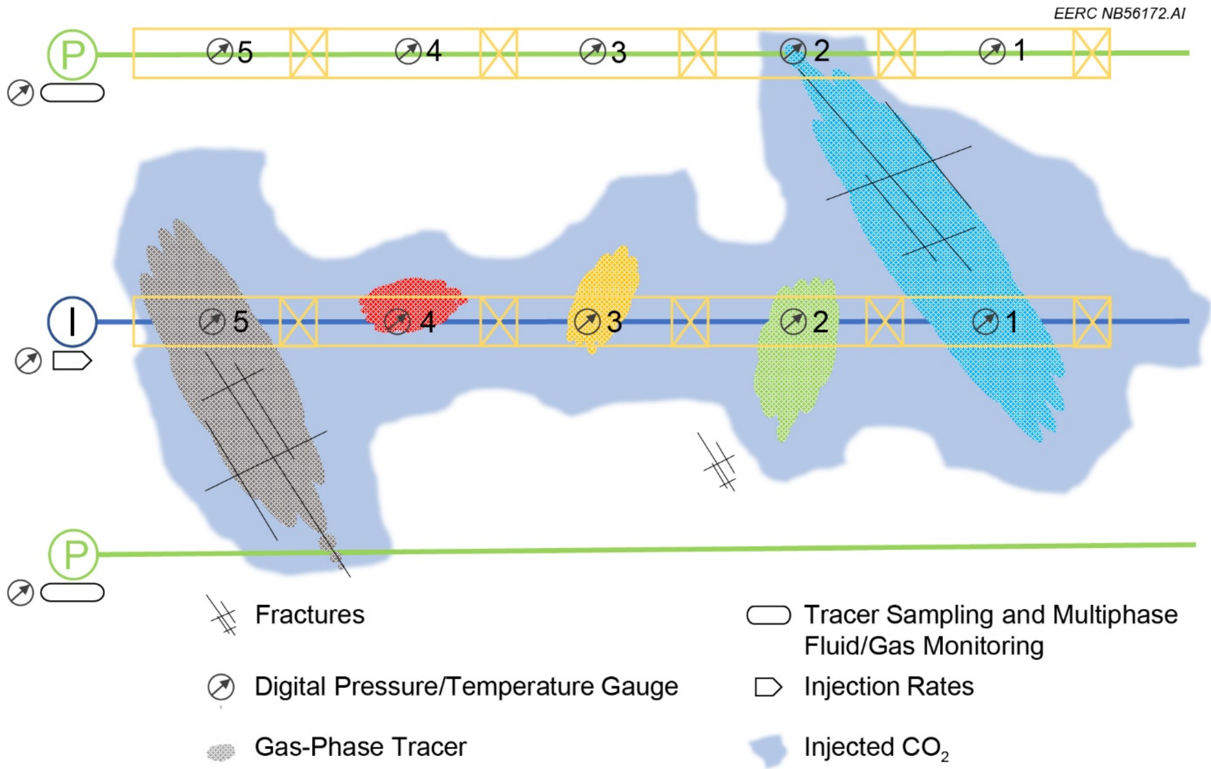

Figure 1. Conceptual ICV pilot test design, including one lateral injection (I) well equipped with an ICV system straddled by two lateral production (P) wells: one with an openhole completion and one equipped with an ICV system. The multicolored gas-phase tracer patches indicate different tracer species injected in each ICV interval.

Business cases for commercial deployment that may be applicable to other potential EOR targets will be evaluated and reported, as well as recommendations and lessons learned.

Objectives: The objectives are to 1) screen and select a CO_2 EOR ICV pilot pattern in the Cedar Hills South Field; 2) install up to ten ICVs into a horizontal CO_2 injection well and up to ten ICVs into a horizontal production well within the identified test pattern; 3) execute a tracer study using ICV interval-specific tracers to quantify connectivity within the reservoir and inform the subsequent operational designs; 4) operate the ICVs during the project to demonstrate reliability and quantitatively show that the deployment of the ICVs can improve conformance, increase CO_2 sweep efficiency, and improve incremental production; 5) collect downhole measurements which, when combined with analytical and numerical simulation models, can provide the empirical data necessary for developing a control system;

and 6) evaluate various business case scenarios using simulation models to quantify EOR performance metrics and the effect of ICVs on these metrics.

Methodology: The objectives of the project will be achieved through the five tasks described below.

Task 1.0 – Project Management and Planning – This task includes the necessary activities to manage the project and ensure coordination and planning of the project with all project sponsors.

Task 2.0 – ICV Pilot Systems Design

Subtask 2.1 – Screening and Selection of Test Pattern – This subtask will evaluate the CHSU (field test site) located on the Cedar Creek Anticline of southwestern North Dakota. Wells within the study area will be evaluated using data provided by Denbury and publicly available data sets. A specific well pattern for the ICV pilot (e.g., a lateral injection well and two offset lateral production wells) will be selected based on well log data, core sample analyses, well completion and operational history, EOR project development schedule, technical risk, and estimated cost to retrofit with an ICV system.

Subtask 2.2 – Characterization – Characterization of the reservoir, wellbore(s), and associated surface systems will be performed to facilitate the design and installation of the ICVs in the selected test pattern. Produced and injected fluid compositional analyses will be used to inform the design and construction of the downhole assemblies (ICV and packer components) for material compatibility. Core analyses will be performed to better understand the geologic characteristics. Geophysical well logs will be acquired from wellbore(s) within the test pattern and interpreted to inform completion design.

Subtask 2.3 – Baseline Modeling – A static geologic model (geomodel) of the reservoir in the area of the selected pattern will be developed. Production and injection history matching of primary and secondary (waterflood) performance will be conducted using simulation software and production data obtained from Denbury and NDIC. Initial simulations will be conducted to predict pattern performance under a range of operational scenarios to inform the pilot test design.

Subtask 2.4 – Pilot Design – An ICV assembly design will be developed including 1) number and location of ICV stages and packer placement, 2) packer selection and design, 3) integration of telemetry with a supervisory control and data acquisition (SCADA) system, and 4) compatibility with anticipated operational parameters. A strategic monitoring plan will be used to manage the operation of the ICVs throughout the pilot test, evaluate performance, and aid in the development of an active control system for the ICVs.

Task 3.0 – Operation and Monitoring

Subtask 3.1 – Install and Test Systems – The project team will coordinate with project partners and service provider(s) to install the ICV assemblies (the injection well and one of the offset production wells will be equipped with ICV assemblies) and monitoring technology. Once installed, the ICV assembly will be tested and adjusted as needed. Power, telemetry systems, data loggers, and control modules will be integrated with the SCADA system to allow for remote monitoring and control.

Subtask 3.2 – System Operation and Monitoring – The ICV system will be initially managed either manually and/or with preexisting control systems supplied by NCS during the pilot test. Active control systems developed in Task 4.0 will be tested and applied to manage the ICV pilot once available. If waterflood operation of the ICV occurs in advance of the CO_2 flood, the results and monitoring data will be analyzed and used to develop an operating strategy for the ICVs during the CO_2 EOR flood. Once CO_2 flood begins, pattern performance monitoring information and data analytics will be used to inform ICV operation. Data collected by the monitoring equipment will be processed and interpreted to support the pilot performance assessment.

Task 4.0 – Active Control System Development

Subtask 4.1 – Database and User Interface Development – A set of protocols will be developed to securely upload and archive pilot test data from the field to the EERC. A dashboard will be developed for accessing the project database that allows the user to dynamically interact with the data and to download the data for analysis within other software platforms.

Subtask 4.2 – Active Control System Development, Testing, and Optimization **–** The active control system will be developed through integration of the monitoring and performance data. At a minimum, these data will include downhole pressure and temperature measurements within each ICV, wellhead temperature and pressure measurements, and production data (oil, gas, and water rates/volumes). The active control system development will involve an exploratory phase using pilot performance data and results of simulation modeling conducted in Task 5. A predictive model will be developed that forecasts the ICV-specific downhole pressure and temperature response and oil, gas, and water production as a function of CO_2 injection rate and ICV state(s). The field performance data and results will be incorporated into business case scenarios developed in Task 5.

Task 5.0 – Business Case Development

Subtask 5.1 – Long-Term Pilot Test Pattern Performance Simulation **–** The geomodel and numerical simulations will be updated (if necessary) and history-matched with learnings generated during pilot operation and monitoring. Predictive simulations will be conducted to assess long-term performance of the pilot pattern, including CO_2 utilization and oil production improvement.

Subtask 5.2 – Business Case Development **–** A series of simulation scenarios will be run using varying reservoir properties, EOR strategies, ICV assembly characteristics, and ICV operational schedule. These scenarios will be used to evaluate potential benefits of ICV implementation across a wider range of potential implementations. The results of these simulations will enable high-level techno-economic assessments. Recommendations, lessons learned, and business cases with potential to increase estimated ultimate recovery and reduce CO_2 utilization factor (for both CHSU and other potential EOR targets) will be developed and summarized.

Anticipated Results: The outcomes of this next-generation approach will be to 1) evaluate perceived risks of deploying semiautonomous controllable completions technology in horizontal wells, 2) quantify how the approach could increase oil recovery and lower net CO_2 utilization, and 3) provide understanding for potential economic (business) cases for implementation of this approach applicable to a wider range of reservoirs and fields. These outcomes will help reduce the uncertainty in CO_2 EOR performance, which will accelerate adoption of the approach across existing operations and support expansion of CO_2 EOR into other locations where current marginal economic outlook or technical conformance challenges deter investment.

