EFFICIENT AND ECONOMICAL FRACTURING USING PRODUCED WATER

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Weatherford®

THE PRODUCED WATER SOCIETY SEMINAR 2016

Why use Produced Water?

- Logistics
- Environmental
- Availability
- Legalities

Water Acquisition Economics

- On Average cost of fresh water $1.50 per bbl
- Average Disposal cost $2.00 per bbl
- On average acquisition of water and transfer exceed actual source costs.

Table 1—Average cost of stimulation completion in the US

Bakken Field-Handling Costs	
Acquisition Costs	Cost, USD/bbl
Raw Water	0.25 - 1.75
Transportation	0.63 - 5.00
Disposal Cost	
Transportation	0.63 - 9.00
Deep-Well Injection	0.50 - 1.75
Average Total Costs	2.00 - 16.80

Source: University of North Dakota's Energy and Enviromental Research Center

Example of U.S. Cost Analysis	
Average water required per well	120,000 bbl
Typical Load Recovery (30%)	36,000 bbl
Typical water truck holds	4,620 gallons/load (110 bbl / load
Each well requires	328 truck trips
Average trucking time	3 hours
Average cost of trucking	$110/hour
Estimated Trucking Costs	$108,240/well
Fresh Water Costs ($0.75/bbl)	$90,000/well
Estimated Disposal Costs ($2.50/ well	$108,242
Total Cost Per Well	$306,482

Produced Water as a Replacement Base Fluid?

- Anionic ions react with divalent to form insolubles
- Generally traditional frac chemistries in Sea Water and Produced Water form complexities.
- Traditional fluids required desal Treatment

Component	Impact
High salinity	Suppress hydration of guar/polymers
Divalent & multivalent ions (Ca, Mg ions)	Interfere in crosslinking of fluid
Boron in water	Over crosslinking of fluid
High iron	Precipitation, plugging of formation
Iron	Precipitate with H2S, plug formation (FeS)
Barium and calcium ion	Form scale that clog pipes
High sulfate	Interfere in crosslinking
Metal ions	Catalyze breakers, premature fluid breaking
Dissolved oil & organics	Quench radical to produce insufficient break
Suspended solids	Plugging formation
Bacteria	Sour the well
Radionuclides and heavy metals	Health hazard
Production chemicals in flowback water	Effect performance of frac fluids

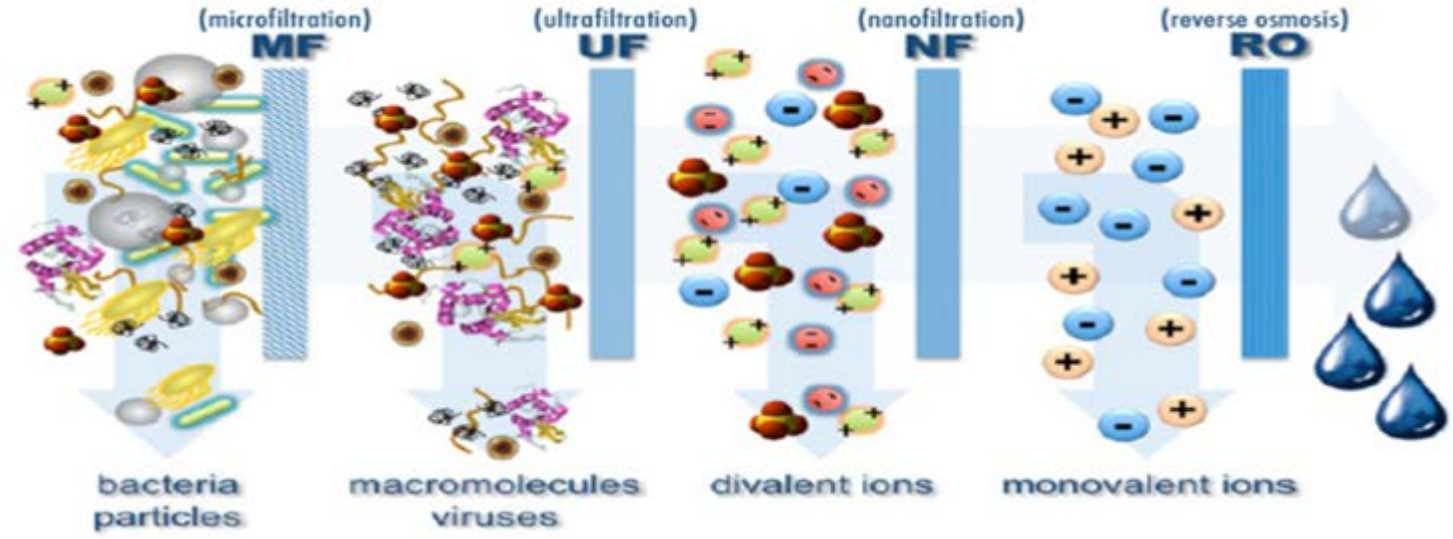
Compatible vs incompatible

- When traditional frac chemistries are used in high divalent environments polymers bond together and divalent incompatibles form.
- Depending on pH range additional incompatibles form from sulfide, resulting in sludge and corrosion.
- Over crosslinking from boron (tetrahydroxy borate)

