# *Bakken Production Optimization Program*

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

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**Kevin Sedivec, Range Science Program Leader, NDSU**

**Minot, ND**
**April 8, 2014**




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## Program Description

- *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.*

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

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

- Phase V – Optimization of Wellsite Operations

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# 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

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# 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

| Sponsors | Y1 | Y2 | Y3 | Total |
|---|---|---|---|---|
| NDIC Share – Cash | $3,550,000 | $3,000,000 | $2,000,000 | **$8,550,000** |
| Industry Share – Cash | $750,000 | $750,000 | $750,000 | **$2,250,000** |
| CLR Share – In-Kind | $40,989,233 | $40,989,233 | $24,051,534 | **$106,030,000** |
| **TOTAL** | **$45,289,233** | **$44,739,233** | **$26,801,534** | **$116,830,000** |

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# Hawkinson Project Update

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

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## 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

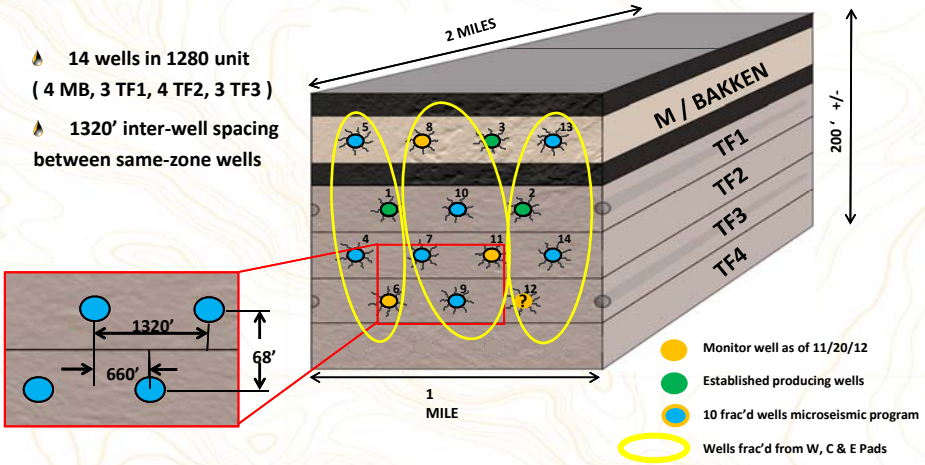
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# Hawkinson Unit

**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**

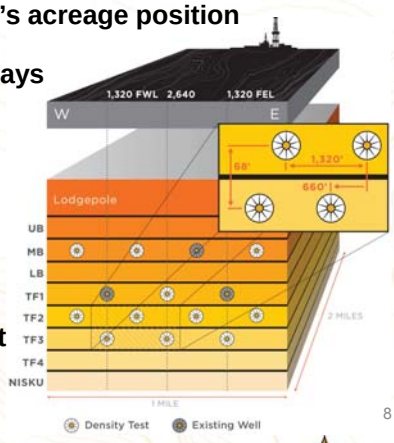



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# Strong Early Performance from Hawkinson Unit

- **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**




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# 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.



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# Hydrocarbon Utilization

## *Associated Gas for EOR*

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# 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 $CO_2$ (and maybe associated gas)*

*Bad News:*

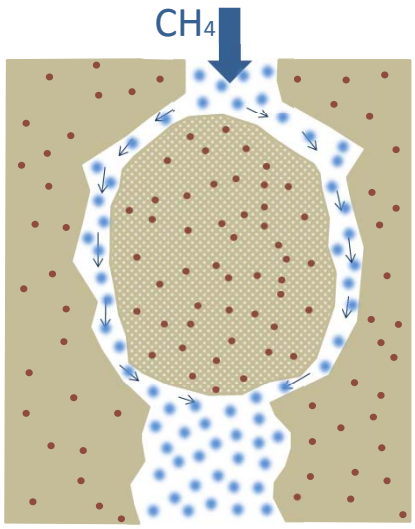
*Need to understand the controlling mechanisms better to make it cost-effective.*

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

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# Hypothetical Step 1

Initial injection: $CH_4$ flows rapidly through fractures.




