Bakken Production Optimization Program

A Briefing to the Energy Development and Transmission Committee
Of the ND Legislature

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Minot, ND
April 8, 2014

Program Description

- Phase I – Drilling 11 New Wells
- Phase II – Completions
- Phase III – Reservoir Engineering
- Phase IV – Expansion Applications via 3-D Seismic
- Phase V – Optimization of Wellsite Operations

- Pilot hole logs, core data, other data-gathering from multiple wells to create a 3-D picture of what happens during and after the hydraulic fracture treatments in a multistage horizontal well. Continental will analyze this data set to:
  - Assess total resource available in the second and third benches of the Three Forks Formation (separate and unique?).
  - Confirm whether these benches are distinct and independent of the existing Middle Bakken.
  - Predict areas of future sweet spots.

- Site logistics, waste management, on-site hydrocarbon utilization, water management, process optimization, and systems failure analysis with an eye on decreased environmental impact.
Program Goals

• Maximize oil production from Bakken and Three Forks wells by employing an “all of the above” approach
  – Advanced reservoir characterization.
  – Improved drilling/stimulation/completion/production techniques and sequences.
  – Optimizing well-site surface operations:
    ♦ Reduce costs
    ♦ Reduce development and operation impacts to surrounding landowners
    ♦ Reduce demands on surrounding infrastructure and water sources

Program Budget Overview

• Commercial Partners
  – Continental Resources, Inc. (CLR)
  – Marathon Oil Co.
  – Whiting Petroleum Corp.
  – Oasis Petroleum
  – XTO Energy
  – ConocoPhilips
  – SM Energy
  – Hess
  – Petro-Hunt
  – Nuverra Environmental Solutions
  – Hitachi Data Systems

<table>
<thead>
<tr>
<th>Sponsors</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Total</th>
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<tr>
<td>NDIC Share – Cash</td>
<td>$3,550,000</td>
<td>$3,000,000</td>
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<td>Industry Share – Cash</td>
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<td>CLR Share – In-Kind</td>
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<td>$106,030,000</td>
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<td>TOTAL</td>
<td>$45,289,233</td>
<td>$44,739,233</td>
<td>$26,801,534</td>
<td>$116,830,000</td>
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</tbody>
</table>
Hawkinson Project Update

Borrowed from a Presentation Made on March 7 by Stan Wilson
Manager, Resource Development, Northern Region
Continental Resources

Hawkinson Project Goals

- Define reservoir drainage of the MBK, TF1, TF2 & TF3
- Confirm whether these formations are distinct and separate from each other
- Determine appropriate well spacing required for most efficient reservoir drainage
- Increase spacing unit ultimate recovery
- Predict areas of future reservoir sweetspots
Hawkinson Unit
Sec. 22 & 27-147N-96W
1,280 Acre Unit Full Development Project

- 14 wells in 1280 unit
  (4 MB, 3 TF1, 4 TF2, 3 TF3)
- 1320' inter-well spacing between same-zone wells

Strong Early Performance from Hawkinson Unit

Industry landmark: unique production from 4 different producing intervals and spaced 1,320 feet apart

Validates CLR vision for full-field development & demonstrates the vast resource potential across CLR’s acreage position

Strong initial performance in first 120 days

14,850 Boepd of initial combined production from 14 wells (Oct. 2013)
  • 13,400 Boepd from 11 new wells
    ✓ 1,480 Boepd avg. 24-hour IP: MB & TF1 (4 wells)
    ✓ 1,070 Boepd avg. 24-hour IP: TF2 & TF3 (7 wells)
  • 1,450 Boepd from 3 pre-existing wells

55% working interest in Hawkinson unit
Hydrocarbon Utilization

**Flaring Task Force and Remote Capture**

**Brief Update on Progress**

Hydrocarbon Utilization

- Ongoing support of NDPC Flaring Task Force.
- Created a database of remote capture alternatives.
- Ongoing evaluation of remote capture options.
- Seeking field demonstration locations and technology priorities.
Next Steps

- Many deployable technologies exist.
- Each technology, if deployed widely, can provide an incremental benefit to gas utilization and flare reduction.
- 60% of the total flared gas is coming from 216 locations flaring at a rate of 300 Mcfd or greater.
- Deploying remote capture to those locations flaring >300 Mcfd for several months may provide the greatest impact.
- The EERC is currently in discussions with NDPC Flaring Task Force members to determine path forward.

Hydrocarbon Utilization

Associated Gas for EOR
The Goal and the Challenge of Using Associated Gas for EOR

**Background:**
Present production methods leave ≈95% of Bakken oil in the reservoir

**Good news:**
In lab studies, >90% oil recovery from upper, lower, and middle Bakken rock using only CO₂ (and maybe associated gas)

**Bad News:**
Need to understand the controlling mechanisms better to make it cost-effective.

*(Even a 1% increase in recovery could be ca. 2-9 billion barrels.)*

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Hypothetical Step 1

Initial injection: CH₄ flows rapidly through fractures.
The International Center for Applied Energy Technology®

**Hypothetical Step 2**

CH$_4$ starts to permeate rock based on pressure gradient.

