BAKKEN PRODUCTION OPTIMIZATION PROGRAM 4.0

Status Report

(For the period January 1, 2024 – June 30, 2024)

Prepared for:
North Dakota Industrial Commission

Partners of the Bakken Production Optimization Program (BPOP) Consortium:
Chord Energy
ConocoPhillips
Corken/IDEX
Devon Energy Corporation
Enerplus
ExxonMobil
Hess Corporation
Liberty Resources LLC
Marathon Oil Company
Petro-Hunt, L.L.C.
Rock Flow Dynamics
U.S. Department of Energy
XTO Energy, Inc.

Overall Project Period of Performance: July 28, 2023 – October 31, 2025
Contract No. G-058-115

Prepared by:

James A. Sorensen
Bethany A. Kurz
Darren D. Schmidt
Alyssa C. Regorrah
Chantsalmaa Dalkhaa
Alexander V. Chakhmakhchev
Nicholas A. Azzolina
Marc D. Kurz
Mathew L. Belobraydic
Lucia Romuld

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

June 2024

EERC DISCLAIMER

LEGAL NOTICE: This research report was prepared by the Energy & Environmental Research Center of the University of North Dakota (UND EERC) as an account of work sponsored by North Dakota Industrial Commission (SPONSOR). To the best of UND EERC's knowledge and belief, this report is true, complete, and accurate; however, because of the research nature of the work performed, neither UND EERC, nor any of their directors, officers, or employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the use of any information, apparatus, product, method, process, or similar item disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by UND EERC. SPONSOR understands and accepts that this research report and any associated deliverables are intended for a specific project. Any reuse, extensions, or modifications of the report or any associated deliverables by SPONSOR or others will be at such party's sole risk and without liability or legal exposure to UND EERC or to their directors, officers, and employees.

NDIC DISLAIMER

"LEGAL NOTICE: This research report was prepared by UND EERC as an account of work partially sponsored by NDIC through the Clean Sustainable Energy Fund. To the best of UND EERC's knowledge and belief, this report is true, complete, and accurate; however, because of the research nature of the work performed, neither UND EERC, NDIC, nor any of their directors, officers, or employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the use of any information, apparatus, product, method, process, or similar item disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by UND EERC or NDIC. NDIC understands and accepts that this research report and any associated deliverables are intended for a specific project. Any reuse, extensions, or modifications of the report or any associated deliverables by NDIC or others will be at such party's sole risk and without liability or legal exposure to UND EERC or to their directors, officers, and employees."

TABLE OF CONTENTS

LIST OF TABLES

BAKKEN PRODUCTION OPTIMIZATION PROGRAM 4.0

EXECUTIVE SUMMARY

The Bakken Production Optimization Program (BPOP) was established to facilitate Bakken petroleum system oil recovery while simultaneously reducing the environmental footprint of oil and gas development. This program is administered by the Energy & Environmental Research Center (EERC) with funding from the North Dakota Industrial Commission Oil and Gas Research Program, the North Dakota petroleum industry, and the U.S. Department of Energy (DOE). Through BPOP, the EERC is working closely with its partners to address emerging opportunities and challenges related to Bakken development. This progress report provides an overview of BPOP activities from January 1, 2024, through June 30, 2024.

Two presentations were given for BPOP partners during this reporting period. On February 28, 2024, a webinar entitled "H_2S Study Update – Do We Have an Answer?" was hosted to share results from the H_2S study. This study revealed that sulfur isotope analysis indicated the H_2S in Bakken production wells likely originated from the Madison Formation above the Bakken reservoir. On May 22, 2024, a webinar entitled "Understanding the Risk of Souring in the Bakken Using Advanced Analytics" was held for BPOP partners. This presentation highlighted recent EERC research that used sulfur isotope analysis and machine learning to identify potential H_2S sources outside the Middle Bakken and Three Forks reservoirs, highlighting long-distance fracture propagation in stimulated wells. Additionally, several abstracts were submitted to the Society of Petroleum Engineers Annual Technical Conference and Exhibition and the Unconventional Resources Technology Conference.

The EERC received notice of selection for an award from DOE for two proposals entitled "Bakken CO_2 EOR and Storage Field Laboratory" and "Polar Bear™ – Effective Gas Capture to Eliminate Flaring." Both projects align with BPOP's areas of interest and will leverage cost share from the program. Negotiations with DOE are ongoing, and it is anticipated that the contract with DOE will be finalized by early fall 2024. Work is anticipated to begin for the Bakken CO_2 EOR and Storage Field Laboratory in December 2024.

