Evaluation of Produced Water Reuse within and outside the Energy Sector

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Module 2: Produced Water Reuse in Unconventional Oil and Gas Operations

Module 3: Produced Water Reuse and Research Needs Outside Oil and Gas Operations
Will Water Issues Constrain Oil and Gas Production in the U.S.? YES

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KEYWORDS hydraulic fracturing, produced water, unconventional oil and gas, tight oil, shale oil, water reuse/recycling

Abstract:
Rapid growth in U.S. unconventional oil and gas made energy more available and affordable globally, but brought environmental concerns, especially related to water. We analyzed water-related sustainability of energy extraction focusing on: (a) meeting rapidly rising water demand for hydraulic fracturing (HF), and (b) managing rapidly growing volumes of water co-produced with oil and gas (produced water, PW). We analyzed historical (2009–2017) HF water and PW volumes in ~73,000 wells and projected future water volumes in major U.S. unconventional oil (semiarid regions) and gas (humid regions) plays. Results show a marked increase in HF water use, depleting groundwater in some semiarid regions (e.g. by ≤58 ft [18 m]/yr in Eagle Ford). PW from oil reservoirs (e.g. Permian) is ~15× higher than that from gas reservoirs (Marcellus). Water issues related to both HF water demand and PW supplies may be partially mitigated by closing the loop through reusing PW for HF of new wells. However, projected PW volumes exceed HF water demand in semiarid Bakken (2.1×) and Permian Midland (1.3×) and Delaware (3.7×) oil plays, with the Delaware accounting for ~50% of projected U.S. oil production. Therefore, water issues could constrain future energy production, particularly in semiarid oil plays.

- PW from oil reservoirs >> than that from gas reservoirs
- Permian PW = 50× Marcellus PW
- Reuse PW for HF
- Projected PW volumes = ~ 4× HF water demand in the Delaware
Highlights

• Irrigation demand exceeds produced water (PW) volumes by 5× in the U.S.
• PW volumes would not substantially alleviate overall water scarcity.
• PW quality is variable with salinity up to 7 that of seawater.
• Intensive treatment is required for PW use outside of energy.
• Knowledge gaps related to PW quality preclude reuse outside of energy.
U.S. ~20% of global total production in oil and gas
Unconventional production: 60% of U.S. oil and 70% of U.S. natural gas

Scanlon et al., ES&T, 2020
Oil plays in semiarid regions

Gas plays in humid regions

Scanlon et al., ES&T, 2020
Basic Questions

1. What is the potential for reusing produced water within and outside the energy sector based on historical data?

2. What is the potential for reusing produced water within and outside the energy sector based on projections?
Data Types
• Geology, hydrology
• Reservoir data
• Well completions
• Production

Historical Trends
• HF water
• Produced water

Future Projections
• Play lifetime HF, PW
• 2018-2050 Outlook

Impacts
• Water scarcity
• GW depletion
• PW management

Mitigation
PW reuse for HF

Scanlon et al., ES&T, 2020
HF water demand in the Permian is ~20% of water use in the play (excluding mining) in 2017.
Total Water Use for Hydraulic Fracturing by Play

HF water use increased by ~ 10× in Permian Basin (2011 – 2017)

Scanlon et al., ES&T, 2020
Total Lateral Length Drilled
= 4 x Earth’s circumference

Lateral length drilled peaked in 2017 in Permian and 2014 in many other plays

HF water use/foot of lateral

HF water use/length of lateral in Permian increased by 4× 2011 – 2017; ~300%

Scanlon et al., ES&T, 2020
HF water use (maximum annual): 3% to 22% of total non-mining water use (TWU; USGS 2015). HF water use in the Permian = 20% of water use in the play.

Scanlon et al., ES&T, 2020
Number of Water Wells Drilled to Supply Water for Hydraulic Fracturing

Total: 8,500 wells in the Permian; 2,500 wells in the Eagle Ford

Scanlon et al., ES&T, 2020
Produced water from oil plays generally much higher than that from gas plays.

PW in the Permian in 2017 = 50× PW in the Marcellus.

Oil plays produce much more water than gas plays

Need to keep drilling wells to maintain production

Scanlon et al., ES&T, 2020
Produced water is mostly managed using Saltwater Disposal Wells.

- **Bakken**: 740 wells
- **Permian**: 1,750 wells
- **Eagle Ford**: 336 wells
- **Haynesville**: 250 wells
- **Marcellus/Utica**: 11 wells in Pennsylvania

Scanlon et al., ES&T, 2020
Induced seismicity highest in Oklahoma attributed to deeper disposal and larger volumes relative to Bakken, Permian, and Eagle Ford.
Recent study: EQs related to HF in Delaware Basin

Lomax & Savvaidis, 2019
Earthquake Events ≥ Magnitude 2 (monthly data; USGS Source)

Seismicity increasing in the Permian and Eagle Ford plays
Main Findings:

High levels of seismicity in Oklahoma related to deep disposal of wastewater near the crystalline basement

Much lower levels of seismicity in the Bakken, Eagle Ford and Permian Basin plays related to shallow disposal of wastewater.

