EERC
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

November 8, 2019

Mr. Brent Brannan
Director
North Dakota Industrial Commission
Oil and Gas Research Program
PO Box 7217
Bismarck, ND 58507

Dear Mr. Brannan:

Subject: Clarification to EERC Proposal No. 2020-0066 Entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse" in Response to North Dakota Industrial Commission Oil and Gas Research Program Recycling Produced Water Study Request for Proposals

The Energy & Environmental Research Center (EERC) submitted the subject proposal on November 4, 2019. After further review of the proposal, I wish to provide additional clarification to Footnote 3 on page 5. To be fully accurate, it should be clarified to read "[3] Based on discussions with current and prior Bakken Production Optimization Program (BPOP) partners (e.g., Equinor, Continental Resources, etc.)."

Please share this letter, enumerating the clarification with reviewers and NDIC OGRP members as you deem appropriate. Please advise if you prefer submission of a revised proposal with the clarification incorporated.

If you have any questions, please contact me by telephone at (701) 777-5421, by fax at (701) 777-5181, or by e-mail at kglazewski@undeerc.org.

Sincerely,

Kyle A. Glazewski
Senior Analyst, Data/GIS Team Lead

KAG/bjr

EERC
Energy & Environmental Research Center
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
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November 4, 2019

Ms. Karlene K. Fine
Executive Director and Secretary
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. 2020-0066 Entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse" in Response to North Dakota Industrial Commission Oil and Gas Research Program Recycling Produced Water Study Request for Proposals

The Energy & Environmental Research Center (EERC) is pleased to submit an original and four copies 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) 777-5421, by fax at (701) 777-5181, or by e-mail at kglazewski@undeerc.org.

Sincerely,

Kyle A. Glazewski
Senior Analyst, Data/GIS Team Lead

Approved by:

Charles D. Gorecki, CEO
Energy & Environmental Research Center

KAG/kal

Enclosures

c/enc: Brent Brannan, Oil and Gas Research Program

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Project Title: Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse

Applicant: Energy & Environmental Research Center

Principal Investigator: Mr. Kyle A. Glazewski

Date of Application: November 4, 2019

Amount of Request: $300,000

Total Amount of Proposed Project: $1,299,993

Duration of Project: 2 years

Point of Contact (POC): Kyle A. Glazewski

POC Telephone: (701) 777-5421

POC E-Mail Address: kglazewski@undeerc.org

POC Address:

15 North 23rd Street, Stop 9018

Grand Forks, ND 58202-9018

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ABSTRACT

The Energy & Environmental Research Center (EERC) proposes to address the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP) Recycling Produced Water Study request for proposals.

Objective: The techno-economic viability of using the Inyan Kara Formation as a geologic solution for produced water treatment and recycling, with the benefit of providing a potential solution to pressurization of the Inyan Kara due to saltwater disposal (SWD) will be assessed. The Stage I effort will provide data on current methods for produced water treatment and recycling. It will also investigate the economic, regulatory, scientific, and technological considerations to assess the commercial viability of a concept, herein referred to as geologic homogenization, conditioning, and reuse (GHCR), for produced water management. GHCR takes advantage of natural processes occurring in the subsurface (such as dilution, mixing, and filtering) to improve water quality prior to extraction for subsequent use.

Expected Results: A produced water assessment report to legislative management, a report of findings from laboratory and field validation, and a techno-economic assessment of the relevant economic, regulatory, financial, scientific, and technological considerations governing commercial viability of the GHCR concept will be developed. Pending a favorable techno-economic disposition, the proposed Stage I effort will provide the requisite information and confidence for project partners to progress the GHCR concept to a Stage II pilot demonstration of beneficial end use of GHCR water.

Duration: 24 months

Total Project Cost: $1,299,993; NDIC OGRP: $300,000 and U.S. Department of Energy (DOE): $999,993.

Participants: EERC, Nuverra Environmental Solutions (site access, produced water samples, and operational support), and DOE. Advisory support has been secured from two prominent oil producers operating in North Dakota. The EERC commits to facilitating interactions with key Bakken Production Optimization Program members representing seven of the top ten producers in North Dakota.

PROJECT DESCRIPTION

Introduction: Produced water management (including flowback water) represents a significant economic and technical challenge for oil and gas production. Produced water volumes associated with Bakken petroleum system (BPS) production in North Dakota have increased dramatically from 32 million barrels per year (bbl/yr) in 2010 to 471 million bbl/yr in 2018 and are forecast to increase to over 1.1 billion bbl/yr by 2035.[1] In 2019, essentially all BPS produced water is managed by saltwater disposal (SWD), of which over 95% is injected into the Inyan Kara Formation. The increase in SWD volumes has resulted in localized areas of high pressure in the Inyan Kara in geographic regions correlated with high oil and gas activity.[1, 2] The increased pressure in the Inyan Kara significantly impacts the economics and risk associated with the drilling of new wells that now require additional intermediate casing strings, increasing well costs by $300,000 to $700,000 per well.[3]

Simultaneously, freshwater demand for well stimulation and maintenance is projected to rise to more than 700 million bbl/yr by 2035.[1] Pressurization of SWD zones and a corresponding increase in freshwater demand will proliferate with the development of the 25,000 to 70,000 additional wells forecast for primary development of the BPS,[4] impacting the cost and accessibility of water disposal. Recycling of produced water within the industry would serve to reduce net SWD volume (thereby prolonging the life of SWD wells and reducing the rate of pressurization in disposal zones) and displace freshwater demand (thereby providing assurance of future water supply).

Commercial techniques for produced water treatment employ a combination of chemical, mechanical filtration, and thermal processes to treat high-salinity waters to a quality acceptable for

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[1] Kurz, B.A., Stepan, D.J., Glazewski, K.A., Stevens, B.G., Doll, T.E., Kovacevich, J.T., and Wocken, C.A., 2016, A Review of Bakken Water Management Practices and Potential Outlook: Final report prepared for members of the Bakken Production Optimization Program, EERC Publication 2016-EERC-03-11, Grand Forks, North Dakota, Energy & Environmental Research Center, March.

[2] Schmidt, D., Miguens, A.C.M., Wong, C.; Hlava, K., and Pinkston, D., 2019, Salt water disposal performance in the Williston Basin: Presented at the SPE Western Regional Meeting, San Jose, California April 23–26, 2019, SPE-195337-MS.

[3] Based on discussions with Bakken Production Optimization Program (BPOP) partners (i.e., Equinor, Continental Resources, etc.).

[4] Helms, L.D., 2019, Agency overview: North Dakota Industrial Commission Department of Mineral Resources presentation to the House Energy and Natural Resources Committee, January 10, 2019, www.dmr.nd.gov/oilgas/presentations/HouseEnergyNaturalResources011019_25.pdf (accessed October 2019).

reuse in well stimulation. However, their application is challenged by the high salinity and variable chemistry of Bakken produced water that can approach 300,000 mg/L total dissolved solids (TDS).[1] The storage of large volumes of produced fluids in on-site open containers such as water corrals and lined ponds is prohibitively expensive because of regulations borne of environmental concerns, effectively precluding the adoption of produced water recycling and reuse. Presently, North Dakota has abundant freshwater available at low cost, limiting incentive to find solutions to these emerging challenges. However, with the increasing pressurization of the Inyan Kara Formation and increasing demand for freshwater, this may not always be the case.

Sustainable energy production requires efficient, economical, and environmentally sound practices for managing produced water. State and industry leaders engaged with the EERC, including representation from seven of the top ten North Dakota oil-producers, place a priority on produced water management and treatment. The EERC, in partnership with Nuverra and the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL), seeks to advance a potentially transformational and innovative approach to produced water management. The proposed geologic homogenization, conditioning, and reuse (GHCR) concept takes advantage of natural processes occurring in the subsurface (such as dilution, mixing, and filtering) to improve produced water quality prior to extraction and reuse (Figure 1).

The proposed effort will evaluate the efficacy of the physical and geochemical filtering, conditioning, and homogenization processes provided by the Inyan Kara Formation. The GHCR concept will be validated by leveraging the Nuverra Environmental Solutions (Nuverra)-operated Johnsons Corner SWD site, host to a DOE-funded brine extraction and storage test (BEST) project (DE-FE0026160) (Appendix A). The site is actively injecting Bakken produced water into the Inyan Kara through two SWD wells and extracting the water that has migrated through the Inyan Kara from a well approximately 1300 feet away from each of the two SWD wells. Those injection and extraction activities are part of a

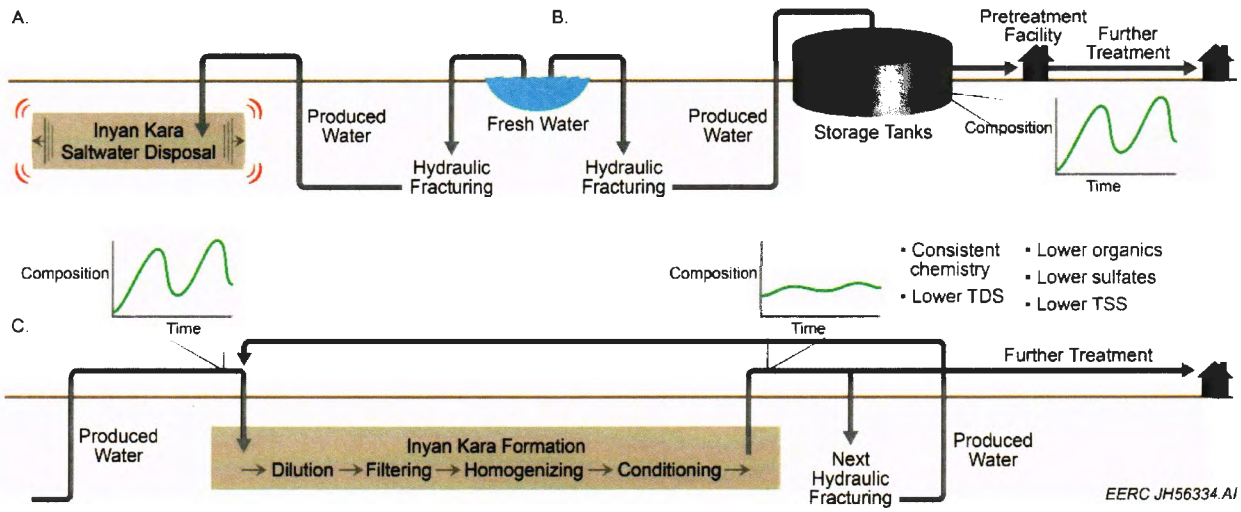


Figure 1. A) Current approach to SWD; results in pressurization. B) Traditional approach to produced water treatment; requires large-volume storage on surface, challenged by variable water chemistry. C) GHCR concept; circumvents limitations of A and B.

field laboratory investigation of brine extraction as a reservoir pressure management strategy for geologic CO_2 storage. The site is ideally suited to validate the GHCR concept. An inventory of Bakken produced water and Inyan Kara water compositions distributed throughout North Dakota will inform laboratory evaluation of GHCR, with consideration for variability in water chemistry. The results of the field and laboratory validation will provide calibration of modeled performance to inform the techno-economic assessment of GHCR as potentially applied across the Bakken play area in North Dakota.