Facilities and Resources: The CHSU is an ideal pilot site as a marginal conventional commercial field (operated by Denbury) with horizontal wells scheduled for a new CO_2 EOR flood. Denbury Resources Inc. is an independent oil company specializing in CO_2 EOR. Denbury's goal is to increase the value of its properties through a combination of exploitation, drilling, and proven engineering extraction practices, with the most significant emphasis relating to CO_2 EOR operations. NCS Multistage Holdings, Inc., headquartered in Houston, Texas, is a leading provider of highly engineered products (including ICVs) and support services that facilitate the optimization of oil and natural gas well completions and field development strategies. NCS products and services are utilized in oil and natural gas basins throughout North America and in selected international markets, including Argentina, China, Russia, and the North Sea. The EERC has a multidisciplinary technical team with extensive research and operational experience. EERC laboratory capabilities include facilities and equipment to support studies of rock and fluid properties. The EERC has extensive modeling and dynamic modeling capabilities to support dynamic modeling of both conventional and unconventional oil and gas reservoirs. In addition, the EERC has expertise in analysis of large, diverse data sets. The EERC is committed to providing the necessary personnel resources to cost-effectively conduct the activities outlined in this proposal.

Techniques to Be Used, Their Availability and Capability: Techniques to be employed are detailed in the methods section above. All techniques are anticipated to be available throughout the project.

Environmental and Economic Impacts While Project Is under Way: The pilot field is already developed, and a majority of the technology and testing will occur downhole, resulting in nominal environmental impact. A SCADA system will be brought on-site for remote monitoring and control and removed following completion of the project. A unique gas-phase tracer test will be performed, and geophysical well logs will be acquired from wellbore(s) within the test pattern; traffic will increase slightly in the test area during the tracer test and logging. Lab-scale testing of the core at the EERC will be in a controlled environment, with very small amounts of material used that will be disposed of according to standard University of North Dakota (UND) Environmental Health and Safety practices once the testing is complete. Economic impacts will also be minimal and will not have appreciable effects on any of the organizations participating, with the exception of regular employment economic effects for those working on the project. An increase in oil recovery for the producers in the field test will be likely; however, since this is at a pilot scale, the overall economic impact from the produced oil is likely low.

Ultimate Technological and Economic Impacts: If the active control system is proven reliable and successful in the marginal conventional field pilot, it could result in a solution that provides a cornerstone technology for conformance control for commercially viable Bakken EOR, which could result in a doubling or more of oil recovery from the Bakken. These improvements will help accelerate the adoption of the approach across existing and future potential CO_2 EOR operations and will support the expansion of CO_2 EOR into other locations where the current marginal economic outlook deters investment. While this project explores the concept in a marginal conventional field, the application of the ICV technology to horizontal wells in the test pattern has potential application in unconventional wells (e.g., the Bakken), creating a major economic impact with increased oil production in North Dakota.

Why the Project Is Needed: The application of ICV technology in horizontal wells has not been rigorously tested, nor have potential economic (business) cases for implementation of this approach been fully vetted. At present, uncertainty regarding flood performance is one of the primary factors limiting initiation of CO_2 EOR projects. The development of technologies that improve downhole well control and improve conformance of injected fluids will reduce uncertainties in EOR flood performance, thereby encouraging investment in these types of projects. Application of ICVs provides a means of operational and engineering conformance control in variable geologic environments along a lateral wellbore, providing a much-needed means of improving sweep efficiency, lowering utilization rates, and accelerating development and investment in EOR.

STANDARDS OF SUCCESS

Success will be measured in the project's ability to demonstrate the field performance and reliability of ICV systems leading to enhanced development of technology that could immediately and substantially improve EOR performance in North Dakota oil fields. The technology could have application in conventional and unconventional reservoirs, creating a high potential benefit to North Dakota with increased tax revenue and added jobs in the oil industry and support services. Measurable metrics will include selection of wells, successful installation and testing of the ICV system, demonstration of performance improvement and reliability, and evaluation of business cases. High-level progress updates will be provided in quarterly reports, in an executive summary format, to OGRP for inclusion on the OGRP website for immediate access by the public. An interim field performance summary report will be submitted following operation and monitoring of the pilot test. A report will be submitted summarizing geologic model construction, numerical simulation sensitivity studies, and high-level economic assessments that evaluate business cases for the use of ICV systems to improve EOR performance. A final report summarizing the project will be prepared. Presentations at technical conferences and public outreach events will cover pertinent topic areas.

BACKGROUND/QUALIFICIATIONS

Project partners have pledged financial support for the awarded EERC-led effort and will provide critical support in the form of site access, operations data, technical operational guidance, and software access and support needed to achieve the project objectives. The EERC is a high-tech, nonprofit branch of UND. Dr. Nicholas Azzolina, Principal Hydrogeologist and Statistician, will serve as Principal Investigator. Jim Sorensen, Interim Director of Subsurface Research and Development and John Hamling, EERC Assistant Director for Integrated Projects, will serve as advisors. Other key EERC personnel will include Lonny Jacobson, Senior Operations Specialist; Nicholas Bosshart, Principal Geoscientist; and Dr. Lu Jin, Senior Reservoir Engineer. Resumes of key personnel are provided in Appendix A. The EERC recently completed a multiyear study to develop an intelligent monitoring system (IMS) using injection and monitoring data from the Aquistore CO_2 storage project in Saskatchewan. That IMS was developed to provide a site operator for a dedicated saline storage site with timely, actionable information about whether subsurface conditions were within normal operating limits. Although this proposed study will build off of the knowledge gained from the previous IMS project, these efforts will significantly extend the prior work. Denbury will provide the pilot test location, access to wells and infrastructure, and operational support and serve as the technical advisor to the project. Kate Ryan, Denbury Principal Reservoir Engineer, will serve as the Field Advisor and provide oversight to field activities. NCS will provide support through field deployment and technology operation guidance. NDGS will provide access to the core library and assist in selection of core samples.

MANAGEMENT

The EERC manages over 200 contracts a year, with a total of more than 1330 clients in 53 countries. Dr. Azzolina will oversee the entire project. Regular internal meetings with project staff and advisors will ensure that the project is being conducted using acceptable scientific methodologies and practices in accordance with the project plan (budget, schedule, and deliverables) and is meeting quality objectives.

The EERC will keep all partners abreast of project progress and coordinate activities as necessary for the execution of a successful project. The EERC will be responsible for timely submission of all deliverables.

TIMETABLE

The estimated period of performance for the proposed work is 5 years. The EERC is currently under contract negotiations with DOE and other project sponsors. Once an agreement is fully executed with DOE, the EERC will initiate the project, which is estimated to be no later than the beginning of October 2019. The project timetable, including project deliverables (D), is presented in Figure 2.

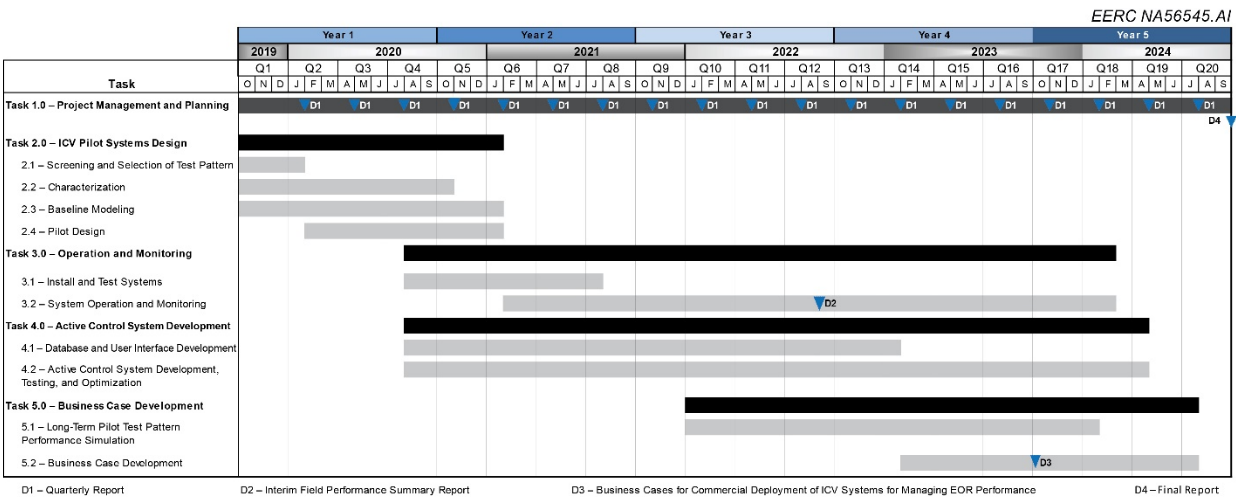

Figure 2. Project timetable.

BUDGET

The total estimated cost for the proposed project is $10,000,000. $500,000 is requested from OGRP. Cost share will include $8,000,000 cash from DOE. Schlumberger and CMG will provide a combined $1,500,000 in-kind cost share in the form of industry-leading software. Letters of commitment can be found in Appendix B. Budget details can be found in Table 1 and Appendix C.

CONFIDENTIAL INFORMATION AND PATENTS/RIGHTS TO TECHNICAL DATA

This proposal has no confidential information. No patentable technologies are expected to be created. Denbury reserves limited data rights to operating costs and Denbury-generated geologic and financial

Table 1. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	Cost Share	Total Project
Labor	$ 331,884	$ 3,033,012	$ 3,364,896
Travel	$ -	$ 165,526	$ 165,526
Equipment > $5000	$ -	$ 73,400	$ 73,400
Supplies	$ -	$ 242,351	$ 242,351
Subcontractor - Field Activities (Denbury)	$ -	$ 2,640,000	$ 2,640,000
Communications	$ 155	$ 1,334	$ 1,489
Printing & Duplicating	$ 188	$ 612	$ 800
Food	$ -	$ 1,500	$ 1,500
Laboratory Fees & Services			
Natural Materials Analytical Research Lab	$ -	$ 21,869	$ 21,869
GC/MS Lab	$ -	$ 13,563	$ 13,563
Graphics Services	$ -	$ 24,536	$ 24,536
Facilities & Administration	$ 167,773	$ 1,782,297	$ 1,950,070
Total Cash Requested	**$ 500,000**	**$ 8,000,000**	**$ 8,500,000**
In-Kind Cost Share			
Schlumberger – Software	$ -	$ 766,676	$ 766,676
CMG – Software	$ -	$ 733,324	$ 733,324
Total In-kind Cost Share	$ -	**$ 1,500,000**	**$ 1,500,000**
Total Project Costs	**$ 500,000**	**$ 9,500,000**	**$ 10,000,000**

models, simulations, interpretations and forecasts that have not been approved for public dissemination or in draft form.

