Brackish Water as a New Water Resource For Developing Domestic Energy

Overview

• Energy issues with water and its associated costs for development
  – Drought conditions are requiring the investigation of different water sources
  – Water required for unconventional plays for oil and gas – 60,000 to 650,000 gals per well for drilling
  – Water required for hydraulic fracturing of 3.5 MG to 5 MG per well
• Is the drought in western US an issue with energy development?
• What issues need to be solved in the future?
Discussion Outline

- Introduction
- Volumes and Quality of water required for energy development
- Water conflicts with energy development
- Role of agriculture
- Cost implications
- Summary

The global situation for water is not improving and will be an impediment to industrialized growth over time.

Global Water Supply

- 28.0% Water for human use
- 26.0% Water for industry
- 6.0% Water for agriculture
- 5.0% Water for energy
- 0.0% Water for other uses
- 97.0% Water for non-human uses

Areas of physical and economic water scarcity

- Shortage of freshwater
- Saline water scarcity
- Skewed distribution water scarcity
- Economic water scarcity
- Risk estimation
Water Use as a Function of Overall Water Management

- What is the percentage of total fracking and energy development = 0.14% of total use in the US typical - (example is Colorado)
- Largest use is Agricultural at 85%
- Second highest use is Municipal and Industrial at 7%
- All others is 8%
- This 0.14% equals the amount of water used on an annual basis by the City of Denver.

So what is the issue? Can't we get more water from Agriculture?

- Agricultural use is increasing
- Environmental groups are fighting fracking and energy development in general
- Agricultural use has to increase
- Issue with the Sacramento River Delta
- Municipal uses are increasing
- Oil and Gas can out bid all others
- Water from Agriculture or Municipalities will be a public relations nightmare
Example of Projected Water Shortages

- Areas of red are water short
- Note that in the western US, there is an opportunity to utilize produced water for beneficial use

Reference: USBR - Water 2025 Study

Where can we get new water for energy development?

- Brackish water – 1,000 to 10,000 ppm of TDS
- Treatment up to 75,000 ppm
- Produced water reuse – discussed in another presentation on Wednesday
- Reuse of other types of wastewaters

**General Categories of Saline Water**

<table>
<thead>
<tr>
<th>Category</th>
<th>PPM Range</th>
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</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>Less than 1,000 ppm</td>
</tr>
<tr>
<td>Slightly saline water</td>
<td>From 1,000 to 3,000 ppm</td>
</tr>
<tr>
<td>Moderately saline water</td>
<td>From 3,000 to 10,000 ppm</td>
</tr>
<tr>
<td>Highly saline water</td>
<td>From 10,000 to 35,000 ppm</td>
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</table>

*Ocean water contains about 35,000 ppm of salt.
Brackish Water in the US

- Efforts to find new untapped water supplies in the US
- NAS study on desalination
- Constraints are not the technology, but the financial, environmental and social factors
- Participation is needed by all in the development of this resource to limit any significant issues associated with this treatment

Produced water can be as high as salt saturation at 320,000 mg/l
Inland Desalination a Now-Attainable Solution

These aquifers extend into Mexico as well.

Depth to Brackish Groundwater

At a depth of less than 500 feet, the cost per bbl is less than $0.05 for pumping.

Oil, Gas and Coal Basins

- Opportunity to convert produced water disposal cost to new water supply

Drought Projections in North America

- Data from UN
- Note the movement of water to the north due to climate change predictions
Problem

- Drought is still a significant issue
- Energy Development can demand water in short supply

What is the impact of the drought on energy production - Texas Example

- Availability of water in Permian Basin with extended drought
  - Colorado River basin issues
  - Municipal water supplies are stretched already
    - Lake JB Thomas 0.50% full (0.1% 6 months ago)
    - EV Spence Reservoir 5.1% full (0.2% 6 months ago)
    - OH Ivie Reservoir 20.7% full
- Requirement for District is to supply water for drinking and public safety – water for E&P operations is not a concern and very limited at this point
- “If you don’t have water, you can’t attract industry”
  - Guy Andrews – Economic Development Director – Odessa, Texas

*U.S. Drought Monitor* June 18, 2013

Available online: http://droughtmonitor.unl.edu/
Water supply is a limiting factor to industry
• Demand leads to increased willingness to pay for water
• Improvements in treatment technologies lead to reduced costs (both capital and O&M)
• Convergence of these factors leads industry to source alternative lower quality water
• New opportunities are created in processing and appropriating water to highest and best use.