Characterization of the produced water being injected into the SWD wells relative to the extracted water that has migrated through the Inyan Kara will enable validation of GHCR compared to several traditional treatment systems (e.g., thermal, chemical, membrane) that are being operated at the brine treatment test bed as part of the DOE-funded BEST project. Performance of GHCR will be assessed in terms of treatment effectiveness, energy and material balance, and costs to inform commercial use cases and a techno-economic assessment of GHCR. The effort will examine relevant and objective economic, regulatory, scientific, technological, and feasibility considerations of the GHCR concept relative to the produced water management practices within North Dakota.

GHCR represents a nontraditional and potentially transformational approach to produced water management that addresses water treatment and reuse barriers in North Dakota. Successful application of GHCR has several potential benefits: 1) uses existing practices and infrastructure to homogenize and condition produced waters for subsequent treatment and/or reuse; 2) enables large-volume storage and a virtually limitless supply of consistent-quality produced water for subsequent beneficial reuse, displacing freshwater demand and thereby providing assurance of water supply in the event of future curtailments on water appropriations; and 3) reduces the net volume of SWD, thus reducing the magnitude and rate of pressurization of the target disposal formation, extending the life of SWD wells and eliminating drilling costs associated with pressurization. The GHCR concept, deployed at scale, could provide an innovative solution to the emerging Inyan Kara pressurization challenge that could increase drilling and disposal costs by $1.5 to $10 billion (if 20% of the projected remaining Bakken development is impacted by Inyan Kara pressurization).

Pending a favorable techno-economic disposition, the proposed Stage I effort will provide the requisite information and confidence for project partners to progress the GHCR concept to a Stage II pilot demonstration of beneficial end use of GHCR water. The Stage II pilot would use GHCR water supplied by the Inyan Kara extraction well at the Johnsons Corner SWD site for hydraulic fracturing and provide field performance data to further inform commercial viability.

Objectives: The proposed effort will assess the techno-economic viability of using the Inyan Kara as a geologic solution for produced water treatment and recycling, with the added benefit of providing a potential solution to pressurization of the Inyan Kara Formation in North Dakota. The Stage I effort will provide data on current methods for produced water treatment and recycling and assess the commercial viability of GHCR for produced water management.

Methodology: This project will develop the requested report for legislative management through Stage IA and evaluate the feasibility and viability of the GHCR concept as Stage IB, which could lead to a future Stage II pilot demonstration project. Project objectives will be achieved by the following activities.

Activity 1 – Produced Water Assessment: The EERC will update the 2016 Bakken Water Management Practice report[1] (Deliverables D1 and D2). The EERC will engage with project partners to evaluate produced water management methods, trends, and costs; capacity of water supply and disposal facilities; economic, regulatory, and technological considerations for water recycling and reuse applications relevant to Bakken produced water management. D1, submitted by March 1, 2020, to the North Dakota Industrial Commission (NDIC), will include annotations that describe how the results of Stage I, including a water quality assessment and relevant learnings from Activities 2–4, will be incorporated into D2.

The EERC will work with project partners and BPOP members to conduct an assessment characterizing the variability and distribution of Inyan Kara and Bakken produced water quality in North Dakota. The assessment will incorporate available water composition data provided by project partners, supplemented by the collection and analysis of water samples from partner locations. The produced water quality assessment will contribute to project Activities 2–4. D2, incorporating updated information provided by project partners, results from the water quality assessment, and relevant available findings from Activities 2–4 will be provided to legislative management by October 1, 2020.

Activity 2 – Field and Laboratory Validation: The GHCR concept will be validated by leveraging the Johnsons Corner SWD site. The site is actively injecting Bakken produced water into the Inyan Kara through two SWD wells and extracting the water that has migrated through the Inyan Kara from a well approximately 1300 feet away as part of a field test of brine extraction as a strategy for pressure and injected fluid plume management. Sampling and characterization of produced water being injected into the SWD wells relative to the extracted water that has migrated through the Inyan Kara will be used to

characterize and validate the efficacy and performance of GHCR. GHCR performance will be benchmarked to several traditional treatment systems that are being operated at the brine treatment test bed as part of the ongoing BEST project. Bakken and Inyan Kara water samples will be used in combination with Inyan Kara outcrop rock samples (collected near Spearfish, South Dakota) to evaluate performance of GHCR relative to the variability in Bakken and Inyan Kara water chemistry defined by Activity 1, as well as variability in Inyan Kara rock mineralogy and geochemistry. The results of the combined field and laboratory validation will provide calibration for geochemical models and inform the techno-economics of GHCR.

Activity 3 – GHCR Modeling and Simulation: The EERC will evaluate the efficacy, performance, and longevity of the GHCR concept using geologic and geochemical models calibrated with the results of Activities 1 and 2. A range of implementation scenarios will be evaluated to assess commercial GHCR strategies. The implementation scenarios will be evaluated based on several factors, including spacing of injection/extraction wells, injection/extraction rates compared to the effectiveness and performance of GHCR treatment, and the impact on the magnitude and extent of formation pressure reduction. Results will inform the techno-economic assessment.

Activity 4 – Techno-Economic Assessment: Building off of results from Activities 1–3, the EERC will assess the techno-economic viability of commercial GHCR applications for a range of implementation strategies. Relevant technical, economic, regulatory, financial, scientific, and technological considerations affecting commercial adoption of GHCR will be examined. Technical, regulatory, and financial barriers that influence commercial adoption throughout North Dakota will be identified. Relevant findings and results will be presented in the draft (D3) and final (D4) GHCR techno-economic reports.

Anticipated Results: The anticipated results of this project will be a Stage IA produced water assessment final report to legislative management and a Stage IB final report of findings from laboratory and field

validation and a techno-economic assessment of the relevant economic, regulatory, financial, scientific, and technological considerations governing commercial viability of the GHCR concept. Pending a favorable techno-economic disposition, the proposed Stage I effort will provide the requisite information and confidence for project partners to progress the GHCR concept to a Stage II pilot demonstration of beneficial end use of GHCR water.

Facilities and Resources: The Nuverra-operated Johnsons Corner SWD site in western North Dakota has wells injecting and extracting Bakken produced water into/out of the Inyan Kara and is actively testing thermal, chemical, and membrane produced water pretreatment systems as part of a DOE-funded project on pressure management. The EERC—a research facility operating as a business unit of the University of North Dakota (UND)—has 254,000 square feet of offices, laboratories, and technology demonstration facilities available to perform the proposed computing and laboratory efforts. The project partners have all necessary technical resources available to assist in the proposed efforts.

Techniques to Be Used, Their Availability, and Capability: Activity 1 includes produced water sample collection from industry partners and the Johnsons Corner site. The EERC possesses laboratory facilities that are available for water sample analysis for pertinent water quality parameters. Activity 2 will utilize EERC laboratories to perform the laboratory-scale demonstration of produced water flowing through Inyan Kara material to evaluate the interactions between produced water and the Inyan Kara environment (i.e., rock and native fluids). The commercial pretreatment system operating at the Johnsons Corner SWD (Appendix A) site will provide benchmark data for traditional produced water treatment for comparison to the GHCR concept. Activity 3 simulation efforts will use ToughReact, a numerical simulation program for predicting and evaluating geologic subsurface processes.

Environmental and Economic Impacts While Project Is under Way: The environmental and economic impacts of the proposed project will be minimal, as the GHCR concept will be validated at an existing SWD operation. The majority of work will be conducted at EERC facilities.

Ultimate Technological and Economic Impacts: In addition to developing and compiling data regarding produced water management methods, the project investigates a new approach to managing produced water while simultaneously addressing North Dakota oil and gas industry challenges related to the management of increasing volumes of produced water and pressure increases in the Inyan Kara Formation. If successful, the GHCR concept offers an attractive technological and economic solution for managing produced water through 1) using existing practices and infrastructure to homogenize and condition produced waters for subsequent treatment and/or reuse; 2) enabling large-volume storage and a virtually limitless supply of consistent-quality produced water for subsequent beneficial reuse, displacing freshwater demand and thereby providing assurance of future water supply; and 3) reducing the net volume of SWD, thus reducing the magnitude and rate of pressurization of the target disposal formation, extending the life of SWD wells, and reducing oil and gas development costs associated with Inyan Kara pressurization.

Why the Project Is Needed: While the GHCR concept appears promising, commercial demonstration and adoption require diligent evaluation and the techno-economic feasibility information that this project will provide. Lacking an imminent threat to produced water management practices in North Dakota, the proposed efforts are unlikely to be undertaken until such a threat (e.g., constraint on SWD injection, freshwater limitations, pervasive pressure regulation, and inflated drilling costs) is present. The proposed effort provides foundational knowledge to enable prudent development and implementation of a next-generation, sustainable produced water management practice.