- CH$_4$ carries oil into the rock (bad).
- and
- CH$_4$ swelling pushes oil out of the rock (good).

**Hypothetical Step 3**

As CH$_4$ permeates into the rock, oil migrates to bulk CH$_4$ in fractures based on swelling and lower viscosity.
CH$_4$ pressures equalize inside of rock.

- Oil production is now based only on concentration gradient driven diffusion.
- Oil in bulk CH$_4$ is swept through fractures to production well.

**Summary of Observations**

- CO$_2$ and associated gas are capable of mobilizing oil from upper, middle, and lower Bakken, but we need to work on increasing the rate of the recovery processes.

- Since nearly all of the oil can be extracted from 1-cm rods, even upper and lower Bakken shales have sufficient connectivity to be accessed by CO$_2$ and associated gas.

- All samples show an initial “fast” recovery of ca. 20-70% of the oil, followed by an exponential decline.

Since even a 1% incremental recovery is significant, perhaps research should focus on the first few percent of the recovery curve.
Waste Management

NORM Waste Handling and Disposal

Scope Defined in Proposal

- The waste management area of work is focused on developing improved means of handling drilling and production wastes, including those that may contain NORM.
Current Regulatory Predicament …

- Adequate characterization of NORM waste has been a major limitation of NORM risk assessments conducted to date.
- Most state regulations focus on specific activity level (pCi/g) of specific isotopes
  - Cannot be directly measured in the field
  - Appropriate protocols are difficult to responsibly employ.
- Producers and state regulators may benefit by promoting better science behind future North Dakota NORM-specific regulations.

Progress

NORM Waste Disposal

- Serving as consultant for the NDPC NORM committee
- Creating education material for the general public, industry and regulators
- Coordinating NORM sampling and analysis efforts
- Providing guidance for next steps
Water Management

Optimization of Bakken Water Use and Reuse

Previous EERC Bakken Water Research

• The key water issue in early Bakken development was availability of freshwater to meet demands for hydraulic fracturing.
• The EERC’s Northern Great Plains Water Consortium completed two early studies
  – Bakken Water Opportunities – Phase 1
    ♦ Assessed flowback water timing and characteristics
  – Bakken Water Opportunities – Phase 2
    ♦ Assessed potential to upgrade marginal-quality, nonpotable groundwater (Dakota Formation) for use in fracturing.
Bakken Developments Affecting Water Use/Reuse

- While highly relevant at the time (2008–2010), the previous Bakken water research is outdated because of new developments
  - Multistage fracturing
  - Salt-tolerant fracturing fluid systems that do not require freshwater for fracturing
  - Multiwell pads
- The dynamic nature of Bakken production and recent technology improvements have created new opportunities in Bakken water management.

Project Pursuits

- Investigate differences in oil production between wells fractured with freshwater versus saltwater.
- Evaluate flowback water characteristics and treatability given the potential use of salt-tolerant fracturing fluid systems.
- Assess future maintenance water needs and availability of freshwater supplies.
- Develop a database of applicable treatment technologies and technology vendors to provide treatment alternatives.
  - Where appropriate, conduct field demonstrations and independent technology evaluation.
Program Expansion

Waste Minimization, Site Reclamation and Spill Remediation

Scope Defined in Proposal

• The expanded work scope includes task areas not previously proposed and targets efforts to mitigate land impacts from Bakken oil production activity.
  – Waste minimization and utilization
  – Spill remediation
  – Land reclamation
• Teamed with North Dakota State University (NDSU) range and soil sciences experts.
Expansion Topic – Waste Minimization

- Anticipating increases in waste production from well sites as the number of wells on each site multiplies during and after infill drilling activities, investigate the following areas:
  - Improved waste management strategies
  - Waste minimization techniques
  - Waste reutilization technologies

Expansion Topic – Spill Remediation

- Investigate improved techniques of spill remediation (both hydrocarbon and brine spills) to return the affected land to productive use.
- Develop best management practices guidelines.
- Site-specific demonstrations of improved practices with producer assistance.
Expansion Topic –
Land Reclamation

• Investigate strategies to accelerate the return of land to productive use after:
  – Drilling activities have ceased.
  – Production ceases and wells are plugged and abandoned.
  – Access road and pipeline rights of way are reclaimed.
• Develop best management practices guidelines.
• Site-specific demonstrations of improved practices with producer assistance.

