

Produced Water Reuse – Issues, Challenges, and Needs

John Veil

Veil Environmental, LLC

Annapolis, MD USA

410-212-0950

john@veilenvironmental.com

www.veilenvironmental.com

January 18-20, 2017

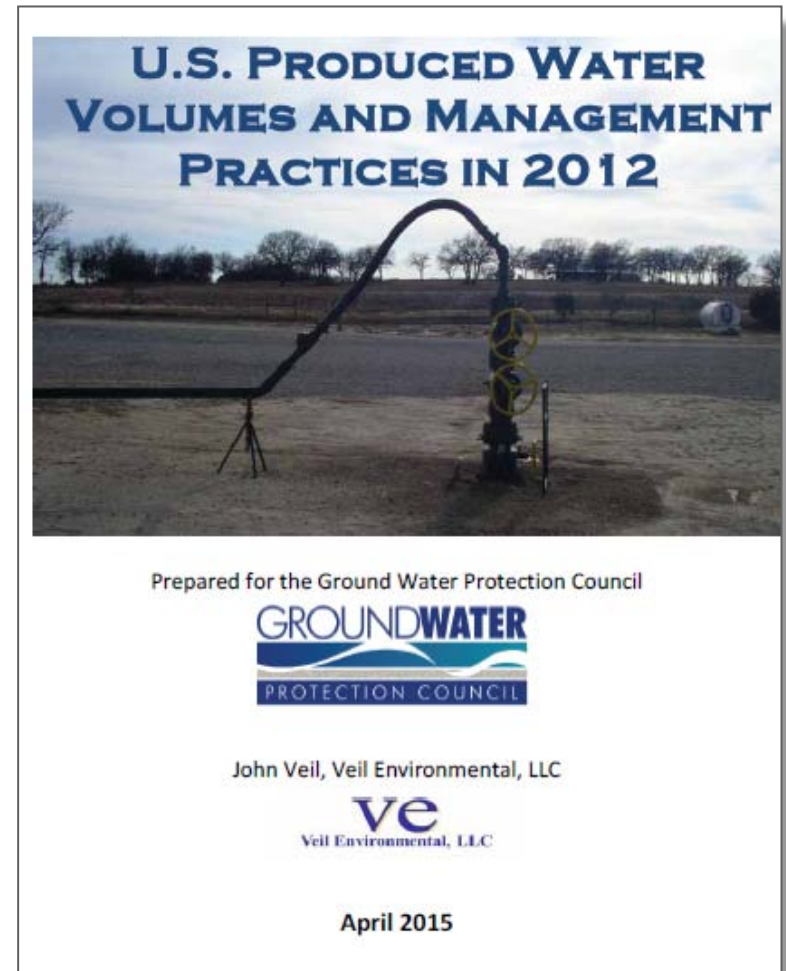
Topics for Discussion

- Produced water volumes
- How is it managed?
- Reuse options
- Why are these options not being used more often?
- Terminology distinctions



Most Current Detailed Produced Water Inventory for the U.S.

- Previous study done in 2009 looked at 2007 year
- The Ground Water Protection Council (GWPC) contracted with Veil Environmental to update a 2009 report using 2012 as the baseline year.
- Data were collected during the second half of 2014
- Report was published in April 2015



http://www.veilenvironmental.com/publications/pw/prod_water_volume_2012.pdf

Water Volume Table - Louisiana Data

Type of Hydrocarbon	# Wells Producing Primarily That Type of Hydrocarbon	Total Volume of Produced Water Brought to Surface (bbl/year)	Volume of Hydrocarbon Produced (bbl/year or Mmcf/year)
Crude oil from conventional formations	19,235	927,634,655	82,111,159 bbl/yr
Natural gas from conventional formations	16,572		1,277,149 Mmcf
Crude oil and natural gas from unconventional formations	13 wells in Tuscaloosa Marine Shale (TMS) and 2,145 wells in Haynesville Shale (HS)		TMS - 251,461 bbl/yr oil and 142 Mmcf gas HS – 418,818 bbl/yr condensate and 2,069,724 Mmcf gas
Total	37,965	927,634,655 (based on total water managed)	82,781,438 bbl/yr crude oil (includes condensate) 3,347,015 Mmcf