STATUS OF ONGOING PROJECTS

The EERC is currently engaged in three OGRP-funded projects. These ongoing projects, listed in Table 2, are current on all deliverables.

Table 2. Current EERC Projects Funded by OGRP

Project Title	Contract Award No.
iPIPE: Intelligent Pipeline Integrity Program	G-046-88
Bakken Production Optimization Program 2.0	G-040-080
Emerging Issues	G-000-004

APPENDIX A

RESUMES OF KEY PERSONNEL

DR. NICHOLAS A. AZZOLINA
Principal Hydrogeologist and Statistician
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5120 (phone), 701.777.5181 (fax), nazzolina@undeerc.org

Education and Training
Ph.D., Environmental Management and Science, Carnegie Mellon University, 2015; M.S., Hydrogeology, Syracuse University, 2005; B.A., Geological and Geophysical Sciences, Princeton University, 1997. Proficient in the use of Microsoft Word, Excel, PowerPoint, and Access; ESRI ArcMap (geospatial mapping); PHREEQC and VisualMINTEQ (geochemical reaction modeling); and Minitab, Netica, PAST, and R (statistical modeling).

Research and Professional Experience
2016–Present: Principal Hydrogeologist and Statistician, EERC, UND. Performs statistical data analyses and supports projects related to CO_2 enhanced oil recovery (EOR), CO_2 storage, unconventional oil and gas production, and chemical contamination of environmental media (soil, groundwater, and sediment). Also specializes in conducting life cycle assessments for carbon capture, utilization, and storage (CCUS) projects and leads risk assessments for CO_2 storage, EOR, and other subsurface projects.

2010–Present: Independent Consultant, The CETER Group, Inc.

2008–2010: Scientist/Project Manager, Foth, Green Bay, Wisconsin.

2005–2008: Scientist/Project Manager, The RETEC Group, Inc., Ithaca, New York.

2004–2005: Scientist, O'Brien and Gere Engineers, Inc., Syracuse, New York.

2003–2005: Research Assistant/Head Teaching Assistant, Syracuse University, Department of Earth Science, Syracuse, New York.

2000–2003: Supervisor, McMaster-Carr Supply Co., Dayton, New Jersey.

1997–2000: Senior Field Engineer, Schlumberger Oilfield Services, Edinburg, Texas.

Publications
Azzolina, N.A., Bosshart, N.W., Burton-Kelly, M.E., Hamling, J.A., and Peck, W.D., 2018, Statistical analysis of pulsed-neutron well logs in monitoring injected carbon dioxide: IJGGC, v. 75, p. 125–133.
Hawthorne, S.B., Miller, D.J., Jin, L., and Gorecki, C.D., 2018, Lab and reservoir study of produced hydrocarbon molecular weight selectivity during CO_2 enhanced oil recovery: Energy & Fuels, v. 32, no. 9, p. 9070–9080.
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Siegel, D.I., Azzolina, N.A., Smith, B.J., Perry, A.E., and Bothun, R.L., 2015, Methane concentrations in water wells unrelated to proximity to existing oil and gas wells in northeastern Pennsylvania: Environ. Sci. Technol., v. 49, no. 7, p. 4106–4112.

Azzolina, N.A., Small, M.J., Nakles, D.V., and Bromhal, G.S., 2014, Effectiveness of subsurface pressure monitoring for brine leakage detection in an uncertain CO_2 sequestration system: Stochastic Environmental Research and Risk Assessment, v. 28, p. 895–909.

Arp, H.P., Azzolina, N.A., Cornelissen, G., and Hawthorne, S.B., 2011, Predicting pore water EPA-34 PAH concentrations and toxicity in pyrogenic-impacted sediments using pyrene content: Environ. Sci. Technol., v. 45, no. 12, p. 5139–5146.

Synergistic Activities

Statistical Analysis of CO_2 EOR Industry Database Conducted statistical analyses of proprietary industry data set of oil reservoir performance data from 31 CO_2 EOR sites in Colorado, Oklahoma, Texas, and Utah. Developed novel two- and four-parameter nonlinear regression models for describing three key metrics that significantly influence long-term performance and economic viability of CO_2 EOR projects: CO_2 retention, incremental oil recovery, and net CO_2 utilization. These results can be used by others to estimate potential range of expected performance for similar candidate oil fields. These statistical models will be used by the U.S. Department of Energy (DOE) to estimate carbon storage resource for CO_2 EOR projects throughout the United States.

Statistical Analysis of Bakken Oil Production Database Analysis, North Dakota Conducted statistical analyses of oil production data from 13 counties in North Dakota for wells producing from Bakken Formation, one of the largest oil plays in the United States. Developed and applied nonlinear regression model fits to more than 140,000 records from over 5000 wells to assess correlations with potential predictors of oil production, including geology, reservoir conditions, and completion design. Work is ongoing and aimed at optimizing oil production in Bakken Formation through Bakken Production Optimization Program.

Statistical Assessment of Groundwater Methane in Northeastern Pennsylvania Analyzed baseline data set (confidential) of over 11,300 dissolved methane analyses from domestic water wells, densely arrayed in Bradford and nearby counties (Pennsylvania) and near to over 4000 preexisting oil and gas wells. Used integrated approach of four different statistical methods to show that there is no statistically significant relationship between methane concentrations in domestic water wells and proximity to preexisting oil or gas wells. Baseline data included more than 75% nondetect measurements with different laboratory minimum reporting limits; therefore, statistical data analysis required unique solutions to appropriately handle correlation analysis and hypothesis testing with these data.

Statistical Assessment of Land Use Impacts in Southern Australia Developed statistical models to support assessment of land disturbance associated with gas well development in ~247,000-acre land parcel in southern Australia. Derived analytical extensions of hypergeometric model, and used these analytical models to validate numerical simulations conducted using Monte Carlo methods. Project resulted in effective and robust method for simulating impact of coal seam gas development and potential disturbance to vegetation and habitat.

Soil Background PAH and Metals Study, Manhattan, New York Project Manager for evaluation of background soil concentrations of PAH and metals in Manhattan. Project was designed to complement statewide survey conducted jointly by NYSDEC and NYSDOH. Managed planning, implementation, and reporting for collecting samples from 27 locations throughout Manhattan. Developed summary statistics and percentile estimates for 46 PAHs and 23 metals, along with descriptions of surface and subsurface soils and measurements of total organic and black carbon.

NICHOLAS W. BOSSHART
Principal Geoscientist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5334 (phone), 701.777.5181 (fax), nbosshart@undeerc.org

Education and Training
M.S., Geology, University of North Dakota, 2014.
B.S., Geology, University of Northern Iowa, 2012.
Proficient in the use of Microsoft Office Suite, Surfer, Petra, Petrel, Neuralog, and CMG software.

Research and Professional Experience
June 2014–Present: Principal Geoscientist, EERC, UND. Mr. Bosshart supervises an interdisciplinary team of researchers focused on understanding deep subsurface geology. Mr. Bosshart's responsibilities include providing oversight for the development and simulation of geophysical reservoir models for hydrocarbon resource assessment and geologic CO_2 storage analyses. Mr. Bosshart has experience and expertise in activities related to geologic characterization, geostatistics, geologic modeling and simulation, unconventional reservoirs, produced water disposal, CO_2 enhanced oil recovery (EOR), and deep saline formation CO_2 storage.

June 2013–June 2014: Intern and Graduate Student Research Assistant, EERC, UND. Mr. Bosshart's responsibilities included 3-D modeling (Petrel) for geologic CO_2 storage and unconventional resources. This experience also included over 120 hours of modeling software and geostatistics training.

May–June 2013: Graduate Student Teaching Assistant, South Dakota School of Mines and Technology, Annapurna Region, Himalayas, Nepal. Mr. Bosshart was a graduate student teaching assistant for geologic field studies of the Himalayas. His responsibilities included identification and mapping of metamorphic rocks associated with the Main Central Thrust Zone of the Himalayas, mapping and developing reports discussing active geomorphic agents in the region, and mapping of glacial sediments.

August 2012−May 2013: Graduate Student Teaching Assistant, Harold Hamm School of Geology and Geologic Engineering, UND. Mr. Bosshart instructed introductory geology laboratory courses.

2006–2014: Unit Supply Specialist, Iowa National Guard, United States Army, Camp Dodge, Johnston, Iowa. Deployed as part of the Multinational Force & Observers (MFO) in the Sinai Peninsula, Egypt, during 2008–2009.

Publications
Bosshart, N.W., Braunberger, J.R., Burton-Kelly, M., Dotzenrod, N.W., and Gorecki, C.D., 2015, Multiscale reservoir modeling for CO_2 storage and enhanced oil recovery using multiple point statistics: Poster presented at the EAGE Petroleum Geostatistics 2015 Conference, Biarritz, France, September 7–11, 2015.

