



April 13, 2018

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission (NDIC)
600 East Boulevard Avenue, Department 405
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

Enclosed please find the Energy & Environmental Research Center (EERC) Quarterly Progress Report for the subject project. If you have any questions, please contact me by phone at (701) 777-5276 or by e-mail at bkalk@undeerc.org.

Sincerely,

A handwritten signature in blue ink that reads "B.P. Kalk".

Brian P. Kalk
Director of Energy Systems Development

BPK/kal

Enclosure

E-Mailed Report Only: Brent Brannan, NDIC Oil and Gas Research Council
Lynn Helms, NDIC Department of Mineral Resources, Oil and Gas
Division
Ron Ness, North Dakota Petroleum Council



April 13, 2018

Mr. Jeffrey Parker
Marathon Oil Company
5555 San Felipe
Houston, TX 77056

Dear Mr. Parker:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Director of Energy Systems Development

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Enclosure

E-Mailed Report Only: Vitaly Kuchinskiy, Marathon Oil Company
B.J. Boening, Marathon Oil Company
Vernon Moore, Marathon Oil Company
Curtis Ryland, Marathon Oil Company



April 13, 2018

Mr. Gordon Pospisil
Vice President of Business Development
Liberty Resources LLC
1200 17th Street, Suite 2200
Denver, CO 80202-5854

Dear Mr. Pospisil:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken
Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Director of Energy Systems Development

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Enclosure

E-Mailed Report Only: Bryan Bugg, Liberty Resources LLC



April 13, 2018

Mr. Jason Swaren
Vice President of Operations
Oasis Petroleum
1001 Fannin, Suite 1500
Houston, TX 77002

Dear Mr. Swaren:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Director of Energy Systems Development

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E-Mailed Report Only: Jim Jolly, Oasis Petroleum
Jay Knaebel, Oasis Petroleum
Steven Cottle, Oasis Petroleum



April 13, 2018

Ms. Stephanie Erickson
Supervisor, Reservoir Characterization/Base Reservoir Engineering
Williston Asset
Rockies Business Unit
ConocoPhillips
600 North Dairy Ashford
EC3-13-13W086
Houston, TX 77079

Dear Ms. Erickson:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken
Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Director of Energy Systems Development

BPK/kal

Enclosure

E-Mailed Report Only: Kyrre Johansen, ConocoPhillips



April 13, 2018

Mr. Jeff Herman
Region Land Manager
Petro-Hunt, LLC
400 East Broadway, Suite 414
PO Box 935
Bismarck, ND 58501

Dear Mr. Herman:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Brian P. Kalk
Director of Energy Systems Development

BPK/kal

Enclosure

E-Mailed Report Only: Jason Stangel, Petro-Hunt, LLC



April 13, 2018

Mr. Brent Lohnes
Director, Field & Plant Operation
Hess Corporation
3015 16th Street Southwest
Minot, ND 58701

Dear Mr. Lohnes:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken
Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Director of Energy Systems Development

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Enclosure

E-Mailed Report Only: Vicky Sund, Hess Corporation



April 13, 2018

Mr. William Westler
WPX Energy
3500 One Williams Center, MD 38
Tulsa, OK 74172

Dear Mr. Westler:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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Director of Energy Systems Development

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Enclosure

E-Mailed Report Only: Brian Wold, WPX Energy



April 13, 2018

Dr. Rafael Longoria
Researcher Reservoir Geology and Petrophysics
R&T ST SOG
Statoil Gulf Services LLC
6300 Bridge Point Parkway, Building 2, Suite 100
Austin, TX 78730

Dear Dr. Longoria:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2018, “Bakken
Production Optimization Program 2.0”; Contract No. G-040-080; EERC Fund 22010

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BAKKEN PRODUCTION OPTIMIZATION PROGRAM 2.0
QUARTERLY PROGRESS REPORT
January–March 2018

BACKGROUND

The Energy & Environmental Research Center (EERC) was awarded an extension to the previously conducted and highly successful North Dakota Industrial Commission (NDIC) Oil and Gas Research Council (OGRC)-sponsored Bakken Production Optimization Program (BPOP). The purpose of this extension is to facilitate a 3-year continuation of the program to address emerging opportunities and challenges related to petroleum production in North Dakota. The extension is a continuation of the collaborative effort between the state of North Dakota and the North Dakota petroleum industry to apply North Dakota resources to provide North Dakota solutions to North Dakota challenges and opportunities.