Water Management Table - Louisiana Data



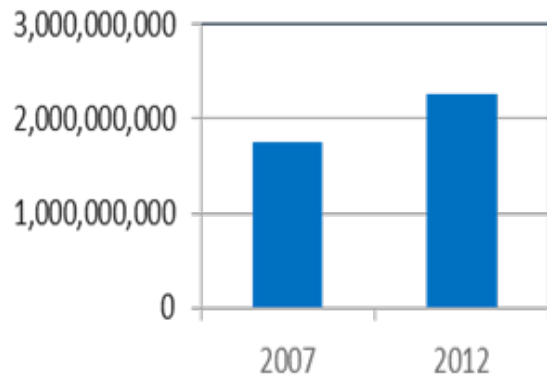
Management Practice	# Wells Using That Practice	Total Volume of Produced Water Managed by That Practice (bbl/year)	Percentage of Produced Water Managed by That Practice
Injection for enhanced recovery	401	31,336,098	3.4%
Injection for disposal	3,231	857,417,339	92.4%
Surface discharge	0	0	0
Evaporation	0	0	0
Offsite commercial disposal	44	38,880,938	4.2%
Beneficial reuse	4 (reuse of flowback)	280	0
Total Volume Managed		927,634,375	

Produced Water Volumes

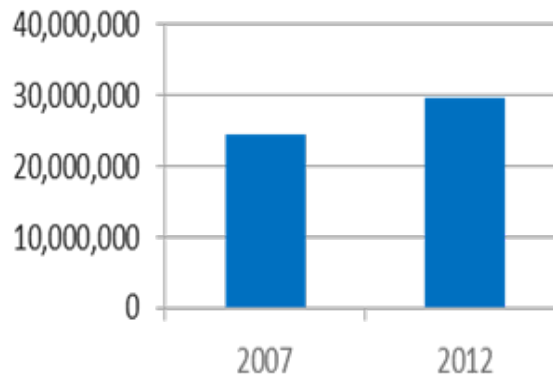
Five Year Changes in Fluid Production

- Between 2007 and 2012
 - U.S. oil production increased by 29%
 - U.S. gas production increased by 22%
 - U.S. water production increased by <1%
 - 21.2 billion bbl vs. 21 billion bbl

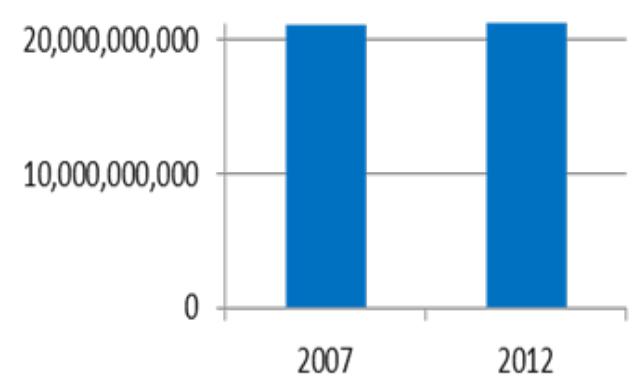
Oil Volume (bbl)



Gas Volume (Mmcf)



Water Volume (bbl)



Putting Produced Water Volume into Perspective

21.2 billion bbl/yr = 2.44 billion gal/day

1. U.S. population = 323 million people
 - 7.5 gals produced water/person/day
2. Niagara Falls average flow = 150,000 gal/sec
 - More than twice the amount of water that typically flows over the Niagara Falls each day is generated as produced water
3. Number of cans of beer or Coke at 12 oz/can
 - If all produced water were placed into cans, it would yield 26 billion cans/day
4. Cubic volume
 - The Empire State Building has a volume of 37 million ft³
 - The U.S. produced water would fill that volume nearly 9 times each day



Top Ten States in 2012 Water Production

Ranking	State	2012 Water (bbl/yr)	% of Total Water
1	Texas	7,435,659,000	35
2	California	3,074,585,000	15
3	Oklahoma	2,325,153,000	11
4	Wyoming	2,178,065,000	10
5	Kansas	1,061,019,000	5
6	Louisiana	927,635,000	4
7	New Mexico	769,153,000	4
8	Alaska	624,762,000	3
9	Federal Offshore	358,389,000	2
10	Colorado	320,191,000	2

Produced Water Management Practices

2012 Produced Water Management Practices

- Water management follows similar trends to the 2007 data
 - Nearly all water from onshore wells is injected
 - Nearly all water from offshore wells is treated and discharged