Bosshart, N.W., Jin, L., Dotzenrod, N.W., Burnison, S.A., Ge, J., He, J., Burton-Kelly, M.E., Ayash, S.C., Gorecki, C.D., Hamling, J.A., Steadman, E.N., and Harju, J.A., 2015, Bell Creek test site – simulation report: Plains CO_2 Reduction (PCOR) Partnership Phase III Task 9 Deliverable D66 (Update 4) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-

FC26-05NT42592, EERC Publication 2016-EERC-10-09, Grand Forks, North Dakota, Energy & Environmental Research Center, August.

Bosshart, N.W., Ayash, S.C., Azzolina, N.A., Peck, W.D., Gorecki, C.D., Ge, J., Jiang, T., Burton-Kelly, M.E., Anderson, P.W., Dotzenrod, N.W., and Gorz, A.J., 2017, Optimizing and quantifying CO_2 storage resource in saline formations and hydrocarbon reservoirs: Final report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0009114, EERC Publication 2017-EERC-06-18, Grand Forks, North Dakota, Energy & Environmental Research Center, June.

Bosshart, N.W., Azzolina, N.A., Ayash, S.C., Peck, W.D., Gorecki, C.D., Ge, J., Jiang, T., and Dotzenrod, N.W., 2018, Quantifying the effects of depositional environment on deep saline formation CO_2 storage efficiency and rate: International Journal of Greenhouse Gas Control, v. 69, p. 8–19.

Bosshart, N.W., Pekot, L.J., Wildgust, N., Gorecki, C.D., Torres, J.A., Jin, L., Ge, J., Jiang, T., Heebink, L.V., Kurz, M.C., Dalkhaa, C., Peck, W.D., and Burnison, S.A., 2018, Best practices for modeling and simulation of CO_2 storage: Plains CO_2 Reduction (PCOR) Partnership Phase III Task 9 Deliverable D69 for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592, EERC

Burnison, S.A., Bosshart, N.W., Salako, O., Reed, S., Hamling, J.A., and Gorecki, C.D., 2017, 4-D seismic monitoring of injected CO_2 enhances geological interpretation, reservoir simulation, and production operations: Energy Procedia, v. 114, p. 2748–2759.

Hamling, J.A., Leroux, K.M., Glazewski, K.A., and Bosshart, N.W., 2016, Adaptive approach to modeling and monitoring 5 million tonnes of CO_2 injection at the Bell Creek oil field: Presented at the 2nd Combined Meeting of the Modelling and Monitoring Networks, Edinburgh, United Kingdom, July 6–8, 2016.

Hamling, J.A., Glazewski, K.A., Leroux, K.M., Kalenze, N.S., Bosshart, N.W., Burnison, S.A., Klapperich, R.J., Stepan, D.J., Gorecki, C.D., and Richards, T.L., 2017, Monitoring 3.2 million tonnes of CO_2 at the Bell Creek oil field: Energy Procedia, v. 114, p. 5553–5561.

Jin, L., Pekot, L.J., Hawthorne, S.B., Gobran, B., Greeves, A., Bosshart, N.W., Jiang, T., Hamling, J.A., and Gorecki, C.D., 2017, Impact of CO_2 impurity on MMP and oil recovery performance of the Bell Creek oil field: Energy Procedia, v. 114, p. 6997–7008.

Peck, W.D., Azzolina, N.A., Ge, J., Bosshart, N.W., Burton-Kelly, M.E., Gorecki, C.D., Gorz, A.J., Ayash, S.C., Nakles, D.V., and Melzer, L.S., 2018, Quantifying CO_2 storage efficiency factors in hydrocarbon reservoirs—a detailed look at CO_2 enhanced oil recovery: International Journal of Greenhouse Gas Control, v. 69, p. 41–51.

Synergistic Activities

- Member, American Association of Petroleum Geologists (AAPG)
- Member, European Association of Geoscientists (EAGE)
- Member, Geological Society of America (GSA)
- Technical reviewer, International Journal of Greenhouse Gas Control
- Presenter at technical conferences, including 2015 EAGE Petroleum Geostatistics, 2015 Annual CCUS, 2014 AAPG Rocky Mountain Section, and 2010–2012 national GSA conferences.

JOHN A. HAMLING
Assistant Director for Integrated Projects
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5472 (phone), 701.777.5181 (fax), jhamling@undeerc.org

Education and Training
B.S., Mechanical Engineering, UND, 2007. A.S./A.A., Williston State College, 2004. Certified EIT.

Research and Professional Experience
2018–Present: Assistant Director for Integrated Projects, EERC. Brings scientific and engineering innovation to field demonstrations, catalyzing and implementing pioneering solutions to facilitate prudent development and use of fossil energy. Focus is to advance commercial application of geologic CO_2 use and improved oil recovery in conventional and unconventional oil plays. Experience includes design, implementation, and oversight of surface, near-surface, deep subsurface, and reservoir characterization and surveillance programs for commercial geologic CO_2 storage and EOR. Led efforts resulting in development, proof-of concept, and validation of improved monitoring techniques applicable to dedicated and associated geologic CO_2 storage and EOR applications. Advises development, testing, and commercial demonstration of IOR techniques to improve EUR of oil in conventional and unconventional tight oil plays. Led and advised development and field demonstration of novel advanced geophysics techniques for commercial surveillance of EOR and IOR. Led evaluation of emerging and novel wellbore stimulation techniques to improve EUR in Williston Basin. Expertise includes well-logging principals and applications; produced water treatment; saltwater disposal; well drilling; well completions; wellbore integrity; risk assessment; logistics; well stimulation; IOR; enhanced recovery in tight oil plays; and HSE programs. PM/PI/task lead for multiyear, multimillion-dollar R&D projects. Leads multidisciplinary team of geophysics, data analytics, operations, and reservoir surveillance experts. Activities encompass contract research and strategic partnership programs with state of North Dakota, DOE, and private industry to propel development and implementation of approaches to benefit practical energy development.

2017–Present: Adjunct Lecturer, Department of Petroleum Engineering, UND.

2009–2018: Principal Engineer/Oilfield Operations Group Lead (2012–2018), Research Manager (2011–2012), Research Engineer (2009–2011), EERC. PM/PI/task lead for multiyear, multimillion-dollar projects, leading multidisciplinary team of scientists and engineers working to develop and implement MVA concepts for large-scale (>1 MT/yr) CO_2 storage and EOR operations. Worked with teams to develop, design, and implement new approaches to benefit economic exploration, development, and production of oil and gas. Worked on design and implementation of new approaches to benefit exploration, development, and production of oil and gas and with PCOR Partnership, evaluating potential for CO_2 storage in geologic formations. Responsibilities included field operations design, deployment, and interpretation related to oilfield technologies applicable to the CO_2 capture and storage industry; laboratory functions related to Applied Geology Laboratory; data analysis; regulatory compliance; communication of operations between service providers, management teams, industry partners, and governmental organizations, and investigation and/or demonstration of techniques and/or technologies that can enhance oil and gas production or economically benefit the oil and gas industry while reducing environmental footprint of drilling and production operations.

2007–2009: Reservoir Evaluation Engineer/HSE Rep/Loss Prevention Team Lead, Schlumberger Ltd.

Publications

Azzolina, N.A., Bosshart, N.W., Burton-Kelly, M.E., Hamling, J.A., and Peck, W.D., 2018, Statistical analysis of pulsed-neutron well logs in monitoring injected carbon dioxide: IJGGC, v. 75, p. 125–133.

Hawthorne, S.B., Miller, D.J., Jin, L., and Gorecki, C.D., 2018, Lab and reservoir study of produced hydrocarbon molecular weight selectivity during CO_2 enhanced oil recovery: Energy Fuels, v. 32, no. 9, p. 9070–9080.

Jin, L., Pekot, L.J., Hawthorne, S.B., Salako, O., Peterson, K.J., Bosshart, N.W., Jiang, T., Hamling, J.A., Wildgust, N., and Gorecki, C.D., 2018, Evaluation of recycle gas injection on CO_2 enhanced oil recovery and associated storage performance: IJGGC, v.75, p. 151–161.

Smith, S.A., Mibeck, B.A.F., Hurley, J.P., Beddoe, C.J., Jin, L., Hamling, J.A., and Gorecki, C.D., 2018, Laboratory determination of oil draining CO_2 hysteresis effects during multiple floods of a conventional clastic oil reservoir: IJGGC, v. 78, p. 1–6.

Schnacke, J.G., Harju, J.A., Hamling, J.A., Sorensen, J.A., and Wildgust, N., 2018, Carbon capture boosting oil recovery: The American Oil & Gas Reporter, v. 61, no. 9, p. 95–99.

Hamling, J.A., 2017, Developments in CO_2, ethane, and rich gas EOR—A Williston Basin perspective: Presented at CO_2 & ROZ Conference Carbon Management Workshop, Midland, TX, Dec 4–7, 2017.

Hamling, J.A., Glazewski, K.A., Leroux, K.M., Kalenze, N.S., Bosshart, N.W., Burnison, S.A., Klapperich, R.J., Stepan, D.J., Gorecki, C.D., and Richards, T.L., 2017, Monitoring 3.2 million tonnes of CO_2 at the Bell Creek oil field: Energy Procedia, v. 114, p. 5553–5561.

Hamling, J.A., Stepan, D.J., and Klapperich, R.J., 2017, Integrating monitoring data—understanding reservoir behavior and CO_2 movement at the Bell Creek commercial CO_2 EOR project: Presented at IEAGHG Monitoring Network Meeting, Traverse City, MI, June 13–15, 2017.

Jin, L., Pekot, L.J., Hawthorne, S.B., Gobran, B., Greeves, A., Bosshart, N.W., Jiang, T., Hamling, J.A., and Gorecki, C.D., 2017, Impact of CO_2 impurity on MMP and oil recovery performance of the Bell Creek oil field: Energy Procedia, v. 114, p. 6997–7008.