Traditional Solution

Reverse Osmosis:

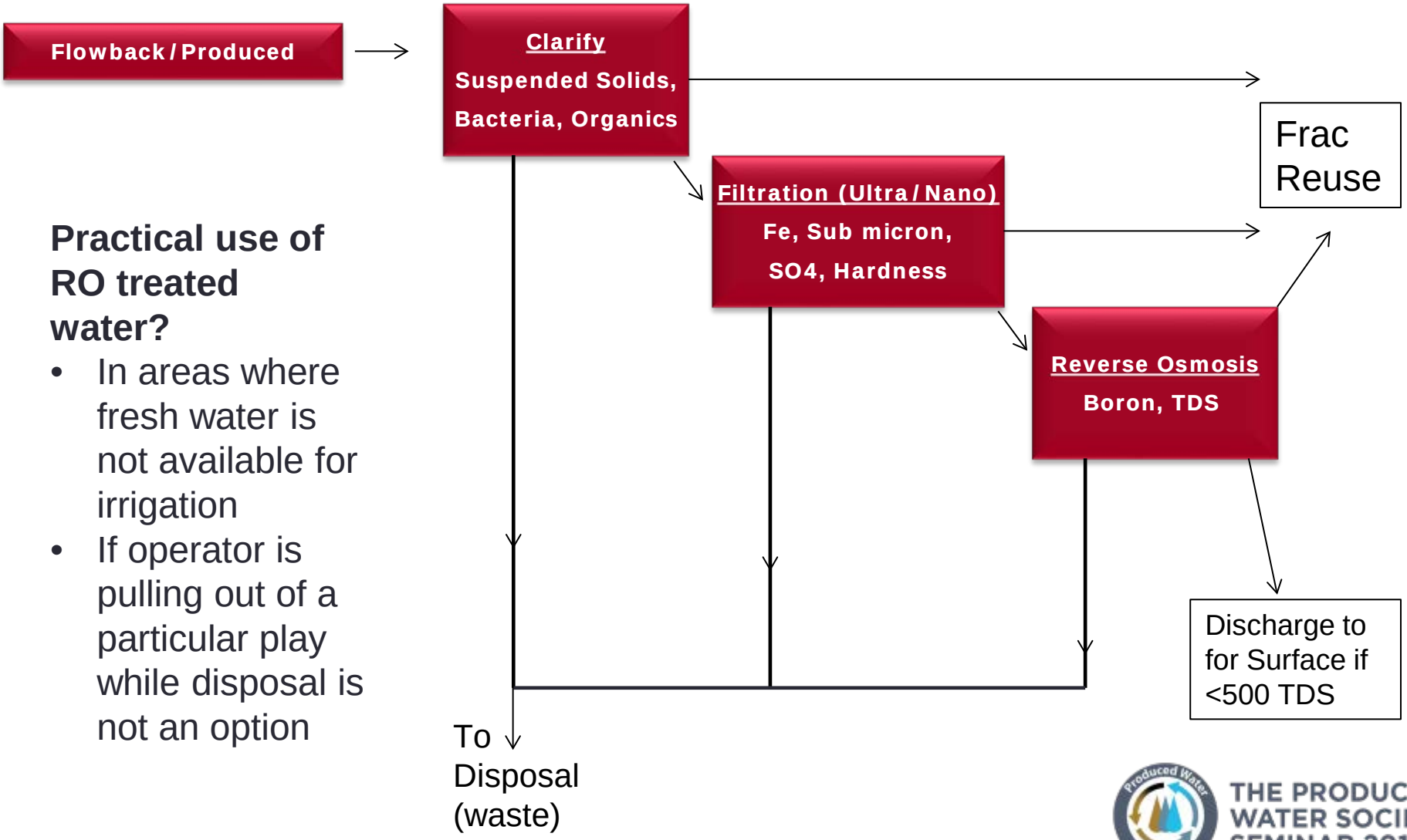
- Reverse osmosis enables for the most filtration in terms of reducing TDS and Boron levels
- Typically generates 15% - 30% waste depending on dewatering and chemical content
- Often RO is the final step in fracturing application filtration, reducing TDS levels to surface discharge quality.
- Evaporation is a technology used for “distillation” of produced water returning water to drinking quality.



Process of Filtration

Practical use of RO treated water?