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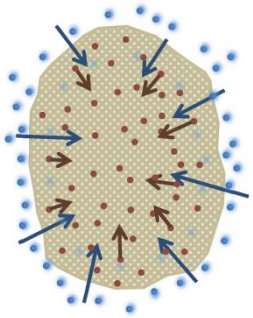
# Hypothetical Step 2

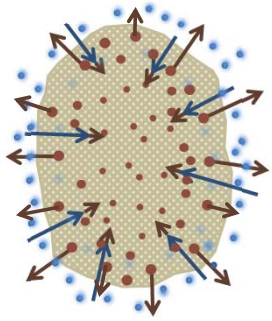
$CH_4$ starts to permeate rock based on pressure gradient.

$CH_4$ carries oil into the rock (bad).

***and or***

$CH_4$ swelling pushes oil out of the rock (good).

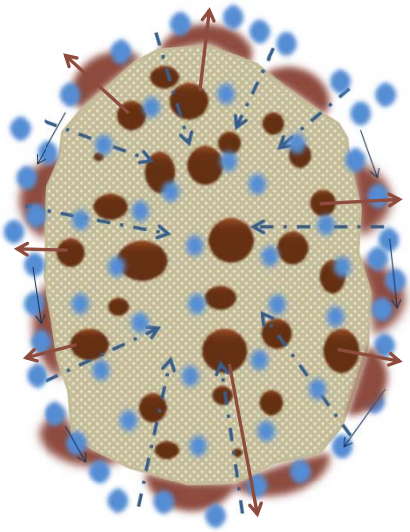




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# Hypothetical Step 3

As $CH_4$ permeates into the rock, oil migrates to bulk $CH_4$ in fractures based on swelling and lower viscosity.

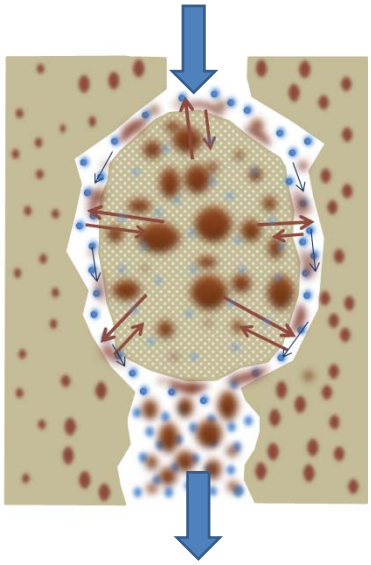


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# Hypothetical Step 4

$CH_4$ 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.



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# 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

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# 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.

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# 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



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# 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



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## 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.

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# 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.



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# 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



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# 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





