Observations and Thoughts on Produced Water Management

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Topics for Discussion

- Background on produced water
- U.S water volumes and management practices
- Different water issues for each type of oil and gas production
- Key concepts for water management
- How clean must water be/choosing technologies
- How regulations/standards play a role

What is Produced Water?

- Water that comes to the surface with oil and gas
  - Mostly natural groundwater
  - Can also be water injected for water flooding or for hydraulic fracturing
- Contains many chemical constituents
  - Salt content (salinity, total dissolved solids [TDS], electrical conductivity)
  - Oil and grease
    - Composite of many hydrocarbons and other organic materials
  - Toxicity from various natural inorganic and organic compounds or chemical additives
  - NORM

Produced Water Volumes and Management Practices

Detailed Produced Water Inventory for the U.S.

- Clark, C.E., and J.A. Veil, 2009, *Produced Water Volumes and Management Practices in the United States*.
- The report contains detailed produced water volume data for 2007
  - ~21 billion bbl/year or 58 million bbl/day
  - 882 billion gallons/year or 2.4 billion gallons/day
  - ~3.3 billion m^3/year or 9.2 million m^3/day
- The report also provides estimates of water-to-oil ratio
  - U.S. estimate – 5:1 to 8:1
  - with more complete data sets that include Texas and Oklahoma data, this would be >10:1

To download a copy of the report, go to:
http://www.veilenvironmental.com/publications/pw/ANL_EVS__R09_produced_water_volume_report_2437.pdf

U.S. Produced Water Volume by Management Practice for 2007 (1,000 bbl/year)

	Injection for Enhanced Recovery	Injection for Disposal	Surface Discharge	Total Managed	Total Generated
Onshore Total	10,676,530	7,144,071	139,002	18,057,527	20,258,560
Offshore Total	48,673	1,298	537,381	587,353	587,353
Total	10,725,203	7,145,369	676,383	18,644,880	20,995,174

- Onshore – 98% goes to injection wells
    - 60% to enhanced recovery
    - 40% to disposal
- Offshore – 91% goes to discharge

2014 Update to Detailed Produced Water Inventory for the U.S.

- John Veil is in the process of updating the 2009 report using 2012 as the baseline year.
- Questionnaires were sent to each oil and gas producing state in July.
  - Replies received already from 15 states.
  - Waiting for data from 18 states:

  CA, CO, FL, IL, KS, MD, MO, MT, NY, ND, OH, OK, PA, SC, TN, TX, UT, and WV

- New report should be available early in 2015

Water Issues by Production Method

Variations in Water Needs and Generation by Production Method

Type of Oil and Gas Production	**Water Needs for Production**	**Produced Water Generated**
Conventional Oil and Gas	- Modest needs for hydraulic fracturing - More needed for enhanced recovery later on	- Low volume initially - Increased volume over time - High lifetime pw production
Coalbed Methane	- Modest needs for hydraulic fracturing	- High volume initially - Decreases over time
Shale Gas	- Large needs for hydraulic fracturing	- Initial flow rate is high, but quickly drops to very low - Low lifetime flowback and produced water production
Heavy Crude	- Steam flood to help move heavy oil to production wells	- Much of the water results from the injected steam used in steam flooding
Oil/Tar Sands	- Steam (or water) injection used in large volumes	- In-situ production methods: some water is formation water, but much is from the injected steam

Water Management Overview

Water Lifecycle for Unconventional Oil & Gas

Source: Energy Water Initiative

Simplified List of Water Management Considerations

- Water
  - Source
  - Storage
  - Transportation
  - Water demands

- Wastewater
  - Volume
  - Characteristics
  - Storage
  - Transportation
  - Management
  - Residual management

Key Concepts for Water Management

Decision Criteria for Choosing a Water Management Solution

Must be practical at your location

Must be allowed by the regulatory agency

Must be sustainable over time

Must pose low risk for future liability

Should be proven to give dependable performance over time

Must have affordable cost

Components Contributing to Total Cost of Wastewater Management

Category	***Cost Component (Some or all may be applicable)***
Prior to Operations	Prepare feasibility study to select option (in-house costs and outside consultants)
	Obtain financing
	Obtain necessary permits
	Prepare site (grading; construction of facilities for treatment and storage; pipe installation)
	Purchase and install equipment
	Ensure utilities are available
During Operations	Utilities
	Chemicals and other consumable supplies
	Transportation
	Debt service
	Maintenance
	Disposal fees
	Management of residuals removed or generated during treatment
	Monitoring and reporting
	Down time due to component failure or repair
	Clean up of spills
After Operations	Removal of facilities
	Long-term liability
	Site remediation and restoration

Upstream Oil and Gas Industry is Segmented into Many Niches

- Different production methods
- Different geographical plays
- Range of climates
- Federal and state regulations
- Availability of infrastructure
- Regional water supply availability

It is important to understand these differences when choosing a water management technology

How Clean Must the Water Be (How Much Treatment Must Be Used)?

