North Dakota Department of Mineral Resources

http://www.oilgas.nd.gov  http://www.state.nd.us/ndgs

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Bismarck, ND 58505-0840
(701) 328-8020    (701) 328-8000
<table>
<thead>
<tr>
<th>Technically Recoverable Shale Gas Resources (Tcf)</th>
<th>Technically Recoverable Shale Oil Resources (Billion Barrels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. U.S. 1,161</td>
<td>1. Russia 75</td>
</tr>
<tr>
<td>2. China 1,115</td>
<td>2. U.S. 48</td>
</tr>
<tr>
<td>3. Argentina 802</td>
<td>3. China 32</td>
</tr>
<tr>
<td>4. Algeria 707</td>
<td>4. Argentina 27</td>
</tr>
<tr>
<td>5. Canada 573</td>
<td>5. Libya 26</td>
</tr>
<tr>
<td>6. Mexico 545</td>
<td>6. Australia 18</td>
</tr>
<tr>
<td>10. Brazil 245</td>
<td>10. Canada 9</td>
</tr>
<tr>
<td>11. Others 1,535</td>
<td>11. Others 65</td>
</tr>
<tr>
<td><strong>TOTAL 7,795</strong></td>
<td><strong>TOTAL 335</strong></td>
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</tbody>
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Hydraulic Fracturing
Lifeline to Shale Energy

Hydraulic Fracturing

• Why
• How
• Risks and Regulations
Hydraulic Fracturing
Lifeline to Shale Energy

• Why
  • Onshore oil and gas that flow without fracturing are already developed
  • Unconventional Reserves reservoirs are tight (look at pictures) uneconomic production rate without fracing must create a path for oil to flow
Hydraulic Fracturing
Lifeline to Domestic Energy

Hydraulic Fracturing
• How
5) Technology = horizontal well + multi stage hydraulic fracturing
The 6½ minute horizontal drilling/hydraulic fracturing video is available to download for free from this web site (you will need Real Player to view it).

http://www.voyageroil.com/drilling
As shown in this historic photograph, the first hydraulic fracture treatment was performed by Halliburton under license to Stanolind Oil Company on March 17, 1949, east of Duncan, Ok. Hydraulic fracturing has since allowed commercial hydrocarbon recovery from more than 1 million wells that could not have produced economically, and that number grows by the day, with nearly every U.S. gas well and the majority of all U.S. oil wells now being hydraulically fractured.

**Not New**

> 65 years
> 1 million wells fractured

**Greatly Improved**

Performing hydraulic fracture stimulation south of Tioga
- all Bakken wells must be hydraulically fractured to produce
- 2-4 million gallons of water
- 3-5 million pounds of sand and ceramic
- cost $2-5 million
Thousands of fractures are created
- pumping 8-10 million gallons of water at 6,000-9,000 psi
- 15-20 millions of pounds of sand and ceramic beads are added to the water to hold the fractures open.

Ball and Sleeve
- up to 50 stages
- ball opens the liner sleeve
Purposes of frac fluid

- crack the reservoir
- gel strength to carry sand

Frac fluid is produced back as flowback and produced water
Hydraulic Fracturing
Lifeline to Shale Energy

Hydraulic Fracturing
• Risks and Regulations
States have been regulating the full life cycle of hydraulic fracturing for decades

- Geology of each sedimentary basin is different
- States Have Water Appropriation Regulations
  - North Dakota Water Commission
- States Have Oil & Gas Regulations
  - North Dakota Industrial Commission
- States Have Health and Environmental Regulations
  - North Dakota Health Department
FOUR AREAS OF RISK &
HOW WE MANAGE THEM

• Sustainability of water supply
• Geology of confining zones
• Well bore construction
• Chemicals and flow back water handling
Unconventional Resource Wells are Thirsty

In North Dakota

2,000 - 3,000 wells / year
20 - 30 million gallons water / day
15 - 25 years duration
Water Commission
Regulate water appropriations
Guard against withdrawals >> recharge

Glacial Drift Aquifers
Frac Water Needs ± 20-30 million gallons per day

Ground water maximum ±7 million gallons per day

Lake Sakakawea (Missouri River) is the most sustainable water resource

• one inch contains ±10 billion gal water
  • enough to fracture 2,500-5,000 wells

• approximately ±10 million gallons per minute flows into and out of Lake Sakakawea
FOUR AREAS OF RISK
&
HOW WE MANAGE THEM

• Sustainability of water supply

• Geology of confining zones

• Well bore construction

• Chemicals and flow back water handling
The properties of geologic confining zone(s) can be determined by science:

- Minimum thickness
- Maximum pressure
- Vertical fracture height
Microseismic events are imaged via PSET, a migration based imaging algorithm.
“Excellent ‘frac saturation’....”

