Guidance for the Evaluation of Produced Water as an Alternative Water Supply

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- Identify potential “new water” sources:
  - brackish surface and groundwater
  - reclaimed wastewater
  - produced water
  - seawater

- Identify location, quantity, quality, and accessibility of water supply and demand

- Determine risk of water shortages and potential conflict

Saline Groundwater Resources USGS, W. Alley (2003) from Feth et al. (1965)
Produced Water Resources in the western United States

- Over 80% of oil and gas production occurs in the western US
- O&G industry water generation and water demand:
  - National produced water volumes > 2 billion gal/day
  - Hydraulic fracturing uses 500,000 gal to >10,000,000 gal of water per fracturing

API (2012), US Gas Shale Plays
Bureau of Reclamation

Where do we fit into produced water?

Western Water Portfolio

Existing Supply

Water Conservation

Produced water

Brackish water

Treatment of Impaired Waters

Wastewater

Seawater

Reclamation (2011), Conventional Oil and Gas
Reclamation Produced Water Management Reports

Science and Technology Program Report No. 157
Oil and Gas Produced Water Management and Beneficial Use in the Western United States

Science and Technology Program Report No.
Produced Water Treatment Primer for Oil and Gas Operations

Science and Technology Program Report No.
Guidance for the evaluation of produced water as an alternative water supply
I. Beneficial Use Opportunities
   • Production Locations
   • Water Quality Requirements
   • GIS Based Examples

II. Produced water characterization
   • Produced Water Volumes
   • Produced Water Quality

III. Water treatment technologies
   • Technology Assessments
   • Technology Comparison

ReclamationProduced Water Management Reports
Beneficial Use Opportunities in the western US

- Irrigation
- Livestock watering
- Stream flow augmentation
- Hydraulic fracturing
- De-icing fluids
- Industrial uses
- Emergency drought supplies

Reclamation (2011), Agricultural areas overlaid with O&G basins
## Produced Water Characterization

### Table 13. Common inorganic constituents in conventional produced water

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Low</th>
<th>High</th>
<th>Reference</th>
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<tbody>
<tr>
<td>TDS</td>
<td>mg/L</td>
<td>100</td>
<td>400,000</td>
<td>USGS produced water database</td>
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<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>0</td>
<td>150,000</td>
<td>USGS produced water database</td>
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<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>0</td>
<td>250,000</td>
<td>USGS produced water database</td>
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<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0</td>
<td>850</td>
<td>Fillo 1992</td>
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<tr>
<td>Strontium</td>
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<td>6,250</td>
<td>Fillo 1992</td>
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<tr>
<td>Sulfate</td>
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<tr>
<td>Bicarbonate</td>
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<td>15,000</td>
<td>USGS produced water database</td>
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<td>Calcium</td>
<td>mg/L</td>
<td>0</td>
<td>74,000</td>
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</table>

**Conventional Oil and Gas**

**Coalbed Natural Gas**
Water Treatment Technologies

• Pretreatment Technologies
  – Bioreactors and Membranes
  – Filtration and Floatation
  – Adsorption and Oxidation

• Desalination Technologies
  – Membrane Filtration
  – Thermal Processes
  – Electrodialysis

• Commercial Process Combinations
  – Veolia OPUS™
  – Higgins Loop™
I. Categorizing water treatment capabilities and performance
   • Describe technologies based on classification of mechanism
II. Technologies and applications
   • Development and implementation of water treatment technologies
III. Catalog of technologies
   • Provide operational experience and performance data when available
Categorizing Water Treatment Capabilities and Performance

Reclamation (2011), Technology Capabilities

<table>
<thead>
<tr>
<th>Technology</th>
<th>Emerging Technology</th>
<th>Previously Employed for Produced Water</th>
<th>Application Range</th>
<th>Overall TDS Rejection (%)</th>
<th>Overall Process Recovery (%)</th>
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<tr>
<td>Membrane</td>
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<td></td>
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<tr>
<td>NF</td>
<td>No</td>
<td>Yes</td>
<td>1,000 to 35,000</td>
<td>&gt; 99</td>
<td>60 to 80</td>
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<tr>
<td>RO</td>
<td>No</td>
<td>Yes</td>
<td>1,000 to 35,000</td>
<td>&gt; 99</td>
<td>30 to 60</td>
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<tr>
<td>ED/EDR</td>
<td>No</td>
<td>Yes</td>
<td>500 to 1,500</td>
<td>55 to 75</td>
<td>60 to 80</td>
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</table>

