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Mobile Clarification for Re-Use of Unconventional Oil and Gas Produced Water to Reduce Costs and Minimize Environmental Footprint

Patrick Horner*, Aqua-Pure Ventures., Jeffrey A. Anderson, Select Energy Services.,
Mark Thompson, Fountain Quail Water Management.

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> "The things which have the greatest value in use have frequently little or no value in exchange; and on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it."
>
> – Adam Smith.

Summary

This publication assesses the impacts of water—both as a much needed resource for production, and in the post production phase (as produced water)—on unconventional resourse production; and the costs and benefits in re-using produced water. Treating produced waters is not without its challenges: this publication discusses some of them, more specifically pertaining to shale gas flowback. It also provides an overview of available produced water treatment technologies. A case study of chemical precipitation/clarification for a shale gas producing site will conclude this publication.

Introduction

In unconventional resource development, water is often a greater asset than liability. Large quantities of water are constantly in play: it is, on one hand, required to stimulate unconventional resource production, on the other hand, being produced (as the result of such production). Examples of water-intensive unconventional-resource production include shale gas, shale oil, tight oil, cool-bed methane and enhanced oil recovery process (such as water flood). Therefore, good management and treatment of the waters associated with unconventional resource development can reduce costs, and enable greater production via increased reservoir compatibility, improved public and regulatory relations, and reduced complications with production equipment and logistics. Over the past decade, many types of unconventional produced water treatment technologies have been trialed and tested. This publication will analyze the benefits of re-using produced water, provide an example of an unconventioal produced water re-use technology (specifically shale gas flowback), and its associated case study.

The Potential Costs of Produced Water

Communities that experience unconventional oil and gas development range from urban, rural, agricultural, to industrial. The community impacts include increased noise, traffic congestion, traffic accidents, extensive road-infrastructure use and damage, and excessive strain on community resources. Trucking associated with the development activities greatly impacts communities. Unconventional development requires the movement of a large amount of equipment and materials, specifically the hauling of water. Large volumes of water need to be transported to location in a short period of time, which further increases the intensity of trucking activity. Many communities also deem activities that impact water supplies (both its quantity and quality) as critical issues. Therefore, strategies that reduce water demand on the supply side and the disposal side, such as re-using of water, have the long-term benefit of improving community relations. Hence, integrating sustainable water management practices into a company's corporate culture can provide green credits and can foster positive public relations. The end result may be an increase in the trust that communities and regulatory bodies have in the company, which then can help accelerate permits, leases, and overall acceptance of a development program.

Transportation and storage of flowback on the surface pose some of the greatest environmental risks associated with hydraulic fracturing (commonly known as fraccing). Environmental release of flowback due to containment leaks, pipe failures, or truck accidents results in soil, ground water, and/or surface water contamination. Water management strategies such as re-using treated frac flowback can significantly reduce need for both storage and transportation of produced water, thus greatly reducing the risk of accidental environmental release.

Benefits of Re-Using Unconventional Produced Water

Since water-related concerns are one, if not the highest, area of regulatory agency concern, the most important way to minimize regulatory risk is to ensure compliance with rules and regulations that govern water management. Companies need not only follow the regulations, but also understand where regulators see best practices evolving, which includes a well developed water management plan. For instance, regional environmental authorities permit injection and other approved means of disposal for frac flowback management.

Most regional environmental authorities also encourage unconventional oil and gas operators to use a waste management hierarchy to manage oil and gas wastes. This hierarchy encourages operators to manage wastes in the preferred order of reduce, re-use, recycle, and then dispose. In other words, reducing water use and recycling flowback are seen by regulators as preferred alternatives to disposal. Using best practices that exceed minimum regulatory requirements builds good will with regulators. A reputation for exceeding minimum standards also benefits perceptions in community relations.

A re-use strategy provides the greatest control over water management supply and water management costs. Typically 10-40% of frac fluid returns to the surface as flowback. Using the flowback as a water source secures a sustainable, known, and uninterrupted water supply required for long-reach horizontal wells and multi-well completions, from the same pad, during a development program (this is also known as the “well factory approach”). This allows operators to accurately forecast water costs, which are a large component of the well completion costs and lease operating expenses.