The goals of BPOP 2.0 are to:

- Employ a “system of systems” approach to enhance overall production efficiency, recognizing that improved coordination among various design factors (reservoir management, well design, surface processing, gas management, waste management) can lead to significant improvements in resource recovery efficiency.
- Conduct applied research in topic areas that positively impact the efficiency of production and reduce the environmental footprint of operations.
- Advise industry and state entities on scientific aspects of exploration and production activities, especially as they pertain to economic and environmental impacts.
- Facilitate collaboration on issues that may not otherwise receive collaborative attention from industry and/or the state of North Dakota.

The anticipated outcomes of BPOP 2.0 are 1) increased well productivity and economic output of North Dakota’s oil and gas resources, 2) decreased environmental impacts of wellsite operations, and 3) reduced demand for infrastructure construction and maintenance. Specific results will include improved resource recovery efficiency, reduced land use impacts, increased royalties and tax revenue from harnessed associated gas and natural gas liquid streams, and increased revenue from added product streams captured earlier in the well life cycle.

This report summarizes achievements of the January–March 2018 quarter.

QUARTERLY PROGRESS REPORT (January–March 2018)

ACCOMPLISHMENTS DURING REPORTING PERIOD

Enhanced Oil Recovery Task

During this reporting period, work was performed under the U.S. Department of Energy (DOE) award to support EERC efforts under the rich gas enhanced oil recovery (EOR) project that is being conducted in close collaboration with Liberty Resources LLC (Liberty). Specific activities conducted during this past quarter are presented below.

- Activities to accomplish the BPOP 2.0 goals for the pilot project stated above were conducted this quarter. Specific activities include the following:
 - Laboratory-based examinations of rich gas interactions with obtained reservoir fluids and core/cuttings are being conducted to determine the ability of various rich gas mixtures to mobilize oil in the Bakken petroleum system. During this reporting period, experiments were conducted in conjunction with the DOE award mentioned previously. Laboratory studies were conducted to determine minimum miscibility pressure (MMP) values for different rich gas components (methane, ethane, propane) and CO₂ (for comparative purposes) in crude oil from the Stomping Horse complex. A modified rising capillary-vanishing interfacial tension technique was used for the MMP studies. The MMP experiments were conducted in duplicate using crude oil from the Three Forks Formation at a temperature of 127°C (260°F). MMP values for CO₂ in Stomping Horse oil were determined as a point of comparison with previous EERC studies focused on the potential for CO₂ EOR in the Bakken, with the results of those previous studies serving as a benchmark to evaluate the relative effectiveness of the rich gas components on MMP. The results of the MMP experiments conducted this past quarter showed that for the Stomping Horse crude oil, MMP values for methane are double those of CO₂, MMP for ethane is half that of CO₂, and MMP for propane is half that of ethane. Activities to develop methods to mix stable methane–ethane–propane mixtures for lab experiments were also initiated during this past quarter.
 - Rock extractions were conducted using pure methane, ethane, and propane on both Middle Bakken and Lower Bakken Shales from four Liberty wells located close to the junction of Burke, Williams, and Mountrail Counties. Extractions with methane and ethane were completed, and extractions with propane were conducted. Analysis of the hydrocarbon recovery rates with the different fluids from the four Middle Bakken and four Lower Bakken Shales was also conducted. Key observations from the results of the rock extraction experimental activities include the following:
 - Methane is significantly slower than ethane and propane when it comes to mobilizing oil from both Middle Bakken and Bakken shale samples.
 - Methane shows a very high bias against the mobilization of higher-molecular-weight hydrocarbons in both Middle Bakken and Bakken shale samples.