The simulation model developed for the enhanced oil recovery (EOR) work at the East Nesson site has been updated. Calibration for the models was adjusted via a re-history-matching process by integrating available pilot data to improve model prediction accuracy. This updated model can now evaluate longer-term pilot performance, including incremental oil production and EOR pilot efficiency.

During this reporting period, the EERC completed integration of the Polar Bear™ prototype within the EERC facilities. The unit has been leak-tested and commissioned, and the programmable logic control has been updated. Modeling was used to design and adapt applications to the field.

The completion and production data analytics team conducted a follow-on study of the 2023 parent–child well interactions to assess how Bakken drilling spacing unit (DSU) development and well completion practices affect parent and child well oil production. The team also developed a forecast model to predict incremental oil production associated with carbon dioxide (CO_2) EOR in North Dakota's unconventional and conventional reservoirs.

The fluids characterization team identified additional fluid chemistry parameters to be analyzed in multiple intervals of geologic core obtained for the purposes of fluid fingerprinting efforts and arranged access to a stimulated and an unstimulated well in the Bakken Formation for future sampling efforts.

The EERC completed probabilistic petrophysical analysis to predict properties (e.g., total and effective porosity, total and effective water saturation, total volume of clay) and lithology for 21 total wells. A collaboration with the University of North Dakota's geology department was initiated to study progradation patterns in a mixed carbonate in the Bakken. To date, seven cores have been logged in centimeter detail and digitized.

The H_2S research team sent samples of produced water to an external laboratory for the sensitive DNA test, which showed the absence of sulfate-reducing bacteria in investigated brine samples. The results of the interpretations were summarized in two presentations delivered to BPOP members, as mentioned above.

The EERC also conducted a review of artificial lift operations in the Bakken. Artificial lift is a means of lifting reservoir fluids to the surface in oil and gas production operations after reservoir pressure declines and can no longer naturally flow fluids to surface. The EERC is working with BPOP partners and Neotek to evaluate a technology that couples an advanced wellhead fluid analyzer for optimizing gas lift operations.

BAKKEN PRODUCTION OPTIMIZATION PROGRAM 4.0

DESCRIPTION OF PROJECT

The Bakken Production Optimization Program (BPOP) was established in June 2013 to facilitate Bakken petroleum system (BPS) oil recovery while simultaneously reducing the environmental footprint of oil and gas development. This program is administered by the Energy & Environmental Research Center (EERC), with funding from the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP) and the North Dakota petroleum industry. Through BPOP, the EERC is working closely with a consortium of industry partners and the state of North Dakota to address emerging opportunities and challenges related to Bakken development. The goals of BPOP are to:

- Develop knowledge that will enhance overall Bakken production efficiency, recognizing that improved coordination among various design factors (reservoir management, well design, surface processing, waste management) can lead to significant improvements in resource recovery efficiency while reducing potential health, safety, and environmental impacts.

- Conduct applied research in topic areas that positively impact production efficiency and reduce operations' environmental footprint, including a reduction in carbon intensity.

- Provide the state and industry with science-based insight to maintain the economic and environmental sustainability of the Bakken play in North Dakota.

- Provide stakeholders with the knowledge needed to plan and implement innovative development strategies that will take the Bakken into the next decade and beyond.

BPOP is a public–private partnership harnessing North Dakota research scientists and industry to maximize the Bakken oil play's productivity while reducing its environmental footprint. This program has demonstrated that the U.S. Department of Energy (DOE), state lawmakers, state regulators, and industry can work together for positive results for taxpayers and shareholders alike.

The BPOP program is currently in its fourth cycle (BPOP 4.0) and spans 27 months, from August 1, 2023, to October 31, 2025.

Key topics to be addressed during BPOP 4.0 include:

- Making progress toward moving Bakken enhanced oil recovery (EOR) from pilot testing to commercial-scale deployment.

- Economically assessing, monitoring, and mitigating fugitive methane emissions.

- Developing and deploying a new flare reduction technology.

- Pursuing research activities identified as being of high priority based on partner feedback.

ACCOMPLISHMENTS DURING REPORTING PERIOD

Project Management and Development

This task focuses on ensuring the overall success of the entire program by providing experienced management and leadership to each of the individual tasks and to the program as a whole. The EERC program manager (PM) along with task leaders hold regular meetings to update on task progress, address issues, and implement any necessary corrective actions.

Task leaders are also responsible for providing the PM with biweekly updates. These updates encompass key accomplishments, trip reports, travel plans, budgetary concerns, staffing issues, technical challenges, and potential opportunities. Throughout this time, the project team continued to engage partners to guide program activities to meet their needs. The project management team has held several meetings internally to discuss and draft updates to the external BPOP website.