EERC and NDSU Capabilities

• Expertise from both entities in soil remediation and land reclamation:
  – Soil science
  – Seed selection
  – Range science
  – Civil engineering
  – In situ hydrocarbon reduction
• Mobile, in situ remediation trailers
• Soil laboratories
• Inorganic chemistry laboratories
• Field sampling teams
Anticipated Activities

• Short-term Output:
  – Develop education material and fact sheets
    ♦ Brine spills
    ♦ Oil spills
    ♦ Land reclamation associated with oil and gas production

• Intermediate time period
  – Develop research projects to address
    ♦ Brine and oil spills
    ♦ Waste management (i.e. drill cuttings)
    ♦ NORM
    ♦ Flaring
  – Develop site-specific demonstration projects

• Long-term Outcomes
  – Develop Best Management Plans
    ♦ Brine spills
    ♦ Oils spills
    ♦ Land reclamation
  – Develop educational workshops
    ♦ Oil and gas producers
    ♦ Contractors
    ♦ Land owners and managers
    ♦ County agents
THANK YOU FOR THE OPPORTUNITY TO DISCUSS THIS PROGRAM

www.undeerc.org/flaring_solutions/Search.aspx
**Remote Capture Technology Type** | **Companies**
--- | ---
NGL Recovery | 12
Power Production | 7
CNG or LNG | 11
Gas-to-Liquids (GTL) Conversion | 11

**Distributed-Scale NGL Recovery**

|  | 1000-Mcfd Location | 270 Locations (>300 Mcfd) |
--- | --- | ---
Total Gas Treated | 1000 Mcfd | 180,000 Mcfd |
Residue Gas Remaining | 850 Mcfd | 153,000 Mcfd |
NGLs Recovered, 4 gal/Mcfd | 4000 gallons/day | 720,000 gallons/day |
Value of NGLs, $1/gal | $4000/day ($1.46M/yr) | $720,000/day ($263M/yr) |
Flared Reduction | 150 Mcfd | 27,000 Mcfd |
Percent of 300,000 Mcfd | 0.05 | 9 |
## Power Generation
### Replacing Diesel Generation

<table>
<thead>
<tr>
<th>1-MW Multiwell Location</th>
<th>100 1-MW Locations</th>
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<tr>
<td><strong>Capital Equipment Cost</strong></td>
<td><strong>$850,000</strong></td>
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<td><strong>Fuel Savings</strong> (diesel: $3.85/gallon) (lean gas: $2.75/Mcf)</td>
<td><strong>$5720/day</strong></td>
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<td></td>
<td><strong>$2.1M/yr</strong></td>
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<td><strong>Flared Reduction</strong></td>
<td>300 Mcf/d</td>
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<td><strong>Percent of 300,000 Mcf/d</strong></td>
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<table>
<thead>
<tr>
<th>56-kW Single-Well Location</th>
<th>100 56-kW Locations</th>
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<td><strong>Capital Equipment Cost</strong></td>
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<td><strong>Fuel Savings</strong> (diesel: $3.85/gallon) (lean gas: $2.75/Mcf)</td>
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<td><strong>$152,570/yr</strong></td>
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<td><strong>Flared Reduction</strong></td>
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<td><strong>Percent of 300,000 Mcf/d</strong></td>
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## Transportation Fuel (CNG/LNG)

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<tr>
<th>1-HD Truck (250 miles/day)</th>
<th>100-HD Truck (250 miles/day)</th>
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<tbody>
<tr>
<td><strong>Vehicle Miles Traveled</strong></td>
<td><strong>91,000 miles/yr</strong></td>
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<tr>
<td><strong>Fuel Savings</strong> (diesel: $3.85/gallon) (lean gas: $2.75/Mcf)</td>
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<td><strong>$32,000/yr</strong></td>
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<td><strong>Flared Reduction</strong></td>
<td>3 Mcf/d</td>
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<tr>
<td><strong>Percent of 300,000 Mcf/d</strong></td>
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### New Questions

- Which flowback water treatment technologies are presently available for use in conjunction with salt-tolerant fracturing fluid systems?
- Do differences in well completion techniques impact flowback water characteristics, and if so, what are the impacts on flowback water treatment?
- What is the role of salt dissolution in enhancing formation permeability?
  - High-salt fracture gels will not dissolve as much salt as freshwater formulations and may result in lower production.
  - Limited number of Bakken wells fractured with salt-tolerant gels (eight).
New Questions (cont’d)

• With existing and planned water infrastructure (water depots, pipelines, etc.….) will there be adequate local access to the freshwater required for well maintenance water?
  – Maintenance water demands will far exceed those for fracturing.
• What is the new pattern of well pad water use, and how can storage/transportation be optimized?

Previous EERC Bakken Water Research

• The key water issue in early Bakken development was availability of freshwater to meet demands for hydraulic fracturing.
• The EERC’s Northern Great Plains Water Consortium:
  – Bakken Water Opportunities – Phase 1
    ◆ Assessed flowback water timing and characteristics
    ◆ Low flowback water recovery (15% to 45% in 10 days)
    ◆ Extremely high total dissolved solids (TDS) levels (>220,000 mg/L)
  – Bakken Water Opportunities – Phase 2
    ◆ Assessed potential to upgrade marginal-quality, nonpotable groundwater (Dakota Formation) for use in fracturing.
    ◆ Reverse osmosis treatment of 150°F groundwater was economically competitive with freshwater acquisition and transportation.