- The results of ethane and propane are similar when it comes to their ability to mobilize oil from the rock samples. Both showed faster rates of oil recovery than methane, and both were better at mobilizing high-molecular-weight hydrocarbons than methane.
- Evaluations of the changes in gas and fluid compositions over time in both the reservoir and surface infrastructure environments are being conducted as well as examinations of how those changes affect reservoir and process facility performance. Additional crude oil and produced water samples were collected from several wells in the Stomping Horse complex to establish baseline compositions and determine the range of variability both spatially and temporally in the Stomping Horse area. Sample collection will continue periodically throughout the first 12 to 18 months of production to provide a temporal aspect to well fluid.
- Iterative modeling of surface infrastructure and reservoir performance was conducted using the data generated by the various project activities to optimize the EOR pilot test design and operations. The DSU (drill-spacing unit) model created in the previous quarter was the basis for history-matching modeling that was performed using data provided by Liberty. Simulation modeling of several potential injection and production scenarios was also conducted. A model of the surface operations and infrastructure of the Stomping Horse complex, including the County Line Gas Plant, has been created. Results from the reservoir and surface modeling are also being used to support the selection and design of gas treatment and compression operations for the pilot test. Modeling results to date show significant improvements in oil production above the base case.
- Biweekly conference calls were held with staff from Liberty to discuss progress on the various aspects of the project.
- Biweekly conference calls with DOE were held to provide updates on the status and progress of the various aspects of the project.

Refracturing Optimization Task

- The original work plan was revised, taking into account the feedback received at the November 14, 2017, membership meeting.
- Production analysis of the refrac wells in the Bakken was completed to evaluate the performance of refracturing by determining the uplift in daily production as well as the incremental estimated ultimate oil recovery.
- The economic analysis of refracturing was conducted and completed to quantify the profit associated with the incremental oil attributable to the refracturing in the Bakken.
- Work to identify the wells across the Bakken that fit a certain criteria that may make them a candidate for refracturing in the near future is in progress.

Produced Fluid Characterization Task

- On January 20, 2018, Marathon Oil Company (Marathon) provided access to collect and analyze samples (gas, oil, and water) from a nonstimulated well in Dunn County. Data obtained from analysis of the sample will be compared to similar data from Bakken and Three Forks wells with multiple stage stimulations. Information obtained may help provide insight into possible sources of produced water in typical stimulated Bakken wells.
- Formal solicitation of produced fluids data from key industry partners has continued as the EERC builds a database of information on produced water, crude oil, and associated gas. These data will be integrated into the EERC-managed Bakken fluids database for support in understanding basinwide characteristics related to production and other reservoir/well statistics.
- Crude and produced water samples have continued to be collected from three newly completed and producing Liberty wells. These samples have been collected since initial production of each well throughout the first several months of production. Sampling will be repeated periodically throughout the first 12 to 18 months of production from each well to provide a temporal aspect to produced fluid composition.
- Analysis of recently acquired cuttings and fluid samples has continued. Data will continue to be analyzed and used to support multiple activities conducted within the program.
- EERC staff traveled to the Liberty well sites near Tioga, North Dakota, to conduct sample collection on January 19, February 1, and March 20, 2018.

Reservoir Performance Modeling Task

- Technical work and a draft topical report were completed on decline curve analysis for the 400-well database and multivariate analysis to identify production drivers for the Bakken petroleum system. Internal technical review is complete, and a final editing is in process.

Water Injection Reservoir Assessment Task

- Additional input on the draft final topical report was received and the report is being modified accordingly.
- The results of the Inyan Kara modeling effort are being used to develop a simplistic model that will allow users to estimate the radius of influence of individual saltwater disposal (SWD) wells based on basic geologic characteristics (cumulative sand thickness, average porosity, average permeability), injection rate, and period of performance.