STANDARDS OF SUCCESS

Pending a favorable techno-economic disposition, the proposed Stage I effort will provide the requisite information and confidence for project partners to progress the GHCR concept to a Stage II pilot demonstration of beneficial end use of GHCR water. The Stage II pilot would use GHCR water supplied

by the Inyan Kara extraction well at the Johnsons Corner SWD site for hydraulic fracturing and provide field performance data to further inform commercial viability.

Successful execution of the Stage I effort will result in an updated Bakken Water Management Practice report (D2) provided to legislative management. The update will incorporate produced water management methods, trends and costs; capacity of water supply and disposal facilities; and economic, regulatory, and technological considerations for water recycling and reuse applications relevant to Bakken produced water management. A techno-economic assessment will be developed that incorporates relevant economic, regulatory, financial, scientific, and technological considerations affecting commercial adoption of GHCR. Relevant findings and results will be presented in the draft (D3) and final (D4) GHCR techno-economic reports. The techno-economic assessment will lay out potential scenarios for commercial-scale implementation.

BACKGROUND/QUALIFICATIONS

The EERC is a high-tech, nonprofit branch of UND. Kyle Glazewski, EERC Senior Analyst, will serve as principal investigator. John Hamling, EERC Assistant Director for Integrated Projects, and Bethany Kurz, EERC Assistant Director for Integrated Analytical Solutions, will serve as advisors. Other key EERC personnel will include Marc Kurz, Senior Geologist; Dr. Chantsalmaa Dalkhaa, Senior Reservoir Engineer; Dr. Chris Martin, Senior Research Engineer; and Loreal Heebink, Senior Project Management Specialist (resumes in Appendix B). The EERC-led BPOP includes partners from seven of the top ten oil-producing companies in North Dakota. BPOP members Oasis and Hess have pledged to support the proposed effort in an advisory role, as indicated in letters of support (Appendix C). The 2016 document entitled "A Review of Bakken Water Management Practices and Potential Outlook" was a product of BPOP efforts.

The EERC is leading a DOE-funded BEST project as a field laboratory evaluating active reservoir management (i.e., pressure and plume management) practices for CO_2 storage. The site, which will be leveraged for the proposed work, is actively injecting Bakken produced water into the Inyan Kara through

two SWD wells and extracting the water that has migrated through the Inyan Kara from a well approximately 1300 feet away for the purposes of pressure and saltwater plume management. As part of the BEST project, the EERC, in collaboration with Nuverra, is also operating a brine treatment technology development and test bed facility for testing thermal, membrane, and chemical treatment systems. These technology demonstrations will provide benchmark performance data for comparison with the GHCR concept. The project is scheduled to be operational through December 2021 (Appendix A).

MANAGEMENT

The EERC manages over 200 contracts a year, with more than 1330 clients in 53 countries. The EERC also leads BPOP. Led by PI Mr. Glazewski, regular internal meetings with project staff and advisors will ensure that the project is 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 24 months. The project timetable, including project deliverables, is presented in Figure 1.

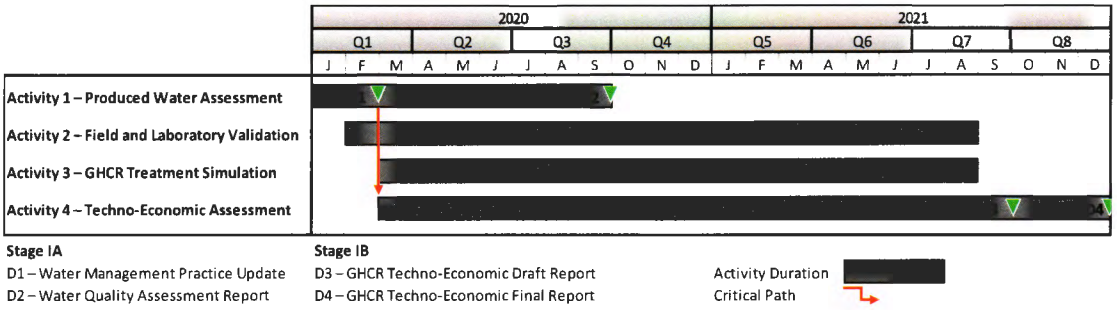


Figure 1. Project timetable.

BUDGET

The total cost for the proposed effort is $1,299,993. $300,000 is requested from the NDIC Oil and Gas Research Program (OGRP). Cost share includes $999,993 cash from DOE. Letters of commitment can be found in Appendix C. The budget is shown in Table 1. Budget notes are provided in Appendix D.

Table 1. Budget Breakdown.

Project Associated Expense	NDIC Share (Cash)	Federal Share (Cash)	Total Project
Labor	$ 183,608	$ 593,734	$ 777,342
Travel	$ 2,396	$ 24,315	$ 26,711
Supplies	$ -	$ 25,995	$ 25,995
Communications	$ 270	$ 290	$ 560
Printing & Duplicating	$ 400	$ 375	$ 775
Laboratory Fees & Services			
Analytical Research Lab	$ 12,000	$ 14,077	$ 26,077
Graphics Services	$ -	$ 3,461	$ 3,461
Total Direct Costs	$ 198,674	$ 662,247	$ 860,921
Facilities & Administration	$ 101,326	$ 337,746	$ 439,072
Total Project Costs	$ 300,000	$ 999,993	$ 1,299,993

CONFIDENTIAL INFORMATION; PATENTS/RIGHTS TO TECHNICAL DATA

This proposal has no confidential information. No patentable technologies are expected to be created.

STATUS OF ONGOING PROJECTS

The EERC is engaged in five OGRP projects, listed in Table 2, which are current on all deliverables.

Table 2. Current EERC Projects Funded by OGRP

Project Title	Contract Award No.
Plains CO_2 Reduction Partnership – Phase III	G-015-030
Bakken Production Optimization Program 2.0	G-040-080
NDIC Emerging Issues	G-000-004
iPIPE: intelligent Pipeline Integrity Program	G-046-88
Underground Storage of Produced Natural Gas – Conceptual Evaluation and Pilot Project(s) (HB 1014)	G-049-092

APPENDIX A

BRINE EXTRACTION AND STORAGE TEST (BEST) SITE PROJECT INFORMATION

WILLISTON BASIN WATER TREATMENT TECHNOLOGY TEST BED

WE SEEK TO PILOT-TEST TECHNOLOGIES CAPABLE OF TREATING HIGH-TDS WATER.

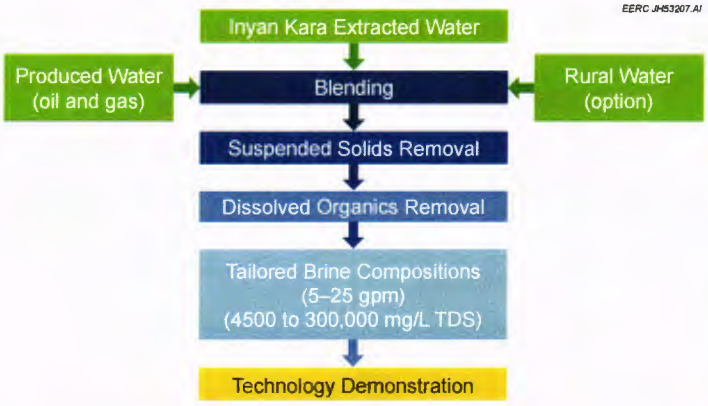
TREATMENT AND HANDLING of high-TDS (total dissolved solids) waters associated with energy production are challenging and not readily or economically accomplished using conventional water treatment techniques. Geologic injection is often required to effectively manage fluids associated with electrical power generation, oil and gas production, and active reservoir management for geologic CO_2 storage.

As part of a public–private collaboration, a facility is being constructed in western North Dakota to pilot-test high-TDS water treatment technologies that can:

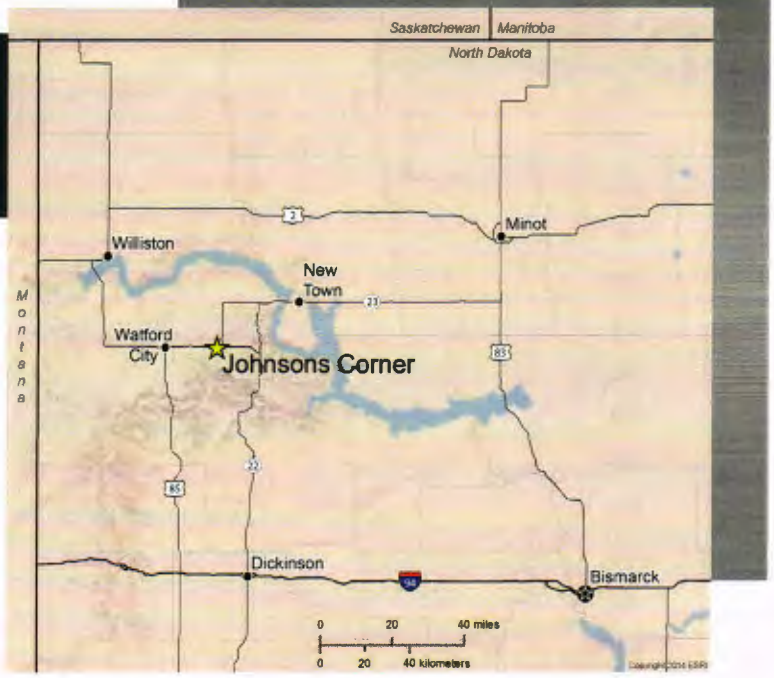
- Produce alternate sources of water for industrial or domestic use.
- Produce salable products.
- Meaningfully reduce brine disposal volumes.

Pilot testing provides critical understanding of technology performance under field operating conditions. This understanding enables the advancement and commercial adoption of viable technologies capable of treating these challenging waters for beneficial use.

The Energy & Environmental Research Center (EERC) is seeking companies interested in pilot-testing water treatment technologies at the facility. This is a collaborative effort with Nuverra Environmental Solutions (Nuverra) and the U.S. Department of Energy (DOE) National Energy Technology Laboratory.



Conceptual extracted water treatment flow diagram.