- 24-Stage Frac / IP: 2,558 BOE/D
- Excellent “frac saturation” evidenced by minimal gaps of unfraced rock along the wellbore with some stages impacting the same rock volume.
- Minimal gaps along NE trending natural fractures where the frac follows large regionally extensive fractures. These areas already have good naturally occurring fractures.
- Lateral frac wings that average 750' on either side of the wellbore. This is consistent with our other fracs and planned spacing pattern for full field development.
FOUR AREAS OF RISK
HOW WE MANAGE THEM

• Sustainability of water supply

• Geology of confining zones

• Well bore construction

• Chemicals and flow back water handling
Potable Waters

Drilled with fresh water

4.5” Frac String

Cement

Packer

• 9 5/8” surface casing
• cement
• 7” production casing
• cement
• 4.5” liner & frac string
  • 30-40 swell packers
  • sliding sleeves
= 5 layers of protection

Upper Bakken Shale
Middle Bakken 10,000’
Lower Bakken Shale
Industrial Commission Regulation

- Well construction for Hydraulic fracturing
  - Failure rate one well/month
- Collaborative rule making process
  - Two cemented casing strings required
    - Frac string liner considered best practice
  - Pressure testing and monitoring required
  - Casing and cement evaluation required
    - Failure rate is zero with these requirements
- Well plugging and abandonment
In North Dakota state inspectors witness every well plugging
FOUR AREAS OF RISK
HOW WE MANAGE THEM

• Sustainability of water supply
• Geology of confining zones
• Well bore construction
• Chemicals and flow back water handling
In North Dakota frac chemicals must be posted within 60 days of pumping.
In North Dakota frac chemicals must be posted within 60 days of pumping.
• **Compound**
  
  – **Purpose**
    
    • **Common application**

• **Fresh Water** – 80.5%

• **Proppant** – 19.0%
  
  – Allows the fractures to remain open so the oil and gas can escape
    
    • Drinking water filtration, **play ground sand**

• **Acids** - 0.12%
  
  – Help dissolve minerals and initiate fractures in rock (pre-fracture)
    
    • **Swimming pool cleaner**

• **Petroleum distillates** – 0.088%
  
  – Dissolve polymers and minimize friction
    
    • **Make-up remover**, laxatives, and candy

• **Isopropanol** – 0.081%
  
  – Increases the viscosity of the fracture fluid
    
    • **Glass cleaner**, antiperspirant, and hair color

• **Potassium chloride** – 0.06%
  
  – Creates a brine carrier fluid
    
    • **Low-sodium table salt substitute**

• **Guar gum** – 0.056%
  
  – Thickens the water to suspend the sand
    
    • **Thickener used in cosmetics**, baked goods, ice cream, toothpaste, sauces, and salad dressing

• **Ethylene glycol** – 0.043%
  
  – Prevents scale deposits in the pipe
    
    • **Automotive antifreeze**, household cleansers, deicing, and caulk
• Sodium or potassium carbonate – 0.011%
  – Improves the effectiveness of other components, such as cross-linkers
    • Washing soda, detergents, **soap**, water softeners, glass and ceramics
• Sodium Chloride – 0.01%
  – Delays break down of the gel polymer chains
    • **Table Salt**
• Polyacrylamide – 0.009%
  – Minimizes friction between fluid and pipe
    • **Water treatment**, soil conditioner
• Ammonium bisulfite – 0.008%
  – Removes oxygen from the water to protect the pipe from corrosion
    • Cosmetics, **food and beverage processing**, water treatment
• Borate salts – 0.007%
  – Maintain fluid viscosity as temperature increases
    • Used in laundry **detergents**, hand soaps and cosmetics
• Citric Acid – 0.004%
  – Prevents precipitation of metal oxides
    • **Food additive**; food and beverages; lemon juice
• N, n-Dimethyl formamide – 0.002%
  – Prevents the corrosion of the pipe
    • Used in **pharmaceuticals**, acrylic fibers and plastics
• Glutaraldehyde – 0.001%
  – Eliminates bacteria in the water
    • **Disinfectant**; Sterilizer for medical and dental equipment
Industrial Commission Regulation

- Water flow back after frac
  - Storage in open pits prohibited
  - Disposal wells permitted through Underground Injection Program
- Disposal zone is 1/2 mile below potable waters with impermeable shale between and >2 miles above seismic zone with many layers including salts between
Sedimentary Rocks of Western North Dakota

- Fresh Water Zone
- Shallow Gas Zone
- Dakota Group
  - Spearfish Formation
  - Tyler Formation
  - Madison Group
  - Bakken-Three Forks
  - Prairie Formation
  - Red River Formation
  - Precambrian Basement

- Fresh water Disposal
- Shale Formations
- Seismic zones

- Piper Formation: Dunham Salt
- Spearfish Formation: Pine Salt
- Opeche Formation: Salt A
  - A Salt
  - D Salt
  - F Salt
- Charles Formation: D Salt
- Prairie Formation: Prairie Salt
The handling of flow back water can be carefully controlled:

- License truckers as waste haulers
- Use GPS to track trucking
- Underground disposal zone(s) must be separated from drinking water and seismic zones
- Recycling of water must be encouraged
Health Department Regulation

- Cleanup of discharges to environment
- Coordinate with local Emergency Managers
- Emergency Planning and Community Right-to-know Act (EPCRA)
  - Congress passed for storing and handling of chemicals
  - Requires material safety data sheet (MSDS) for each chemical on location
1975

Two Movies
About 2.4 million viewers
Over 200 million tickets sold
Which movie would you rather watch?

Which should guide how we manage sharks and beaches?