Daly, D.J., Crocker, C.R., and Hamling, J.A., 2013, Installing a casing-conveyed permanent downhole monitoring system [DVD]: Steadman, E.N., and Dambach, B., executive producers, Prairie Public Broadcasting and Energy & Environmental Research Center.

Synergistic Activities

- Continuous collaboration with Denbury Onshore LLC since 2009 focused on Bell Creek oil field, including geologic characterization and modeling, reservoir simulation, and field testing of >16 research-monitoring techniques through PCOR Partnership large-scale field demonstration project and other DOE-funded projects. Activities included drilling/recompletion of five wells, collection of >90 PNL logs, deployment and processing of permeant geophone array and casing-conveyed downhole pressure/temperature gauges.
- Senior project advisor for two Williston Basin unconventional tight oil rich gas/CO_2 EOR field injection tests.
- Managed drilling and completion of ten new wells; design, construction, and operation of million-dollar brine treatment and produced water test bed facility; deployment of casing-conveyed pressure/temperature systems; installation, operation, and interpretation of permanent geophone array for passive and active seismic monitoring; acquisition and interpretation of time-lapse 3-D seismic surveys in active commercial EOR project covering >40 mi^2; development and field testing of novel geophysical monitoring systems for commercial EOR floods; collection and analysis of over 500 ft of core; and collection and interpretation of well logs for over 400 wells for characterization and time-lapse monitoring (including production log to evaluate well performance (i.e., time-lapse corrosion logs, time-lapse fluid saturation logs, flow logs, pressure and fluid sampling).

- Schlumberger Wireline Engineer. Designed and oversaw open and cased-hole logging operations for >300 wells in both conventional and unconventional oil and gas plays. Field testing and validation of pre-commercialization applications of logging tools for unconventional reservoirs. Also served as HSE officer, loss prevention team lead, and explosives and radiation safety officer for wellsite activities.
- Vice-Chair and Communications Chair, Society of Petroleum Engineers International Williston Basin Section since 2012. Developed and coordinated technical program on evolving drilling and stimulation practices and emerging technologies in Williston Basin.

LONNY L. JACOBSON
Senior Operations Specialist and Oilfield Operations Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5331 (phone), 701.777.5181 (fax), ljacobson@undeerc.org

Education and Training
B.A., Economics, University of North Dakota, 2007. H_2S Certification, 2014; OSHA 10-hour Hazard Recognition Training, 2017; Well Control Training, Workover and Completion, 2015.

Research and Professional Experience
August 2015–Present: Senior Operations Specialist and Oilfield Operations Team Lead, EERC, UND. Leads field activities for the EERC related to drilling, logging, coring, completion and site infrastructure build. Analyzes hydraulic fracturing practices and conducts oil and gas pipeline evaluations and inspections in conjunction with EERC oilfield projects. Performs economic evaluations (e.g., cost–benefit analysis) of projects. Principal areas of expertise include drilling and completion design, optimizing wellsite layout for well servicing/completions, hydraulic fracturing techniques, logistics, field implementation planning, site management, and economic cost–benefit analysis of projects.

2007–2015: Operation Manager/Consultant, Bonetraill Rentals, LLC, Williston, ND. Performed hydraulic fracturing procedures, workover operations, completions, drilling operations, coil tubing, wireline, installation, independent third-party inspection of gas and production water pipelines, invoicing, daily reports, and consultant oversight for an oilfield service company that provides services to some of the largest oilfield operations in the Williston Basin region. Took projects from concept through to production. Worked as a site manager for over 100 workover operations and has experience working in multiple formations, including the Bakken/Three Forks, Midale, Spearfish, Dakota, Red River, and Mission Canyon. Other experience includes drilling and completion of produced-water disposal wells in the state of North Dakota. Managed health, safety, and environment (HSE) during all operations, except in extreme sour/H_2S environments. Specific site management projects included the following:
- Site Manager, Sundance Energy, Inc., which included site acquisition; site management during site preparation, drilling, completion (hydraulic fracturing, drill outs/cleanouts), and flow testing; site facilities and equipment installation; daily reporting; and site restoration.
- Site Manager, Cornerstone Natural Resources, LLC, which included site management during completion (hydraulic fracturing, drillout/cleanouts), flow testing, site facilities and equipment installation, and daily reporting.
- Site Manager, Crescent Point Energy US Corporation, which included site management during completion (hydraulic fracturing, drillout/cleanouts), flow testing, and daily reporting.

Site management for these projects also included controlling site access, serving as first point of contact for on-site contractors performing work, coordinating on-site activities among all on-site contractors, scheduling equipment deliveries and services, participating in daily phone conferences, ensuring maintenance/snow removal of pad and access roads, arranging fueling services, managing on-site analysis of fluids, arranging and managing off-site analysis of fluids, and scheduling and supervising water hauling and proper disposal of fluids. Led all scheduling and work performed on-site during well activities, ensuring all testing/work did not impact/damage the formation or future testing procedures.

2010–2011: Shop Supervisor, R&M Energy Systems, Williston, ND. Manufactured sucker rod guides, oversaw a small work staff, maintained machinery and inventory, orders from different companies, and quality control procedures. Maintained the second-best profit margin in the company within the first year of operations.

2006–2006: Consultant, Bonetraill Rentals, LLC, Williston, ND. Performed hydraulic fracturing procedures, workover operations, drilling operations, daily reports, and invoicing.

Publications

Hamling, J.A., Klapperich, R.A., Stepan, D.J., and Jacobson, L., 2018, Implementing and validating reservoir pressure management strategies in the Willison Basin: Presented at IEAGHG Modelling and Risk Management Network Meeting, Grand Forks, North Dakota, June 18–22, 2018.

Leroux, K.M., Ayash, S.C., Klapperich, R.J., Jensen, M.D., Kalenze, N.S., Azzolina, N.A., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Stevens, B.G., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Doll, T.A., Wilson IV, W.I., Gorecki, C.D., Pekot, L.J., Hamling, J.A., Burnison, S.A., Smith, S.A., Botnen, B.W., Foerster, C.L., Piggott, B., Vance, A.E., 2018, Integrating carbon capture and storage with ethanol production for potential economic benefit: Presented at GHGT-14, Melbourne, AU, Oct 21–25, 2018.

Pekot, L.J., Ayash, S.C., Ge, J., Jiang, T., Jacobson, L.L., and Gorecki, C.D., 2018, CO_2 storage efficiency in deep saline formations – Stage 2: Presented at GHGT-14, Melbourne, AU, Oct 21–25, 2018.

Sorensen, J.A., Pekot, L.J., Torres, J.A., Jin, L., Hawthorne, S.B., Smith, S.A., Jacobson, L.L., and Doll, T.E., 2018, Field test of CO_2 injection in a vertical Middle Bakken well to evaluate the potential for enhanced oil recovery and CO_2 storage: URTeC Paper No. 2902813.

Hamling, J.A., Klapperich, R.J., Stepan, D.J., and Jacobson, L.L., 2017, Implementing and validating reservoir pressure management strategies in the Williston Basin: Poster presented at the Carbon Capture, Utilization & Storage Conference, Chicago, Illinois, April 10–13, 2017.

Sorensen, J.A., Jacobson, L., Pekot, L.J., Torres, J.A., Jin, L., Hamling, J.A., Doll, T.E., Zandy, A., Smith, S.A., Wilson, W.I., Hawthorne, S.B., Kurz, B.A., Harju, J.A., Steadman, E.N., and Gorecki, C.D., 2017, Bakken CO_2 Storage and Enhanced Recovery Program: Presented at Mastering the Subsurface Through Technology Innovation, Partnerships & Collaboration-Carbon Storage & Oil & Natural Gas Technologies Review Meeting, Pittsburgh, Pennsylvania, August 1-3, 2017.

Sorensen, J.A., Hawthorne, S.B., Jin, L., Bosshart, N.W., Torres, J.A., Azzolina, N.A., Kurz, B.A., Smith, S.A., Jacobson, L.L., Doll, T.E., Gorecki, C.D., Harju, J.A., and Steadman, E.N., 2018, Bakken CO_2 Storage and Enhanced Recovery Program – phase II: Final report for DOE NETL Cooperative Agreement No. DE-FC26-08NT43291, XTO Energy, Hess Corporation, Marathon Oil Company, Continental Resources, and North Dakota Industrial Commission Oil & Gas Research Program; April.

Leroux, K.M., Klapperich, R.J., Azzolina, N.A., Jensen, M.D., Kalenze, N.S., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Ayash, S.C., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Wilson IV, W.I., Doll, T.E., Hamling, J.A., Gorecki, C.D., Pekot, L.J., Peck, W.D., Harju, J.A., Burnison, S.A., Stevens, B.G., Smith, S.A., Butler, S.K., Glazewski, K.A., Piggott, B., and Vance, A.E., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Final report for North Dakota Industrial Commission and Red Trail Energy, May.

Pekot, L.J., Ayash, S.C., Bosshart, N.W., Dotzenrod, N.W., Ge, J., Jiang, T., Jacobson, L.L., Vettleson, H.M., Peck, W.D., and Gorecki, C.D., 2017, CO_2 storage efficiency in deep saline formations – Stage 2: Final report for IEA Greenhouse Gas R&D Programme Agreement No. IEA/CON/16/234, August.

Hamling, J.A., Klapperich, R.J., Stepan, D.J., Sorensen, J.A., Pekot, L.J., Peck, W.D., Jacobson, L.L., Bosshart, N.W., Hurley, J.P., Wilson IV, W.I., Kurz, M.D., Burnison, S.A., Salako, O., Musich, M.A., Botnen, B.W., Kalenze, N.S., Ayash, S.C., Ge, J., Jiang, T., Dalkhaa, C., Oster, B.S., Peterson, K.J., Feole, I.K., Gorecki, C.D., and Steadman, E.N., 2016, Field implementation plan for a Williston Basin brine extraction and storage test: Phase I topical report for DOE NETL Cooperative Agreement No. DE-FE0026160, Grand Forks, North Dakota, Energy & Environmental Research Center, April.

Synergistic Activities

- Site management for approximately 100 well operations with multiple companies.
- Experience working in multiple formations, including the Bakken/Three Forks, Midale, Spearfish, Dakota, Red River, and Mission Canyon.
- Aided in design of drilling and completions plans. Aided in design of MVA activities. Aided in design of coring/logging program.

DR. LU JIN
Senior Reservoir Engineer
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5316 (phone), 701.777.5181, ljin@undeerc.org

Education and Training
Ph.D. (2013) M.S. (2009), Petroleum Engineering, Louisiana State University (LSU), 2013. B.S., Petroleum Engineering, Northeast Petroleum University, 2005.

Research and Professional Experience
July 2018–Present: Senior Reservoir Engineer, EERC, UND. Develops dynamic numerical models for fluid flow monitoring and prediction in different reservoirs; designs well testing plans for both producers and injectors to support long-term success of field operations; develops innovative fractured reservoir models for Bakken projects; and serves as simulation task lead for joint inversion project. Expertise includes reservoir modeling and simulation, CO_2 enhanced oil recovery (EOR) and associated CO_2 storage in conventional and unconventional reservoirs, water coning control, and multiphase flow in porous media. Particular interests include subsurface oil–water–gas interactions, EOR techniques, and development of old oil fields/unconventional resources.

2015–July 2018: Reservoir Engineer, Reservoir Modeling and Simulation, EERC, UND. Developed geophysical models of the subsurface and ran dynamic simulations to determine long-term fate of produced/injected fluids, including hydrocarbons, CO_2 storage, and brine, using oil and gas industry simulation software.

2014–2015: Reservoir Engineer, InPetro Technologies, Inc., Houston, TX. Developed simulation and analytical models for unconventional reservoir development, especially for shale oil reservoirs; analyzed fluid PVT (pressure, volume, temperature) change during depletion and considering pore-size distribution (PSD) in simulations. Application of a new model in the Eagle Ford and Bakken Formations showed that oil reserves could be improved as much as 30% by integrating PVT and PSD effects.

2013–2014: Reservoir Consultant, Joint Industrial Program (JIP), LSU, and Pluspetrol, Baton Rouge, LA. Simulated cold production of heavy oil in Massambala Field, Angola, identifying the mechanisms of high water cut in current wells, optimizing perforation length for conventional wells, and proposing two well systems, which could improve cumulative oil up to 80% or reduce produced water 75%, respectively.

2011–2013: Senior Teaching Assistant, Drilling Fluids Laboratory, LSU, Baton Rouge, LA. Served as lecturer and oversaw four teaching assistants and 80–100 students each year as well as supervised three senior students completing their senior design projects.

2007–2013: Research Assistant, Department of Petroleum Engineering, LSU, Baton Rouge, LA. Modeled and evaluated performance of downhole water loop (DWL) well system in different oil fields, developed economic models for evaluation of DWL system in various reservoir and market conditions, and identified best reservoir candidates for the system; oil production rate could be improved as much as 200%. Constructed software (toolbox) using ECLIPSE and VBA for complex well system simulation, applied batch processing technology in simulation, achieved automatic task queuing, and reduced simulation time 67%.

Summer 2012: Internship, High Plains Operating Company, LLC (HPOC), San Francisco, CA. Simulated and analyzed extra water production problems in Ojo Encino Field, New Mexico, designing a DWS well system to produce oil from thick transition zone, which could improve oil production rate by up to 20%.

Summer 2011: Internship, JIP, LSU, and HPOC, Baton Rouge, LA. Simulated performance of vertical and horizontal wells in Ojo Encino Field, New Mexico, diagnosing water coning/cresting problems in thick transition zone, determined best location for water injection to minimize pressure interference, and suggested well type to develop the field, which saved costs up to 30%.

2005–2007: Production Consultant, JIP, China University of Petroleum, and CNPC. Optimized large gas pipeline network in China, proposing new optimization algorithm and programming software package for best operation in different conditions, reducing operational cost up to 23% (more than $20,000/day).

Publications

Hawthorne, S.B., Miller, D.J., Jin, L., and Gorecki, C.D., 2018, Lab and reservoir study of produced hydrocarbon molecular weight selectivity during CO_2 enhanced oil recovery: Energy & Fuels, v. 32, no. 9, p. 9070–9080.

Jin, L., Pekot, L.J., Hawthorne, S.B., Salako, O., Peterson, K.J., Bosshart, N.W., Jiang, T., Hamling, J.A., Wildgust, N., and Gorecki, C.D., 2018, Evaluation of recycle gas injection on CO_2 enhanced oil recovery and associated storage performance: IJGGC, v.75, p. 151–161.

Jin, L., Pekot, L.J., Smith, S.A., Salako, O., Peterson, K.J., Bosshart, N.W., Hamling, J.A., Mibeck, B.A.F., Hurley, J.P., Beddoe, C.J., and Gorecki, C.D., 2018, Effects of gas relative permeability hysteresis and solubility on associated CO_2 storage performance: IJGGC, v. 75, p. 140–150.

Jin, L., Sorensen, J.A., Hawthorne, S.B., Smith, S.A., Pekot, L.J., Bosshart, N.W., Burton-Kelly, M.E., Miller, D.J., Grabanski, C.B., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2018, Improving oil recovery by use of carbon dioxide in the Bakken unconventional system—a laboratory investigation: SPE Reservoir Evaluation & Engineering, v. 20, no. 3, p. 602–612.

Salako, O., Jin, L., Barajas-Olalde, C., Hamling, J.A., and Gorecki, C.D., 2018, Implementing adaptive scaling and dynamic well-tie for quantitative 4-D seismic evaluation of a reservoir subjected to CO_2 enhanced oil recovery and associated storage: IJGGC, v. 78, p. 306–326.

Smith, S.A., Mibeck, B.A.F., Hurley, J.P., Beddoe, C.J., Jin, L., Hamling, J.A., and Gorecki, C.D., 2018, Laboratory determination of oil draining CO_2 hysteresis effects during multiple floods of a conventional clastic oil reservoir: IJGGC, v. 78, p. 1–6.

Jin, L., Hawthorne, S.B., Sorensen, J.A., Pekot, L.J., Kurz, B.A., Smith, S.A., Heebink, L.V., Herdegen, V., Bosshart, N.W., Torres, J., Dalkhaa, C., Peterson, K.J., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2017, Advancing CO_2 enhanced oil recovery and storage in unconventional oil play—experimental studies on Bakken shales: Applied Energy, v. 208, p. 171–183.

Hawthorne, S.B., Miller, D.J., Jin, L., and Gorecki, C.D., 2016, Rapid and simple capillary-rise/vanishing interfacial tension method to determine crude oil minimum miscibility pressure—pure and mixed CO_2, methane, and ethane: Energy & Fuels, v. 30, no. 8, p. 6365–6372.

Jin, L., Hawthorne, S.B., Sorensen, J.A., Pekot, L.J., Bosshart, N.W., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2017, Utilization of produced gas for improved oil recovery and reduced emissions from the Bakken Formation: Presented at 2017 SPE Health, Safety, Security, Environment & Social Responsibility Conference – North America, New Orleans, LA, April 18–20, 2017, SPE-184414-MS.

Jin, L., Pekot, L.J., Hawthorne, S.B., Gobran, B., Greeves, A., Bosshart, N.W., Jiang, T., Hamling, J.A., and Gorecki, C.D., 2017, Impact of CO_2 impurity on MMP and oil recovery performance of the Bell Creek oil field: Energy Procedia, v. 114, p. 6997–7008.

Synergistic Activities

- Member, Society of Petroleum Engineers.
- Technical reviewer for multiple professional journals, including SPE Production and Operations, Journal of Energy Resources Technology, and Journal of Unconventional Oil and Gas Resources.
- Reservoir engineer for U.S. Department of Energy (DOE)-sponsored Plains CO_2 Reduction (PCOR) Partnership Bell Creek CO_2 enhanced oil recovery (EOR) simulation, analysis, and prediction activities; DOE-sponsored PCOR Partnership Aquistore CO_2 storage simulation and prediction activities; DOE-sponsored Bakken CO_2 storage and EOR program unconventional reservoir simulation and production analysis activities; and a variety of DOE-sponsored seismic projects for CO_2 EOR simulation and monitoring activities.

JAMES A. SORENSEN
Assistant Director for Subsurface Strategies
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5287 (phone), 701.777.5181 (fax), jsorensen@undeerc.org

Education and Training
B.S., Geology, University of North Dakota, 1991; postgraduate coursework in Geology and Hydrogeology, 1993–1995.

Research and Professional Experience
July 2018–Present: Assistant Director for Subsurface Strategies, EERC, UND. Develops business opportunities, provides technical support and guidance regarding emerging areas of research, and serves as a principal investigator (PI) and task manager for projects related to the sustainable development of unconventional tight oil resources. Primary areas of expertise are unconventional tight oil resource assessment and development, and pilot-scale field testing of concepts and technologies to improve oil production from conventional and unconventional reservoirs.

1999–July 2018: Principal Geologist, EERC, UND. Served as manager and co-PI for multi-year, multi-million-dollar, industry/government consortium programs to develop strategies for CO_2 utilization and storage in a variety of conventional and unconventional reservoirs in the Williston Basin, including the Bakken unconventional tight oil play.