The extracted water treatment test bed facility is located approximately 13 miles east of Watford City, North Dakota, immediately adjacent to North Dakota Highway 23 on the Johnsons Corner site, a Nuverra-operated commercial saltwater disposal (SWD) facility.

The test bed will feature the ability to blend extracted and produced waters in order to generate tailored brine compositions ranging from ~4500 to ~300,000 mg/L TDS.

EERC engineering staff will be on-site during all demonstration activities to assist with connections to the test bed facility and to monitor and gather process performance data. Technology developers are expected to provide their own operations staff. During steady-state operation, EERC engineering staff will conduct energy and material balances (power consumption, process flows, and influent and effluent quality analyses).

A report summarizing demonstration activities and detailing performance data and technology capabilities will be prepared and submitted to DOE. Nondisclosure and site access agreements between the EERC, Nuverra, and technology developers will be negotiated prior to demonstration.

Currently, no guarantee is offered that DOE or other funding will be available to assist interested treatment technology developers. However, the field site and facilities for water treatment demonstrations, including potential cost offsets for power, cooling water, and effluent disposal, may be made available at no or reduced cost to selected demonstrations.

BLENDED AND PRETREATED WATER CHARACTERISTICS

The table below shows the typical composition of a blended water that could be treated at the site.

Parameter	Value, mg/L
B	303
Li	46
Na	49,900
K	5010
Mg	680
Ca	13,800
Sr	1140
Ba	24
Fe	46
Mn	12
P	<15
Si	<20
Fluoride	<7
Sulfate	167
NO_2 and NO_3 (as nitrogen)	<4
Chloride	108,700
TSS[1]	–
TOC[2]	–
TDS	180,000
Total Hardness as $CaCO_3$	38,700

[1]TSS (total suspended solids).
[2]TOC (total organic carbon).

TEST BED FEATURES

The site will include a heated building with a concrete floor that is integrated with the on-site formation water extraction and disposal infrastructure. The building will accommodate a standard semi tractor–trailer (53 ft long).

UTILITIES

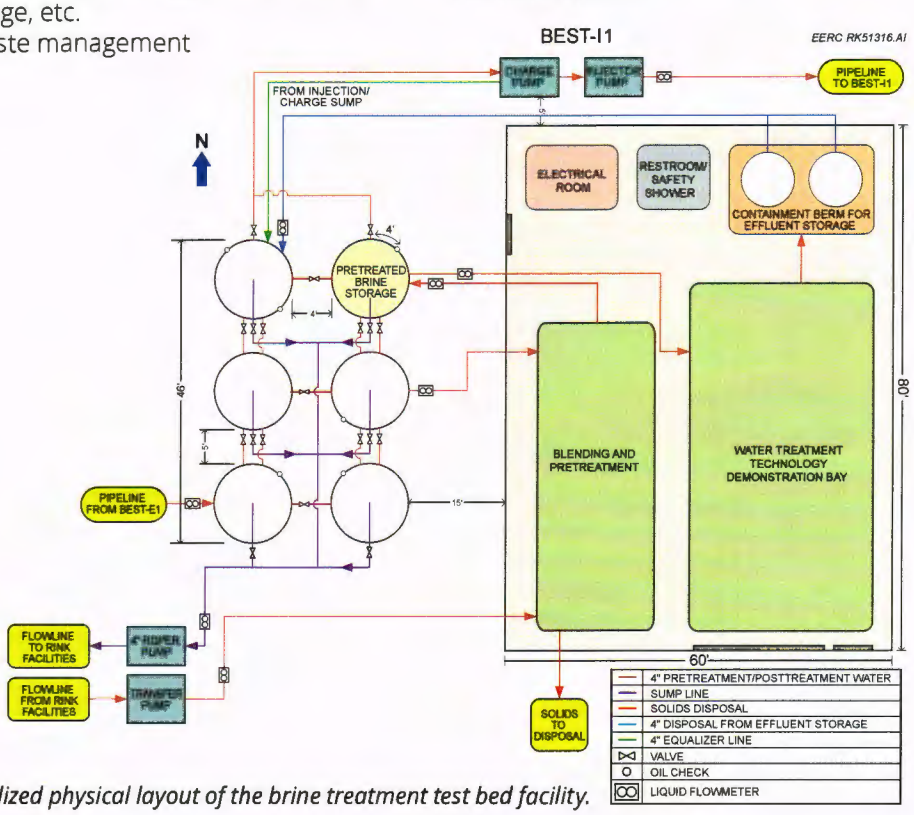
- Up to 300 kW of electric power
- Propane (5000-gal tank)
- Noncontact cooling water (30 gpm)

DEMONSTRATION TEST TRIALS

- Pilot treatment rates ranging from 1 to 25 gpm
- 30–60+-day extended-duration tests (desired minimum of two maintenance cycles)
- Monitoring of energy, flow, chemical usage, etc.
- Waste management

EXTRACTED WATER PRETREATMENT

- Blending of formation waters (Bakken and Inyan Kara Formations) to target a TDS level of 180,000 mg/L or tailored blends to suit capabilities and/or limitations of specific technologies
- Suspended solids removal
- Dissolved organics removal
- Ability to provide Bakken produced and/or flowback water for suitable demonstrations



Conceptualized physical layout of the brine treatment test bed facility.

If you are interested in demonstrating a brine treatment technology at this site or for more information, please contact:

Marc Kurz
Senior Geologist and Process Chemistry and Development Team Lead
(701) 777-5278, mkurz@undeerc.org

John Hurley
Principal Materials Scientist
(701) 777-5159, jhurley@undeerc.org

John Hamling
Assistant Director for Integrated Projects
(701) 777-5472, jhamling@undeerc.org

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

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BEST

Brine Extraction and Storage Test

The Energy & Environmental Research Center (EERC) and Nuverra Environmental Solutions (Nuverra) have partnered on a multiyear project to demonstrate new strategies and methods of injection well operation. These strategies could reduce the number of injection wells needed for fluid disposal and increase availability of water for beneficial use.

WHAT IS THE GOAL OF THE PROJECT?

The project will test new injection strategies that have the potential to improve the performance and management of injection sites. Geologic disposal of fluids is necessary for energy production (both electric energy generation and oil production and refining) and for a broad cross section of other industries. In North Dakota, approximately 500 active and closely regulated injection wells are being used to dispose of fluids into deep brine-filled rock layers. This project will investigate extraction and treatment of native brine from the injection formation as a means to manage reservoir pressure, minimize the footprint of the injected water within the formation, and improve overall injection performance.

WHAT ARE THE BENEFITS OF THE PROJECT?

If successful, the engineering strategies employed at the site may be commercially adopted and applied at other fluid injection sites in North Dakota and beyond. Ultimately, this may extend the life of injection wells, reduce net brine disposal volumes, and provide new sources of water for beneficial use.

WHO IS INVOLVED IN THE PROJECT?

The project is being conducted by the EERC in partnership with Nuverra. The EERC, at the University of North Dakota, is an organization dedicated to providing practical, pioneering solutions to the world's energy and environmental challenges. Nuverra specializes in providing environmentally compliant and sustainable solutions to national customers who demand the highest level of environmental compliance and accountability from their service providers. Together, we are committed to developing sustainable energy generation and American energy independence.

Site map showing layout.

WHERE IS THE PROJECT HAPPENING?

The project is being conducted at the Nuverra-operated Johnsons Corner site, which was established in 2008 as a commercial saltwater disposal (SWD) facility. Nuverra operates two existing saltwater injection wells at this facility. These wells, regulated by the North Dakota Industrial Commission, inject into the thick Inyan Kara sandstone at a depth of 5400 ft.

WANT TO LEARN MORE? PLEASE CONTACT:

Energy & Environmental Research Center
University of North Dakota
John Hamling, (701) 777-5472, www.undeerc.org

Nuverra Environmental Solutions
Landtech Enterprises
Kirk Johnson, (406) 488-4006, www.nuverra.com

APPENDIX B

RESUMES OF KEY PERSONNEL

KYLE A. GLAZEWSKI
Senior Analyst, Data/GIS 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
701.777.5421 (phone), 701.777.5181 (fax), kglazewski@undeerc.org

Principal Areas of Expertise
Mr. Glazewski's principal areas of interest and expertise include wellbore evaluation, corrosion assessment, water management, geospatial analysis, and geographic information system (GIS) technology.

Qualifications
M.S., Geography, University of North Dakota, 2005.
B.S., Geography, University of North Dakota, 2003.

Software Experience
ESRI ArcView 3.2 and 3.3, ArcMap 8.x, ArcGIS 9.x, and ArcGIS 10.x
Spatial Analyst Extension for GIS
ERDAS Imagine
HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) atmospheric dispersion model
AnnAGNPS (Annual Agricultural Non-Point Source Pollution) watershed model
Soil and Water Assessment Tool (SWAT)
Microsoft Office

Professional Experience
2008–Present: Senior Analyst, Data/GIS Team Lead, EERC, UND. Mr. Glazewski oversees data analysis and GIS activities in subsurface research and development. He performs water quality assessment and watershed-scale water quality modeling to determine beneficial management practices and develop total maximum daily loads (TMDLs) as well as regional geologic formation characterization and wellbore integrity evaluations.

2005–2008: Watershed Coordinator, Grand Forks County Soil Conservation District, Grand Forks, ND. Mr. Glazewski administered and managed all aspects of two U.S. Environmental Protection Agency (EPA) 319 water quality projects, including field data collection, watershed modeling, data organization and analysis, final assessment report preparation, project implementation proposal writing, assisting with TMDL development, assisting with water quality assessment project planning, budget management and planning, public outreach, and assisting landowners with conservation planning to improve water quality as well as working with other agencies on water quality projects.

2005: Associate Geographic Technician, Special Projects Team, NAVTEQ, Fargo, ND. Mr. Glazewski updated a global mapping database, completed quality checks on map data, and helped develop steps for new network-updating process using ArcMap 8.3 software, providing feedback to simplify the process.

2003–2005: Graduate Teaching Assistant, Department of Geography, UND, Grand Forks, North Dakota. Mr. Glazewski's responsibilities included teaching Introduction to Physical Geography and Introduction to Climatology labs and assisting department professors as needed.