<table>
<thead>
<tr>
<th>Technology</th>
<th>Robustness¹</th>
<th>Reliability²</th>
<th>Flexibility³</th>
<th>Mobility⁴</th>
<th>Modularity⁵</th>
<th>Residual Disposal/Management</th>
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<tbody>
<tr>
<td>Membrane</td>
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<td>++</td>
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<td>++</td>
<td>Yes</td>
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</tr>
<tr>
<td>ED/EDR</td>
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<td>+++</td>
<td>+</td>
<td>++</td>
<td>Yes</td>
<td>+</td>
</tr>
</tbody>
</table>

¹ Excellent: +++  Good: ++  Fair: +  Poor: -
Common Challenges

- Variable water quality and quantity
- Removal of trace metals
- Minimize energy consumption
- Reduce chemical consumption
- Decrease concentrate/residuals
- Robust system designs
- Cost effective water treatment
- Flexible, mobile, modular systems
Reclamation Funding of Produced Water Treatment Technologies

- R&D efforts with commercialized technologies used in O&G
  - Altela Rain™ (Upper picture)
  - Freeze-thaw (Lower picture)
- Research areas of interest to O&G
  - Concentrate management
  - Zero liquid discharge
  - Mineral recovery
  - Membrane distillation
  - Forward osmosis
Catalog of Commercial Treatment Technologies

- Categorical technology classification
- Applicable contaminants removed
- Description of technology
- Example treatment train
- Examples of commercial technology manufactures
  - Technology surveys
  - Pilot and full scale applications of technology
Reclamation Produced Water Management Reports

I. Locations of opportunity
   • Regional GIS Mapping
   • Water Quantity Estimates

II. Supply/demand balance
   • Alternative water resource
   • Facilitating industry reuse

III. Water Treatment Plants
   • Matching Appropriate Technology
   • Developing/implementing innovative technologies
   • Demo/Pilot Study Examples
Locations of Opportunity

Information for water managers to assess:

- Production locations
- Produced volumes
- General water quality
- Potential water management opportunities:
  - Beneficial use
  - Conveyance systems
  - Disposal options
  - Facility co-location
Supply and Demand Balance

- Direct reuse of hydraulic fracturing flowback and produced water
  - Compatible with the producing formation
  - Available on-site (reduces transport cost)
  - Reduces disposal wells
- Brackish groundwater as an alternative to fresh water for fracturing
- Industrial/commercial reuse sources
  - Increased volume in water ways
  - Free/natural conveyance system
Existing Water Treatment Plants

Case Studies of Existing Hydraulic Fracturing Flowback and Produced Water Treatment Facilities

- Facility Description
- Location
- Feed Water
- Capacity
- Treatment Process
- Treated Water Use
- Concentrate Disposal
- Operational experience
- Performance data
- Permits

McKean County, PA
San Ardo, CA
Clarion County, PA
Wellington, CO
Pinedale, WY
Powder River Basin, WY
On-going Research Efforts

Collecting Information:

• **Published Studies** (Department of Energy, US Geological Survey, Argonne National Labs, National Energy Technology Laboratory, A&E)

• **Regulatory Guidelines** (Environmental Protection Agency Centralized Waste Treatment Facilities for Oil and Gas)

• **Reclamation Experience** (Missouri River Bakken Shale Fracturing Water Supply Agreements)

• **Commercial Treatment** (Commercial Technology Survey, Technology Evaluation at Reclamation Facilities)

• **Industry Collaboration** (Industry Water Management Expertise Survey, Produced Water Treatment Community of Practice)

Research Project Websites:
