Enhanced Oil Potential at the Grieve Field, Natrona County, Wyoming

SEPTEMBER 2010
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Wind River Basin; Infrastructure

- Extensive oil, gas, some CO₂ pipeline network

Grieve-CO₂ Flood EOR

- Ryder Scott confirmed 3P reserves of 18.6 million barrels in April 2008
- Extensive negotiations (2006-2008) with parties who currently emit, sell or use CO₂
- Attempts to secure suitable CO₂ contracts were unsuccessful

Grieve-Chemical Flood EOR

- Preliminary results encouraging for Grieve rocks/fluids
- Started extensive program of laboratory testing and field development planning with Surtek Inc. started in December 2008
- Ryder Scott confirmed 2.39 MMBO P2 reserves and 2.43 MMBO P3 reserves, in July 2010.
- **Cumulative Production:**
  - $\approx 30$ Million Barrels Oil,
  - $\approx 73.5$ BCF Gas, and
  - $\approx 34$ Million Barrels Water
- Peak production in 1960: over 12,000 BOPD
- **OOIP**
  - $\approx 75$ Million Barrels (Nitec history match number).
- Therefore only $\approx 40\%$ oil recovery to end 2009.
- Never water flooded
- One well currently producing (around 10 BOPD)
Stratigraphic trap in the Lower Cretaceous Muddy Sandstone

- 6,800 feet average reservoir depth
- Reservoir thickness ranges from 0 to 90 feet
- 30 wells have core data. Large data set to build reservoir model and provide high confidence level in projections
Muddy Sandstone Outcrop Northwest of Grieve

Muddy B
Planar Laminate
Sandstone, Fine Grained

Muddy A
Cross-Bedded Sandstone, Massive appearance, Fine grained
The Muddy Sandstone Section is Completely Oil Saturated
Wyoming Stratigraphy: Second to None

Very few places in the World can you produce a reservoir and within 20 miles explore the stratigraphic relationships at the outcrop scale.
Stratigraphic Trap
- Thins and pinches out up-dip
- Average Dip: 15°
- Moderately well defined Gas/Oil contact but poorly defined Oil/Water contact

Reservoir Properties
- Porosity: 20.4%; permeability: 220 md
- Average Thickness: 45 feet
- These indicate excellent reservoir characteristics for an EOR project
- Original Hydrocarbon Column:
  - Oil – 700 feet; Gas – 900 feet

Production
- Oil gravity –37° API
- Drive Mechanism - Gas cap expansion and partial flank water drive
Grieve Field: Gross Sand Map

- A Southeast to Northwest trending incised valley system
- Field developed in an meander loop of the valley system
- 15° regional dip to the Northeast creates the trap
- Maximum sand thickness of 90 feet is seen at the Northwest side of the field
Grieve Unit: Outline and Pipeline Infrastructure
Ternary view of oil, gas, and water distributions after 27 months of CO$_2$ injection followed by 21-month injection/production in Scenario 3, top view (left) and bottom view (right).
# Nitec: EOR Sensitivity Groups

## Repressure Strategy

<table>
<thead>
<tr>
<th>Q_000</th>
<th>Q_001</th>
<th>Q_002</th>
<th>Q_003</th>
<th>Q_004</th>
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<tbody>
<tr>
<td><strong>Incremental Np@2035 (MSTB)</strong></td>
<td>18,924</td>
<td>18,430</td>
<td>16,401</td>
<td>972</td>
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<tr>
<td><strong>Incr Recovery (% of OOIP)</strong></td>
<td>28.0%</td>
<td>27.3%</td>
<td>24.3%</td>
<td>1.4%</td>
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<tr>
<td><strong>CO2 Purchased (MMSCF)</strong></td>
<td>170,932</td>
<td>157,794</td>
<td>252,229</td>
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<tr>
<td><strong>CO2 Injected (MMSCF)</strong></td>
<td>748,960</td>
<td>707,754</td>
<td>746,377</td>
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<tr>
<td><strong>CO2 Utilization (MSCF/STB)</strong></td>
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<td>8.6</td>
<td>15.4</td>
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<tr>
<td><strong>Time to Oil Peak Rate (months)</strong></td>
<td>48</td>
<td>47</td>
<td>57</td>
<td>226</td>
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<tr>
<td><strong>Peak Oil Rate (STB/D)</strong></td>
<td>10,000</td>
<td>9,700</td>
<td>9,300</td>
<td>247</td>
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<tr>
<td><strong>Np @ fifth year (MSTB)</strong></td>
<td>6,838</td>
<td>5,065</td>
<td>2,423</td>
<td>0</td>
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<tr>
<td><strong>Time to First Oil Prod (100 STB/D)</strong></td>
<td>22</td>
<td>32</td>
<td>39</td>
<td>131</td>
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</table>

