Bakken Production Optimization Program

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Bakken Production Optimization Program Goals

To facilitate ongoing efforts by industry and the state of North Dakota to optimize Bakken/Three Forks production:

– Advanced reservoir characterization and more accurate resource estimates.
– Improved drilling, stimulation, completion, and production techniques and sequences.
– Optimization of wellsite surface operations and reduced surface impacts.
Why Optimization Is Important…

- World-class resource

- Currently, only 3%–10% recovery factor.

- Small improvements in recovery could yield over a billion barrels of oil.
Past Reservoir Development Model

MB and TF wells on 320 acre spacing

Slide courtesy of Continental Resources
Current Development: Bakken & Three Forks

<table>
<thead>
<tr>
<th>LODGEPOL</th>
<th>Middle Bakken</th>
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<tbody>
<tr>
<td>Upper Bakken shale</td>
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<tr>
<td>Middle Bakken</td>
<td></td>
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<tr>
<td>Lower Bakken shale</td>
<td>660' 660' 1320'</td>
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<tr>
<td>Upper Three Forks 1st Bench</td>
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<tr>
<td>Lower Three Forks 2nd Bench</td>
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<tr>
<td>Lower Three Forks 3rd Bench</td>
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<tr>
<td>Lower Three Forks 4th Bench</td>
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<td>NISKU</td>
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10,000' below surface

Multiple fracture stages

Slide courtesy of Continental Resources
EERC Focus Areas

• Flare gas collection and utilization.
• Improved waste handling and options for beneficial reuse.
• Options for water recycling, treatment, and reuse.
• Other surface and downhole operational issues (corrosion, scaling, casing integrity).
Benefits of Wellsite Operations Optimization

- Reduce costs and improve efficiency.
- Reduce development and operational impacts to surrounding landowners, infrastructure, and the environment.
- Reduce demands on freshwater resources.
Public Education

Value of Products from One Produced Barrel

Acceptability

- Human: 2 pCi/g
- Banana: 4 pCi/g
- Cat Litter: 5 pCi/g
- Brazil Nuts: 6 pCi/g
- Coffee Grounds: 27 pCi/g
- Granite Countertop: 27 pCi/g
- Phosphate Fertilizer: 123 pCi/g

Center pivot irrigation in North Dakota requires about 4 million gallons of water a day for a 1-square-mile section of land.
Completed EERC Projects Leading to the Optimization Program Concept

- Evaluation of options for flare gas utilization.
- Demonstration of flare gas utilization in a bifuel drilling application.
- Evaluation of options for nontraditional water supply sources for hydraulic fracturing:
  - Feasibility of recycling and reuse of fracture flowback.
  - Demonstration of brackish groundwater treatment and subsequent use in fracturing.
Observations Regarding Flaring

- Current flaring in the Williston Basin is a result of:
  - A rapid increase in oil production.
  - Growing but still insufficient intrabasin infrastructure to move rich gas to processing.
  - Growing but still limited infrastructure to move dry gas and NGLs to markets outside the state.

- With that said,
  - Forecasts indicate that oil and gas production should stabilize.
  - Industry is investing significant amounts of money to develop infrastructure and processing capabilities.

- The opportunity to capture revenue from flared gas is a moving target.
  - Location-specific (geographic)
  - Time-limited (temporal)
Flare Gas Data – November 2013

Flaring Allocation by Total Gas Flared in November

- 1,650,072 Mcf (21%)
- 3,126,130 Mcf (41%)
- 1,509,912 Mcf (20%)
- 1,393,045 Mcf (18%)
- 4,388 Mcf (<1%)

Flaring Rate (Mcf/day)
- <1 Mcf
- 1-299 Mcf
- 300-599 Mcf
- 600-1199 Mcf
- 1200+ Mcf

Flaring Allocation by Number of Wells/Locations

- 2237 Locations (48%)
- 2148 Locations (47%)
- 70 Locations (1%)
- 125 Locations (3%)
- 32 Locations (1%)