Furthermore, mobile treatment and re-use of flowback (and produced water) eliminates trucking, and minimizes transfer costs for the volume of water treated. Trucking and transportation costs are typically the major component of the total water management cost. In some basins, the Permain for example, wells re-use their complete frac load volumes and continue to generate water from produced water over the life of the well. This enables a ready, locally available supply, though it will require treatment before re-use on new wells.

In the following sections, this publication will deal more specifically with shale gas flowback, so that a more concrete cost and benefit analysis (in the case study) may be provided.

Unconventional Produced Water Re-Use Technology

The treatment of unconventional reservoir produced water is complex. For example, shale gas flowback has a a high degree of variability in both quantity and composition. Early stage flowback has relatively high flowrates, but low total dissolved solids (TDS). Late-stage flowback has low flowrates, but high TDS. The chemical frac additives can vary depending on the type of shale and the completion required. The shale geology also varies, usually only slightly from wells in the same play and dramatically in different plays. Typical hydraulic fracs can be broken down into three basic categories: Slickwater, Linear Gel, and Cross-Linked Gel. These types of fracs vary with respect to the type and quantities of chemicals involved.

Water (either fresh or re-use) is the primary ingredient of any frac fluid and the water quality and chemistry differences can impact the type, dose, and behavior of frac chemical additives. Each frac fluid system has an upper limit for various components such as chlorides, iron, hardness, pH, and boron. Other components, such as hydrogen sulfide and total suspended solids, can be problematic for both management of water on the surface as well as down hole. On the surface, hydrogen sulfide poses a safety and corrosion risk. Suspended solids can accumulate in surface storage as well as potentially reduce well conductivity due to proppant fouling, reducing long-term well production.

The key issues associated with re-using produced water are as follows:

- Corrosion due to increased chloride, sulfate, ammonia, or sulfide. This can cause accelerated corrosion on surface and downhole equipment. If severely corrosive waters are to be used, often equipment must be replaced with that of more sophisticated and costly metallurgy.
- Scale formation due to calcium, strontium, barium, magnesium, alkalinity, sulfate, phosphate, or silica. This poses a risk to surface equipment, subsurface equipment, and potentially the formation.
- Fouling from increased suspended solids, iron, magnesium, aluminum, or organics. This poses risks similar to scale formation.
- Microbial growth from increased phosphate, ammonia, and organics. In particular, sulfate reducing bacteria (SRB) is problematic as it has the potential to produce hydrogen sulfide (which poses serious satefy concerns on the surface) and residual SRB can sour the well.
- Normally occurring radioactive material (NORM) – Shale gas waters can have varying levels of NORM, typically in the form of Radon or Radium-226. Radium-226 tends to co-precipitate with barium sulfate and can accumulate on equipment where BaSO4 scale is a concern.
- Interference with chemical additives (specifically friction reducers, polymers, and gels). Contaminants in the water can reduce the effectiveness of chemical additives requiring either higher doses or more sophisticated chemicals. This can result in higher chemical costs and reduced predictability of the injection fluid.
- Potential subsurface interference – suspended solid accumulation, scale formation, and incompatible waters introduced into the reservoir pose a risk in reducing formation conductivity and reduced production.
- Solid accumulation is surface storage equipment – solids can drop from solution in tanks, pits, and other equipment. This reduce the effectiveness of the equipment and potentially distrupt activity to allow for cleaning.

Re-use technology can be used to reduce components of concern to levels that allow for a safe, effective, frac fluid that is chemically compatible with formation geochemistry. Effective re-use technology can help to mitigate the negative impacts of these issues. That said, successful re-use treatment technology must meet the following key criteria:

Broad treatment spectrum: the technology must be able to effectively treat water with a broad composition range. Flowback component concentration, such as hardness, iron, total dissolved solids, total suspended solids, organics, hydrogen sulfide, residual frac chemicals, and bacteria, can vary significantly. Testing for components on each truckload of water is not practical or logistically possible. The system must be able to treat effectively any flowback brought to the facility. Systems with constraints on certain components can quickly render the treatment operation ineffective and potentially stall the overall completion.

Adaptability: each shale play has different geology and each producer has its own unique completions strategy that dictates the water chemistry requirements for the frac. The technology must be able to adapt to meet differing effluent specifications and completion stratergies.

Cost efficiency: most often, shale gas flowback is re-used directly with no (or very minimal) treatment. The cost of re-use treatment technology must kept minimal. The benefits of re-use treatment include reducing complications on the surface (corrosion and solid accumulation), reduced frac chemical cost, increased predictability (water quality variables are controlled), and potentially improved frac performance (some theories suggest accumulation of suspended solids and precipitated salts in proppant sections reduce conductivity and overall production). Comparatively, the benefits of re-use technology must outweigh the cost.

Robustness: re-use treatment technology must be capable of operating in the oil field under demanding and harsh conditions. Often sites are in remote locations, far from support services. Systems made of durable and simple components can be repaired or replaced in the field if required. Systems made with complex and specialized components are vulnerable to significant downtime in the event of failures.

Mobility: systems that can relocate quickly to the point of treatment allows re-use treatment to be as accessible as possible.

Many types of technology have been trialed and tested for the treatment of shale gas flowback for re-use. The following is a summary of some of the key technologies:

Media Filtration: a media filter is a type of filter that typically uses loose media such as sand, diatomaceous earth (DE), or other material to filter solids from water. Media filters typically have two modes of operation: filtration and backwash. During the filtration mode, water is run through the filter and solid particulate accumulates on the media. When the media has reached its maximum solid loading, the filter is put into backwash mode and flushed to remove the accumulated solids from the media. Media filtration achieves very high total suspended solids (TSS) removal rates and can provide a filtrate with a defined maximum particle size, depending on the type of media selected. Media filters are typically effective when the maximum TSS in the water is less than 50-to-100 mg/L. When TSS loading exceeds this value, the backwash frequency increases, which reduces the system's capacity and the overall volume of backwash water required to clean the filter. Shale gas flowback TSS can range from 300-to-1000 mg/L. Media filters in shale gas applications require high backwash frequencies, reducing the amount of water recovered significantly, which increases the associated cost of either processing or disposing of the backwash. Media filtration will only remove suspended solids; all dissolved material (such as iron) will remain in solution unless other additional treatment is used to precipitate these components. Media filters are excellent polishing filters downstream of primary TSS separation equipment when very low TSS levels or a small defined particle size are criteria.

Bag/Cartridge Filtration: a cartridge or bag filter is a type of filter that uses disposal elements to filter solids from the water. The filter elements have a specific nominal micron size. Elements are commonly made from pleated polysulfone, woven polypropylene, or pleated paper. When the filter elements become loaded with solids, they need to be removed, cleaned, and replaced with new elements. Most of the solids in flowback are small colloidal particles and are difficult to remove without coagulating the solids prior to filtration. Cartridges with a small particle size tolerance require very frequent changes, which are expensive and labor intensive. Cartridges with a large particle size tolerance allow the bulk of components of concern to pass through and do little to treat the water. Cartridge filtration is typically used as a guard system for the removal of small amounts of suspended solids.

Membrane Filtration: a membrane filter is a type of filter that has media with very small pore sizes. Pressure is used to drive permeate (filtered water) through the membrane and then a reject stream containing the contaminants is discharged from the system. Membrane filters (such as micro and ultra filtration) are able to reduce TSS and other components down to very low levels with very small particle sizes. Membranes tend to have low solid loading capacities and are vulnerable to fouling (which can reduce the membranes' capacity to filter water over time). Membrane filters typically require upstream pre-treatment to remove the bulk of the TSS and potential fouling components to be effective. In high fouling applications (such as shale gas), membrane replacement cost due to fouling and high reject rates can make this type of treatment expensive. Membrane filtration is typically used in applications where high water quality is required (such as reverse osmosis (RO) pre-treatment) and TSS and overall fouling potential is low.