Additionally, the EERC submitted a proposal entitled "Bakken CO_2 EOR and Storage Field Laboratory" under DOE Funding Opportunity Announcement (FOA) DE-FOA-0003015. The objective of this project is to investigate the concept that carbon dioxide (CO_2) injected into an unconventional reservoir in the Bakken Formation will result in incremental oil recovery while simultaneously storing CO_2, resulting in lower-carbon-intensity oil production. The project's goals align with BPOP's scope, and BPOP will provide cost-share support throughout the 48-month duration. The proposal has been selected for funding, and the EERC has begun negotiations with DOE.

The EERC also submitted a proposal entitled "Polar Bear™ – Effective Gas Capture to Eliminate Flaring" under FOA DE-FOA-0003017. The project will demonstrate Polar Bear™ at wellsite(s) within the Williston Basin of North Dakota in cooperation with an industry partner. The demonstration includes the capture of tank vapors, heater-treater gas, production of liquids, on-lease gas use, and pressure management. This scope complements the methane emission and flare reduction work already being conducted through BPOP. This proposal was selected for award, and the EERC has begun contract negotiations with DOE.

Webinars

BPOP partners were invited by the EERC to the following webinars during this reporting period:

- On February 28, 2024, a BPOP webinar entitled "H_2S Study Update – Do We Have an Answer?" was held for BPOP partners. The presentation shared results from the H_2S study, revealing that sulfur isotope analysis indicated the H_2S in Bakken production wells likely originated from the Madison Formation above the Bakken reservoir. This migration

occurred through artificial channels created by out-of-zone well stimulation, rather than through bacterial or thermochemical sulfate reduction processes.

- On May 22, 2024, a webinar entitled "Understanding the Risk of Souring in the Bakken Using Advanced Analytics" was held for BPOP partners. This presentation highlighted recent EERC research that used sulfur isotope analysis and machine learning to identify potential H_2S sources outside the Middle Bakken and Three Forks reservoirs, highlighting long-distance fracture propagation in stimulated wells. A random forest model pinpointed the top predictors of higher H_2S concentrations, including completed lateral length, Middle Bakken pressure gradient, Bakken temperature, lodgepole depth, early water production, and maximum injection rate, with heat maps quantifying souring risk across the Bakken.

These presentations can be found on the BPOP partners-only website at: https://bpop.undeerc.org/.

Products and Presentations

The following products were created or presented during the reporting period:

- A presentation and publication entitled "Investigating H_2S Occurrence in Bakken Oil-Producing Wells Using Sulfur Isotopes in Gas, Water, and Rock Samples" was featured in OnePetro and at the Unconventional Resources Technology Conference (URTeC) in June 2024, held in Houston, Texas. OnePetro is an online library offering technical literature for the oil and gas industry. It features contributions from 23 publishing partners and provides access to over 1.3 million searchable documents.

- An abstract was produced and submitted detailing the second EOR pilot injection and performance for the Society of Petroleum Engineers (SPE) Annual Technical Conference and Exhibition (ATCE). The abstract was accepted, and the team is in the process of developing a manuscript for the conference, which is scheduled for September 23–25, 2024, in New Orleans, Louisiana.

- The URTeC Technical Program Committee accepted the submission of the abstract entitled "Field Implementation and Surveillance of Gas Injection Enhanced Oil Recovery in the Bakken." This paper was prepared for presentation at URTeC in Houston, Texas, June 17–19, 2024.

Deliverable Tracking

BPOP 4.0 Contract Deliverables

Product Name	Reporting Period	Due Date	Completion Date
Status Report 1	Jul 2023 – Dec 2023	Dec 31, 2023	Dec 31, 2023
Status Report 2	Jan 2024 – Jun 2024	Jun 30, 2024	Jun 28, 2024
Status Report 3	Jul 2024 – Dec 2024	Dec 31, 2024	–
Status Report 4	Jan 2025 – Jun 2025	Jun 30, 2025	–
Final Report and Project Summary	Jul 2023 – Oct 2025	Oct 31, 2025	–

Reports on Any Deviations from the Original Scope of Work, the Rationale for Such Deviations, and Any Lessons Learned

There was no deviation from the original scope during this reporting period.

Enhanced Oil Recovery

The goal of the EOR task is to develop knowledge that will support broad commercial implementation of EOR in the Bakken play. Field-based EOR research within BPOP began in partnership with Liberty Resources, LLC (Liberty Resources) during BPOP 2.0 at Liberty Resources' Stomping Horse location.

As part of BPOP 3.0, Liberty Resources conducted an EOR pilot at its East Nesson location that included coinjecting rich gas and a freshwater–surfactant blend. The East Nesson pilot was successful at building reservoir pressure, containing the injected gas in the reservoir, and increasing oil production from the pilot site.