- In areas where fresh water is not available for irrigation
- If operator is pulling out of a particular play while disposal is not an option



Filtration

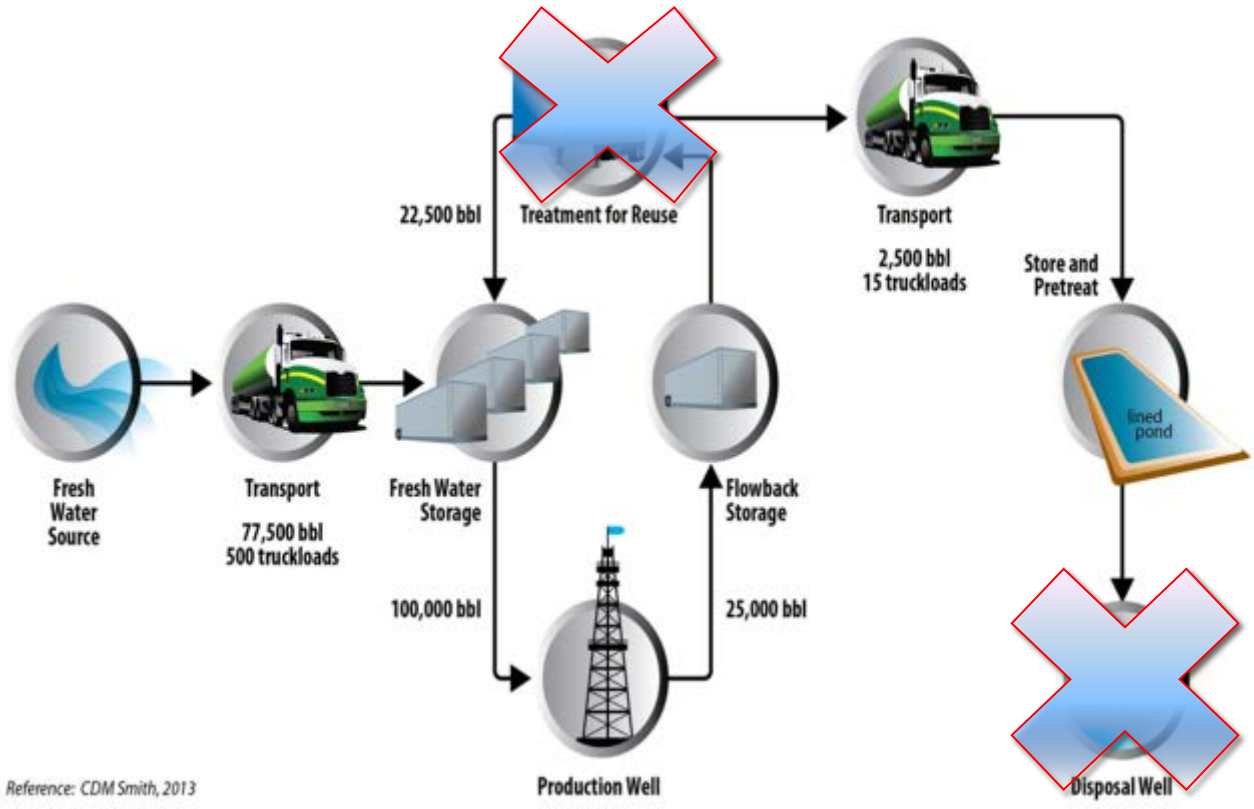
- As filtration methods becomes more elaborate yielded cost per bbl increases.
- On average filtration required for a crosslink system, equates to a per bbl cost of water ~$6.00 per bbl.

Average U.S. Filtration Costs	
Suspended Solid Removal (Clarify)	$1.05 - $1.50/bbl
Nanofiltraion, Ultrafiltrarion (iron, submicrons, sulfates, hardness)	$3.00 - $6.90/bbl
Dewatering, Reverse Osmosis, Evaporation (Boron, TDS)	$6.00 - $10.00+/bbl
Average Filtration Costs of filtration (Boron Removal and TDS reduction)	$6.00/bbl ($600,000+ / 100,000 bbls)

TDS of Water

Completion Cycle

- More than half water recycling costs are accrued at treatment and Disposal phases
- Reducing filtration additionally reduces waste generated during filtration process, as high as 30% of inbound water source is considered waste



CleanSure™

Oxidization of FeS and iron transforms them from soluble ferrous to ferric iron and results in accelerated settling of flocculated particles by final composition of ferric hydroxide.

Increased acceptance of oxidizing bactericides, such as chlorine dioxide, which quickly penetrate encapsulated bacteria, has further enabled the use of produced water with reduced filtration for optimal well completion.