Discussion regarding the water – energy – agricultural nexus

Water Resources May be Augmented by New Technology
“The single most frequent failure in the history of forecasting has been grossly underestimating the impact of technologies”

Peter Schwartz from The Art of the Long View
Hierarch of the Nation’s Water Solution Toolbox

Technology - Benefits of Desalination of Brackish Water

- Easier to treat that reuse from produced water or hydraulic flowback water
- Increased supply from non-traditional sources
- Drought proofing – does not depend on the climate changes that are likely to occur
- Local control
- Regional redundancy, security – transportation is reduced
- High quality supply
- Reduced costs, improved technology
- Avoid competition for limited water sources (agricultural, urban, environmental)
Heavy Metal Removal – Ceramic Microfiltration Presentation

<table>
<thead>
<tr>
<th>Water Supply Options</th>
<th>Cost (US $/1,000 gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Mgmt/Repair leaks</td>
<td>$0.38 – 2.65</td>
</tr>
<tr>
<td>Desalination of Brackish water</td>
<td>$0.75 – 1.50*</td>
</tr>
<tr>
<td>Wastewater reuse &amp; Produced Water Reuse</td>
<td>$0.38 – 3.75</td>
</tr>
<tr>
<td>Long distance transfer</td>
<td>$1.15 - $3.75</td>
</tr>
<tr>
<td>Desalination of Sea Water</td>
<td>$2.25 – 3.60</td>
</tr>
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</table>

* Very dependent on chemical make up of brackish water

Impaired / Brackish Water – Highest & Best Use

Current Best Uses of Brackish / Impaired Ground Water
- Energy Exploration Water
- Industry
- Power Production
- Drought Reserve
- Agriculture

Current Best Uses of Produced Water
- Energy Exploration Water
- Industry
- Agriculture

Portfolio of Water Rights is the key to success – brackish water can be part of the portfolio
Most Common Core Treatment Technologies

Desalination Processes

- Thermal (Distillation)
  - Multistage-Flash Distillation (MSF)
  - Multi Effect Distillation (MED or ME)
  - Vapor Compression (VC)
  - Solar Distillation

- Membrane
  - Reverse Osmosis (RO)
  - Electrodialysis (ED)

Thermal vs Membrane Desalination
(NAS, 2007)

Bruce Thomson
Dept. of Civil Engineering
University of New Mexico
Inland Impaired Brackish Water vs. Seawater

- Inland Waters are new frontier, seawater is relatively defined
- Major differences include:
  - Treatment & Recovery Objectives
    - Brackish can recover over 90% of the water – 10% brine solution
  - Water Chemistry
    - Removal of scale formers in situ is the most important item for treatment
  - Brine Disposal Options
    - Recovery of rare earth minerals such as lithium

- Highest & Best Use may not include desalination / RO
- In a lot of projects, NF can be used in place of RO
- Removal of scale forming compounds
- Factors Limiting High Water Recovery:
  - Brackish inland water contains numerous ions
    - Anions: Sulfate, Fluoride, Carbonate…
    - Cations: Calcium, Strontium, Barium…
  - High Recovery concentrates ions through use of sequestration techniques
  - Salts precipitate at solubility
  - Osmotic pressure increases with recovery > applied pressure
Membrane Fouling

- Membrane Filtration Plants are challenged with fouling
- Colloidal, Inorganic, Organic, Biological
- Inorganic fouling is most challenging
- Colloidal particles are also important and can cause issues for membranes
- Inland impaired/brackish water may cause all four fouling types
- New treatment unit process designs can minimize issues
- Impaired / Brackish water chemistry is very dynamic
- No single process is ideal for all treatment

Variation of Water Types

<table>
<thead>
<tr>
<th>Composition</th>
<th>Seawater Reference</th>
<th>Groundwater Tularosa Basin, NM</th>
<th>Groundwater Las Vegas, NV</th>
<th>Groundwater Huco Bolson, TX</th>
<th>Wastewater Plant Stream Rio Rancho, NM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>10000</td>
<td>114</td>
<td>755</td>
<td>116</td>
<td>150</td>
</tr>
<tr>
<td>K</td>
<td>300</td>
<td>2</td>
<td>72</td>
<td>7</td>
<td>25</td>
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<tr>
<td>Ca</td>
<td>410</td>
<td>420</td>
<td>576</td>
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<td>Cl</td>
<td>19400</td>
<td>170</td>
<td>954</td>
<td>202</td>
<td>142</td>
</tr>
<tr>
<td>NO₃</td>
<td>NR</td>
<td>30</td>
<td>31</td>
<td>NR</td>
<td>79</td>
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<tr>
<td>PO₄</td>
<td>NR</td>
<td>0</td>
<td>NR</td>
<td>NR</td>
<td>20</td>
</tr>
<tr>
<td>SO₄</td>
<td>2710</td>
<td>1370</td>
<td>2290</td>
<td>294</td>
<td>110</td>
</tr>
<tr>
<td>HCO₃</td>
<td>143</td>
<td>270</td>
<td>210</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>SiO₂</td>
<td>2.1</td>
<td>22</td>
<td>77</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>TDS</td>
<td>35340</td>
<td>2630</td>
<td>5270</td>
<td>1200</td>
<td>640</td>
</tr>
</tbody>
</table>
Requirements for hydraulic fracturing makeup water