The goal for BPOP 4.0 EOR activities is to support Liberty Resources in conducting a second injection cycle at the East Nesson site. The second cycle is focused on a more traditional water alternating gas (WAG) using rich gas and produced water (without surfactant added) to optimize the economics of operations. Specific BPOP activities to support the Liberty Resources pilot include modeling and simulation to evaluate the reservoir response and performance of the second injection cycle. The data generated throughout the project will be processed and interpreted by the EERC in close coordination with Liberty Resources to assess the pilot performance.

Accomplished This Reporting Period

The second WAG pilot injection at the East Nesson location took place from September 22, 2023, through November 30, 2023. Several months of injection into the Haley 10MBH at the East Nesson pilot site was followed by a production cycle without any soaking period and has been ongoing since December 3, 2023. Key technical activities accomplished during this reporting period included:

- Monitoring, processing, and analysis of post-pilot production data from the wells on the pilot pad continued.

- The simulation model has been updated. Calibration was adjusted via a re-history-matching process. This was done by integrating the available pilot data to improve model prediction accuracy. This model can be used to evaluate longer-term pilot performance such as incremental oil production and efficiency of the EOR pilot.

- Weekly and biweekly project meetings were held to provide project partners with updates regarding pilot performance and progress in modeling and simulation efforts.

- An abstract was produced and submitted detailing the second EOR pilot injection and performance for the SPE ATCE) scheduled for September 23–25, 2024, in New Orleans, Louisiana. The abstract was accepted, and the team is currently in the process of planning and developing a manuscript for the conference.

- The planned cost analysis of the pilot has begun.

- A paper entitled "Field Implementation and Surveillance of Gas Injection Enhanced Oil Recovery in the Bakken" was submitted to URTeC and presented on June 18, 2024, at the conference held in Houston, Texas.

The EERC, in close collaboration with Chord Energy Corporation (Chord Energy), prepared and submitted a proposal to DOE to establish the Bakken CO_2 EOR and Storage Field Laboratory in McKenzie County, North Dakota. The proposed project will include laboratory-, modeling-, and field-based activities, including a cumulative 18 months of CO_2 injection into a Bakken reservoir. These efforts will generate data regarding the viability and effectiveness of injecting CO_2 into the Bakken for EOR while accounting for associated geological storage of CO_2. Funding for this 4-year project includes $11.6 million from DOE, $900,000 for Chord Energy, and $2 million for BPOP. The proposal was submitted on January 26, 2024. On April 19, 2024, DOE notified the EERC that the proposal had been selected for award. Negotiations between the EERC and DOE were initiated.

Methane Emission Mitigation and Flare Reduction

Cost-effectively mitigating methane emissions and reducing flaring have long been priorities of the state and industry and are important elements of reducing the carbon intensity of Bakken oil. Data from NDIC indicate that approximately 66% of current flaring is sourced from medium to small facilities where traditional gas capture techniques are uneconomical. The EERC's response to flare reduction is Polar Bear™ technology, innovative low-cost compression that can be useful for gas capture at locations where capture is otherwise not technically or economically viable. Polar Bear™ was initially acquired through a license agreement with Equinor, a major energy company headquartered in Norway that was a member of BPOP when it had assets in the Bakken play. The EERC and BPOP partnerships have advanced technology, resulting in new intellectual property and steps toward commercialization.

Currently, the EERC is under a joint development agreement with Steffes Corporation, a leading oilfield facility manufacturer in North Dakota. Steffes aided in prototype design and testing. A laboratory has been developed at the EERC to test compressors. Multiple nondisclosure agreements have been signed with BPOP partners to test prototypes in the field. Equation-of-state (EOS) modeling has been completed for the process. The U.S. Patent and Trade Office have issued six patents. Through BPOP 4.0, and with funding from DOE and BPOP partner support, this effort will test a prototype in a relevant environment to advance technology readiness for field implementation. The objectives of the effort are to 1) develop and validate a novel technology to capture vapors from storage tanks to achieve zero or near-zero methane emissions; 2) complete engineering-scale testing of a prototype design functioning with anticipated gas components and at dynamic conditions to validate process controls, design parameters, and safety; and 3) advance the technology for field implementation.

Accomplished This Reporting Period

A prototype system was delivered to the EERC during the previous quarter. During this reporting period, the EERC completed the integration of the prototype within the EERC facilities. The unit has been leak-tested and commissioned, and upgrades have been completed to the programmable logic control (PLC) system. Modeling was used to design and adapt applications to the field.