- What is the quality of the untreated water?
  - Types of constituents
  - Concentrations
  - Does it change over time?
- What will be done next with the water?
  - Disposal
    - Discharge
    - Injection
    - Evaporation
    - Send to third-party disposal company
  - Reuse
    - In oil and gas operations
    - Other

What Type of Criteria Determine How Clean the Water Must Be?

- Regulatory standards (set by government)
  - Discharge standards
    - Zero discharge
    - Limits on oil and grease, pH, TDS, metals, others
  - Air quality standards
    - Emissions from evaporation ponds or holding tanks
- Operational standards (set by operators)
  - Injection standards are designed to protect the injection formation from plugging
  - Reuse for drilling and frac fluids must meet criteria set by the oil and gas companies
  - Reuse for other purposes must meet the needs of those activities

Treatment Options

Basic Separation of Oil, Gas, and Water

- Free-water knockout tank separates three fluid phases plus solids
- Emulsions
  - Heater-treater
  - Demulsifying chemicals
- Most common practice
  - Onshore – pass through tank battery, then inject
  - Offshore – discharge

Treatment before Injection

- Make sure water is compatible with formation
  - Solids
  - Dissolved oil
  - Microbes
  - Corrosion sources
- Typically use various treatment chemicals
- May need filtration

Produced Water Management Options

- Follow 3-tier water management/pollution prevention hierarchy
  - Water minimization
  - Recycle/reuse
  - Treatment and disposal

- Tier 1 - Options for Minimizing Produced Water
  - Mechanical blocking devices
  - Water shut off chemicals
  - Downhole separation
  - Sea floor separation

Those technologies that are commonly used are highlighted in red color

Tier 2 - Options for Recycle and Reuse of Produced Water

- Injection for recovering more oil
- Agricultural use
- Industrial use
- Secondary use
- Injection for future use
- Injection for hydrological purposes
- Drinking water and other domestic uses

Tier 3 - Options for Treatment and Disposal of Produced Water

- *Practices to dispose of produced water*
  - Discharge
  - Injection
  - Evaporation
  - Offsite commercial disposal
- *Practices to remove salt and other inorganics from produced water*
  - Membrane processes
  - Ion exchange
  - Capacitive deionization
  - Thermal distillation
  - Other emerging technologies
    - Forward osmosis
    - Membrane distillation

Tier 3 - continued

- *Practices to remove oil and grease and other organics from produced water*
  - Physical separation
  - Flotation
  - Coalescence
  - Combined physical and extraction
  - Solvent extraction
  - Adsorption
  - Oxidation

Additional Considerations for Shale Plays

Shale Gas Wastewater - Flowback and Produced Water

- Some of the injected water returns to the surface over the first few hours to weeks. This ***frac flowback*** water has a high initial flow, but it rapidly decreases
  - Over the same period of time, the concentration of TDS and other constituents rises

TDS values (mg/L) in flowback from several Marcellus Shale wells

Location	Day 0*	Day 1	Day 5	Day 14	Day 90
A	990	15,400	54,800	105,000	216,000
B	27,800	22,400	87,800	112,000	194,000
C	719	24,700	61,900	110,000	267,000
D	1,410	9,020	40,700		155,000
E	5,910	28,900	55,100	124,000	

* Day 0 represents the starting frac fluid conditions

Source: Tom Hayes, 2009.

Management of Shale Gas Wastewater

- Onsite treatment vs. offsite centralized treatment
  - Key consideration is what will be done next with the treated water

- Five management options
  - Injection into disposal well (offsite commercial well or company-owned well)
  - Treatment to create clean brine (e.g., chemical addition, flocculation, clarification; advanced oxidation)
  - Treatment to create clean fresh water (one of the thermal distillation processes)
  - Evaporation or crystallization (allows zero discharge of fluids)
  - Filtration of flowback to remove suspended solids (i.e., sand grains and scale particles), then blend with new fresh water for future stimulation fluid.