## Purchase and Gas Processing Limits

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<tr>
<th>Q_005</th>
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<td><strong>Incremental Np@2035 (MSTB)</strong></td>
<td>13,925</td>
<td>18,924</td>
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<tr>
<td><strong>Incr Recovery (% of OOIP)</strong></td>
<td>20.6%</td>
<td>28.0%</td>
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<tr>
<td><strong>CO2 Purchased (MMSCF)</strong></td>
<td>128,181</td>
<td>170,932</td>
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<tr>
<td><strong>CO2 Injected (MMSCF)</strong></td>
<td>502,023</td>
<td>748,960</td>
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<tr>
<td><strong>CO2 Utilization (MSCF/STB)</strong></td>
<td>9.2</td>
<td>9.0</td>
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<td><strong>CO2 Injection (MSCF/STB)</strong></td>
<td>36.1</td>
<td>39.6</td>
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<td><strong>Time to Oil Peak Rate (months)</strong></td>
<td>58</td>
<td>48</td>
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<tr>
<td><strong>Peak Oil Rate (STB/D)</strong></td>
<td>6,400</td>
<td>10,000</td>
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<tr>
<td><strong>Np @ fifth year (MSTB)</strong></td>
<td>1,793</td>
<td>6,838</td>
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<tr>
<td><strong>Time to First Oil Prod (100 STB/D)</strong></td>
<td>42</td>
<td>22</td>
</tr>
</tbody>
</table>
CO2 EOR: Cumulative Oil Production by Injection Volume Scenario

Purchase/Production 110/200 MMCF/D
Purchase/Production 75/150 MMCF/D
Purchase/Production 50/100 MMCF/D
Purchase/Production 25/50 MMCF/D
Chemical Flood Process

- Injects chemical “soup” mixed with water into injection wells
- Chemicals reduce the interfacial tension between the rock and the oil and move fluid towards production wells
- Fluids are separated at surface; chemicals are re-used

ASP Chemical Flood

- **Alkalis;** React with oils to produce natural surfactants
- **Surfactants;** Reduce interfacial tension between oil and water. Mobilize oil and reduce oil content remaining in reservoir rock. Mix with polymers to contact additional oil in reservoir
- **Polymers;** Increase viscosity of injected water. Improve sweep efficiency. Divert water from high permeability zones to aid additional oil recovery
Chemical Flood Analog 1 – Thompson Creek

- Located in the Northern Powder River Basin
- Muddy sand channel trending NE to SW
- Down-dip to the Northwest
- Stratigraphic Trap

- Chemical formulation and simulation conducted by Surtek in 2003
- AP Chemical Flood initiated in 2004
- Production increased from 60 BOPD to 600 BOPD
Chemical Flood Analog 2 – Cambridge Field

- Located in the Northern Powder River Basin
- Minnelusa Stratigraphic Trap
- Down-dip to the Southwest

- Chemical formulation and simulation conducted by Surtek
- ASP Chemical Flood initiated in February 1993
- In 6 months production increased from 100 BOPD to 1000 BOPD
Surtek undertook a pilot flood of a fresh Grieve field core and developed a full field simulation

- **Initial Assessment of Grieve**
  - Good chemical flood prospect
  - Phased development proposed

- **Fluid Test**
  - Examined chemicals’ effects on Grieve oil & water & rock
  - Interfacial tension reductions, phase behavior determined

- **Linear Flood**
  - Examines viscous effects of chemicals on fresh reservoir rock