The project's scope also includes societal considerations and impacts (SCI) work. During this reporting period, the EERC attended the Tools Trades Torque Tech (T4) Summit, an educational event held across North Dakota for students in grades 6–12. The EERC team prepared materials to create an interactive learning experience and presentation for the summit. The T4 Summit, attended by Watford City, North Dakota, students on April 24 and 25, introduced students to workforce skills, training, and networking opportunities with industry leaders and technicians.

The DOE contract associated with the scope of work for this project requires a continuation application to receive Budget Period 2 funding from DOE. The application has been submitted and reviewed, and approval is pending for the remaining contract funds.

The EERC also submitted a proposal to DOE for an additional $2,000,000 of federal funding to support field demonstrations of Polar Bear™ at Bakken wellsites with at least one industry partner. The proposed demonstration includes the capture of tank vapors, heater-treater gas, production of liquids, on-lease gas use, and pressure management. This scope complements the methane emission and flare reduction work already being conducted through BPOP. This proposal was selected for award, and the EERC has begun contract negotiations with DOE. Negotiations are expected to be finalized in late fall 2024. This project will be cost shared by BPOP over its 2-year duration.

Completion and Production Data Analytics

Since 2016, the EERC has evaluated BPS oil production and well completion data using statistical and machine learning (ML) methods. These investigations aim to apply data analysis methods to a broad (basinwide) dataset to explore historical trends and draw inferences about the

effects of well completion practices on oil production. The data analytics team is continuing these pursuits under BPOP 4.0.

Accomplished This Reporting Period

The project team finished updating the data file of well completion, production, and drilling spacing unit (DSU) data, which will serve as the basis for analysis conducted under BPOP 4.0 data analytics work.

Using the updated data file, a follow-on study of the 2023 parent–child well interactions study (Min, 2023) was conducted to assess how Bakken DSU development and well completion practices affect parent and child well oil production. ML-based predictive models were developed to quantify the change in 5-year production and estimated ultimate recoveries (EURs) for parent and child wells based on factors such as well vintage (completion date), parent well depletion, well spacing, proppant amounts, and fluid volumes. Predictive models were developed for different DSU development scenarios. The project team is currently focusing on summarizing and visualizing the results.

A forecast model was developed to predict incremental oil production associated with CO_2 EOR in North Dakota's unconventional and conventional reservoirs. This was accomplished by using the updated data file and a grid-based, stratified sampling approach to unitize DSUs. The forecast targeted potential development scenarios over 20 years and predicted incremental oil production and CO_2 supply demand. The unconventional reservoirs included in the study were the Bakken and Three Forks Formations of the BPS. The conventional reservoirs included in the study were 21 fields representing approximately 28% of conventional oil in place identified by Peck and others (2019): Cedar Creek Anticline (four fields), Nesson Anticline area (12 fields), and Billings Nose area (five fields). The modeling and sensitivity analyses were completed. A draft report is under EERC internal review.

Fluids Characterization

The optimization of oil production in North Dakota requires an accurate understanding of the fluids being produced. Oil, associated gas, and produced water are complex mixtures, and their chemical and physical properties can vary geographically and over the life of a well. Bakken fluids data collected by BPOP over 9 years have been used to identify and follow evolving trends in key basinwide performance indicators such as gas–oil ratio, oil–water ratio, and produced fluid compositions. Detailed fluids data generated under this task will be used in the completion and production data analytics task.

Accomplished This Reporting Period

The fluids characterization team identified additional fluid chemistry parameters to be analyzed in multiple intervals of geologic core obtained for the purposes of fluid fingerprinting efforts. In addition, sample analytical procedures have been initiated. During this reporting period, the EERC accomplished two key technical activities:

- The team arranged access to a stimulated and an unstimulated well in the Bakken Formation for future sampling efforts. These previously sampled wells will be sampled again in late summer or early fall 2024. The information obtained from fluid production and chemistry will help in understanding water production volumes and identify possible contributing zones of influence.

- The team supported the H_2S study to investigate the potential movement mechanisms of hydrogen sulfide. Specifically, a future sampling plan was developed and discussed with a member partner to gain access to various wells.

Geological and Petrophysical Evaluations

To support the optimization of well completions and EOR, the quality of reservoir and source rock within the BPS will be assessed through use of sequence stratigraphy techniques and advanced petrophysical analyses. Leveraging previously gathered core analyses and logs, wells will be evaluated for lithology, water saturation, kerogen volumes, permeability, and reservoir quality. The EERC will apply learnings from high-tier datasets to wells with a more common data suite to build a reliable database for reservoir characterization through ML algorithms. The EERC will also work with at least one graduate student in the University of North Dakota (UND) Harold Hamm School of Geology and Geological Engineering to develop a Bakken depositional framework which, in turn, may guide future Bakken development strategies.