Crossover Point

- The ability to reuse all the wastewater from a field depends on:
  - **How much wastewater is generated**
  - **The near-term and mid-term needs for drilling and fracturing new wells**
  - Relationship between point of generation and point of need for reuse
  - An infrastructure to collect, store, treat, and deliver water as needed
- Wastewater generation volumes (look at hypothetical analysis similar to Marcellus Shale; assumptions for the following analysis are underlined below)
  - Flowback water (first two weeks) – <u>one-time batch of 1 million gals/well</u>
  - Produced water (<u>as long as well is producing assume 250,000 gals/year/well</u>)
  - As more and more wells are drilled and begin production, the cumulative produced water volume increases continuously while the flowback volume stays relatively the same (assuming the same number of wells are drilled each year).

Crossover Point (2)

- Each new well requires about 5 million gals/well for drilling and fracturing
- In the early years of a field, there is much greater demand for water than supply
- Over time, with the steadily increasing produced water volume plus the constant flowback volume, the field reaches a point at which the volume of water generated matches the volume of water needed for drilling and fracturing
  - This is the **crossover point**
- After that point in the field's life, the total volume of produced water and flowback will exceed the demand for new wells. The excess water that cannot be recycled will need to be managed in some other way
- This is the point at which high level treatment (desalination) can play a more significant and growing role
- When will the crossover point be reached?

Hypothetical Data

Year in life of field	No wells/year	Total Wells in Field	Flowback Volume (million gals)	Produced Water Volume (million gals)	Total Wastewater Generated (million gals)	Water needed (5 million gals/well)
1	100	100	100	25	125	500
2	500	600	500	150	650	2,500
3	1,000	1,600	1,000	400	1,400	5,000
4	1,500	3,100	1,500	775	2,275	7,500
5	2,000	5,100	2,000	1,275	3,275	10,000
6	2,000	7,100	2,000	1,775	3,775	10,000
7	2,000	9,100	2,000	2,275	4,275	10,000
8	2,000	11,100	2,000	2,775	4,775	10,000
9	2,000	13,100	2,000	3,275	5,275	10,000
10	2,000	15,100	2,000	3,775	5,775	10,000
11	2,000	17,100	2,000	4,275	6,275	10,000
12	2,000	19,100	2,000	4,775	6,775	10,000
13	2,000	21,100	2,000	5,275	7,275	10,000
14	2,000	23,100	2,000	5,775	7,775	10,000
15	2,000	25,100	2,000	6,275	8,275	10,000
16	1,800	26,900	[illegible]	6,725	8,525	9,000
17	1,600	28,500	[illegible]	7,125	**8,725**	**8,000**
18	1,400	29,900	1,400	7,475	**8,875**	**7,000**
19	1,200	31,100	1,200	7,775	**8,975**	**6,000**
20	1,000	32,100	1,000	8,025	**9,025**	**5,000**

Crossover point

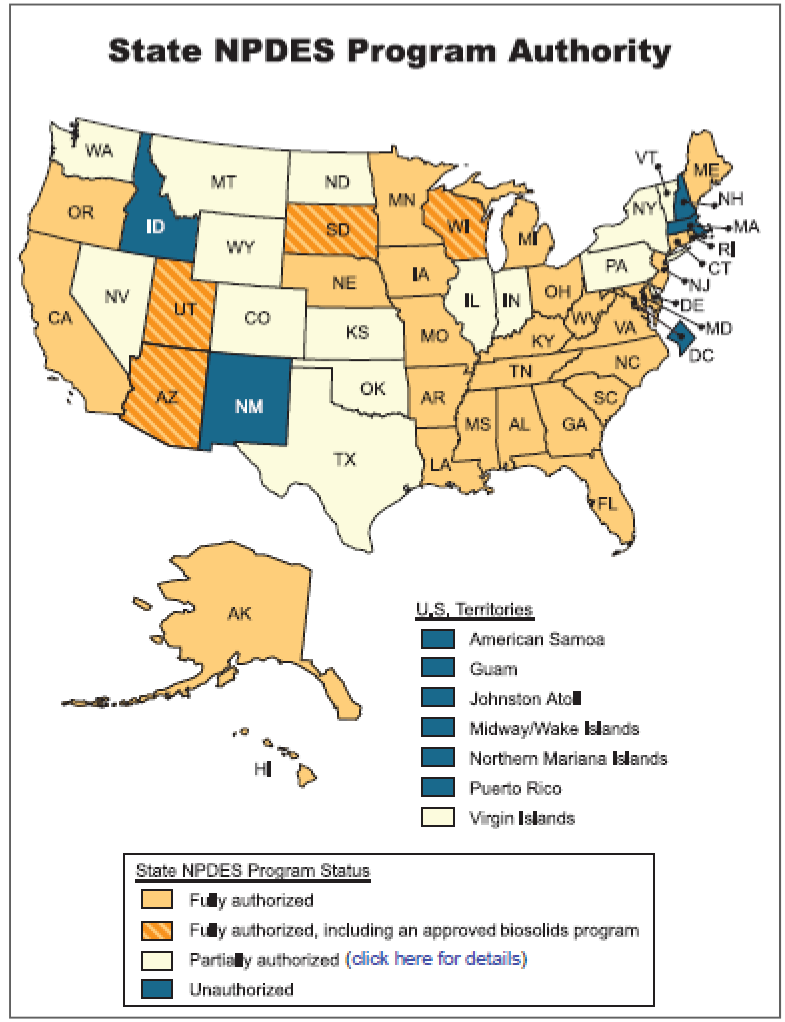
Factors That Can Cause Sudden Changes to Water Management Practices