Dissolved Air Floatation (DAF): dissolved air flotation is a process that clarifies water by the removal of suspended matter, such as oil or solids. The removal is achieved by dissolving air in the water, or wastewater under pressure, and then releasing the air in a flotation tank. The released air forms tiny bubbles, which adhere to the suspended matter, causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. Many of the solids in flowback are heavier than water. A DAF will remove a portion of the solids, but tend to get high levels of carryover as portions of the heavier solids sink, especially in applications with high solids loadings. DAFs can be optimized for low carryover, but, as conditions change, they require a high level of monitoring and adjustment to ensure they are working properly. DAFs are effective in applications where the nature of the water is consistent and the primary target components for removal are buoyant (oil, etc.).

Oxidation (such as ozone or chlorine dioxide): oxidation technology is very effective at precipitating iron, breaking down organics, removing hydrogen sulfide, and disinfecting (bacteria control). Ozone and chlorine dioxide have significant safety issues and require careful oversight to be used safely. Oxidation systems can be effectively incorporated with other technology to eliminate bacteria, hydrogen sulfide, and precipitate metals (such as iron), but require secondary technology for the removal of suspended solids. Stand-alone oxidation systems are not practical in shale gas applications, since they do not remove suspended solids.

Electrocoagulation (EC): electrocoagulation uses electrical current to release iron and/or aluminum into the wastewater, function ascoagulants. EC can be an effective technology for coagulating and precipitating suspended solids and does not require the use of bulk chemicals, which has logistical advantages in remote applications. A certain level of oxidation takes place during EC, which also aids in the breakdown of hydrogen sulfide, organics, and bacteria. EC electrodes do have a tendency to foul in high fouling applications, such as shale gas applications, which result in the need for frequent cleanings (specifically with residual friction reducers and gels). EC relies on the salinity (conductivity of the water) to transmit electricity and to dissolve the coagulant metals from the electrodes. If the conductivity of the water is variable, such as in shale gas applications, EC requires frequent monitoring and adjustment to ensure the coagulation reaction is taking place adequately and that residual levels of iron and aluminum do not exceed effluent specifications. EC also tends to be more expensive due to the sophisticated equipment required and must also be coupled with an effective solids removal system. EC has proven to work in shale gas applications, but is not necessarily the most reliable or cost effective.

Chemical Precipitation/Clarification: chemical precipitation/clarification uses chemical coagulants to precipitate components from the wastewater (such as sludge), which settle in a clarifier and can be removed and dewatered with equipment, such as a filter press. Chemical coagulation proved to be the most effective across a wide range of flowback qualities. Clarification is the most effective at managing the greatest range of suspended solids and the chemical program can be adapted to manage a wide range of feed water characteristics and effluent specifications. These systems are typically made up of very simple components that are not prone to breakdown or fouling. Fountain Quail Water Management conducted extensive pilot studies with filtration, electrocoagulation, dissolved air floatation, and oxidation, and determined that chemical precipitation/clarification best meets the criteria for re-use treatment of shale gas flowback.

Example of a Chemical Precipitation and Clarification System

Fountain Quail's ROVER is an example of a chemical precipitation and clarification system. The ROVER consists of a low-profile clarification trailer and an auxiliary support trailer. Flowback is pumped from the customer's source (frac tank, pit, etc.) into the unit via an adaptable location feed pump. Suspended solids and organics are precipitated from the solution using an adjustable chemical system. The solids settle to the bottom where they are collected and de-watered. Clean brine is pumped out of the system to a designated location specified by the customer. This mobile clarifier allows producers to recycle water ondemand, providing a powerful and flexible tool in managing oilfield operations. Capacity is 10,000 bbl/day of feed water. The unit is DOT approved for non-permit transportation in the United States and Canada.

