TREATMENT OF SHALE GAS PRODUCED WATER FOR DISCHARGE

Technical Workshops for the Hydraulic Fracturing Study
Water Resources Management
March 29-30, 2011

David Alleman, ALL Consulting, LLC
ACKNOWLEDGEMENT

• Much of the information is derived from a project that was funded by DOE’s National Energy Technology Laboratory (NETL)

• Part of NETL’s program to promote domestic natural gas production by providing technologies to overcome the technical and environmental challenges associated with unconventional resources.
**INTRODUCTION**

- Managing produced water from shale gas wells can be a challenge
- Management and treatment decisions depend on many variables and are inter-related
- Treatment can alleviate some disposal issues
- Treatment options are limited by cost, treatment capabilities, and availability
PW MANAGEMENT OPTIONS

• Three Basic Options
  – Injection
  – Surface Discharge/Beneficial use
  – Reuse in HVHF

• All options have challenges

• All options may require some level of treatment
Treatment Goals

• Three primary treatment goals
  – Reduce TDS (desalination) for discharge/beneficial use
  – Reduce volume for disposal
  – Reduce TDS, scaling, and/or bio-fouling for reuse or UIC
**TREATMENT CHALLENGES**

- Shale gas produced water quality varies
  - Between plays
  - Within plays
  - Over time

- High Total Dissolved Solids (TDS) concentrations limit treatment options

- All treatment processes result in a waste stream – may be liquid, solid, or both

- Treatment in the field is very different than the lab

- All of the PW management options and treatment goals may be inter-related
# Shale Gas PW Quality/Variation

<table>
<thead>
<tr>
<th>Play</th>
<th>Range of TDS (mg/L)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett</td>
<td>500 – 200,000</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>3,000 – 80,000</td>
</tr>
<tr>
<td>Haynesville</td>
<td>500 – 250,000</td>
</tr>
<tr>
<td>Marcellus</td>
<td>10,000 – 300,000</td>
</tr>
</tbody>
</table>

*TDS Concentrations gathered from a combination of various published reports and personal conversations with operators.*
LOGISTICS/PRACTICAL CONSIDERATIONS

• Sources of PW change over time as new wells are drilled and development expands over an operator’s lease-holdings

• Treatment facility location:
  – Mobile?
  – Permanent?
  – Semi-permanent? - Most common

• Treatment facility ownership:
  – Commercial?
  – Owned and run by operator?
  – Contracted by operator? - Most common
Management/Treatment Drivers

- Social/Community
- Environmental
  - Conservation of Resources
  - Aquatic Impacts
- Regulatory
- Economic
  - Cost of withdrawals
  - Cost of transportation
- Technical
  - Lack of injection capacity
  - Treatment limitations
  - Treatment availability
- Company policies
INJECTION

Benefits:

• Can be a low-cost option
• Well-established and (mostly) widely accepted disposal method
• Several States encourage as the preferred option

Challenges

• Limited UIC well capacity/locations in some shale plays
• Lack of near-by wells creates transportation issues
DISCHARGE/BENEFICIAL USE BENEFITS

- Returns water to the local ecosystem
- Reduces disposal volume
- Can help community relations
- Can be a cost-effective management option
DISCHARGE/BENEFICIAL USE CHALLENGES

• Treatment required
• Shale gas produced water not conducive to most beneficial uses
  – Small volume/well with scattered sources
  – Water production is episodic and moves over time
• Disposal of treatment concentrate
• Changing regulatory requirements
• Potential environmental/liability issues
**REUSE**

**Benefits:**
- Reduced withdrawals (and associated concerns)
- Reduced Disposal needs
- Reduced environmental concerns

**Challenges**
- Blended water must be suitable for fracture fluid
- May require treatment for TDS, scale, microbes
- Not necessarily a “no-treatment” option
Mixing and Scale Affinity Model

- Predicts chemical composition of mixed waters, allowing the user to see how waters will react when mixed
- Analyzes the mixing of multiple source waters, identifies the affinity for scale formation and the potential species of scale that will be formed
- Identify the most favorable mix ratio of available waters to meet specified targets for quality parameters – create an engineered water
- www.all-llc.com/projects/produced_water_tool/
TREATMENT FOR DISCHARGE

Available Technologies
• Thermal Distillation
• Reverse Osmosis
• Will also briefly mention Thermal Evaporation

Pre-Treatment/Conditioning
• Remove suspended solids and organics, adjust pH, etc.
• Each of these technologies require some pre-treatment
  – Handled by vendors as part of their system
  – Discussed in other presentations
**THERMAL DISTILLATION**

