

**PROGRAM TO DETERMINE THE UNIQUENESS OF THREE FORKS BENCH
RESERVES, DETERMINE OPTIMAL WELL DENSITY IN THE BAKKEN POOL, AND
OPTIMIZE BAKKEN PRODUCTION (BAKKEN PRODUCTION OPTIMIZATION
PROGRAM)**

**QUARTERLY PROGRESS REPORT
January – March 2016**

BACKGROUND

The goal of the Bakken Production Optimization Program (BPOP) being conducted by the Energy & Environmental Research Center (EERC) in close coordination with Continental Resources, Inc. (Continental) and several of the Williston Basin's other premier operating companies is to simultaneously improve Bakken system oil recovery while reducing its environmental footprint. The program is investigating new technologies and approaches to simultaneously increase the understanding of potential petroleum reserves in the Bakken–Three Forks system and decrease recovery costs in an environmentally sound manner.

The anticipated outcomes of BPOP are to increase the well productivity and economic output of North Dakota's oil and gas resources, decrease environmental impacts of wellsite operations, and reduce demand for infrastructure construction and maintenance. Specific results will include a) a greater understanding of Bakken–Three Forks reservoirs and subsequent significant increases to estimates of recoverable hydrocarbons; b) less truck traffic, resulting in decreased diesel emissions, road dust, and spills; c) reduced road maintenance costs, wastewater production, disposal costs, and freshwater use; d) reduced land use impacts; and e) increased revenue for the state, royalty owners, and operators from added product streams captured earlier in the well life cycle.

The following quarterly report summarizes the program activities from January through March 2016.

ACCOMPLISHMENTS DURING REPORTING PERIOD

Continental leads Phases I–IV. The EERC leads activities in Phase V.

Phases I–IV (Continental)

- No activity occurred during this reporting period.

Phase V – Optimization of Wellsite Operations (EERC)

Hydrocarbon Utilization (EERC Task 1)

- North Dakota Petroleum Council (NDPC) Flaring Task Force/database development.

- The EERC continued to work with technology/service providers capable of utilizing associated gas upstream of traditional gas-gathering and processing infrastructure, and gathered information describing their remote capture offerings. To date, nearly 70 companies have provided company and technical information to the database. Approximately 20% of them have had systems deployed in North Dakota.
- The Flaring Solutions Web site has been changed to simplify navigation. It is now possible to access flaring-related documents, review company information within the database, or add technologies to the database from one location: www.undeerc.org/Flaring_Solutions.
- The EERC continued to review technical data provided by vendors and is supporting ongoing vendor efforts to develop offerings that address the challenges leading to gas flaring.
- The EERC continued to work with producers and vendors to identify opportunities for demonstration projects that have the potential to improve gas utilization and reduce the risk of implementing new technologies and strategies. Work continues to assess the relative impact that individual technologies can have on gas use, thereby decreasing the fraction of flared gas in North Dakota.
- Flaring statistics data were reviewed and analyzed to assess the quantity of flaring locations and amount of gas being flared. A PowerPoint presentation with updated flaring statistics was prepared and posted on the Flaring Solutions Web site. The PowerPoint slides contain statistics through December 2015 and show:
 - 84% of all associated gas produced in North Dakota is captured or put to other beneficial use.
 - Approximately 5500 producing locations have some amount of flaring.
 - 51% of all flared gas comes from 141 locations, flaring 300 mcf/d or greater.

Crude Oil Characterization

- In an effort separate from this program but closely related to it, the EERC is supporting a U.S. Department of Energy (DOE)-funded study focused on characterizing tight oil properties relative to safe storage and transport. Phase II of this work has begun and included preparing a sampling plan to evaluate sampling methods and analytical procedures and their impact on characterization of volatile crude oils. It is anticipated that a limited sample collection and analysis effort will occur in the spring of 2016. The EERC is seeking industry partners willing to allow crude oil sampling to occur at their facilities.