Brine Treatment and Storage Assessment

- During the reporting period, geochemical modeling was conducted using PHREEQC to evaluate the potential for scale and NORM (naturally occurring radioactive material)

precipitation if Bakken produced water is concentrated as a result of treatment. Until specific water treatment technologies of interest are identified by member companies, a generic evaluation was performed using Bakken water chemistry data compiled by the EERC and assuming no selective removal of ions from the brine stream.

- Information was gathered on several brine treatment technologies that may be of interest to member companies. One technology in particular, developed by MGX Minerals Inc., couples brine treatment with resource recovery (i.e., lithium). The company claims that the technology has been commercially applied to recover metals from oilfield brines. EERC staff have reviewed several of the technical reports published by the company and plans to hold a call with them this coming quarter.

Facility Process Optimization Task

- Facility design, operational data, and crude oil samples have been obtained from two operating companies. Computational models have been developed, and work is ongoing to validate model predictions with actual system performance.
- Crude oil samples have been submitted to a third-party lab, and analysis is pending.

Aromatic/Aliphatic Study Task

- Forty Lower and Upper Bakken Shale samples were obtained that represent both the geographical and thermal maturity variations throughout the Bakken reservoir. These were provided to the Canadian Geological Survey both as native rock samples for “extended slow-heating rock-eval” analysis and as polished epoxy casts for vitrinite reflectance. These analyses are currently being performed by the Canadian Geological Survey in a collaborative study with the EERC. The data will be compared to the aromatic/aliphatic tracers measured by the EERC on the same sample suite. These investigations are expected to yield a better understanding of the shale thermal maturity across the basin as well as the relationship of the aromatic/aliphatic tracers to thermal maturity, oil sources and migration, and basin location and geology. Initial rock-eval analyses have already been provided to the EERC by the Canadian group.
- Fifteen of the 40 rock samples described above had previously had their aromatics/aliphatics measured. During this quarter, the additional 25 rock samples from 11 new wells have been prepared and analyzed for aromatic/aliphatic ratios so that we have complete data sets to match with the thermal maturity analyses described above. Data reduction for the 25 samples was begun.
- Eleven crude oil samples collected over 3 months starting at initial production in a new well were analyzed for aromatic/aliphatic ratios to determine if the relative contributions of the shales compared to the Middle Bakken to the produced crude would shift over production time. These initial samples show no significant shifts in aromatic/aliphatic ratios, but samples will continue to be collected and analyzed.

Environmental Support Task

- EERC staff participated in the third education day of the Hydrocarbon Remediation Task Force on January 26, 2018, along with North Dakota Petroleum Council (NDPC) members, North Dakota Department of Health (NDDH) staff, and representatives of the Northwest Landowner's Association (NWLTA). At this meeting, EERC staff presented on two subjects: 1) past research by the Total Petroleum Hydrocarbon Criteria Working Group and 2) the risk-based corrective action program used by Oklahoma to remediate crude oil spills.
- EERC staff participated in a working group meeting to compile and discuss several other state risk-based corrective action programs in anticipation of the next Hydrocarbon Remediation Task Force meeting.
- EERC staff began compiling additional hydrocarbon remediation material to update the previously published North Dakota Remediation Resource Manual.

Program Management and Development

- EERC staff traveled to San Antonio, Texas, to attend an ASTM International crude oil sampling and analysis workshop and Crude Oil Quality Association meeting February 19–23, 2018.
- EERC staff traveled to Denver, Colorado, to attend the NDPC Natural Gas Capture and Infrastructure Development (NGCID) meeting, held March 21, 2018. The EERC is supporting the NGCID group by leading the subcommittee focused on assessing remote capture use. The EERC also coordinated the creation of an industry survey which was distributed to NDPC membership to gather information about a variety of factors influencing flaring in North Dakota. Survey results were reviewed and compiled by EERC staff and provided to the NGCID committee to support its goal of improved gas capture.
- EERC staff traveled to Calgary, Alberta, Canada, to take a training course on Unconventional Reservoir Rate-Transient (Production Data) Analysis on March 12, 2018.
- EERC staff traveled to Calgary, Alberta, Canada, to attend the Society of Petroleum Engineers Canada Unconventional Reservoirs Conference on March 13–14, 2018.
- EERC staff traveled to Nashville, Tennessee, to attend the Carbon Capture Utilization & Storage Conference, held March 18–23, 2018.
- EERC staff traveled to Houston, Texas, to present at the Houston Geological Society Mudrocks Conference, held March 5–7, 2018.