	Injection for Enhanced Recovery (bbl/yr)	Injection for disposal (bbl/yr)	Surface discharge (bbl/yr)	Evaporation (bbl/yr)	Offsite Commercial Disposal (bbl/yr)	Beneficial Reuse (bbl/yr)	Total Prod Water Managed (bbl/yr)
2012							
Onshore Total	9,225,152,000	7,947,716,000	605,129,000	691,142,000	1,373,131,000	125,737,000	19,968,007,000
%	46.2	39.8	3.0	3.5	6.9	0.6	100.0
Offshore Total	62,703,000	62,703,000	515,916,000	0	0	0	641,322,000
%	9.8	9.8	80.4	0.0	0.0	0.0	100.0
U.S. Total	9,287,855,000	8,010,364,000	1,121,045,000	691,142,000	1,373,131,000	125,737,000	20,609,274,000
%	45.1	38.9	5.4	3.4	6.7	0.6	100.0
2007							
Onshore Total	10,676,530,000	7,144,071,000	139,002,000	No data	No data	No data	17,959,603,000
%	59.4	39.8	0.8	No data	No data	No data	100.0
Offshore Total	48,673,000	1,298,000	537,381,000	No data	No data	No data	587,353,000
%	8.3	0.2	91.5	No data	No data	No data	100.0
U.S. Total	10,725,203,000	7,145,369,000	676,383,000	No data	No data	No data	18,546,955,000
%	57.8	38.5	3.6	No data	No data	No data	100.0

States Reporting Volumes for Produced Water Reuse

State	PW Reuse Volume (bbl/yr)	How It Is Reused
AR	2,000,000	Reused to make up new frac fluids
CA	46,251,000	Not specified by the State. But there are some examples in the literature. In the San Ardo field some of the pw is treated and reused for cooling tower makeup water. The remaining water undergoes further treatment to create water suitable to recharge a shallow aquifer that was used in the area for crop irrigation. Up to 50,000 barrels/day of brackish pw was transformed into freshwater for agricultural reuse, which was enough to irrigate about 800 acres of farmland per year.
CO	47,648,000	Reused to make up new frac fluids
OH	756,000	129,575 bbl were used for deicing and dust control on roads, and 626,208 bbl were recycled to make new drilling fluids and frac fluids.
PA	29,082,000	Reused to make up new frac and drilling fluids

- Several other states reported that they believed produced water was reused, but were uncertain about the volume and/or how it was actually used: KS, MI, NY, TX, UT, WV, WY

Ways in Which Produced Water Can Be Reused

Options for Reuse of Produced Water

- Reuse in the oil and gas fields
 - Produce more oil
 - Use for drilling fluids and frac fluids
- Industrial use
- Roadway use
- Injection for future use
- Injection for hydrological purposes
- Agricultural use
- Drinking water and other domestic uses
- Secondary use

Reuse for Producing More Oil

- Nearly half of all U.S. produced water is separated from the oil and gas at the surface and then reinjected back into an oil-bearing formation to help produce more oil
- This can be done using water (water flooding) or steam (steam flooding)
 - SAGD and other steam processes are common in Canada
- Although this practice is not always viewed as beneficial reuse, it provides a valuable service to the industry and avoids injection of millions of barrels of surface and ground water to accomplish the same enhanced recovery activities
- I believe it is truly beneficial reuse and should be given credit as such

Other Reuse in the Oil and Gas Fields

- In some parts of the country, a very large percentage of flowback water and produced water are given simple filtration or other treatment and then are reused to make up new drilling fluids and frac fluids
- Data in the table show management practices in the Pennsylvania portion of the Marcellus Shale during 2012
 - 98% of flowback
 - 78% of prod water

	Flowback	Prod Water	Total	%
Centralized treatment for reuse	1,398,438	2,131,496	3,529,934	13
Injection - disposal	70,679	3,493,527	3,564,206	13
Residual waste processing and reuse	30,612	105,358	135,970	0.5
Reuse other than roadspreading	8,149,339	11,418,150	19,567,489	72
Storage waiting for disposal or reuse	63,981	256,948	320,929	1.2
Landfill	6,366	278	6,644	<0.1
Discharge	105	105	210	<0.1
Roadspread	425	425	850	<0.1
Total	9,719,945	17,406,287	27,126,232	100

Industrial Use

- Cooling water makeup
- Vehicle washwater
- Process water
- Other



Roadway Use

- Dust control on unpaved roads
- Snow and ice control during winter storms
- Road stabilization



Injection for Future Use

- Aquifer storage and recovery
 - Inject treated produced water into shallow aquifer
 - Withdraw it later as a water supply
- Example in Wellington, CO

Injection for Hydrological Purposes

- Subsidence control
- Salt water intrusion
- Flow augmentation



Agricultural Use

- Irrigation
- Livestock and wildlife watering
- Managed wetlands
 - Reed beds in Oman



Source: USDA



Source: USFWS



Source: USFWS

Drinking Water and Other Domestic Uses



Secondary Use

- Geothermal power
- Feedstock for obtaining uncommon minerals and chemicals
 - Lithium
 - Rare earth metals



Source: DOE – Rocky Mountain Testing Center

Why is Produced Water Not Reused More?