Minimization of Fugitive Associated Gas Emissions

- No activity occurred during the reporting period.

Investigation of Rich Gas for Enhanced Oil Recovery (EOR)

- Several experiments were conducted to determine the potential for utilizing ethane as an injectant for EOR in the Bakken. Tests included measuring multiple-contact minimum miscibility pressure (MMP) under Bakken reservoir conditions, evaluating Bakken crude oil that mobilized into the upper “miscible phase during MMP tests, and exposing rock samples to ethane to determine the rate of crude oil recovery from untreated Bakken rocks. Results from these tests are in review and will be provided next quarter.
- A preliminary EOR model was developed to compare CO₂ to ethane for EOR. Results indicate ethane could provide superior recovery response compared to pure CO₂ injection. Data generated by this model may provide a basis for further investigation of ethane as an EOR fluid. Results from this modeling exercise will be reviewed and provided in the next quarterly report.

Waste Management (EERC Task 2)

NORM (naturally occurring radioactive material) Waste Disposal

- A member of the EERC staff attended the NORM North America Conference in Houston, Texas. At this conference, Dale Patrick of the North Dakota Department of Health provided an update on the new TENORM (technology enhanced NORM) disposal rules in North Dakota. EERC staff also exchanged useful information with TENORM waste handlers working in the state of North Dakota and elsewhere. Staying current on this issue is one means of supporting the BPOP membership and state of North Dakota interests.

Wellsite Waste Assessment

- No activity occurred during this reporting period.

Water Management (EERC Task 3)

Bakken Water Opportunities Assessment

- A final version of the report, “A Review of Bakken Water Management Practices and Potential Outlook,” was posted to the members-only Web site for distribution to BPOP partners.

Inyan Kara Modeling

- Regional model bounds were drafted for agreement with the recent investigation by Bader (2015).
- A literature review and data collection were conducted for the Inyan Kara Formation of western North Dakota, including well locations, well logs, and tops for 5017 wells.

- Construction began on a geologic model using Schlumberger's Petrel.
 - Well logs were imported from the North Dakota Industrial Commission (NDIC) database into the Petrel project. Of the original 5017 wells, 299 wells had gamma ray (GR) logs through the Inyan Kara Formation.
 - Well logs for an additional 47 wells are being digitized for incorporation into future modeling efforts.
 - The 299 GR curves were normalized using Schlumberger's Techlog software.
 - An initial coarse model grid was constructed with X and Y increments of 1000 m.
 - GR logs were upscaled within the model grid. Lithology and facies modeling activities are ongoing.

Site Logistics (EERC Task 4)

- No activity occurred during this reporting period.

Process Optimization and System Failure Analysis (EERC Task 5)

- No activity occurred during this reporting period.

Waste Minimization and Utilization (EERC Task 6)

- No activity occurred during this reporting period.

Spill Remediation (EERC Task 7)

Spill Remediation Science

- EERC staff have continued their involvement with the NDPC Saltwater Spills Task Force, led by BPOP members Oasis Petroleum Company (Oasis), Continental, Hess Corporation (Hess), XTO Energy Company, and Whiting Petroleum Corporation (Whiting), to provide technical documents establishing best practices for mitigating brine and hydrocarbon spills. In collaboration with these BPOP members, the EERC continued discussions on the direction and format of the North Dakota Remediation Resource Manual. This document is now completed. Plans for release are being finalized by the Saltwater Spills Task Force, largely directed by BPOP members.
- The EERC, along with BPOP members, participated in a meeting with the entire Saltwater Spills Task Force to review and discuss the North Dakota Department of Health spill remediation guidance document and the role that each document should play. Also attending this meeting were representatives from the North Dakota Department of Agriculture, relevant landowner groups, academia, and consultants.

Pipeline and Facility Leak Detection

- No activity occurred during this reporting period. This activity was engaged within a separate project, mandated by the North Dakota Legislature in April 2015, and funded through NDIC.