- Introduction of new technologies
  - Simple filtration in Marcellus
- New regulations/policy decisions
  - Notice from PA DEP to stop sending wastewater to POTWs and small industrial treatment plants
- Unexpected events
  - Earthquakes in Ohio, Arkansas, Texas, Oklahoma

U.S. Regulatory Requirements and How They Affect Water Management

State vs. Federal Authority

- Both discharge and injection are administered through regulatory programs
  - Major regulatory programs can be delegated
    - State can seek approval from the EPA for the day-to-day implementation and enforcement of programs
  - When states do not have delegated authority, programs are administered by EPA regional offices



Discharge Permits

- Discharge permits contain limits on several pollutants and give limits expressed as mg/L or pounds/day
  - Limits are based on national discharge standards and water quality protection
- Discharge permits require self-monitoring and reporting

EPA National Discharge Standards for Oil and Gas (Effluent Limitation Guidelines - ELGs)

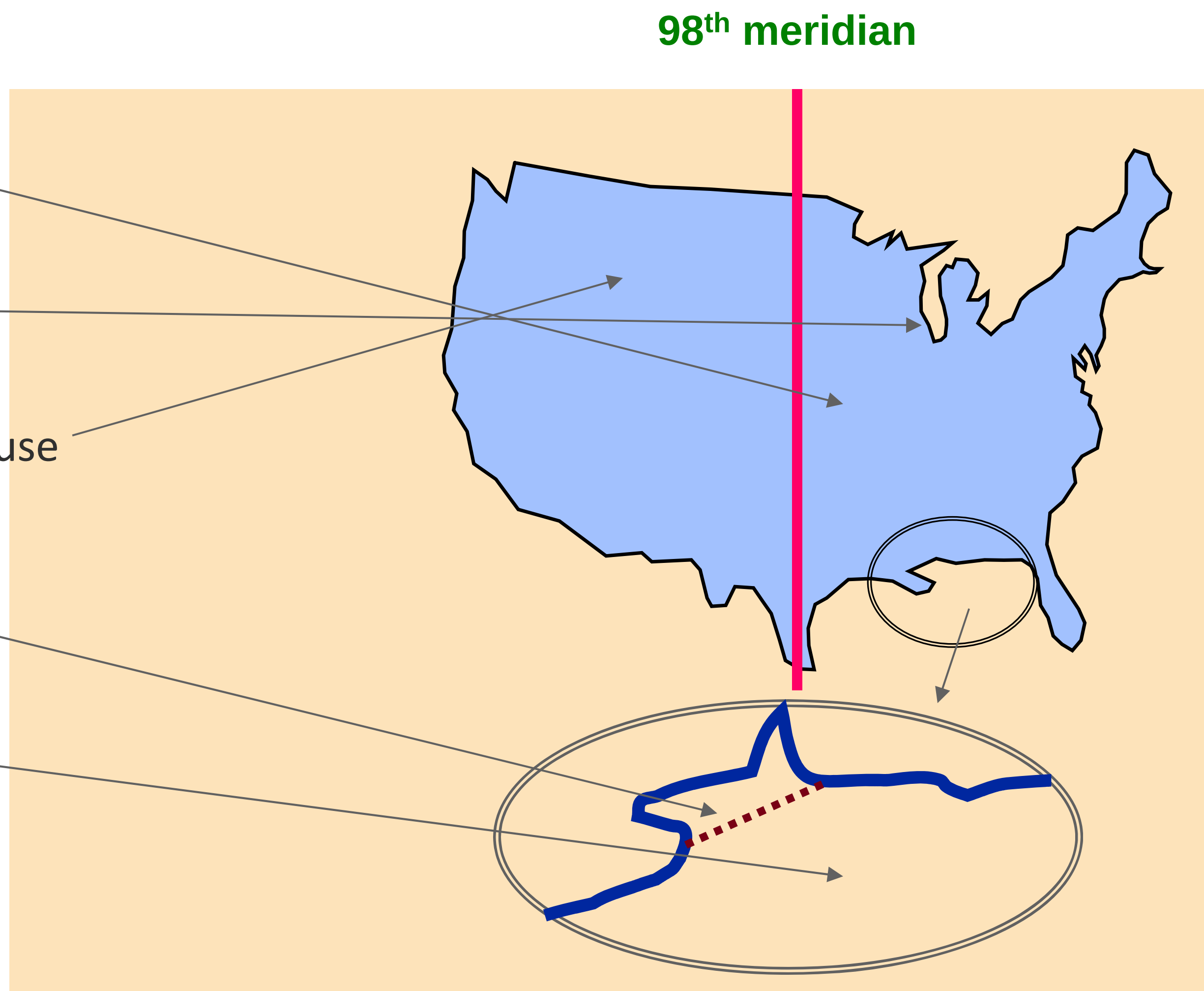
Onshore

Stripper
(<10bbl/day)

Agricultural and wildlife use

Coastal

Offshore



Discharge Standards for Wells Located Onshore

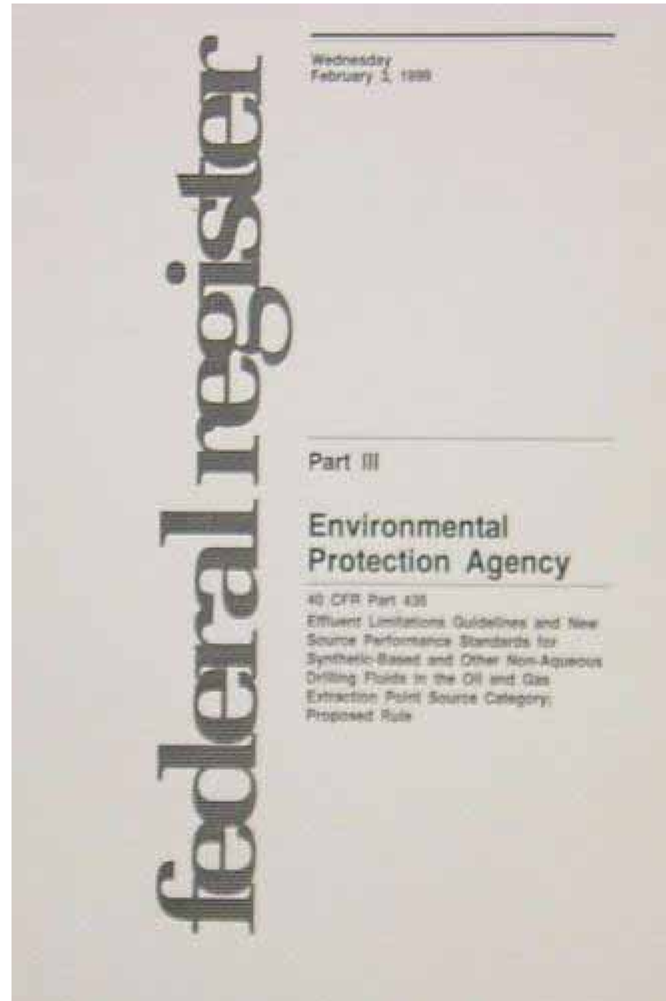
- Onshore subcategory
  - zero discharge

This is very important – it takes away a major water management option and drives companies to use injection

- Stripper subcategory
  - No national requirements
  - Jurisdiction left to state or EPA region
- Agricultural and Wildlife Use subcategory (not common)
  - produced water must have a use
    - Water must be of good enough quality for wildlife, livestock, or other agricultural use
  - Oil and grease limit of 35 mg/l maximum

Offshore and Coastal ELGs

- Best Available Technology (BAT) for offshore produced water:
  - Oil and grease limits before discharge
    - 29 mg/l monthly average
    - 42 mg/l daily maximum
- BAT for coastal produced water
  - zero discharge except in Cook Inlet, Alaska
  - Offshore limits are required there



Injection Permits

- Injection permits include requirements on:
  - Well location and construction
  - Operations
  - Monitoring
  - Pressure
  - Flow rate
  - Volume
  - Plugging and abandonment

Injection permits do not include standards on how clean the injected water must be. Any standards associated with injection are based on operational requirements to protect the formation.

Final Thoughts

- Oil and gas wells generate a large volume of water that must be managed
- Management of that water must be practical and comply with regulations
- Discharge is not allowed at most onshore wells but is used commonly for offshore wells
- Most of the produced water in the U.S. is injected
  - 60% for enhanced recovery
  - 40% for disposal
- The presentation describes the criteria and concepts that should be considered when choosing water management programs and systems
- There is no single "best practices" that can be used everywhere