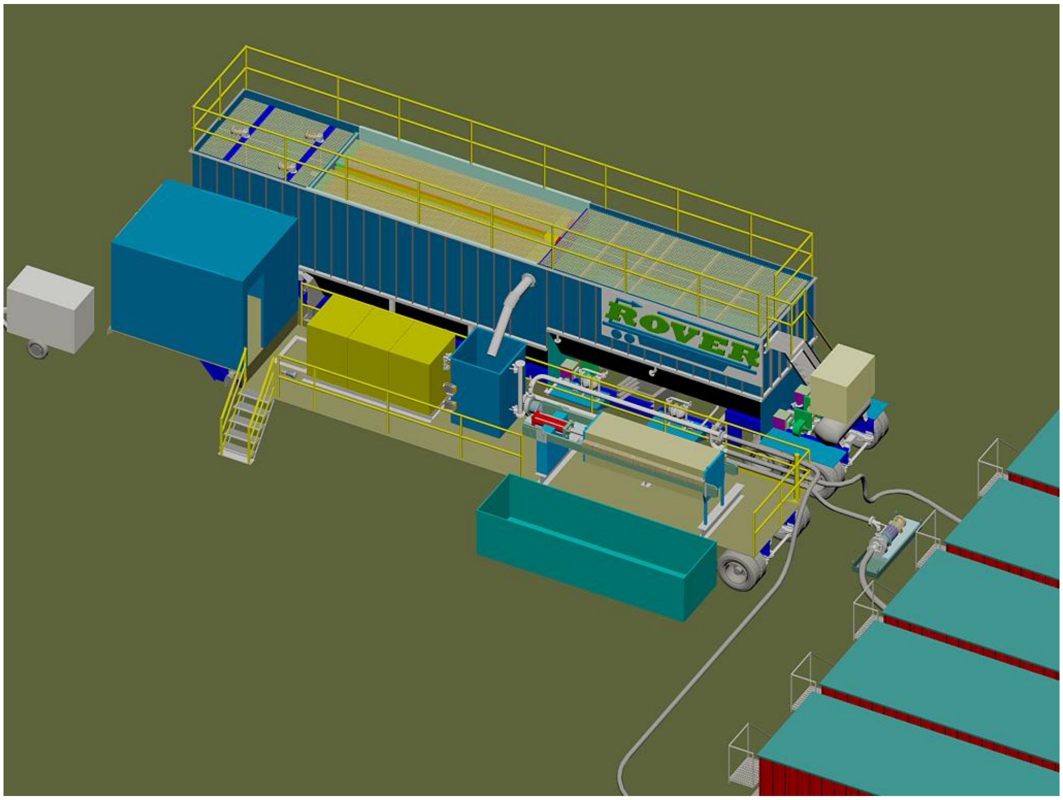


Figure 1: Conceptual CAD ROVER Facility Layout

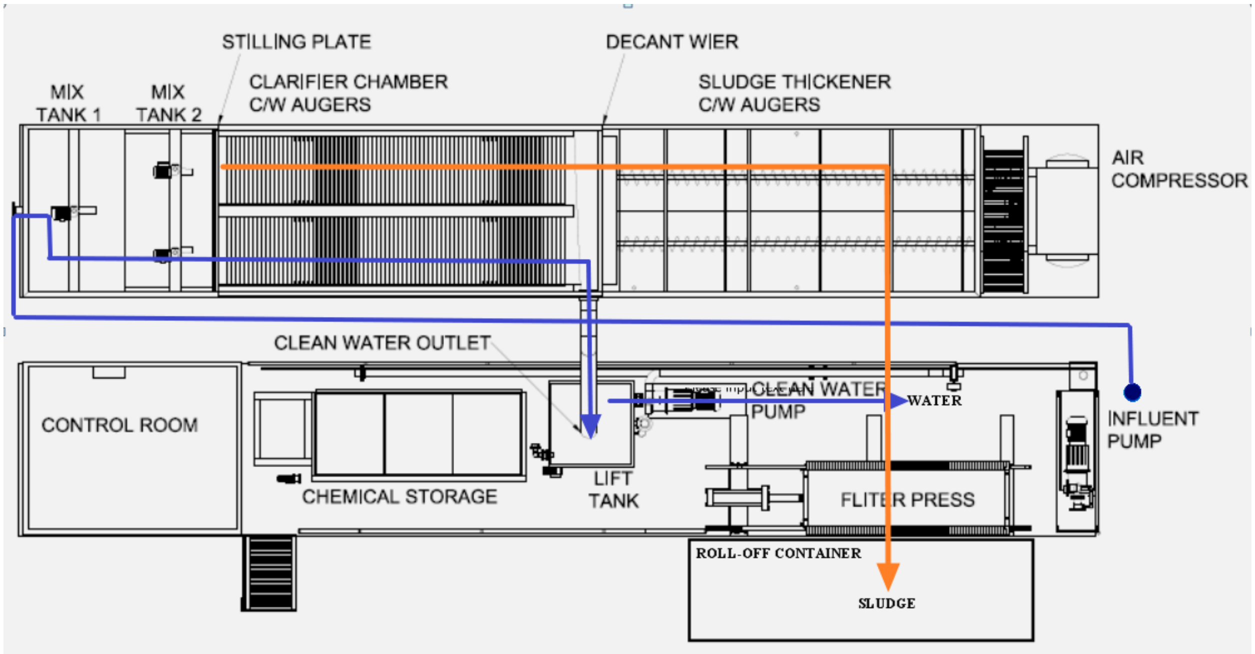


Figure 2: ROVER Layout and Process Flow

The ROVER layout is shown above. The raw flowback water is pumped via the influent pump (please refer to the blue dot in the graft) from an above-ground storage pit, or frac tanks, into the ROVER. As the water enters the clarifier, it flows first into a mixing chamber where conventional water treatment coagulants and/or pH control chemicals are added to initiate coagulation. The coagulated water then flows into a second mix tank, where a flocculent is added to aid in the formation of larger, more easily settled particles. Between the second mixing chamber and the clarifier is a stilling plate with a number of small holes in it. The stilling plate is intended to reduce turbulence as the water enters the clarifier, which allows for quicker sedimentation of the flocculated solids.

Once the flocculated water enters the clarifier, the clear water flows up through the lamella plate pack, which allows for more efficient separation. At the top of the plate pack, the clear water flows through a weir plate into a system of collection troughs that convey the water out of the clarifier trailer to the auxiliary trailer via an 8” PVC pipe. The clarifier trailer has a lift tank that provides some head pressure for the clear water transfer pump, which delivers the clarified water out of the ROVER to a designated holding tank nearby.

The solid particles that flow through the stilling plate fall to the bottom, where a set of augers drag them toward the back of the tank. At the back of the clarifier section, there are a set of pump-out boxes which are connected to a pair or 2” air-operated diaphragm pumps. These pumps transfer the sludge from the