MEMBERSHIP AND FINANCIAL INFORMATION

The original budget as proposed to NDIC OGRP is \$13,280,000, as shown in Table 1.

Table 1. BPOP 2.0 – Original Budget

Sponsors	Y1	Y2	Y3	Total
	Nov 2016 to Oct 2017	Nov 2017 to Oct 2018	Nov 2018 to Oct 2019	
NDIC Share – Cash	\$2,000,000	\$2,000,000	\$2,000,000	\$6,000,000
Industry Share (Marathon) – In-Kind	\$2,500,000	\$3,500,000	\$1,280,000	\$7,280,000
Total	\$4,500,000	\$5,500,000	\$3,280,000	\$13,280,000

The EERC continues to seek support for this program, and to date, additional cost share has been secured from the following Bakken producers: Petro-Hunt, Hess Corporation, ConocoPhillips, Oasis Petroleum, WPX Energy, Marathon, Liberty, and Statoil.

In addition, the EERC has secured \$2,000,000 from DOE to complement the ongoing work to determine the feasibility of reinjecting captured rich gas into a Bakken reservoir to enhance oil recovery. Liberty is providing in-kind contributions that support this programmatic scope.

Table 2 presents a revised expected budget based on the additional cost share secured by the EERC, an increase of more than 20%. Expenses to date are also listed in Table 2.

Table 2. BPOP 2.0 – Expected Budget and Expenses to Date

Sponsors	Expected Budget	Actual Expenses as of 3/31/17	Balance
NDIC Share – Cash	\$6,000,000	\$2,147,769	\$3,852,231
Industry Share – Cash	\$600,000	\$318,387	\$281,613
Marathon – In-Kind	\$7,280,000	\$4,749,086	\$2,530,914
Liberty – In-Kind*	\$141,103	\$141,103	–
DOE – Cash	\$2,000,000	\$274,317	\$1,725,683
Total	\$16,021,103	\$7,630,662	\$8,390,441

* An estimate for the total expected in-kind cost share from Liberty is not available. Liberty will periodically report actual costs to the EERC, which will be subsequently presented in the quarterly report.

FUTURE ACTIVITIES

The planned activities for the next quarter are detailed below.

Enhanced Oil Recovery Task

- Future activities under this task will be focused on supporting the rich gas EOR pilot test at Liberty's Leon-Gohrick DSU in the Stomping Horse complex.
- Gas-handling and compression strategies will continue to be evaluated, with a goal of identifying cost-effective, timely solutions.
- Reservoir-, facility-, and gas compression-modeling activities will be coordinated to ensure the development of an integrated EOR strategy.
- Sampling and analysis of fluids (oil, gas, and water) from the Stomping Horse complex will continue.
- A final set of comparative rock extraction hydrocarbon recoveries using pure methane, ethane, and propane on Middle Bakken and Lower Bakken Shale rock samples will be conducted under lower-pressure conditions to determine the effect of pressure on the performance of those gas
- Methods to mix stable methane–ethane–propane mixtures for lab experiments will continue.
- Reservoir-modeling activities will continue. In particular, additional potential injection and production schemes will be modeled as part of the effort to support the determination of final design and operational parameters of the pilot test.
- At the direct request of Liberty, the EERC has begun testing the effect of lower (1500 and 2500 psi) light hydrocarbon gas pressures on recovering crude oil hydrocarbons from shale and Middle Bakken rock samples collected from a well near the Leon-Gohrick DSU. We hope to complete these extractions and related analyses during the next quarter to support Liberty's injection plans.