2002–2003: GIS Technician, Upper Midwest Aerospace Consortium, Grand Forks, ND. Mr. Glazewski worked on a western North Dakota wetlands project and study of greenhouse gases in agricultural fields in eastern North Dakota and western Minnesota.

Relevant Publications

Laumb, J.D., Glazewski, K.A., Hamling, J.A., Azenkeng, A., Kalenze, N.S., and Watson, T.L., 2017, Corrosion and failure assessment for CO_2 EOR and associated storage in the Weyburn Field: Energy Procedia, v. 114, v. 5173–5181.

Peck, W.A., Glazewski, K.A., Klenner, R.C.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, A workflow to determine CO_2 storage potential in deep saline formations: Energy Procedia, v. 63, p. 5231–5238.

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Kurz, B.A., Stepan, D.J., Glazewski, K.A., Stevens, B.G., Doll, T.E., Kovacevich, J.T., and Wocken, C.A., 2016, A review of Bakken water management practices and potential outlook: Final report for Members of the Bakken Production Optimization Program, EERC Publication 2016-EERC-03-11, Grand Forks, North Dakota, Energy & Environmental Research Center, March.

Peck, W.D., Glazewski, K.A., Braunberger, J.R., Grove, M.M., Bailey, T.P., Bremer, J.M., Gorz, A.J., Sorensen, J.A., Gorecki, C.D., and Steadman, E.N., 2014, Broom Creek Formation outline: Plains CO_2 Reduction (PCOR) Partnership Phase III value-added report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592, EERC Publication 2014-EERC-09-09, Grand Forks, North Dakota, Energy & Environmental Research Center, August.

DR. CHANTSALMAA DALKHAA
Senior Reservoir Engineer, Reservoir Engineering Team
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5448 (phone), 701.777.5181 (fax), dalkhaa@undeerc.org

Principal Areas of Expertise

Dr. Dalkhaa's principal areas of interest and expertise include numerical modeling and simulation of various enhanced oil recovery (EOR) techniques, including solvent and thermal methods and cold heavy oil production with sand (CHOPS); CO_2 sequestration and monitoring; and production evaluation and estimation of ultimate recovery of unconventional shale oil plays.

Qualifications

Ph.D., Petroleum and Natural Gas Engineering, Middle East Technical University (METU), Ankara, Turkey, 2010.
M.S., Petroleum and Natural Gas Engineering, METU, Ankara, Turkey, 2005.
B.S., Petroleum and Natural Gas Engineering, METU, Ankara, Turkey, 2003.
Proficient in the use of Petrel (geologic modeling), Eclipse (fluid flow reservoir simulation), CMG IMEX/STARS/GEM/CMOST, TOUGH2/TOUGHREACT, ArcGIS/Arcmap, and IHS Harmony/DeclinePLUS/RTA/Petra.

Professional Experience

June 2019–Present: Senior Reservoir Engineer, Reservoir Engineering Team, EERC, UND. Dr. Dalkhaa supervises junior reservoir engineers and student research assistants and works with reservoir engineers, geologists, and geophysicists to develop and calibrate geologic models of the subsurface and run dynamic simulations to evaluate CO_2 EOR performance of oil fields and the long-term fate of CO_2 sequestration into saline aquifers, estimate ultimate oil recovery, evaluate production performance of unconventional oil and gas reservoirs, and assess refracturing potential in the Bakken petroleum system.

2015–May 2019: Reservoir Engineer, Reservoir Modeling and Simulation, EERC, UND. Dr. Dalkhaa worked with teams of reservoir engineers, geologists, and geophysicists to develop and calibrate geologic models of the subsurface and run dynamic simulations to evaluate CO_2 EOR performance of oil fields and the long-term fate of CO_2 sequestration into saline aquifers, estimate ultimate oil recovery, and evaluate production performance of unconventional oil reservoirs.

2014–2015: Postdoctoral Fellow, Department of Chemical and Petroleum Engineering, University of Calgary, Calgary, Alberta, Canada. Dr. Dalkhaa's activities included the following:

- Construction of a geologic model of heavy Canadian oil fields using Petrel.
- Simulation of a wormhole formation and growth in CHOPS reservoir and history matching of reservoir fluid and sand productions.
- Assessment of reservoir performance of thermal, solvent, and hybrid EOR methods using CMG STARS.

2011–2014: Postdoctoral Fellow, Department of Geoscience, University of Calgary, Calgary, Alberta, Canada. Dr. Dalkhaa's activities included the following:

- Stimulation of microbial activities in a CHOPS reservoir in the Lloydminster area, Canada, to enhance oil recovery for a project funded by Natural Sciences and Engineering Research Council of Canada and Husky Oil Operation Ltd.

- Reactive transport simulation of CO_2 injection into a reservoir and CO_2 leakage to shallower formations for the Quest Project, funded by Shell Canada.
- Application of stable isotopic techniques in monitoring of injected CO_2 for the Quest Project and Swan Hills and PennWest CO_2 pilot projects.
- Simulation of CO_2 injection into a H_2S-containing aquifer located in central Alberta for a project funded by Carbon Management Canada.
- Oilfield fluid sampling and analysis at various fields (Pembina Cardium CO_2 EOR pilot, Swan Hills CO_2 EOR fields in the Western Canadian Sedimentary Basin).
- Laboratory work on CO_2 reactivity and microbial EOR in CHOPS reservoirs.

2006–2011: Research and Teaching Assistant, Department of Petroleum & Natural Gas Engineering, METU, Ankara, Turkey. Dr. Dalkhaa's activities included the following:
- Reservoir simulation of immiscible CO_2 and water alternating gas injection into a heavy oil field in Europe in southeastern Turkey using Eclipse/Petrel (2007–2009).
- Mentorship and guidance of senior year students for graduation projects and coordination of courses (2007–2011).
- Evaluation of coalbed methane production capacity from the Soma coal bed in Turkey (2011).

August 2002: Intern, Perenco, Ankara, Turkey. Dr. Dalkhaa's activities included the following:
- Update of a production history database.
- Evaluation of reservoir performance of oil wells using decline analysis.

July 2001: Turkish Petroleum Company, Adiyaman, Turkey. Dr. Daklhaa's activities included the following:
- Field office work to experience field working conditions.
- Drillstem test analysis.

Relevant Publications

Kurz, B.A., Martin, C.L., Dalkhaa, C., Pekot, L.J., and Azzolina, N.A., 2017, Trends in Bakken water and oil production: Presented at the Williston Basin Petroleum Conference, Regina, Saskatchewan, May 2–4, 2017.

Mayer, B., Humez, P., Becker, V., Dalkhaa, C., Rock, L., Myrttinen, A., and Barth, J.A.C., 2015, Assessing the usefulness of the isotopic composition of CO_2 for leakage monitoring at CO_2 storage sites—a review: International Journal of Greenhouse Gas Control, v. 37, p. 46–60. doi:10.1016/j.ijggc.2015.02.021.

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Dalkhaa, C., and Okandan, E., 2013. Numerical modeling of CO_2–water–caprock interaction at a potential CO_2 storage site in Turkey: Geochemical Journal, v. 47, no. 5, p. 499–511.

Johnson, G., Dalkhaa, C., Shevalier, M., Nightingale, M., Mayer, B., and Haszeldine, S., 2014, Pre-, Syn- and Post-CO_2 Injection Geochemical and Isotopic Monitoring at the Pembina Cardium CO_2 Monitoring Pilot, Alberta, Canada: Poster presented at GHGT-12, Austin, Texas, USA, October 5–9, 2014.

Nightingale M., Mayer, B., Shevalier, M., Dalkhaa, C., and Becker, V., 2013, Carbon isotope fractionation of injected CO_2 in carbonate reservoirs—comparison of results from the laboratory and enhanced oil recovery field sites in Alberta, Canada: Poster presented at Goldschmidt, Florence, Italy, August 25–30, 2013.

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

Principal Areas of Expertise

Mr. Hamling has over 10 years of combined experience in unconventional oil and gas development, enhanced oil recovery (EOR), and carbon capture, utilization, and storage (CCUS). He is a Principal Engineer at the EERC, where he integrates science and operations to catalyze pioneering solutions for geologic CO_2 utilization and the exploration, development, and production of oil and gas in unconventional plays.

Mr. Hamling's areas of expertise include development, implementation, and oversight of surface, near-surface, deep subsurface, and reservoir characterization and surveillance programs for geologic CO_2 storage and EOR. His experience includes well-logging principals and applications; well drilling, well completions; wellbore integrity; risk assessment; logistics; well stimulation and enhanced recovery in tight oil plays; and health, safety, and environmental (HSE) programs.

Mr. Hamling has served as project manager (PM), principal investigator (PI), and task lead for several multiyear, multimillion-dollar research and demonstration projects. He leads the data analytics, operations, and reservoir surveillance groups at the EERC as well as several adaptive multidisciplinary project teams. These activities encompass both contract research as well as several strategic partnership programs between the state of North Dakota, the U.S. Department of Energy (DOE), and private industry designed to propel the development and implementation of approaches that benefit practical energy development. In addition, he is an Adjunct Lecturer in the Department of Petroleum Engineering at UND.

Qualifications

B.S., Mechanical Engineering, University of North Dakota, 2007.
Associate of Science, Associate of Arts, Williston State College, 2004.
Certified Engineer in Training (EIT)

Professional Experience

2018–Present: Assistant Director for Integrated Projects, EERC, UND. Mr. Hamling Designs, implements, and oversees surface, near-surface, deep subsurface, and reservoir characterization and surveillance programs for commercial geologic CO_2 storage and EOR, resulting in development, proof-of concept, and validation of improved monitoring techniques for dedicated and associated geologic CO_2 storage and EOR applications. Experience includes well-logging principals and applications, well drilling, well completions, wellbore integrity, risk assessment, logistics, well stimulation, produced water management and enhanced recovery in tight oil plays, and HSE programs. Mr. Hamling serves as PM/PI/task lead on multiyear, multimillion-dollar research and demonstration projects, including serving as PI for the North Dakota Brine Extraction and Storage Test (BEST) Project, demonstrating active reservoir management (ARM) through brine extraction and operating a brine treatment test bed facility. He leads a geophysics–data analytics–operations–reservoir surveillance team involved in contract research and strategic partnership programs with the state of North Dakota, DOE, and industry.

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

2012–2018: Principal Engineer, Oilfield Operations Group Lead, EERC, UND. Mr. Hamling served as PM, PI, and task lead for several multiyear, multimillion-dollar projects, where he led a multidisciplinary team of scientists and engineers working to develop and implement monitoring, verification, and accounting (MVA) concepts for large-scale (>1 million tons per year) CO_2 storage and EOR operations. He also worked with a multidisciplinary team in the development, design, and implementation of new approaches that benefit the economic exploration, development, and production of oil and gas.

2011–2012: Research Manager, EERC, UND. Mr. Hamling's responsibilities included managing characterization and monitoring research activities and operations for large-scale (>1 million tons per year) combined EOR and CO_2 storage projects for the Plains CO_2 Reduction (PCOR) Partnership. He also led various research activities related to oil and gas production, infrastructure, and development from unconventional reservoirs.

2009–2011: Research Engineer, EERC, UND. Mr. Hamling's focus was on the design and implementation of new approaches that benefit the exploration, development, and production of oil and gas and with the PCOR Partnership, where he evaluated the potential for CO_2 storage in geologic formations. Specific responsibilities included field operations design, deployment, and interpretation relating to oilfield technologies applicable to the CO_2 capture and storage (CCS) industry; laboratory functions relating to the Applied Geology Laboratory (AGL); data analysis; regulatory compliance; and communication of operations between service providers, management teams, industry partners, and governmental organizations. Additional responsibilities included 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 the environmental footprint of drilling and production operations.

2007–2009: Reservoir Evaluation Engineer; HSE Representative; and Loss Prevention Team Leader, Reservoir Evaluation segment, Schlumberger Limited. Mr. Hamling was responsible for providing tailored geophysical solutions for specific and unique oilfield applications, executing basic and advanced reservoir evaluations utilizing real-time wellbore measurement technologies, reservoir pressure and fluid sampling, and interpretation of reservoir measurement data. In this role, Mr. Hamling designed and oversaw all aspects of openhole and cased-hole logging operations for over 300 wells in both conventional and unconventional oil and gas plays. He also served as an HSE officer, loss prevention team lead, and explosives and radiation safety officer for wellsite activities.

2004–2007: Student Research Scientist/Engineer, EERC, UND. Mr. Hamling was responsible for conducting research related to the development of new methods to join high-temperature, creep-resistant alloys and advanced processing and manufacture techniques for silicon carbide ceramic composites; materials testing in accordance with ASME (American Society of Mechanical Engineers), ASTM International, and ISO (International Organization for Standardization) standards; analyzing scanning electron microscopy micrographs; designing and fabricating composite micrometeorite shielding; and literature and patent review.

Relevant Publications

Hamling, J.A., 2019, Developing and validating pressure management and plume control strategies in the Williston Basin through a brine extraction and storage test (BEST): Presented at the 2019 Annual Project Review Meeting for Crosscutting, Rare-Earth Elements, Gasification Systems, and Transformative Power Generation, Pittsburgh, Pennsylvania, April 10, 2019.

Jensen, M.D., Azzolina, N.A., Schlasner, S.M., Hamling, J.A., Ayash, S.C., and Gorecki, C.D., 2018, A screening-level life cycle greenhouse gas analysis of CO_2 enhanced oil recovery with CO_2 sources from the Shute Creek natural gas-processing facility: International Journal of Greenhouse Gas Control, v. 78, p. 236–243.

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enhanced oil recovery (CO_2-EOR) sites: International Journal of Greenhouse Gas Control, v. 51, p. 369–379.

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Hamling, J.A., Klapperich, R.J., and Vettleson, H.M., 2017, U.S. Department of Energy Brine Extraction and Storage Test (BEST) project update: Presented at the mid-year meeting of the Carbon Sequestration Leadership Forum, Abu Dhabi, United Arab Emirates, May 1, 2017.

Hamling, J.A., 2016, Brine extraction and storage test (BEST) Phase II: Presented at the Regional Carbon Sequestration Partnerships RCSP Water Working Group Annual Meeting, Pittsburgh, Pennsylvania, August 17, 2016.

Holubnyak, Y.I., Bremer, J.M., Mibeck, B.A.F., Hamling, J.A., Huffman, B.W., Klapperich, R.J., Smith, S.A., Sorensen, J.A., and Harju, J.A., 2011, Understanding the souring at Bakken oil reservoirs: Paper presented at the 2011 SPE International Symposium on Oilfield Chemistry, The Woodlands, Texas, April 11–13, 2011, No. SPE 141434-PP.

Glazewski, K.A., Aulich, T.R., Wildgust, N., Nakles, D.V., Azzolina, N.A., Hamling, J.A., Burnison, S.A., Livers-Douglas, A.J., Peck, W.D., Klapperich, R.J., Sorensen, J.A., Ayash, S.C., Gorecki, C.D., Steadman, E.N., Harju, J.A., Stepan, D.J., Kalenze, N.S., Musich, M.A., Leroux, K.M., and Pekot, L.J., 2018, Best practices manual – monitoring for CO_2 storage: Plains CO_2 Reduction (PCOR) Partnership Phase III Task 9 Deliverable D51 for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592, EERC Publication 2018-EERC-03-15, Grand Forks, North Dakota, Energy & Environmental Research Center, March.

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LOREAL V. HEEBINK
Senior Project Management Specialist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5116 (phone), 701.777.5181 (fax), lheebink@undeerc.org

Principal Areas of Expertise

Ms. Heebink's principal areas of interest and expertise include assisting in the planning, development, and management of projects related to core assessment, carbon storage and/or CO_2-based enhanced oil recovery (EOR), and beneficial use of wastes and data management and interpretation. She is responsible for progress reporting under the U.S. Department of Energy's Plains CO_2 Reduction (PCOR) Partnership, the Bakken Production Optimization Program (BPOP), and other projects. She develops management and tracking systems for projects and groups at the EERC.

Qualifications

B.S., Chemistry, Magna Cum Laude, University of North Dakota, 2000.
A.S., Chemistry, Summa Cum Laude, Minot State University–Bottineau, Bottineau, North Dakota, 1997.
Certification: Smartsheet Solution Certified User

Professional Experience

2015–Present: Senior Project Management Specialist, EERC, UND. Ms. Heebink is responsible for assisting in the planning, development, and management of projects related to core assessment, carbon storage and/or CO_2-based EOR, and beneficial use of oilfield wastes. She is responsible for progress reporting under DOE's PCOR Partnership, BPOP, and other projects. Her duties continue to include tracking project activities and deliverables, assisting in the workflow management of the Applied Geology Laboratory, technical report writing, data management and interpretation, data sheet generation, and database development and maintenance.

2012–2015: Research Chemist, EERC, UND. Ms. Heebink's responsibilities were focused on assisting in the workflow management of the Applied Geology Laboratory, technical report writing, data management and interpretation, and data sheet generation. Additional activities included database development and maintenance, beneficial use evaluations, Karl Fischer titrations, helium porosimetry, 3-D scanning for bulk volume, Dean–Stark and Soxhlet extraction techniques, and investigation of carbon dioxide mineralization materials.

2000–2012: Research Chemist, Coal Combustion Product Research, EERC, UND. Ms. Heebink's responsibilities included research focused primarily on the environmental impacts of CCP use and disposal, ultratrace mercury analysis, data interpretation and management, and sample inventory management. She managed the research efforts of the Coal Ash Resources Research Consortium® (CARRC®) from 2010–2012 and other CCP research at the EERC. She also managed several research projects concurrently and was responsible for the technical oversight and fund management of these projects. Areas of interest and expertise included ash chemistry, leaching procedures, ultratrace mercury analysis with a double-gold amalgamation atomic fluorescence apparatus, and database development and maintenance.

1997–1999: Stockroom Assistant, Department of Chemistry, UND. Ms. Heebink's responsibilities included preparing solutions weekly for classroom laboratories, assisting students and instructors with chemicals, and organization of the stockroom.

Selected Publications

Azenkeng, A.; Mibeck, B.A.F.; Eylands, K.E.; Butler, S.K.; Kurz, B.A.; Heebink, L.V. Advanced Characterization of Unconventional Oil and Gas Reservoirs to Enhance CO_2 Storage Resource Estimates – Organic Structure and Porosity of Organic-Rich Shales. Presented at Mastering the Subsurface Through Technology Innovation, Partnerships & Collaboration: Carbon Storage & Oil & Natural Gas Technologies Review Meeting, Pittsburgh, PA, Aug 1–3, 2017.

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.; Harju, J.A., Advancing CO_2 Enhanced Oil Recovery and Storage in Unconventional Oil Play—Experimental Studies on Bakken Shales. *Applied Energy* **2017,** *208*, 171–183.

Jin, L.; Hawthorne, S.B.; Sorensen, J.A.; Pekot, L.J.; Kurz, B.A.; Smith, S.A.; Heebink, L.V.; Bosshart, N.W.; Torres, J.A.; Dalkhaa, C.; Gorecki, C.D.; Steadman, E.N.; Harju, J.A. Extraction of Oil from the Bakken Shales with Supercritical CO_2. Paper presented at the 2017 Unconventional Resources Technology Conference, Austin, TX, July 24–26, 2017; URTeC Paper No. 2671596.

Wildgust, N.; Gorecki, C.D.; Ayash, S.C.; Peck, W.D.; Hamling, J.A.; Sorensen, J.A.; Daly, D.J.; Jensen, M.D.; Klapperich, R.J.; Heebink, L.V.; Pekot, L.J.; Steadman, E.N.; Harju, J.A. Demonstration of Secure CO_2 Geological Storage Associated with Enhanced Oil Recovery in the PCOR Partnership Region. Presented at the Carbon Management Technology Conference 2017, Houston, TX, July 17–20, 2017.