clarifier section into the sludge thickener, which is located on the back half of the clarifier trailer. In the sludge-thickening section, there is a second set of augers that move the sludge to the back of the thickener section into another set of pump-out boxes. Sludge is continuously pumped into the thickener, where it compacts under its own weight, releasing water. The relatively low TSS water in the sludge thickener is then allowed to decant from the sludge-thickener back to the clarifier trailer, where it combines with the treated water and goes back through the clarification process.

From the pump-out boxes at the back of the sludge thickener, the sludge from the clarifier is transferred, using another 2” air-operated diaphragm pump, to the filter press for dewatering. The filter press consolidates the sludge into a firm filter cake, which can be sent to landfill for disposal. The filter press permeate, or clear water, is directed to the transfer tank on the auxiliary trailer and removed from the system with the clarified water.

Additional information as follows for ROVER:

- Flow rate: the Rover flow rate is adjustable up to 10,000 bbl/day (300 gpm).
- Power: a portable 75 kW diesel power generator unit powers the ROVER treatment equipment, including all pumps, lighting, and related equipment.
- Solid waste: the ROVER has an integrated filter press, which empties into a roll-off box.

- Performance monitoring: the ROVER is equipped with the necessary analytical equipment to monitor effluent quality for key performance indicators including the following:
    - Flow Rate
    - pH
    - Specific Gravity and Conductivity
    - Turbidity
    - Iron
    - Total Hardness
    - Alkalinity
    - Temperature
    - Hydrogen Sulfide

Additional analysis can be completed via third-party laboratories.