## Reducing Tradeoffs Between Shallow and Deep Disposal

<table>
<thead>
<tr>
<th>Shallow disposal</th>
<th>Deep disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could impact overlying aquifer</td>
<td>Little or no impact on aquifers</td>
</tr>
<tr>
<td>Impact oil well drilling (over-pressuring, extra casing)</td>
<td>Little or no direct impact on oil well drilling</td>
</tr>
<tr>
<td>Can impact oil production</td>
<td>Little direct impact on oil production</td>
</tr>
<tr>
<td>Less seismicity</td>
<td>More seismicity</td>
</tr>
<tr>
<td>Inexpensive, drill many</td>
<td>Under-pressured, high injectivity</td>
</tr>
<tr>
<td></td>
<td>Expensive, few wells, high rates</td>
</tr>
</tbody>
</table>
Potential for Reusing Produced Water for Hydraulic Fracturing
2009-2017 Billion gals

SWD = 8 × HF water use in OK

Source: US National Park Service
Temporal Variations in PW to HF Ratios by Play

Scanlon et al., ES&T, 2020
Options for Managing Produced Water

- Irrigation Use
- Municipal Use
- Industrial Use
- Surface Water Discharge
- Hydraulic Fracturing
- Groundwater Recharge

Produced Water
Irrigation = $5 \times PW$ (UOG)
Irrigation = $50 \times PW$ (CBM)
Produced Water Quality: Total Dissolved Solids

USGS Produced Waters Database

Literature
Produced Water Quality

Wolfcamp Reservoir

~200 points
Clean Brine for HF

Industri al Uses

Agricultural Uses

Groundwater recharge, potable uses

PW treatment costs increase with higher salinity in PW and product water quality improvement

Separation of oil, grease, suspended solids

Removal of target constituents (e.g., organics, Fe, Ba, Ca, Mg, Sr, SiO₂, SO₄, microbes)

Desalination - Removal of dissolved solids

Post-treatment and restabilization (e.g., B)

• Hydrocyclone
• Gas flotation
• Oil/Water separator
• Settling tank
• Media filtration (sand, walnut shell, etc)
• Cartridge filtration
• Membrane filtration

• Biological treatment
• Electrocoag. & flotation
• Adsorption (carbon, zeolite, etc)
• Chemical oxidation
• Disinfection (ClO₂, UV, etc)

• Disinfection (Cl₂, UV)
• Ion Exchange
• AOP
• pH adjust. & remineral.

Applicable TDS range (g/L)

N F
Basic Questions

1. What is the potential for reusing produced water for hydraulic fracturing based on historical data?

2. What is the potential for reusing produced water for hydraulic fracturing based on projections?
Projections of water demand for HF and produced water

Projections based on **Technically Recoverable Resource Development**: all potential future wells could be drilled using current technology over the life of the plays.


Scale: 1 square mile.
Historical and Projected Drilling Density at grid scale

Scanlon et al., ES&T, 2020
Projections based on Technically Recoverable Resource development

- Bakken 68,700 wells
- Eagle Ford 105,000 wells
- Midland Basin 113,000 wells
- Delaware Basin 207,000 wells
- Marcellus 124,000 wells

Projected Totals – Bgal

- Bakken: 440 Bgal
- Midland Basin: 1,900 Bgal
- Delaware Basin: 2,800 Bgal
- Permian: 1,400 Bgal

Permian: = 4,700 Bgal = ~14 maf
= TX total water use in 2017

Scanlon et al., ES&T, 2020
Projections based on Technically Recoverable Resource development

Bakken 69,000 wells

Marcellus 124,000 wells

Delaware Basin 192,000 wells

Midland Basin 106,000 wells

Eagle Ford 105,000 wells

Permian Basin: PW, 40 maf

= 3× TX total water use in 2017

Produced Water

Source: US Geological Survey

Scanlon et al., ES&T, 2020
Projected Produced Water at Grid Scale

Scanlon et al., ES&T, 2020
Ratio of Produced Water to Hydraulic Fracturing Water Demand

Scanlon et al., ES&T, 2020
Can we reuse PW for HF?

Bakken 69,000 wells
Projected Totals – Bgal

Marcellus 124,000 wells

Midland Basin 113,000 wells

Eagle Ford 105,000 wells

Delaware Basin 207,000 wells

Scanlon et al., ES&T, 2020
Can we reuse PW for HF?

**Projected Totals – Bgal**

- **Bakken 69,000 wells**
  - 950
  - 440

- **Marcellus 124,000 wells**
  - 1,380
  - 580

- **Midland Basin 113,000 wells**
  - 2,620
  - 1,960

- **Eagle Ford 105,000 wells**
  - 860
  - 300

- **Delaware Basin 207,000 wells**
  - 10,400
  - 2,850

**Scanlon et al., ES&T, 2020**
Subsurface Water and Energy Laboratory (SWEL)

Mission

Establish an understanding of the water cycle in all major U.S. unconventional plays developed using hydraulic fracturing (HF) through multiscale data and modeling, promote sustainable water management while minimizing adverse environmental impacts, and integrate water management with energy development scenarios through this proposed Subsurface Water and Energy Laboratory (SWEL) research consortium.
Main Findings

Produced Water Management

- Oil plays produce much more water than gas plays (Permian PW = 50 × Marcellus PW in 2017)
- Potential issues with PW management (e.g. induced seismicity, disposal capacity)

Management strategies

- Reusing PW for HF of new wells should mitigate water issues in most plays, except Oklahoma or Delaware Basin where PW volume >> HF water demand
- Beneficial reuse in other water sectors, problems with water quality, economics, and regulations
Project Sponsors:

EXXON Mobil

The Cynthia & George Mitchell Foundation

Alfred P. Sloan Foundation

The University of Texas at Austin

Jackson School of Geosciences

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