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Sorensen, J.A.; Smith, S.A.; Kurz, B.A.; Hawthorne, S.B.; Jin, L.; Bosshart, N.W.; Torres Rivero, J.A.; Nyberg, C.M.; Heebink, L.V.; Butler, S.K. *Improved Characterization and Modeling of Tight Oil Formations for CO_2 Enhanced Oil Recovery Potential and Storage Capacity Estimation*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0024454; EERC Publication 2018-EERC-03-04; and North Dakota Industrial Commission; EERC Publication 2017-EERC-12-01; Energy & Environmental Research Center: Grand Forks, ND, Dec 2017.

BETHANY A. KURZ
Assistant Director for Integrated Analytical Solutions
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5050, Fax: (701) 777-5181, E-Mail: bkurz@undeerc.org

Principal Areas of Expertise

Ms. Kurz's principal areas of interest and expertise include geologic and geochemical characterization of subsurface media for carbon storage and/or CO_2-based enhanced oil recovery, produced water and drilling waste management, assessment of high-value materials in coal and produced brine, and resource management related to energy development.

Qualifications

M.S., Hydrogeology, University of North Dakota, Grand Forks, ND, 1998.
B.S., Geochemistry, Bridgewater State University, Bridgewater, MA, 1995.

Professional Experience

2018–Present: Assistant Director for Integrated Analytical Solutions, EERC, UND. Ms. Kurz is responsible for assisting the EERC's management team with developing business opportunities and successfully executing research projects related to oil and gas; natural resource management; and carbon capture, utilization, and storage. She oversees a multidisciplinary team of scientists and engineers who work in the EERC's applied research laboratories. In that role, she is responsible for ensuring the quality assurance/quality control of data and results generated by the EERC's laboratories and integrating those results into the applied research efforts conducted by the Subsurface R&D team.

2011–July 2018: Principal Hydrogeologist, Lab Analysis Group Lead, EERC, UND. Ms. Kurz oversaw a multidisciplinary team of scientists and engineers and several of the EERC's analytical research laboratories that focus on classical and advanced wet-chemistry analyses; petrochemical, geochemical and geomechanical evaluation of rocks and soils; and advanced characterization of various materials, including metals, alloys, catalysts, and corrosion and scale products. Her primary areas of interest included the evaluation of water supply sources for the oil and gas industry, produced water management, characterization of geologic media for carbon storage and development and testing of proppants for use in hydraulic fracturing.

2002–2011: Senior Research Manager, Water Management and Flood Mitigation Strategies, EERC, UND. Ms. Kurz's responsibilities included project management, technical report and proposal writing, public outreach, and the development of new research focus areas. Research activities included the evaluation of nontraditional water supply sources for municipal and industrial use, flood and drought mitigation, watershed-scale water quality assessments using hydrologic models, and public education and outreach on various water and energy issues.

1998–2002: Research Scientist, Subsurface Remediation Research, EERC, UND. Ms. Kurz's responsibilities included managing and conducting research involving remediation technologies for contaminated groundwater and soils, groundwater sampling and analysis, technical report writing, and proposal research and preparation.

Relevant Publications

Butler, S.K., Azenkeng, A., Mibeck, B.A.F., Kurz, B.A., and Eylands, K.E., 2019, Unconventional rock requires unconventional analysis—methods for characterization: Paper presented at the

Unconventional Resources Technology Conference, Denver, Colorado, July 22–24, 2019, URTeC Paper No. 971.

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MARC D. KURZ
Senior Geologist, Process Chemistry and Development 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
701.777.5278 (phone), 701.777.5181 (fax), mkurz@undeerc.org

Principal Areas of Expertise

Mr. Kurz's principal areas of interest and expertise include design, operation, and maintenance of laboratory- and pilot-scale reactor systems for biofuel development, biofuel chemistry and analysis, design and implementation of subsurface and groundwater remediation technologies, and geophysical characterization testing.

Qualifications

B.S., Environmental Geology and Technology, University of North Dakota (UND), 1993.
Postgraduate coursework in soil sciences, groundwater remediation, global change issues, satellite image processing, and geographic information systems (GIS), 2001–2007.
40-hour OSHA Training for Hazardous Waste Site Personnel, 1997 (refresher course, 2002).

Professional Experience

2010–Present: Senior Geologist, Process Chemistry and Development Team Lead, EERC, UND. Mr. Kurz coordinates and conducts the analysis of various laboratory- and pilot-scale reactor product and by-product effluents to provide data for the calculation of material balances, conversions, and product qualities in support of EERC projects. Mr. Kurz provides a variety of general and specialized analytical testing, including wet-chemical testing, thermogravimetric analysis (TGA)/differential calorimetry scanning (DSC), gas chromatography/mass spectrometry, flash point and cold-flow properties of fuels, and refinery gas analysis (RGA).

2007–2010: Research Scientist, Renewable Energy and Biofuel Technology, EERC, UND. Mr. Kurz served as a research scientist on projects related to alternative energy technologies. His primary responsibilities included conducting laboratory- and pilot-scale research experiments related to biofuel technology and operating various laboratory analytical instruments.

2000–2007: Research Scientist, Subsurface Treatment and Remediation Research, EERC, UND. Mr. Kurz served as a manager and co-principal investigator on a variety of research projects related to groundwater remediation and oil and gas industry-related issues. His responsibilities included supervision of graduate research assistants and fieldwork personnel, proposal writing, budget management, and presentation of project research at a variety of technical conferences.

1996–2000: Geologist/Research Scientist, Groundwater Remediation Program, EERC, UND. Mr. Kurz's responsibilities included researching and report writing on various remediation technologies for contaminated groundwater and soils, conducting extensive fieldwork activities, and performing analytical laboratory testing. In addition, he was involved in research related to the exploration, production, and environmental aspects of coalbed methane exploitation.
1994–1996: Research Assistant, Water and Wastewater Treatment, EERC, UND. Mr. Kurz's primary responsibilities included various field- and laboratory-based research on a variety of water and wastewater remediation projects.

Relevant Publications

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.D.; Dalkhaa, C.; Peck, W.D.; Burnison, S.A. *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 Publication 2018-EERC-03-13; Energy & Environmental Research Center: Grand Forks, ND, March 2018.

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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.; Steadman, E.N. *Field Implementation Plan for a Williston Basin Brine Extraction and Storage Test*; Phase I Topical Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0026160; Energy & Environmental Research Center: Grand Forks, ND, April 2016.

Ye, D.; Kurz, B.A.; Kurz, M.D. *Subtask 1.22 – Microbial Cycling of CH_4, CO_2, and N_2O in a Wetlands Environment*; Final Report (March 1, 2006 – Dec 31, 2008) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40320; EERC Publication 2009-EERC-02-08; Energy & Environmental Research Center: Grand Forks, ND, Feb 2009.

Wang, X.; Kurz, B.A.; Kurz, M.D. *Subtask 1.18 – A Decision Tool for Watershed-Based Effluent Trading*; Final Report (April 1, 2004 – Nov 30, 2006) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40320; EERC Publication 2007-EERC-02-05; Energy & Environmental Research Center: Grand Forks, ND, Feb 2007.

DR. CHRISTOPHER L. MARTIN
Senior Research Engineer, Advanced Thermal Systems
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5083 (phone), 701.777.5181 (fax), cmartin@undeerc.org

Principal Areas of Expertise

Dr. Martin's principal areas of expertise include thermal energy conversion, utilization, and system analysis; mitigation of environmental effects from power generation including the prevention of air emissions from combustion and gasification systems, and the minimization of water use during energy conversion processes.

Qualifications

Ph.D., Mechanical Engineering, University of Florida, Gainesville, FL, 2004.
M.S., Mechanical Engineering, University of Florida, Gainesville, FL, 2000.
B.S., Mechanical Engineering, University of North Carolina, Charlotte, North Carolina, 1998.
Engineer In Training, North Carolina State Board of Registration, June 1998.

Technical Skills/Computer Skills

Thermodynamic modeling with Aspen Plus, C++, and Matlab programming
AutoCAD
Parametric modeling and FEA experience with IDEAS
Knowledge of instrumentation requirements for various engineering measurements (e.g., force acceleration, strain, flow, etc.) and data acquisition software
Hands-on experience with a variety of manual and CNC machine tools
Trained welder with practice in all common processes

Professional Employment

2005–Present: Senior Research Engineer, Advanced Thermal Systems, EERC, UND. Dr. Martin's responsibilities include assisting with current projects in environmentally compatible power generation, contributing to research proposals, and developing new project areas for the EERC. Notable project areas include the following:

- **Water-saving cooling technology for power plants.** The focus of these projects was a technology conceived by Dr. Martin to improve the efficiency and cost-effectiveness of dry cooling for power plants. This development effort has earned phases of state, federal and commercial support.

- **Gasification technology for nontraditional fuels.** Dr. Martin devised and evaluated gasification-based systems to recover energy from industrial and commercial solid waste streams. These efforts also include a system for high-efficiency waste processing at remote military forward operating bases.
- **Air emissions control at coal-fired utilities.** Dr. Martin managed a portfolio of emission control research projects by serving as a program area manager for the EERC's Center for Air Toxic Metals® program. He also evaluated novel emissions control technologies using laboratory, pilot plant, and field demonstrations.

2002–2005: Research Assistant, Solar Energy and Energy Conversion Laboratory, University of Florida. Dr. Martin researched the conversion of low-temperature thermal energy resources using advanced thermodynamic cycles.

2001–2002: Teaching Assistant, Control Systems Laboratory, University of Florida. Dr. Martin taught lecture and laboratory components for an undergraduate control systems laboratory.

2000–2001: Design Engineer, Manufacturing Laboratories, Inc., Gainesville, Florida. Dr. Martin aided the design, manufacture, and assembly of a precision machine tool.

1998–2000: Research Assistant, Machine Tool Research Center, University of Florida. Dr. Martin conducted applied research in the areas of machine tool dynamics and cutting tool testing.