1997–1999: Program Manager, EERC, UND. Managed projects focused on produced water management and environmental fate of natural gas-processing chemicals.

1993–1997: Geologist, EERC, UND. Conducted field-based hydrogeologic investigations focused on natural gas production sites.

1991–1993: Research Specialist, EERC, UND. Assembled and maintained comprehensive databases related to oil and gas drilling, production, and waste management.

Publications
Jin, L., Sorensen, J.A., Hawthorne, S.B., Smith, S.A., Pekot, L.J., Bosshart, N.W., Burton-Kelly, M.E., Miller, D.J., Grabanski, C.B., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2018, Improving oil recovery by use of carbon dioxide in the Bakken unconventional system—a laboratory investigation: SPE Reservoir Evaluation & Engineering, v. 20, no. 3, p. 602–612.
Jin, L., Hawthorne, S.B., Sorensen, J.A., Pekot, L.J., Kurz, B.A., Smith, S.A., Heebink, L.V., Herdegen, V., Bosshart, N.W., Torres, J., Dalkhaa, C., Peterson, K.J., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2017, Advancing CO_2 enhanced oil recovery and storage in unconventional oil play—experimental studies on Bakken shales: Applied Energy, v. 208, p. 171–183.
Kurz, B.A., Sorensen, J.A., Hawthorne, S.B., Smith, S.A., Sanei, H., Ardakani, O., Walls, J., Jin, L., Butler, S.K., Beddoe, C.J., and Mibeck, B.A.F., 2018, The influence of organics on supercritical CO_2 migration in organic-rich shales: Paper presented at the Unconventional Resources Technology Conference, Houston, Texas, July 23–25, 2018, URTeC Paper No. 2902743.

Sorensen, J.A., Pekot, L.J., Torres, J.A., Jin, L., Hawthorne, S.B., Smith, S.A., Jacobson, L.L., and Doll, T.E., 2018, Field test of CO_2 injection in a vertical Middle Bakken well to evaluate the potential for enhanced oil recovery and CO_2 storage: Paper presented at the Unconventional Resources Technology Conference, Houston, Texas, July 23–25, 2018, URTeC Paper No. 2902813.

Hawthorne, S.B., Jin, L., Kurz, B.A., Miller, D.J., Grabanski, C.B., Sorensen, J.A., Pekot, L.J., Bosshart, N.W., Smith, S.A., Burton-Kelly, M.E., Heebink, L.V., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2017, Integrating petrographic and petrophysical analyses with CO_2 permeation and oil extraction and recovery in the Bakken tight oil formation: Presented at the SPE Canada Unconventional Resources Conference, Calgary, Alberta, February 15–16, 2017, SPE-185081-MS.

Sorensen, J.A., Kurz, B.A., Hawthorne, S.B., Jin, L., Smith, S.A., and Azenkeng, A., 2017, Laboratory characterization and modeling to examine CO_2 storage and enhanced oil recovery in an unconventional tight oil formation: Energy Procedia, v. 114, p. 5460–5478.

Sorensen, J.A., Kurz, B.A., Smith, S.A., Walls, J., Foster, M., and Aylsworth, B., 2016, The use of advanced analytical techniques to characterize micro- and nanoscale pores and fractures in the Bakken: Paper presented at the SPE/AAPG/SEG Unconventional Resources Technology Conference, Aug 1–3, 2016, URTeC Paper No. 2447958.

Sorensen, J.A., Braunberger, J.R., Liu, G., Smith, S.A., Hawthorne, S.A., Steadman, E.N., and Harju, J.A., 2015, Characterization and evaluation of the Bakken petroleum system for CO_2 enhanced oil recovery: Paper presented at the SPE/AAPG/SEG Unconventional Resources Technology Conference, San Antonio, Texas, July 20–22, 2015, URTeC Paper No. 2169871.

Synergistic Activities

Since 2009, Mr. Sorensen has conducted a variety of research projects to develop an improved understanding of the Bakken petroleum system, including efforts to examine the potential to use CO_2 and rich gas for improved oil recovery in the Bakken.

In 2011, Mr. Sorensen conducted an assessment of North American tight oil resources that was included as a section in the National Petroleum Council's report to the U.S. Secretary of Energy on the potential of North America's abundant natural gas and oil resources.

In 2017, he led the design and execution of a pilot-scale CO_2 injection test into an unconventional tight Bakken reservoir for carbon storage and improved oil recovery.

In 2017, Mr. Sorensen also served as the Cochair for the Society of Petroleum Engineers Forum on Enhanced Oil Recovery in Unconventional Reservoirs.

Member, Unconventional Resources Subcommittee of the National Petroleum Council.

Kate M. Ryan
Director of Reservoir Engineering
Denbury Resources

Education and Training
B.S., Chemical Engineering, University of Texas at Austin, 2008.

Research and Professional Experience
April 2019–Present: Director of Reservoir Engineering, Denbury Resources. Ms. Ryan guides all subsurface technical work from a staff of over 50 reservoir and production engineers. She has a strong background in various forms of enhanced oil recovery and has designed and implemented CO_2 and miscible hydrocarbon gas floods from pilot to full field design.

July 2017–March 2019: Principal Reservoir Engineer, Denbury Resources.

August 2016–July 2017: Manager – Reservoir Management, Denbury Resources.

October 2015–August 2016: Reservoir Engineer, Denbury Resources.

February 2013–September 2015: Reservoir Engineer, C12 Energy.

October 2011–January 2013: Reservoir Engineer II, Chesapeake Energy, Oklahoma City, OK.

January 2010–September 2011: Senior Reservoir Engineer, ConocoPhillips, Anchorage, AK.

June 2008–December 2009: Associate Engineer, Heavy Oil, ConocoPhillips, Houston, TX.

May 2006–July 2007: Engineering Intern, ConocoPhillips, Farmington, NM, and Anchorage, AK.

Synergistic Activities
At Denbury, Director of Reservoir Engineering involves in strategic project selection and portfolio management (>260 MMBOE proved reserves). As Principal Reservoir Engineer, ensured technical consistency for Denbury Resources (≈60,000 net BOE/D), built technical basis for a megaproject (>$500 million capital), and created and led career development plans for all engineers. Reservoir management included managing geologists, engineers, and technicians for six fields; responsibility for ≈23,000 net BOE/D, nearly 10,000 BOE/D from CO_2 flooding; installing flood expansion (increased field production greater than 25%). Reservoir engineering responsibilities included serving as lead reservoir engineer for CO_2/waterflood that generated >7000 BOE/D; building a forecasting tool for CO_2 harvest with artificial lift in a mature field; and serving as project coordinator for a ≈$600K pilot project to test artificial lift.

As reservoir engineer at C12 Energy, responsible for reservoir engineering and project management for a planned CO_2 flood in central Kansas; full-field history match/forecasting in CMG IMEX for a Kansas asset; and sole engineering responsibility for company-wide reserves since company started.

As reservoir engineer at Chesapeake Energy, managed a rig schedule (>20 rigs); developed simulation-based production type curves for six different lithologies; and built a mechanistic reservoir model, based on geochemical and petrophysical data.

As senior reservoir engineer at ConocoPhillips, designed a redevelopment project for an underperforming viscous oil waterflood; provided guidance on field reservoir management strategies for a viscous oil waterflood; and worked on a thermal pilot design for a heavy oil field.

APPENDIX B

LETTERS OF COMMITMENT

Schlumberger

Wayne Rowe
Schlumberger Technology Corporation
1875 Lawrence St. Suite 810
Denver, CO 80202 USA

April 10, 2019

Dr. Nicholas Azzolina
Principal Hydrogeologist and Statistician
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Subject: EERC Proposal No. 2019-0104 Entitled "Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions"

Dear Dr. Azzolina,

I am writing to confirm Schlumberger's commitment to join the team led by the Energy & Environmental Research Center (EERC) to validate controllable completion and active control system technologies in horizontal wells as a means of improving enhanced oil recovery (EOR). This effort is presented in the subject proposal in response to U.S. Department of Energy (DOE) Funding Opportunity Announcement DE-FOA-0001988.

Schlumberger is a recognized leader in modeling complex geologic systems and understanding reservoir response to the injection of fluids, with decades of experience field-testing for the oil and gas industry. As such, Schlumberger is focused on providing practical solutions to challenging questions related to improving recovery from oil and gas reservoirs. Schlumberger's expertise and proven software tools, coupled with the EERC's research capabilities and wealth of knowledge regarding geologic characterization, 3-D geocellular modeling, and the Williston Basin create an ideal formula to validate the use of controllable completion and active control system technologies to improve CO2 EOR.

To support the proposed scope of work, Schlumberger is pleased to provide cost share in the form of geologic modeling and data interpretation software licenses and maintenance. Specific software packages to be contributed include two licenses with select modules of Petrel, Schlumberger's leading geologic modeling package, and one license with select modules of Techlog, our leading data interpretation and aggregation software package. These licenses and maintenance will be provided at no cost for the duration of the 5-year project and are valued at an amount not less than $2,000,000. We understand these software licenses and maintenance may be used as non-cash cost share to leverage DOE funding and certify that it is from nonfederal sources.

We are excited to collaborate with the EERC and the rest of the team on this important topic. If you have any questions, please contact me by telephone at (303) 594-1219 or by e-mail at rowe5@slb.com.

Sincerely,

Wayne Rowe

Business Development Manager – Low Carbon Projects

COMPUTER MODELLING GROUP INC.