- **Radial Flood**
  - Simulation of reservoir recoveries using produced water and then chemicals (complete by mid December 2009); 10% to 60% incremental recovery for this core material

- **Model Simulation**
  - History match to confirm model and OOIP (end Dec. 2009)
  - Forecast production from the chemical flood (Feb 2010)
Chemical Flood Pilot

Radial Corefloods

The Optimum Chemical Combination is Defined in Radial Corefloods

- Retainer ring
- Injection
- Pressure monitors
- Radial Coreflood
- Production
- Core sample
- Bladder

Additional Recovery

Cumulative Produced Fluids (PV)

SURTEK
Drilled the GU #39A in July 2009 to recover fresh core for laboratory analysis

Conducted fluid/fluid analysis with produced waters and oil

Conducted linear core floods to determine initial chemical and rock compatibility

Conducted 16 radial core floods to fine tune the chemical mix and define the inputs for the full field simulation model
## Grieve Field: ASP Recoveries

### Table of Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Average of 16 Core Floods</th>
<th>Average of 8 Core Floods with Specified Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Permeability</td>
<td>milli darcy</td>
<td>273</td>
<td>257</td>
</tr>
<tr>
<td>Initial Oil Saturation</td>
<td>pore volume</td>
<td>0.743</td>
<td>0.739</td>
</tr>
<tr>
<td>Residual Oil after Waterflood</td>
<td>pore volume</td>
<td>0.408</td>
<td>0.395</td>
</tr>
<tr>
<td>Waterflood Recovery</td>
<td>% of OOIP</td>
<td>45.2%</td>
<td>46.6%</td>
</tr>
<tr>
<td>Residual Oil after Chemical Flood</td>
<td>pore volume</td>
<td>0.301</td>
<td>0.277</td>
</tr>
<tr>
<td>Chemical Flood Recovery</td>
<td>% of OOIP</td>
<td>14.4%</td>
<td>16.0%</td>
</tr>
</tbody>
</table>

### Diagram:

- **Waterflood**
- **Chemical Flood**

### Note:

The diagram illustrates normalized cumulative oil recovery and produced fluids for both waterflood and chemical flood conditions.
Original oil in place (Green outline) is 68.4 MMSTBO (whole field)

Area involved in the proposed development Stages 1, 2, 3 and 4 only (Purple outline) contains 36.9 MMSTB OOIP (flooded area)

Therefore just over half of the Original Oil in Place is presently targeted by Stages 1, 2, 3 and 4 of the Grieve Development Plan

Development Plan

- Build a central ASP injection facility capable of injecting 15,000 BFPD
- 4 Stage approach to field development, moving from north to south
- Focus effort on the original oil leg of the reservoir
- Utilize as many of the existing wells and infrastructure as possible and minimize new drilling
- CAPEX estimate for Stages 1 US$17.5 MM
  Stages 2-4 estimate $10.1 MM (self funding)
- Minimize capital expenditures
Grieve Field: ASP Injection Plant Designed by Fabrication Technologies of Casper

SODA ASH + DRY POLYMER BUILDING

INJECTION PUMPS

POLYMER AND INJECTION PUMP BUILDING
Each Stage will inject ASP for 1 to 2 years

ASP injection will be followed by polymer injection for 1.5 years to increase sweep efficiency

Final stage of injection is only water

Peak production is achieved in 2013 at 2,200 BOPD

Total recovery within the prescribed 4-stage field development plan is 5.8 million barrels of oil

• represents an incremental 16% recovery of OOIP within the swept area
Grieve Field: Project Economics*

Elk Economics

- Maximum drawdown allows for purchase and refurbishment of pipeline
- NPV\textsubscript{10}: $62.8\,\text{MM}$
- Net Payout Date: 01/2013
- Rate of Return: 53%
- Return on Investment: 5.74

Ryder Scott Reserves and Valuation

Probable 2,921\,\text{MBO} \quad \text{NPV}_{10} 64.882\,\text{MM}\$ 

Possible 2,972\,\text{MBO} \quad \text{NPV}_{10} 34.667\,\text{MM}\$ 

* All values are in US$