Accomplished This Reporting Period

During the reporting period, the team continued to perform probabilistic petrophysical analysis for wells that have passed the quality control process. The petrophysical zone of interest is defined as the lower 100 ft of the Lodgepole, Bakken, Three Forks, and upper 40 ft of the Birdbear Formations. Geophysical well log data for 39 total wells have gone through quality review and been added to the database. Probabilistic petrophysical analysis to predict properties (e.g., total and effective porosity, total and effective water saturation, total volume of clay) and lithology (e.g., limestone, dolostone, quartz, kerogen) was completed for 21 total wells.

A study entitled "Bakken Geology Study – Progradation Patterns in a Mixed Carbonate–Siliciclastic System, and Related Diagenetic Signatures – Middle Bakken Member, North Dakota, USA," in collaboration with UND, began in January 2024. A total of 42 cores have been selected for analysis from different parts of the Williston Basin that have a complete Middle Bakken succession. These transects extend either north-south or east-west across the basin, allowing for a comprehensive exploration of the basin's various regions and their sedimentological evolution. To date, seven cores have been logged in centimeter detail and digitized. The data from these cores have been used to conduct an assessment of the sequence stratigraphy of the Bakken Formation and create an initial depositional model.

Understanding and Mitigating H_2S in Bakken Production Streams

H_2S is an undesired by-product of oil and gas production in both conventional and unconventional plays. Recent H_2S characterization activities under BPOP, including the analysis

of H_2S isotope signatures, laboratory experiments simulating H_2S generation, and sulfate-reducing bacteria tests, suggested that souring in the BPS is likely linked to well stimulation. In BPOP 4.0, the EERC will finalize the analysis of sulfur isotopes and focus on solutions and technologies to manage and/or mitigate H_2S generation, including the evaluation of completion practices to reduce the risk of souring.

Accomplished This Reporting Period

During the reporting period, the research team focused on four main activities: 1) testing the produced water sample for the presence of sulfate-reducing bacteria using a bacterial activity reaction test (BART) and a more sensitive DNA test; 2) finalizing interpretation and forming conclusions about the source of H_2S in Bakken production based on available evidence—the team documented these interpretation results in a research paper and a PowerPoint presentation and these discoveries were presented to BPOP members; 3) applying advanced analytics and ML to investigate the impact of geology, completion design, and production volumes to the H_2S concentrations in Bakken wells; and 4) investigating fracture propagation in stimulated wells using computer modeling.

- Within the first activity, the research team sent samples of produced water to an external laboratory for the sensitive DNA test, which showed the absence of sulfate-reducing bacteria in investigated brine samples.

- Under the second activity, the results of the interpretations were summarized in two presentations delivered to BPOP members in February and May in 2024. The abstract, entitled "Investigating H_2S Occurrence in Bakken Oil-Producing Wells Using Sulfur Isotopes in Gas, Water, and Rock Samples," and a paper were accepted. A presentation under the same title was featured in OnePetro and at URTeC in June 2024, held in Houston, Texas.

- The third activity used a predictive model to understand the importance of various parameters for predicting H_2S concentration. The results of statistical modeling supported earlier conclusions based on laboratory work and sulfur isotope data.

- Under the fourth activity, optimized and nonoptimized completion designs were simulated, and vertical and horizontal fracture propagation was evaluated. Analyzing the 11 pilot wells and other producing wells within a 15-mile radius suggested that optimization might reduce the risk of souring.

Two webinars were presented under this task (see more details in the project management section of this report):

- February 28, 2024: H_2S Study Update – Do We Have An Answer?

- May 22, 2024: Understanding the Risk of Souring in the Bakken Play Using Advanced Analytics.

Production Technology Optimization Assessment

This activity focuses on advancing concepts and technology to improve the efficiency of production facilities. Irregular flow behavior inherent in horizontal wellbores because of the undulating borehole trajectory has been modeled and studied within BPOP. Based on fundamental knowledge, the EERC will evaluate advanced concepts that can improve flow behavior and increase the efficiency of artificial lift. The EERC intends to work with BPOP partners and Neotek to evaluate a technology, developed by Neotek, that couples an advanced wellhead fluid analyzer (WFA) with artificial intelligence (AI) to guide real-time optimization of a gas lift system, with the goal of ultimately demonstrating the use of the technology in the field.