Relevant Publications

Gorecki, C.D., Sorensen, J.A., Kurz, B.A., Wocken, C.A., Harju, J.A., Dalkhaa, C., Hawthorne, S.B., Heebink, L.V., Kurz, M.C., Azzolina, N.A., Chakhmakhchev, A., Martin, C.L., Romuld, L., and Stevens, B.G., 2019, Bakken Production Optimization Program 2.0: Annual progress report (October 1, 2018 – September 30, 2010) for North Dakota Industrial Commission Contract No. G-040-080, Grand Forks, North Dakota, Energy & Environmental Research Center, October.

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Martin, C.L; Dunham, D.J.; Sprengelmeyer, D.J. *Application of Amorphous Metals for Plastic Pipeline Detection*; Final Report for U.S. Department of Transportation Office of Pipeline Safety; EERC Publication 2017-EERC-09-05; Energy & Environmental Research Center: Grand Forks, ND, Sept 2017.

Martin, C.L.; Zhuang, Y. Water-Saving Liquid-Gas Conditioning System. U.S. Patent 8,628,603, January 14, 2014.

Martin, C.L.; Folkedahl, B.C.; Dunham, D.J.; Kay, J.P. Application of Liquid Desiccant Dehumidification to Amine-Based Carbon Capture Systems. *Int. J. Greenhouse Gas Control* **2016,** *54*, 557–565.

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APPENDIX C

LETTERS OF COMMITMENT

October 31, 2019

Mr. John Hamling
Assistant Director for Integrated Projects
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Hamling:

Subject: Support for EERC Proposal No. 2020-0066 in Response to North Dakota Industrial Commission (NDIC) Oil and Gas Research Program Recycling Produced Water Study Request for Proposals

Hess is pleased to support the Energy & Environmental Research Center (EERC) proposed project entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse."

Produced water management (including flowback water) represents a significant economic and technical challenge for oil and gas production and will continue to be a challenge as production in the Bakken continues to increase. The proposed EERC effort aligns with our interest in developing practical treatment and reuse options for produced waters that slow/reduce pressurization of saltwater disposal (SWD) injection zones, thereby extending the lifespan of SWD facilities. The proposed concept is scalable and can contribute to a meaningful reduction in the demand for freshwater resources within the region and protect the oil and gas industry from any future supply constraints due to water appropriations.

Pending positive results and demonstration of a viable business case, Hess would be interested in the possibility of leveraging the existing relationship with the EERC in progressing the proposed concept toward commercial implementation. We look forward to this exciting opportunity and to continue the efforts of reducing the environmental impacts associated with oil and gas production in the North Dakota.

Sincerely,

Brent Lohnes
Hess Corporation
General Manager – North Dakota

OASIS PETROLEUM

October 31, 2019

Mr. John Hamling
Assistant Director for Integrated Projects
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Hamling:

Subject: Support for EERC Proposal No. 2020-0066 in Response to North Dakota Industrial Commission (NDIC) Oil and Gas Research Program Recycling Produced Water Study Request for Proposals

Oasis Petroleum is pleased to support the Energy & Environmental Research Center (EERC) proposed project entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse."

Produced water management (including flowback water) represents a significant economic and technical challenge for oil and gas production and will continue to be a challenge as production in the Bakken continues to increase. The vast amount of produced water injected into the Inyan Kara Formation has resulted in localized areas of high pressure, significantly affecting the economics and risk associated with drilling of new Bakken wells in North Dakota. The proposed EERC effort aligns with our interest in developing practical treatment and reuse options for produced waters that slow/reduce pressurization of saltwater disposal (SWD) injection zones, thereby extending the lifespan of SWD facilities. The proposed concept is scalable and can contribute to a meaningful reduction in the demand for freshwater resources within the region and protect the oil and gas industry from any future supply constraints due to water appropriations.

Pending positive results and demonstration of a viable business case, Oasis Petroleum would be interested in the possibility of leveraging the existing relationship with the EERC in progressing the proposed concept toward commercial implementation. We look forward to this exciting opportunity and to continue the efforts of reducing the environmental impacts associated with oil and gas production in the North Dakota.

Sincerely,

P.P.

Jay Knaebel
Vice President, Williston Business Unit

1001 Fannin, Suite 1500 • Houston, Texas 77002 • Phone (281) 404-9500 - Fax: (281) 404-9501

Nuverra
Environmental Solutions™

October 28, 2019

Mr. John Hamling
Assistant Director for Integrated Projects
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Hamling:

Subject: Support for EERC Proposal No. 2020-0066 in Response to North Dakota Industrial Commission Oil and Gas Research Program Request for Proposals Entitled "Recycling Produced Water Study"

Nuverra Environmental Solutions (Nuverra) is pleased to support the Energy & Environmental Research Center (EERC) in Stage I of a proposed project entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse."

Practices that can extend the lifespan of saltwater disposal (SWD) facilities and produce viable waste-to-value streams can provide tremendous benefit to the oil and gas industry and other industrial and domestic end users of water. The proposed effort aligns with our interest in developing practical treatment and reuse options for produced waters that eliminate the need for temporary surface storage of large volumes of high-total dissolved solids (TDS) fluids. Other benefits include a reduction of net disposal volumes (i.e., SWD minus extraction for treatment) slowing pressurization of injection zones, thereby extending the lifespan of SWD facilities while providing a virtually limitless supply of consistent-quality feedstock of produced water for treatment and beneficial use. The proposed concept—geologic homogenization, conditioning, and reuse (GHCR)—is scalable and can contribute to a meaningful reduction in the demand for precious freshwater resources between end users of water within the region and bulletproofing the oil and gas industry from any future supply constraints due to water appropriations. Concepts like the one proposed are needed as we prepare for produced water disposal to grow from 115 million barrels annually in 2009 to a projected volume of 1.1 billion barrels annually by 2035 as 40,000 additional wells are drilled and completed in North Dakota during the coming decades.

Should the project be awarded, Nuverra is committed to leveraging the existing partnership with the EERC at the Nuverra-operated brine extraction and storage test (BEST) site as a field laboratory. Nuverra agrees to support the proposed effort by providing the EERC with access to the Johnsons Corner BEST site and attendant facilities as a field laboratory and providing injected and extracted produced water samples to validate the proposed concept. Nuverra will also support the EERC in operating the existing brine treatment test bed on Bakken produced water, a test system that employs commercially available pretreatment technology as a benchmark for the techno-economic assessment of the proposed concept. Pending a successful Stage I effort and a positive techno-economic assessment, Nuverra will work with the EERC, the North Dakota Industrial Commission Oil and Gas Research Program, and commercial partners to advance a Stage II field pilot demonstration of a beneficial end use for GHCR waters.

We look forward to this exciting opportunity to continue working closely with the EERC.

Sincerely,

Robert Fox
President and Chief Operating Officer
Nuverra Environmental Solutions

Williston District

4607 2nd Avenue West
Williston, ND 58801

T: 701.577.1001
F: 701.577.1005

EERC
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

November 4, 2019

Ms. Karlene Fine
Executive Director and Secretary
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: Cost Share for EERC Proposal No 2020-0066, Entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse"

The Energy & Environmental Research Center (EERC) is conducting complementary research and development efforts under a multimillion-dollar 10-year Cooperative Agreement with the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL), entitled "Joint Program on Research and Development for Fossil Energy-Related Resources." Through this joint program, nonfederal entities can team with the EERC and DOE on projects that address the goals and objectives of DOE's Office of Fossil Energy.

The proposed project to the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program is a viable candidate for funding under the EERC–DOE NETL Program. Therefore, the EERC intends to secure $1,000,000 of cash cost share for the proposed project through its Cooperative Agreement with DOE, providing that NDIC commits $300,000 of cash cost share.

Once the EERC has commitment from NDIC, the EERC will submit a proposal to DOE for its concurrence. Proposals submitted to DOE under this program receive expeditious consideration, and the success rate is traditionally very high. However, there is no guarantee of approval.

As a cosponsor of the project, DOE would require access to all data generated and a royalty-free right to practice. However, certain project details can often be held confidential for some period of time.

Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement between the EERC and each of the project sponsors.

If you have any questions, please contact me by phone at (701) 777-5157 or by e-mail at jharju@undeerc.org.

Sincerely,

John A. Harju
Vice President for Strategic Partnerships

JAH/kal

APPENDIX D

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: If equipment (value of $5000 or more) is budgeted, it is discussed in the text of the proposal and/or identified more specifically in the accompanying budget detail.

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.

Subcontracts: Not applicable.

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.

Laboratory and analytical recharge fees are charged on a per-sample, hourly, or daily rate. Additionally, laboratory analyses may be performed outside the university when necessary. The estimated cost is based on the test protocol required for the scope of work.

Graphics recharge fees are based on an hourly rate for production of such items as report figures, posters, and/or images for presentations, maps, schematics, Web site design, brochures, and photographs. The estimated cost is based on prior experience with similar projects.

Shop and operations recharge fees cover specific expenses related to the pilot plant and the required expertise of individuals who perform related activities. Fees may be incurred in the pilot plant, at remote locations, or in EERC laboratories whenever these particular skills are required. The rate includes such items as specialized safety training, personal safety items, fall protection harnesses and respirators, CPR certification, annual physicals, protective clothing/eyewear, research by-product disposal, equipment repairs, equipment safety inspections, and labor to direct these activities. The estimated cost is based on the number of hours budgeted for this group of individuals.

Engineering services recharge fees cover specific expenses related to retaining qualified and certified design and engineering personnel. The rate includes training to enhance skill sets and maintain certifications using Webinars and workshops. The rate also includes specialized safety training and related physicals. The estimated cost is based on the number of hours budgeted for this group of individuals.

Software solutions services recharge fees are for development of customized Web sites and interfaces, software applications development, data and financial management systems for comprehensive reporting and predictive analysis tools, and custom integration with existing systems. The estimated cost is based on prior experience with similar projects.

Freight expenditures generally occur for outgoing items and field sample shipments.

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 estimated cost for the proposed project is $1,299,993. The EERC requests $300,000 from the North Dakota Industrial Commission Oil and Gas Research Program. Matching cash funds of $999,993 will be provided by the U.S. Department of Energy.