~ 60% volume from 4% of locations
Flare Data Analysis – November 2013

- 3,992,400 Mcf (52% of Total Flared)
- 3,691,159 Mcf (48% of Total Flared)

Legend:
- Blue: Unconnected Wells
- Red: Gathered Wells
Evaluation of Associated Gas Use

- Associated gas alternative use study – analysis of gas use options upstream of gas-processing plants
  - Small-scale gas processing
  - Compressed natural gas (CNG)/liquefied natural gas (LNG) for vehicles
  - Electric power production
  - Chemical production

- Bifuel rig demonstration – assessment of fuel savings and operational impacts of associated gas–diesel mix

EERC Study and Final Project Report
www.undeerc.org/Bakken/researchstudies.aspx
A Use for Flared Natural Gas

- Power production for drilling rigs is a near-term opportunity.
- Diesel engines properly outfitted with bifuel systems can utilize a mixture of diesel and natural gas.
- Significant fuel savings can be achieved:
  - 30%–60% reduced fuel costs
  - Reduced fuel delivery and associated traffic, engine emissions, and fugitive dust
Summary of Results

• Diesel fuel consumption reduced by 18,000 gallons for two wells over a period of 47 days.
• Fuel-related net cost savings of nearly $60,000.
• Reduced delivery truck traffic.
• Reduced \( \text{NO}_x \) emissions and increased CO and HC emissions compared to diesel-only operation. Mitigation achievable with exhaust gas treatment.
• Seamless engine operation using the GTI Bi-Fuel® system.
• Currently ECO-AFS has Bi-Fuel on 21 rigs and 200 generators in North Dakota.
<table>
<thead>
<tr>
<th>Technology</th>
<th>Possible Impact to Flare Volume</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGL Removal</td>
<td>9% reduction deployed at 227 largest flaring locations</td>
<td>• Ease of deployment&lt;br&gt;• Ease of operation&lt;br&gt;• Extracts highest value product from rich gas</td>
<td>• Best deployed during first 12 months of operation&lt;br&gt;• Increases truck traffic, liquids storage</td>
</tr>
<tr>
<td>Power Diesel Replacement</td>
<td>0.5% reduction Power production at 100 1-well locations</td>
<td>• Fuel cost savings&lt;br&gt;• Ease of deployment&lt;br&gt;• Ease of operation</td>
<td>• Limited applicable sites</td>
</tr>
<tr>
<td>Power Local Load, diesel replacement</td>
<td>10% reduction Power production at 100 1-MW locations</td>
<td>• Reduces overall electrical load growth&lt;br&gt;• Ease of deployment&lt;br&gt;• Ease of operation</td>
<td>• Limited applicable sites</td>
</tr>
<tr>
<td>Power Grid Support</td>
<td>5% reduction One 45-MW grid connect plant</td>
<td>• Supports utility in electrical load growth management&lt;br&gt;• Ease of deployment&lt;br&gt;• Ease of operation</td>
<td>• Grid interconnect&lt;br&gt;• Guaranteed fuel supply</td>
</tr>
<tr>
<td>CNG/LNG</td>
<td>0.1% reduction 25,000 mile/day fleet</td>
<td>• Fuel cost savings</td>
<td>• Low demand for fuel&lt;br&gt;• Infrastructure and vehicle conversion takes time</td>
</tr>
<tr>
<td>Truck Transport</td>
<td>30% reduction 100 1-MMCFD sites</td>
<td>• Significant flaring impact</td>
<td>• 900 trucks&lt;br&gt;• 9 trucks/day/1-MMCFD</td>
</tr>
<tr>
<td>GTL</td>
<td>8% reduction 2500 bpd production</td>
<td>• Conversion of gas to a higher value liquid product</td>
<td>• Immature at relevant scale&lt;br&gt;• High capital cost&lt;br&gt;• Complex operation&lt;br&gt;• Requires large, consistent gas supply</td>
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Technology Summary Points