Land Reclamation (EERC Task 8)

Optimization of Land Reclamation Practices

- No activity occurred during this reporting period, although this topic area is covered in the North Dakota Remediation Resource Manual.

Program Management and Development

- A meeting of the program members was hosted by the EERC at Hess headquarters in Houston, Texas, on March 31, 2016. This was a follow-up meeting to the meeting held at the EERC in December 2015. Both meetings focused entirely on the issue of potential changes to North Dakota's drill spacing unit (DSU) setback rules and modeling that various member companies have performed to justify these potential changes. The purpose of the March meeting was to compare results of additional modeling performed during the months of December–March by Continental, Marathon Oil Company (Marathon), and Hess. The EERC served as moderator of the discussion and referee of the modeling to ensure that results were as objective as possible and to add insight to differences in results that are driving varying opinions on rule changes among program members. BPOP membership is attempting to determine whether concurrence can be reached on a possible recommendation to the North Dakota Department of Mineral Resources. One possibility being explored is to extend BPOP as a vehicle to assist collaboration on this topic between industry and state entities.

Attending the March meeting were representatives from ConocoPhillips, Continental, Hess, Hitachi, Marathon, Oasis, and XTO Energy.

MEMBERSHIP AND FINANCIAL INFORMATION

BPOP is sponsored by the NDIC Oil and Gas Research Council, Continental, and a consortium of Bakken producers and service companies. Table 1 presents the current budget for this program. Continental's expected in-kind contribution over the project duration is \$106,030,000.¹ The anticipated contribution from other industry sponsors is \$750,000 a year for a total of \$2,250,000. Payments totaling \$1,500,000 have been received from all members for Years 1 and 2. It is expected that equal payments will be provided by the industry partners in Year 3. Year 3 invoices were provided to members in October 2015. Year 3 payments are still pending from Whiting, Oasis, Hess, and Hitachi. The EERC will continue to seek broader industry participation.

¹ No additional cost-share reporting is expected from Continental for this project. The final cost-share total is approximately \$6.9 million less than what was projected at the start of the project. This differential is largely attributed to actual expenditures coming in slightly lower than original estimates. The differential amounts to 6.4% variance, which may be considered within expectations for a project of this magnitude.

Table 1. BPOP – Expected Budget

| Sponsors | Y1 | Y2 | Y3 | Total |
|--|---------------------|---------------------|---------------------|----------------------|
| NDIC Share – Cash* | \$3,134,512 | \$3,204,944 | \$2,215,044 | \$8,554,500 |
| Industry Share – Cash (confirmed participation) | \$750,000 | \$750,000 | \$750,000 | \$2,250,000 |
| Continental Share – In-Kind | \$40,989,233 | \$40,989,233 | \$24,051,534 | \$106,030,000 |
| Total | \$44,873,745 | \$44,944,177 | \$27,016,578 | \$116,834,500 |

* Includes \$6.26M subcontract to Continental.

Expenses to date by funding source are listed in Table 2.

During this quarter, Continental indicated that a net credit of \$17,812 was received as a result of correcting entries/equipment credits related to the production facility. Subsequently, Continental's in-kind cost share reported is reduced from \$99,170,743 to \$99,152,931.

Table 2. BPOP – Expenses to Date

| | Funding Source | | Total |
|----------------------------|-----------------------|----------------------|----------------------|
| | NDIC | Industry | |
| EERC | \$1,629,281 | \$1,160,862 | \$2,790,143 |
| Continental – Subcontract* | \$5,905,000 | | \$5,905,000 |
| Continental – In-Kind** | | \$99,152,931 | \$99,152,931 |
| Total | \$7,534,281 | \$100,313,793 | \$107,848,074 |

* Invoiced to the EERC.

** Reported to the EERC.

FUTURE ACTIVITIES

The planned activities for the next quarter are detailed below.

Phases I–IV (Continental)

- No further work is planned. Phases I–IV are now complete.