Paragon Center One
450 Gears Road, Suite 860
Houston, Texas
U.S.A. 77067

Phone: (281) 872-8500
Fax: (281) 872-8577
E-mail: cmgl@cmgl.ca
Website: www.cmgl.ca

April 12, 2019

Dr. Nicholas Azzolina
Principal Hydrogeologist and Statistician
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Dr. Azzolina:

Subject: EERC Proposal No. 2019-0104 Entitled "Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions"

I am writing to confirm Computer Modelling Group Ltd.'s (CMG's) commitment to partner with the team that is being assembled by the Energy & Environmental Research Center (EERC) to investigate the use of controllable well completion technologies and active control systems to improve the performance of enhanced oil recovery (EOR) in horizontal wells. This investigation is being proposed in response to U.S. Department of Energy Funding Opportunity Announcement DE-FOA-0001988.

CMG is focused on providing practical solutions for modeling and simulation of oil and gas reservoirs to understand how to improve recovery from these reservoirs. CMG's software and the EERC's research capabilities, established relationship with the project team, knowledge of the Williston Basin, field testing experience, and subsurface static and dynamic modeling proficiency create an ideal formula to field-test controllable completions and active control systems to improve EOR in conventional horizontal wells.

As indicated in the subject proposal, CMG is committed to provide in-kind cost share in the form of reservoir simulation software licenses and technical support for the duration of the 5-year project. We will provide two licenses each of *IMEX* (including iSegWell, an advanced wellbore modeling tool), *GEM* (full-field unlimited grid cell version), *WINPROP*, and *CMOST*, plus four *SOLVE IMEX/GEM* parallel tokens (allowing *IMEX* and *GEM* to run in eight-way parallel mode). The total value of this contribution is shown below.

Software Type (Number of Licenses)	IMEX (2), GEM (2), WINPROP (2), CMOST (2), SOLVE IMEX/GEM PARALLEL TOKEN (4)

Total License Fees (per year)	$374,200
Portion Contributed as Cost Share (per year)	$374,200
Amount to Be Paid	$0
Total Cost-Share Contribution	$1,871,000

We welcome this opportunity to collaborate with the EERC and the rest of the team on improving EOR through controllable completion and active control system technologies.

Sincerely,

James C. Erdle

Jim Erdle
Vice President – USA and Latin America

North Dakota Geological Survey

Edward C. Murphy - State Geologist

Department of Mineral Resources

Lynn D. Helms - Director

North Dakota Industrial Commission

https://www.dmr.nd.gov/ndgs/

April 12, 2019

Dr. Nicholas Azzolina
Principal Hydrogeologist and Statistician
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Dr. Azzolina:

Subject: Support for EERC Proposal Entitled *Improving EOR Performance through Data Analytics and Next-Generation Controllable Completions*; DOE Funding Opportunity No. DE-FOA-0001988

The North Dakota Geological Survey is excited to support the Energy & Environmental Research Center and Denbury Onshore LLC's efforts to demonstrate a technology that could substantially improve enhanced oil recovery performance in legacy oilfields. The ability to manage injection and production with machine learning and data analytics techniques along horizontal wellbores could improve enhanced oil recovery performance and reduce CO_2 utilization rates. In addition, the successful application of this technology along horizontal wells with controllable valves has the potential to significantly reduce the number of new wells needed to transition hundreds of legacy North Dakota oilfields fields to enhanced oil recovery.

To support this effort the North Dakota Geological Survey has committed to providing access to 375,000 feet of core and 30,000 boxes of drill cuttings obtained from oil and gas wells throughout the state of North Dakota to facilitate the activities outlined in the subject proposal.

We look forward to working with the Energy & Environmental Research Center and the other team members on this project.

Sincerely,

Edward C. Murphy
State Geologist

NCS MULTISTAGE

April 16, 2019

Mr. Nicholas Azzolina
Principal Hydrogeologist and Statistician
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Nicholas:

Subject: **EERC Proposal Entitled "Improving EOR Performance through Data Analytics and Next-Generation Controllable Completions"**

NCS Multistage is pleased to partner with the Energy & Environmental Research Center (EERC) in the subject proposed project submitted to the U.S. Department of Energy (DOE) Office of Fossil Energy (FE) in response to Funding Opportunity No. DE-FOA-0001988 (AOI-1B).

Pending successful award, negotiation and progression of the proposed work, NCS Multistage will work with EERC and Denbury Onshore LLC to deploy two Qumulus™ EOR control systems, one each into an injection well and a production well at the proposed project field location in North Dakota. The Qumulus™ system integrates an array of individually addressable interval control valves (ICVs) with active sensing, cloud-based machine learning and remote control to automate the management of several isolated zones within a well to reduce or eliminate injection into inter-well fast flow pathways. The system as proposed combines emerging technologies that NCS Multistage has recently developed with new elements being developed by NCS to improve EOR performance. In support of the proposed effort NCS is prepared to provide necessary engineering and operational support to accomplish the objectives of the proposed effort and in-kind support valued at $274,000 to partially defer the cost of the technology deployment.

NCS Multistage is committed to advancing technologies to improve hydrocarbon recovery and EOR performance in both new and legacy fields. We believe the field site and project team are particularly well suited for accomplishing the proposed work and genuinely look forward to working with the EERC, Denbury and the DOE in a collaborative and productive relationship to accomplish the goals of the proposed research project.

Sincerely,

Warren MacPhail
EOR Product Line Manager
NCS Multistage, LLC
wmacphail@ncsmultistage.com
(403) 598-0215

APPENDIX C

BUDGET NOTES

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

INTELLECTUAL PROPERTY

The applicable federal intellectual property (IP) regulations will govern any resulting research agreement(s). In the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this project, such IP, including rights, title, interest, and obligations, may be transferred to the EERC Foundation®, a separate legal entity.

BUDGET INFORMATION

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) and among funding sources of the same scope of work is for planning purposes only. The project manager may incur and allocate allowable project costs among the funding sources for this scope of work in accordance with Office of Management and Budget (OMB) Uniform Guidance 2 CFR 200.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the university's current fiscal year (July 1 – June 30). Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: Salary estimates are based on the scope of work and prior experience on projects of similar scope. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the average rate of a personnel group with similar job descriptions. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project may be paid an amount over the normal base salary, creating an overload which is subject to limitation in accordance with university policy. As noted in the UND EERC Cost Accounting Standards Board Disclosure Statement, administrative salary and support costs which can be specifically identified to the project are direct-charged and not charged as facilities and administrative (F&A) costs. Costs for general support services such as contracts and IP, accounting, human resources, procurement, and clerical support of these functions are charged as F&A costs.

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits. Only the actual approved rate will be charged to the project. The second component is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

Travel: Travel may include site visits, fieldwork, meetings, and conferences. Travel costs are estimated and paid in accordance with OMB Uniform Guidance 2 CFR 200, Section 474, and UND travel policies, which can be found at http://und.edu/finance-operations (Policies & Procedures, A–Z Policy Index, Travel). Daily meal rates are based on U.S. General Services Administration (GSA) rates unless further limited by UND travel policies; other estimates such as airfare, lodging, ground transportation, and miscellaneous costs are based on a combination of historical costs and current market prices. Miscellaneous travel costs may include parking fees, Internet charges, long-distance phone, copies, faxes, shipping, and postage.

Equipment: The EERC budgeted four pieces of equipment to be purchased: two computer modeling workstations to perform modeling and simulation and two cluster computer nodes to perform simulation and machine learning. The cost of the equipment is estimated at $11,700 for the computer modeling workstation and $25,000 for the cluster computer node.

Supplies: Supplies include items and materials that are necessary for the research project and can be directly identified to the project. Supply and material estimates are based on prior experience with similar projects. Examples of supply items are chemicals, gases, glassware, nuts, bolts, piping, data storage, paper, memory, software, toner cartridges, maps, sample containers, minor equipment (value less than $5000), signage, safety items, subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the F&A cost. A project-specific supply list is included.

Contractor: A contract will be executed with an engineering services company to ensure site/wellbore access, site/well preparation, and installation and operation of internal control valve (ICV) systems. Additionally, they will provide engineering and operational support and access to field and operational data. The cost for these services is estimated at $2,640,000. Denbury Onshore LLC is expected to be the general contractor.

Professional Fees: Not applicable.

Communications: Telephone, cell phone, and fax line charges are included in the F&A cost; however, direct project costs may include line charges at remote locations, long-distance telephone charges, postage, and other data or document transportation costs that can be directly identified to a project. Estimated costs are based on prior experience with similar projects.

Printing and Duplicating: Page rates are established annually by the university's duplicating center. Printing and duplicating costs are allocated to the appropriate funding source. Estimated costs are based on prior experience with similar projects.

Food: Expenditures for project partner meetings where the primary purpose is dissemination of technical information may include the cost of food. The project will not be charged for any costs exceeding the applicable GSA meal rate. EERC employees in attendance will not receive per diem reimbursement for meals that are paid by project funds. The estimated cost is based on the number and location of project partner meetings.

Professional Development: Fees are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout the development and execution of the project by the research team.

Operating Fees: Operating fees generally include EERC recharge centers, outside laboratories, and freight. EERC recharge center rates are established annually and approved by the university.

Facilities and Administrative Cost: The F&A rate proposed herein is approved by the U.S. Department of Health and Human Services and is applied to modified total direct costs (MTDC). MTDC is defined as total direct costs less individual capital expenditures, such as equipment or software costing $5000 or more with a useful life of greater than 1 year, as well as subawards in excess of the first $25,000 for each award.

Cost Share: The U.S. Department of Energy will provide $8,000,000 of cash for the current scope. Nonfederal in-kind cost share will be provided in the form of software licenses for simulation and modeling efforts, with $733,324 provided from CMG and another $766,676 provided from Schlumberger, with the balance of $500,000 provided by NDIC. It should be noted the letters of commitment from CMG and Schlumberger state $1,871,000 and $2,000,000 of in-kind cost share respectively, but the EERC is choosing to commit to the minimum cost share, required by the Federal Opportunity Announcement.