- Mechanical Vapor Recompression (MVR)
- Condenses steam for reuse
- Corrosion/scale can be problems
- TDS up to about 200,000 mg/L
- Fresh water recovery rates of 50 – 90%
- Costs range from $3.00 to $5.00/Bbl
**Reverse Osmosis (RO)**

- Force water through an osmotic membrane
- Pre-treatment to prevent premature membrane fouling is critical
- Membrane replacement costly
- TDS up to about 50,000 mg/L
- Fresh water recovery rates of 40 – 90%
- Costs range from $0.42 to $3.50/Bbl
Vendor Costs and Capabilities

- Vendors have limited operating experience/data for shale gas produced water
- Cost and capability data developed in the lab or in other industries may not be valid
  - Produced water quality variability
  - High TDS
  - Field Conditions
- Even when there is no intent to deceive, lack of consistent information on what is included in a quoted cost makes cost comparisons difficult
  - CAPEX/OPEX, Transportation, Disposal of reject water, etc.
- Vendors are constantly improving their processes as they gain experience
Volume Reduction

May want to reduce the volume that must be transported to UIC wells

• Thermal Distillation
• Reverse Osmosis
• Thermal Evaporation
  – Reduce liquid volume
  – Dispose of concentrate
• Crystallization
  – No limit on TDS
  – Zero Liquid Discharge
  – Dispose of solids
**Treatment Availability**

- Availability varies by basin
- New vendors entering the market almost daily
- Several pilots underway/planned

- Treatment for shale gas PW remains in its infancy
## Thermal Availability

<table>
<thead>
<tr>
<th>Treatment Vendor</th>
<th>Shale Gas Play</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marcellus</td>
</tr>
<tr>
<td></td>
<td>Barnett</td>
</tr>
<tr>
<td></td>
<td>Haynesville</td>
</tr>
<tr>
<td></td>
<td>Fayetteville</td>
</tr>
<tr>
<td></td>
<td>Woodford</td>
</tr>
<tr>
<td><strong>Thermal Distillation/Evaporation</strong></td>
<td></td>
</tr>
<tr>
<td>212 Resources</td>
<td>✓</td>
</tr>
<tr>
<td>Fountain Quail</td>
<td>✓</td>
</tr>
<tr>
<td>Aquatech</td>
<td>✓</td>
</tr>
<tr>
<td>Veolia</td>
<td>✓</td>
</tr>
<tr>
<td>INTEVRAS</td>
<td>✓</td>
</tr>
<tr>
<td>GE Water &amp; Process Tech.</td>
<td>✓</td>
</tr>
<tr>
<td>Total Separation Solutions</td>
<td>✓</td>
</tr>
</tbody>
</table>
## RO Availability

<table>
<thead>
<tr>
<th>Treatment Vendor</th>
<th>Shale Gas Play</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marcellus</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td></td>
</tr>
<tr>
<td>GeoPure</td>
<td></td>
</tr>
<tr>
<td>Siemens</td>
<td>✓</td>
</tr>
<tr>
<td>GPRI</td>
<td></td>
</tr>
<tr>
<td>Auxsol</td>
<td></td>
</tr>
<tr>
<td>Veolia</td>
<td>✓</td>
</tr>
<tr>
<td>MI SWACO</td>
<td>✓</td>
</tr>
<tr>
<td>Ecosphere</td>
<td></td>
</tr>
<tr>
<td>GE Water &amp; Process Tech.</td>
<td></td>
</tr>
<tr>
<td>Innovative Water Solutions</td>
<td></td>
</tr>
</tbody>
</table>
Key Points

• The decision to treat shale gas produced water for surface discharge is based on many inter-related considerations
• Shale gas PW has high TDS concentrations that require desalination prior to discharge
• Treatment for discharge options are effectively limited to Thermal Distillation and Reverse Osmosis.
• Cost data for many vendors is limited/unproven
• Technology Availability is limited/unproven
• Treatment technologies are advancing and changing
Contact Information

David Alleman
dalleman@all-llc.com
ALL Consulting
1718 S. Cheyenne Avenue
Tulsa, Oklahoma 74119

To cite this presentation:
THERMAL DISTILLATION

Produced Water

Pretreatment

Discharge Or Reuse

Distilled Water

Clean Brine

Concentrate

UIC Disposal

Discharge Or Reuse

Steam

Heat and Pressure

Concentrate

Discharge Or Reuse

Or Reuse
Reverse Osmosis (RO)

Produced Water

Pretreatment

Clean Brine

Clean Water

Concentrate to UIC Disposal

Discharge Or Reuse