# Anticipated Activities

- 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

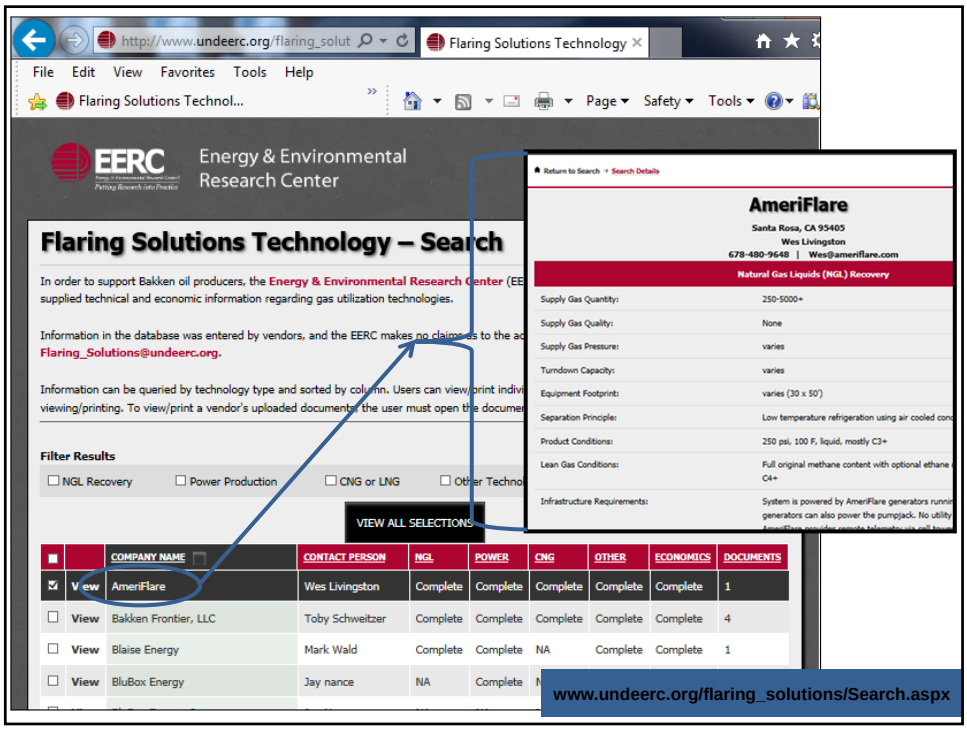




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# THANK YOU FOR THE OPPORTUNITY TO DISCUSS THIS PROGRAM

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# Flaring Solutions Database Technology and Vendor Summary

| Remote Capture Technology Type | Companies |
|---|---|
| NGL Recovery | 12 |
| Power Production | 7 |
| CNG or LNG | 11 |
| Gas-to-Liquids (GTL) Conversion | 11 |

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# 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/Mcf | 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 |

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# Power Generation
# Replacing Diesel Generation

| | 1-MW Multiwell Location | 100 1-MW Locations |
|---|---|---|
| Capital Equipment Cost | $850,000 | $85,000,000 |
| Fuel Savings<br>(diesel: $3.85/gallon)<br>(lean gas: $2.75/Mcf) | $5720/day<br>$2.1M/yr | $572,000/day<br>$209M/yr |
| Flared Reduction | 300 Mcfd | 30,000 Mcfd |
| Percent of 300,000 Mcfd | 0.1 | 10 |

| | 56-kW Single-Well Location | 100 56-kW Locations |
|---|---|---|
| Capital Equipment Cost | $50,000 | $5,000,000 |
| Fuel Savings<br>(diesel: $3.85/gallon)<br>(lean gas: $2.75/Mcf) | $418/day<br>$152,570/yr | $41,800/day<br>$15M/yr |
| Flared Reduction | 16 Mcfd | 1600 Mcfd |
| Percent of 300,000 Mcfd | 0.005 | 0.5 |

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# Transportation Fuel (CNG/LNG)

| | 1-HD Truck (250 miles/day) | 100-HD Truck (250 miles/day) |
|---|---|---|
| Vehicle Miles Traveled | 91,000 miles/yr | 9,125,000 miles/yr |
| Fuel Savings<br>(diesel: $3.85/gallon)<br>(lean gas: $2.75/Mcf) | $88/day<br>$32,000/yr | $8800/day<br>$3M/yr |
| Flared Reduction | 3 Mcfd | 330 Mcfd |
| Percent of 300,000 Mcfd | 0.001 | 0.11 |

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# GTL

| | Single Large Production Well | Multiwell Location or Intermediate Gathering Site |
|---|---|---|
| Capital Cost | | $250,000,000 |
| Total Gas Processed | 700 Mcfd | 25,000 Mcfd |
| Syncrude Produced | 50 bpd | 2500 bpd |
| Lean Gas Value ($2.75/Mcf) | $1925 | $68,750/day |
| Syncrude Value ($85/bbl) | $4250 | $212,500/day |
| Flared Reduction | 700 Mcfd | 25,000 Mcfd |
| Percent of 300,000 Mcfd | 0.2 | 8 |

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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).

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## 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?

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## 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.

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Northern Great Plains Water Consortium