Accomplished This Reporting Period

The EERC conducted a review of artificial lift operations in the Bakken. Artificial lift is a means of lifting reservoir fluids to the surface in oil and gas production operations after reservoir pressure declines and can no longer naturally flow fluids to surface. The objective was to consider Neotek's WFA for optimizing gas lift operations. Gas lift is an artificial lift operation that poses some unique advantages when compared to rod lift. Given a total active well count of 15,061, 6.3% or 956 wells were identified as gas lift. Operators typically only use gas lift as a percentage of total production operations. For operators that utilize gas lift, the percentage can be 20% of production operations. Therefore, optimization can be meaningful for increased production. Neotek has demonstrated through previous testing and publication that understanding real-time wellhead flow behavior for oil, water, and gas can help dial in optimized production that is significant (on the order of 100% improvement). The EERC presented the technology to BPOP members at the end of 2023, and Neotek provided a presentation on March 12, 2024, at the North Dakota Petroleum Council's technology solutions group meeting. Presently, the EERC is seeking partners to test the technology in the field.

PARTNERSHIP AND FINANCIAL INFORMATION

The BPOP 4.0 budget proposed to NDIC OGRP is $8,000,000, shown in Table 1 along with attendant expenses as of the end of May 2024.

Table 1. BPOP 4.0 – Budget and Current Expenses

Sponsors	Budget	Actual Expenses as of 5/31/2024	Balance
NDIC Share – Cash	$4,000,000	$1,470,109	$2,529,891
Industry Share – Cash	$636,361	$515,988	$120,373
Liberty Resources – In-Kind	$363,639	$323,258	$40,381
DOE – Cash	$1,000,000	$578,178	$421,822
Devon – In Kind	$2,000,000	$0	$2,000,000
Total	**$8,000,000**	**$2,887,533**	**$5,112,467**

It is anticipated that this table will be revised significantly in the coming months to reflect the new contributions expected from DOE and Chord Energy for the Bakken CO_2 EOR and Storage Field Laboratory project as well as the anticipated new contributions from DOE for field demonstrations of the Polar Bear™ flare mitigation technology project. $500,000 of BPOP 4.0 NDIC funds will be used as cost share to match DOE contributions to the Bakken CO_2 EOR and Storage Field Laboratory project, and another $500,000 will be used as cost share to match DOE contributions to the Polar Bear™ field demonstration project.

ANTICIPATED ACTIVITIES FOR NEXT REPORTING PERIOD (JULY 2024 TO DECEMBER 2024)

Project Management

Activities for the next reporting period will include continued engagement with BPOP partners to advance concepts to guide project activities. The BPOP management team anticipates finalizing negotiations with DOE during this reporting period for both the Bakken CO_2 EOR and Storage Field Laboratory and Polar Bear™ – Effective Gas Capture to Eliminate Flaring projects. Work will be initiated for these projects within the next reporting period. In addition, the annual meeting hosted by the EERC will be scheduled in late fall 2024. It is anticipated that an update to the public-facing BPOP website will be launched during the next reporting period.

Enhanced Oil Recovery

The Bakken EOR pilot project in partnership with Liberty Resources will officially end on September 30, 2024. The project team will conclude all the remaining activities such as the ongoing modeling and simulation activities, pilot data processing and analysis, and developing the manuscript. The project results, lessons learned from conducting the two pilots at the East Nesson site, and recommendations for future EORs in the Bakken will be presented at SPE ATCE and in a BPOP webinar which will be scheduled for summer 2024.

The EERC will be partnering with Chord Energy to establish the Bakken CO_2 EOR and Storage Field Laboratory in McKenzie County, North Dakota. The objective of the project is to investigate the concept that CO_2 injected into an unconventional reservoir in the Bakken Formation will result in incremental oil recovery while simultaneously storing CO_2, resulting in lower-carbon-intensity oil production. This objective will be met by conducting laboratory-, modeling-, and field-based activities, including a cumulative 18 months of CO_2 injection into a Bakken reservoir. These efforts will generate a wealth of data regarding the viability and effectiveness of injecting CO_2 into hydraulically fractured horizontal wells in an unconventional reservoir for EOR while accounting for associated geological storage of CO_2. The project will have a 4-year period of performance and will include the collection of samples of rocks and fluids taken from the Bakken Formation to be analyzed to support laboratory experiments designed to better understand the mechanisms controlling CO_2 EOR and storage. Geologic modeling and numerical simulations will be conducted to support design, permitting, and execution of field tests. The effects of CO_2 injection on the reservoir will be closely monitored, including the collection of data to support future life cycle analysis (LCA) for future CO_2 EOR and storage in the Bakken Formation. This

project will also include efforts to work with the Mandan, Hidatsa, and Arikara (MHA) Nation, which now earns 90% of its revenue from royalties on oil and gas development, to examine the potential for CO_2 EOR on the Fort Berthold Indian Reservation (FBIR). Successful completion of the project will provide stakeholders with new critical data and scientifically validated insights regarding the potential to broadly deploy CO_2 EOR and storage to unconventional oil reservoirs. It is anticipated that the contract with DOE will be finalized by late summer 2024, with an anticipated project start date of September 1, 2024.