Refracturing Optimization Task

- All the technical work will be completed. A draft report will be prepared, finalized, and submitted to NDIC.

Produced Fluid Characterization Task

- Additional sampling, analysis, and data review will continue as new opportunities arise.
 - The temporal analysis of the three newly installed Liberty wells will continue for several more months.
 - The EERC recently received a significant amount of fluids characterization and production data from BPOP partner Oasis Petroleum and is currently conducting a review of the data.

- Data collection and additional sampling and analysis will continue as needed to support BPOP goals.
- An expanded sampling and analysis program is being conducted on several Liberty wells in the northern portion of the basin in support of the rich gas EOR demonstration. These analyses are intended to evaluate potential changes in oil, gas, and water composition in several wells in the Bakken and Three Forks Formations during an EOR demonstration.
- All fluid data and associated well production information collected will be entered into the EERC-specific database to support BPOP goals. The database structure will be refined to enhance use by BPOP researchers.
- Industry partnerships will continue to be developed to further understand specific needs related to Bakken production issues and practices and to expand the geographical extent of the sampling and analysis effort.

Reservoir Performance Modeling Task

- The draft of the final topical report will be finalized and submitted to NDIC.

Water Injection Reservoir Assessment Task

- Work will continue on the development of a simplistic model to evaluate the radius of influence of individual SWD wells.

Brine Treatment and Storage Assessment

- The EERC team will continue to evaluate potential brine treatment technologies of interest to member companies. A conference call/WebEx will be scheduled with MGX Minerals to further evaluate the applicability of its technology for Bakken brines.

Facility Process Optimization Task

- Upon creation of site-specific model validation, a series of simulations will be performed to assess the impacts of different conditions (system design, equipment, operating conditions, and ambient conditions) on crude quality and vapor pressure.
- A summary of results will be prepared and shared with BPOP members.

Aromatic/Aliphatic Study Task

- Analysis and data reduction of the aromatic/aliphatic ratios on the additional Three Forks, Lower Bakken, Middle Bakken, and Upper Bakken Shale samples collected across the reservoir will continue, and the aromatic/aliphatic results will be compared with the extended slow heating rock-eval and vitrinite reflectance results as they become available from our Canadian Geological Survey collaborators.

- We anticipate beginning the aromatic/aliphatic analyses on rock samples collected from multiple depths in the same lithofacies, including two or three depths each in the Upper Bakken Shale, the Middle Bakken, the Lower Bakken Shale, and the Three Forks from single wells. These results will give us a better understanding of the variations of the aromatic/aliphatic ratios in the oil from different depths in the same lithofacies.
- The operator who agreed to collect crude oil samples for aromatic/aliphatic ratio analyses from the beginning of crude oil production into the decline curve has continued to provide temporal samples. Although the aromatic/aliphatic ratios over the first 3 months did not show significant changes, as samples are collected over longer times, we will analyze them to determine any changes in aromatic/aliphatic ratios. These samples will be used in an attempt to determine the relative contribution of the Upper and Lower Bakken Shales to crude production over the life of the well.

Environmental Support Task

- The EERC prepared materials in anticipation of attending the fourth education day event scheduled for March 23, 2018 (meeting was postponed because of weather and will likely take place in April or May 2018). Topics of discussion will include:
 - Risk-based corrective action programs in other regulatory jurisdictions, specifically Alberta, Saskatchewan, and Montana.
 - A push by industry to wrap up the education day meetings, and a discussion of NDDH draft guidance final format.
- EERC staff plan to update the previously published North Dakota Remediation Resource Manual with additional hydrocarbon remediation material.

Program Management and Development

- The EERC will continue to solicit additional industry membership in the BPOP consortium during the coming quarter.