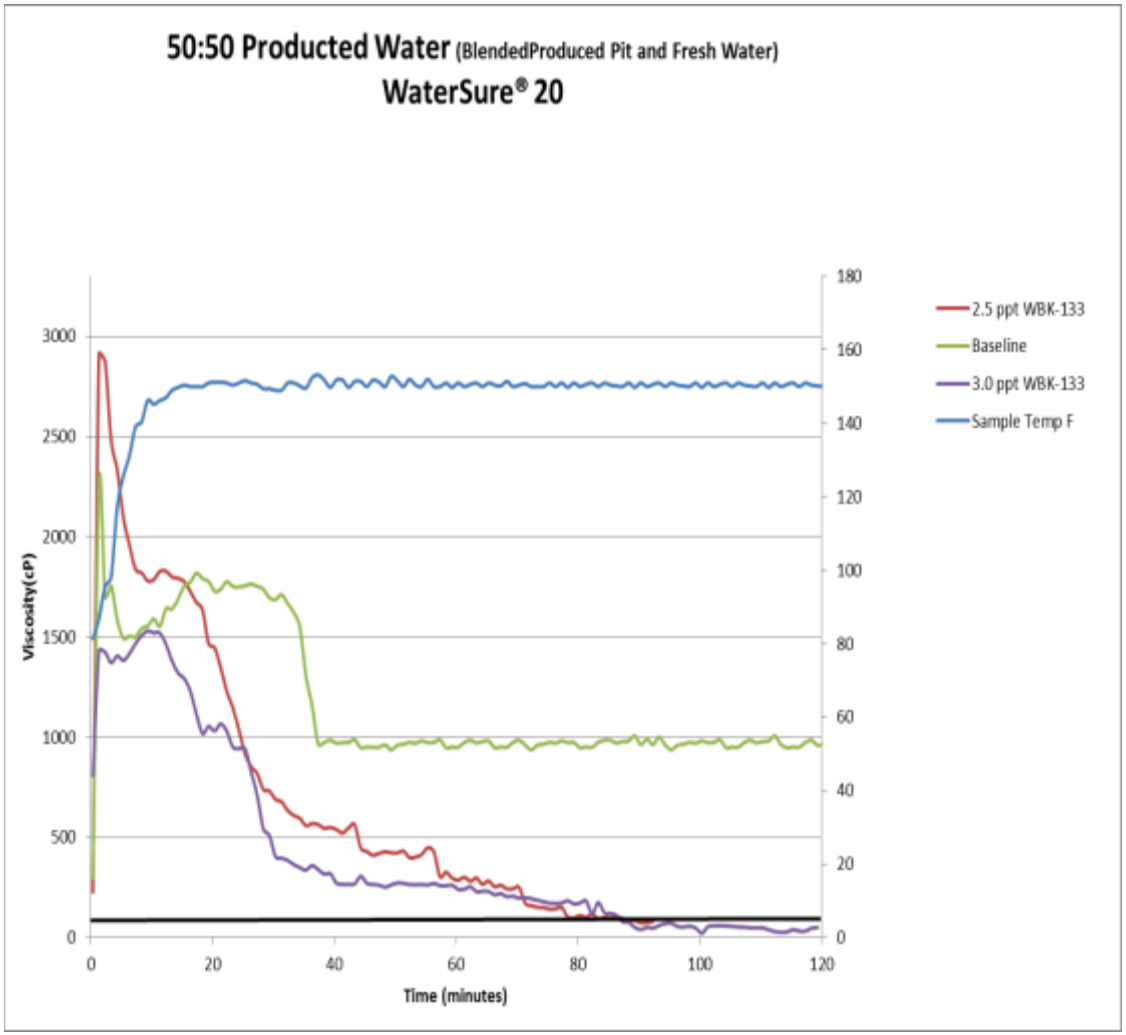
SPE-177678-MS

Case Study Using WaterSure®

- Objective completed of utilizing inbound produced water without filtration of boron, hardness TDS etc.
- Lower scaling tendency by optimizing at neutral pH.
- Eliminated filtration waste generation nominally associated with produced water usage.

Case Study Using WaterSure®

- Success of using 2-step process of oxidizing bacteria control and suspended solids removal.
- Savings amounted to approx. a 78% or $4.00/bbl savings per treated barrel across 65 stages over membrane filtration.
- Increased filtration from per day amounts to real-time filtration.



- Bi-Polymer technology mitigations filtration, generating greater completion savings in completion efficiencies.
- Less impact on formation damage, on average regain permeability is >85% when using 100% produced water with bi-polymer technology
- The more produced or high TDS water is filtered completion costs increase in addition to loss of usable water.
- Recycled fluid reduces the amount of disposal required at time of flowback, resulting in OP savings and positive impact to local society
- Mitigating filtration such as RO, Dewater and Distillation discharged waste is reduced by up to 20%

Thank You, Questions?

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