Methane Emission Mitigation

The Polar Bear™ prototype system will undergo testing and data collection to inform EOS over the next reporting period. In addition, field conditions will be simulated at the EERC to understand dynamic process control and mass balance.

The EERC will finalize negotiations with DOE to bring an additional $2,000,000 of federal funding to support a field demonstration of the Polar Bear™ technology at a wellsite(s) in cooperation with an industry partner. The demonstration includes the capture of tank vapors, heater-treater gas, production of liquids, on-lease gas use, and pressure management. The technology overcomes the higher costs of conventional vapor recovery systems so that low-pressure gas can be economically captured from wells that are past the initial production phase. Innovations include capturing tank vapors to use as fuel on-site, recovering the liquid value from the gas to recombine with oil, and providing new compressors to the industry that significantly reduce maintenance cost. Laboratory tests demonstrate that a prototype can be automated in a relevant environment ready for field demonstration. The technical objectives of this project are to demonstrate economic application, gas capture efficiency, and mechanical performance to accelerate commercial adoption. The intent is to operate test units over a period of 9 months to demonstrate gas capture efficiency, maintenance intervals, and cost-effective operation. It is anticipated that the contract with DOE will be finalized by early fall 2024, with an anticipated project start date of December 1, 2024.

Completion and Production Data Analytics

The follow-on study of the 2023 parent–child well interactions study will be completed, and the results will be summarized in a PowerPoint presentation and/or short report. In addition, the draft report summarizing the methods and results of the forecast model to predict incremental oil production and CO_2 supply demand associated with CO_2 EOR in North Dakota's unconventional and conventional reservoirs will be finalized.

Fluids Characterization

Fluid sample collection and analysis will continue through the next several months and results will be reported as received. The added parameters for chemical determination will be compared to fluid samples collected from nearby producing wells and potentially help identify contributing zones of fluid production. In addition, the existing database of information will continue to be updated and interpreted as appropriate. The fluids characterization team will

continue communicating with BPOP partners to determine areas of interest and solicit access to additional sample collection locations.

Geological and Petrophysical Evaluation

The petrophysical team will prepare the high-tier probabilistic well model for application to conventional log suites by adjusting the mineral model and equations to predict accurate porosity, saturations, and permeability. The goal will be to quality-control and apply the model to as many wells with conventional log suites as possible to create a training set for possible cluster analysis or ML applications.

The work in collaboration with UND, entitled "Bakken Geology Study – Progradation Patterns in a Mixed Carbonate–Siliciclastic System, and Related Diagenetic Signatures – Middle Bakken Member, North Dakota, USA," plans to continue core work on the remaining 35 cores and digitize them. A Bakken depositional model will be developed based on core to gain a more complete picture of sediment architecture, with the goal to establish depositional timelines in the Middle Bakken at high resolution. In addition, the UND team will begin drafting a report for publication. The report is intended to highlight 1) the depositional model of the Middle Bakken and 2) the difference of parasequences in the regressive versus the transgressive part.

Understanding and Mitigating H_2S in Bakken Production Streams

The H_2S research team will work to improve the completion simulation models using various modeling tools and possibly detailed reservoir and completion information provided by the operator.

Production Technology Optimization Assessment

The EERC will collaborate with partners to test wellhead fluid analyzer technology for optimizing gas lift.

REFERENCES

Min, K., Chakhmakhchev, A., Yu, X., Azzolina, N.A., Schmidt D.D., Kurz, B.A., and Sorensen, J.A, 2023, A data-driven, machine learning analysis of parent–child well interactions in the Bakken: Value-added report for North Dakota Industrial Commission Oil and Gas Research Program and Members of the Bakken Production Optimization Program (BPOP), Contract No. G-051-98, Grand Forks, North Dakota, Energy & Environmental Research Center.

Peck, W.D., Azzolina, N.A., Barajas-Olalde, C., Burton-Kelly, M.E., Kalenze, N.S., Feole, I.K., Glazewski, K.A., Ayash, S.C., Hurley, J.P., Jensen, M.D., Gorecki, C.D., Harju, J.A., Bangsund, D.A., and Cook, B., 2019, Techno-economic assessment of implementing lignite-based CO_2 EOR in North Dakota: Final report (October 1, 2017 – March 31, 2019) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No.

DE-FE0024233; EERC Publication 2019-EERC-04-14, Grand Forks, North Dakota, Energy & Environmental Research Center, April.