Phase V (EERC)

Hydrocarbon Utilization (Task 1)

Flaring Reduction

- The EERC will continue working with vendors to identify opportunities to deploy technology and/or services that match the needs of producers in their efforts to improve gas capture and utilization.

- The EERC will continue working with industry partners and vendors to identify opportunities to conduct demonstration projects that allow stakeholders the ability to evaluate technologies capable of improving gas use.
- The EERC will continue to monitor industry's progress toward meeting the gas capture targets in North Dakota and continue to assess the technical and economic viability of remote capture use.

Crude Oil Characterization

- Phase II work will continue based on the tasks outlined in the sampling, analysis, and experiment plan developed previously under Phase I. Pending identification of an appropriate sampling location, crude oil samples will be collected to assess sampling and analytical methods relative to their ability to adequately characterize the crude oil.

Minimization of Fugitive Associated Gas Emissions

- An investigation into fugitive emissions is expected to begin next quarter. Activities will be focused on characterizing available methane and volatile organic contaminants (VOC) emission measurement technologies and identifying possible improvement to support industry efforts to meet regulatory requirements.

Investigation of Rich Gas for EOR

- A summary report describing results from testing ethane as an EOR fluid will be reviewed and submitted in the next quarterly report.
- Modeling of ethane as an EOR fluid will be completed next quarter, and results will be reviewed and compiled into a follow-on summary report, which will be provided next quarter.

Waste Management (Task 2)

NORM Waste Disposal

- No activity is anticipated on this topic during the coming quarter.

Wellsite Waste Assessment

- No activity is anticipated on this topic during the coming quarter.

Water Management (Task 3)

Bakken Water Opportunities Assessment

- Considering the significant financial contribution of the state toward the report and the efforts therein and the fact that the members of BPOP have had ample time to review and digest the information, we are planning to release the report to the public April 1, 2016.

Inyan Kara Modeling

- Work will continue on modeling of the Dakota Sandstone as a saltwater disposal target.

Site Logistics (Task 4)

- No activity is currently planned in this area during the coming quarter.

Process Optimization and Systems Failure Analysis (Task 5)

- EERC staff will discuss with select BPOP members whether EERC capabilities might be applied to common well failure problems experienced across the Bakken. The EERC has developed multiple pathways via which it believes it may be of assistance to members. Two program members have approached program staff to determine how BPOP might address their well issues. It is suspected that many companies across the basin experience similar issues.

Waste Minimization and Utilization (Task 6)

Drill Cuttings Disposal and Reuse Options

- No activity is currently planned in this area during the coming quarter.

Spill Remediation (Task 7)

Spill Remediation Science

- The North Dakota Remediation Resource Manual is planned for release during the second quarter of 2016.

Pipeline and Facility Leak Detection

- No further work is anticipated in this area under this program, but work will continue under funding separate from this program on the pipeline study mandated by HB1358.

Land Reclamation (Task 8)

Optimization of Land Reclamation Practices

- The North Dakota Remediation Resource Manual is planned for release during the second quarter of 2016.

Program Development and Management

- This will be the final quarter of performance on the existing BPOP contract. The EERC is currently engaged in discussions to extend this highly successful program for another 3 years, with a scope of work refined to address new priorities held by the state of North Dakota.
- The EERC will seek continued membership from industry stakeholders for an extension of this program; however, with today's oil price environment and the resulting fiscal constraints on industrial partners, that is expected to be a challenging task. However, the EERC has found some initial encouragement from existing members, in particular their interest in providing in-kind support to bolster a continued state investment.
- The EERC will continue to serve in a collaborative capacity for industry and state entities as decisions are made regarding recommendations for alterations of existing heel/toe offsets and along parallel spacing unit boundaries.

REFERENCE

Bader, J.W., 2015, Inyan Kara Sandstone Isopach Map, Watford City 100K Sheet, North Dakota: North Dakota Geological Survey GI189. www.dmr.nd.gov/ndgs/documents/Publication_List/pdf/GEOINV/GI-189.pdf (accessed on March 6, 2016).