• Many technologies exist that can be deployed to utilize flared gas.
• Each technology, if deployed widely, can provide a small incremental benefit to gas utilization and flare reduction.
• Distributed-scale technology alone cannot be economically deployed widely enough to achieve the target of 90% gas conservation.
• Additional alternatives may be investigated to improve gas conservation without adversely impacting oil production or exacerbating other challenges such as truck traffic:
  – Gas reinjection for pressure maintenance and improved overall oil recovery
NDPC Flaring Task Force

- EERC’s involvement is one outcome of the Bakken Production Optimization Program.
- NDPC’s Flare Reduction Goals:
  - Capture 74% by 4th Qtr. 2014
  - Capture 77% by 1st Qtr. 2015
  - Capture 85% by 1st Qtr. 2016
- Key mechanisms to achieve reduction goals:
  - Gas processing expansions and new processing plants
  - New and expanded infrastructure (over $1.7B investment)
  - Requiring Gas Capture Plans to be included with ADPs
Water Needs for Fracturing

- Hydraulic fracturing requires ~ 2 to 5 million gallons of freshwater per well.
- The water is mixed with chemicals (biocides, proppants, polymers) prior to injection.
- A percentage of the frac water returns to the surface (flowback) and is recovered and disposed of (or recycled).
  - Typically contains dissolved solids (salts), suspended solids, residual hydrocarbons, and fracturing chemicals.
Putting Water Needs in Perspective

- Estimated water demand assuming 2200 wells per year at 4 million gallons per frac: ~ 24.1 MGD
  - 1.8% of total ND fresh water withdrawals
  - Equivalent to about 1.8 inches per year off the surface of Lake Sakakawea.
- Daily pumping volume for a center-pivot irrigator on a ¼ section of land in ND: ~ 1 million gallons
- Typically daily use for a 50,000-person Midwestern city: 10 million gallons.
Bakken Water Opportunities Assessment: Phase 1

• Partners
  – DOE NETL
  – North Dakota Industrial Commission (NDIC) Oil and Gas Research Council (OGRC)
  – North Dakota Petroleum Council (NDPC)
  – Five major producers

• Goal was to evaluate the feasibility of recycling hydraulic fracturing flowback waters in the Bakken play.

• **At the time of the study (2009-2010),** we concluded that because of low initial flowback water recovery rates (15% to 40% of original volume within 10 days) and extremely high dissolved salt content, recycling of Bakken fracture flowback water would be challenging.
Water Costs for Fracturing the Bakken

- Acquisition costs
  - $0.25–$1.26/bbl of raw water
  - $0.63–$5.00/bbl for transportation
- Disposal costs
  - $0.63–$9.00/bbl for transportation
  - $0.50–$1.75/bbl for disposal via deep well injection
- Total costs
  - $2.01–$17.01/bbl
Bakken Water Opportunities Assessment: Phase 2

• Partners
  – DOE NETL
  – NDIC OGRC
  – NDPC
  – Hess Corporation

• Goals were to assess the technical and economic feasibility of upgrading nonpotable groundwater for use in hydraulic fracturing.

• The EERC and Hess conducted a pilot project using a portable reverse osmosis (RO) system provided by GE Water and Process Technologies to treat brackish groundwater for use in hydraulic fracturing.

• This approach was economically competitive with existing water supply sources.
A Key Advancement in Water Recycling and Reuse

• Development of customized fracturing fluid systems that can tolerate higher salinities and various impurities.
• Still requires some form of pretreatment to remove constituents of concern, such as organics and suspended solids.
• Not yet widely employed in the Bakken, but a handful of successful demonstrations have occurred.
Potential Benefits of Salt-Tolerant Frac Fluid Systems

• Less demand for freshwater
• Lower transportation costs
• Less truck traffic for freshwater acquisition and wastewater disposal
  – Reduced road maintenance
  – Less dust
  – Fewer air emissions
• Increased versatility for industry in terms of makeup water sources for hydraulic fracturing
We Need a Paradigm Shift

• Issues related to oil and gas development should not be the sole responsibility of industry.
• North Dakota and its citizens benefit from the strong economy created by oil and gas production.
• Let’s tackle optimization of this resource collectively.
For More Information…

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