Barriers and Solutions to Overcome Them - Economics

■ Barriers

- Salt removal is very expensive and is often necessary prior to reuse
- Water is heavy and expensive to move long distances
- Injection into disposal wells has been convenient, inexpensive, and accepted by regulators
 - Little incentive to look at other water management options in many regions

■ Solutions

- Continue development of cost-effective desalination approaches that can work dependably in harsh oil field environments
- Induced seismicity in a few regions has reflected negatively on disposal wells and created a new opportunity for beneficial use of produced water

Barriers and Solutions to Overcome Them - Data Availability

- Barriers
 - Most states do not collect quantitative data on actual reuse applications
 - Few states provide publically available data on well-by-well produced water volumes
 - Little is publically available about the chemical and physical characteristics of specific produced waters and how they vary over time

- Solutions
 - Encourage more/better data collection with the opportunity to make information available to the public
 - Look to applications like the Ground Water Protection Council's RBDMS (Risk-Based Data Management System) used by over 20 states and commercial data vendors for better data visualization
 - Water Tracker module
 - Initiate research efforts to collect more data on produced water quality

Barriers and Solutions to Overcome Them - Social

- Barriers

- Some potential end users may not want to use produced water for agricultural applications
- The public may have concerns over treating produced water and reusing it for drinking water

- Solutions

- Develop and publish case examples to help educate potential consumers

Barriers and Solutions to Overcome Them - Volume and Timing

- Barriers
 - End users need water of specific quality, volume, and duration. Availability of produced water in sufficient volume may not meet the long-term needs of the end user

- Solutions
 - Look at opportunities to share/combine water from multiple producers to ensure long-term needs of the end users
 - May need to form consortia or clearinghouses to help with this
 - Regulations may need to be revised to allow these interactions

Barriers and Solutions to Overcome Them - Policy

■ Barriers

- Water rights
 - As long as produced water is a waste, water rights owner is not too concerned. But if produced water can be sold, water rights owner wants a cut of the fee.
- Liability
 - Large oil and gas companies are worried about the risk of later lawsuits if produced water is sold or given to end users

■ Solutions

- Try to educate lawmakers and staffers
- Look to establish third-party entities that can accept produced water and distribute it to end user (mitigates liability)
- Look to states that have developed innovative regulatory programs to allow and encourage beneficial use

Meetings in Recent Months to Discuss Beneficial Use of Produced Water

- National Science Foundation Workshop on Food-Energy-Water Nexus Issues in Energy, Arlington, VA, December 7–8, 2015
- Ground Water Protection Council UIC Conference, Denver, CO USA, February 23-25, 2016
- National Academy of Sciences Roundtable, Beneficial Use of Produced & Flowback Water: Innovations and Challenges, Washington, DC, May 25-26, 2016
- States First Initiative, Produced Water Forum, Oklahoma City, OK, August 17-18, 2016
 - This meeting involved many persons and organizations interested in using produced water in place of other water sources
 - The participants discussed and voted on the key issues and concerns -- the top five are listed on the next slide
- Ground Water Protection Council, Annual Forum, Orlando, FL, September 12-14, 2016

Key Issues and Concerns Relating to PW Beneficial Use from August 2016 Meeting in Oklahoma City

- Standardized approaches to verify and test new water analysis and treatment technologies
- Comprehensive modeling methods to calculate and compare environmental impact, carbon intensity, risk, costs and other characteristics of using produced water when compared to other fresh and non-fresh water sources.
- Estimating the cost and environmental impact to use produced water relative to the use of other fresh and non-fresh water sources.
- Clarification of produced water ownership as it is treated and put to beneficial use.
- Clarification of liability as produced water is treated and put to beneficial use.

Terminology - Important Distinctions or Much Ado About Nothing

How to Describe Using Produced Water for Another Purpose

- Are these terms different? If so, how?
 - Water is treated vs. untreated before it is used
 - Used within the industry vs. used outside the industry

Recycle

Reuse

Repurpose

Upcycle

Example Using Yogurt Containers



Recycle



Reuse

Repurpose

Upcycle - ?????



Using Produced Water for Another Purpose (2)

Reuse

Use

- Produced water is a byproduct of oil and gas production
- It has not had any specific primary use before it is brought to the surface (with some possible exceptions)
 - Water used for water flood that is later produced to the surface
 - Used within the industry vs. used outside the industry
- Some people are concerned about how the choice of terms affects the applicability of the RCRA E&P waste exemption or treatment under water rights