- Texas A&M Study
  - Need to remove scale forming compounds
- Service companies claims for being able to use high TDS waters
- BP study on low TDS waters for higher recovery of oil/gas – Less than 5,000 ppm TDS

### Scale Forming Salts – Removal Targets

<table>
<thead>
<tr>
<th>Salt</th>
<th>Saturation Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Carbonate (CaCO$_3$)</td>
<td>8</td>
</tr>
<tr>
<td>Calcium Fluoride (CaF$_2$)</td>
<td>29</td>
</tr>
<tr>
<td>Calcium Orthophosphate (CaHPO$_4$)</td>
<td>68</td>
</tr>
<tr>
<td>Calcium Sulfate (CaSO$_4$)</td>
<td>650</td>
</tr>
<tr>
<td>Strontium Sulfate (SrSO$_4$)</td>
<td>148</td>
</tr>
<tr>
<td>Barium Sulfate (BaSO$_4$)</td>
<td>3</td>
</tr>
<tr>
<td>Silica, amorphous (SiO$_2$)</td>
<td>120</td>
</tr>
</tbody>
</table>
Difficult Issues for Water Reuse

- Control of scale formers
  - Barium sulfate
  - Calcium carbonate
  - Calcium sulfate (gypsum)
- Control of Salt
  - Discharge to water ways
  - Control of SAR (Sodium Absorption Ratio)
- Control of microbes
  - Difficult filtration issue
  - Sulfate reducing bacteria
- Water injection into Formation – TAMU study
- Water Discharge Issues – CSM RPSEA Study

Technical Challenges / Opportunities

- Energy Efficiency
  - Pressure recovery techniques
- Osmotic Pressure
  - Future can use Forward Osmosis
- Solubility & Scaling
  - Understanding high salinity precipitation is very important
- Membrane Process adjustment – highest & best use output
- Selective sequestration of salts and elements
  - Fundamental shift – salts/metals as a resource!
Current Brine Disposal Methods

• Inland –
  • Surface Water Discharge (reuse for energy and agriculture)
  • Evaporation Pond (air pollution issues in the future)
  • Class II Well (Deep Injection Well)
  • Land Application
  • Solid/Hazardous Waste Landfill
• Offshore –
  • Discharge to ocean (very limited in ability to discharge water to the ocean)

Beneficial Use of Brine / Recovered Materials

• Salt Commodities
  • NaCl, Na$_2$SO$_4$, Na$_2$NO$_3$, K$_2$SO$_4$, MgSO$_4$, KNO$_3$…
• Industrial Chemicals
  • Cl$_2$, NaOH……
• Aquiculture
  • California – recovery of gypsum for clay soils
• Solar Power
• Commodity Metals
Where does this lead us?

- Non-discharging facilities
- West Texas – SE New Mexico facility example
  - Capitan Reef
  - Need for water for energy production
  - Severe drought in the area
  - Public water supplies are limiting their water resources to only domestic use

Design Non-discharging Treatment Facilities

- Water saturated with gypsum
- Technology to remove saturated gypsum with RO and Ceramic Microfiltration (patented and trade secret)
- No Waste – water is sold and gypsum is recovered for sale to gypsum mining concern

SMU Conference, 2008, Prentice Creel, PE
Economics

- Economics is the key issue
  - Transportation costs will trump costs in most cases
  - This results in facilities needing to be near the energy development site to reduce costs

Connecting the Dots – Appropriation & Sale

Water Law
- Brackish groundwater – surface owner – brackish water in the western US
- Treatment of brackish water for agriculture and potentially for the Monterey Shale Project – Grasslands Basin Drainers project
- Tributary / Non-Tributary – Colorado example

Bottom Line
- Technology Choice is full dependant upon both input and output requirements
- The Market & Technical Drivers have both converged to enable considerable opportunity to those who connect the dots
Summary & Conclusions – What have we learned?

- Water use for E&P operations is critical to the future of the industry
- Brackish water and water treatment is a viable technology, especially in water short areas
- Brackish water can result in non-discharging facilities
- Brine reuse and recycling should be considered
- Harvesting of metals should be considered in the future to offset costs

Treatment – becoming more refined
- Customized to influent characteristics & output req.
- Mobile or Centralized depending on volumes and transportation
- Removal of scale forming compounds is key to success
  - Hardness & Metals
  - Carbonates
  - Silica
  - Barium
  - Sulfate/Carbonates
- If scaling compounds removed, water use may be achieved without TDS removal in some cases (sodium chloride)