Rover, a Case Study

A producer is developing a field in West Texas. A severe fresh water shortage exists in the immediate area. The nearest water depot is 50 miles away, resulting in a 100 mile round trip for water haulers. The drilling and completions schedule outruns water availability. The existing field has a produced water collection system that gathers 15,000 bbls/day from existing wells. Average completions in this field require 85,000 bbls/completion. Due to the high hardness of the produced water and the associated impacts on frac chemical compatibility, a 50/50 blend of fresh water and treated produced water is required. Prior to using the produced water as part of the completion fluid, it must be treated for hydrogen sulfide (H_2S levels range from 80 to 120 mg/L), bacteria control (disinfection), iron removal, and total suspended solid removal to prevent sludge accumulation in surface storage pits and tanks. The average distance to disposal wells is 50 miles, often with long wait times for unloading (100 mile round trip plus wait time). If treated produced water is used as 50% of the completion fluid, the produced water will reduce fresh water use from 85,000 bbl to 42,500 bbl/completion and eliminate disposal (42,500 bbl/completion). Securing water for completions and reducing water transportation costs become the key drivers for implementing a re-use strategy. A re-use facility is set up within an average of 5 miles to well completions. This allows for a great reduction of water transportation (both for fresh and produced water), securing water supplies, and reducing the need for fresh water, which effectively ensures that water availability (or the lack thereof) does not impact completion schedule.

The following figures illustrate the water management plan for both the Disposal and Re-Use scenario:

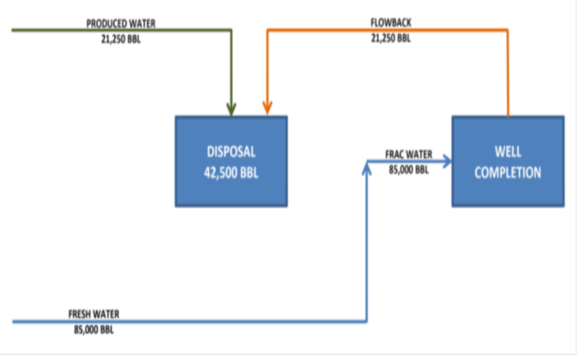


Figure 3: Disposal Scenario Process Flow Diagram

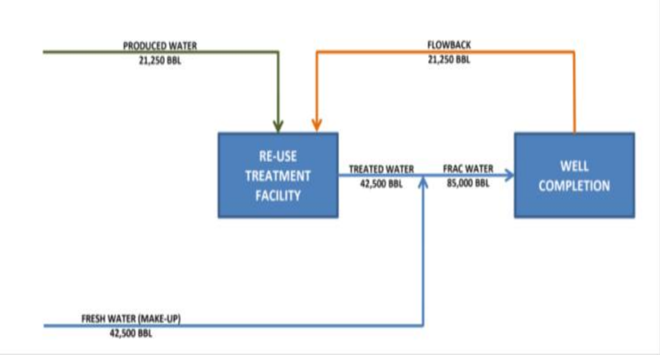
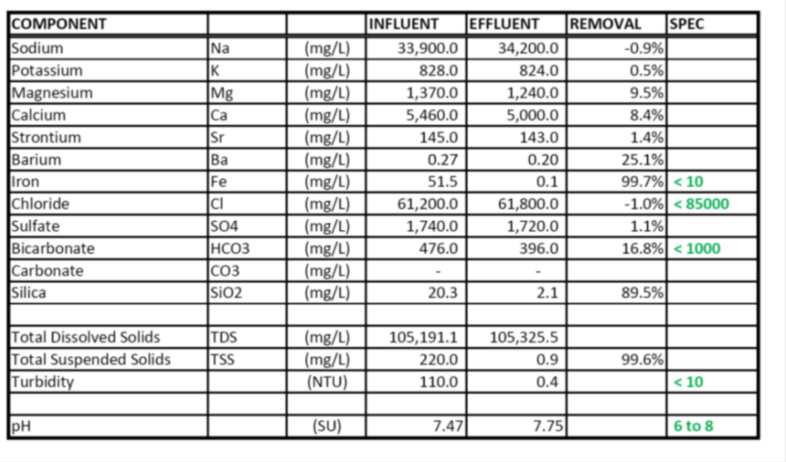
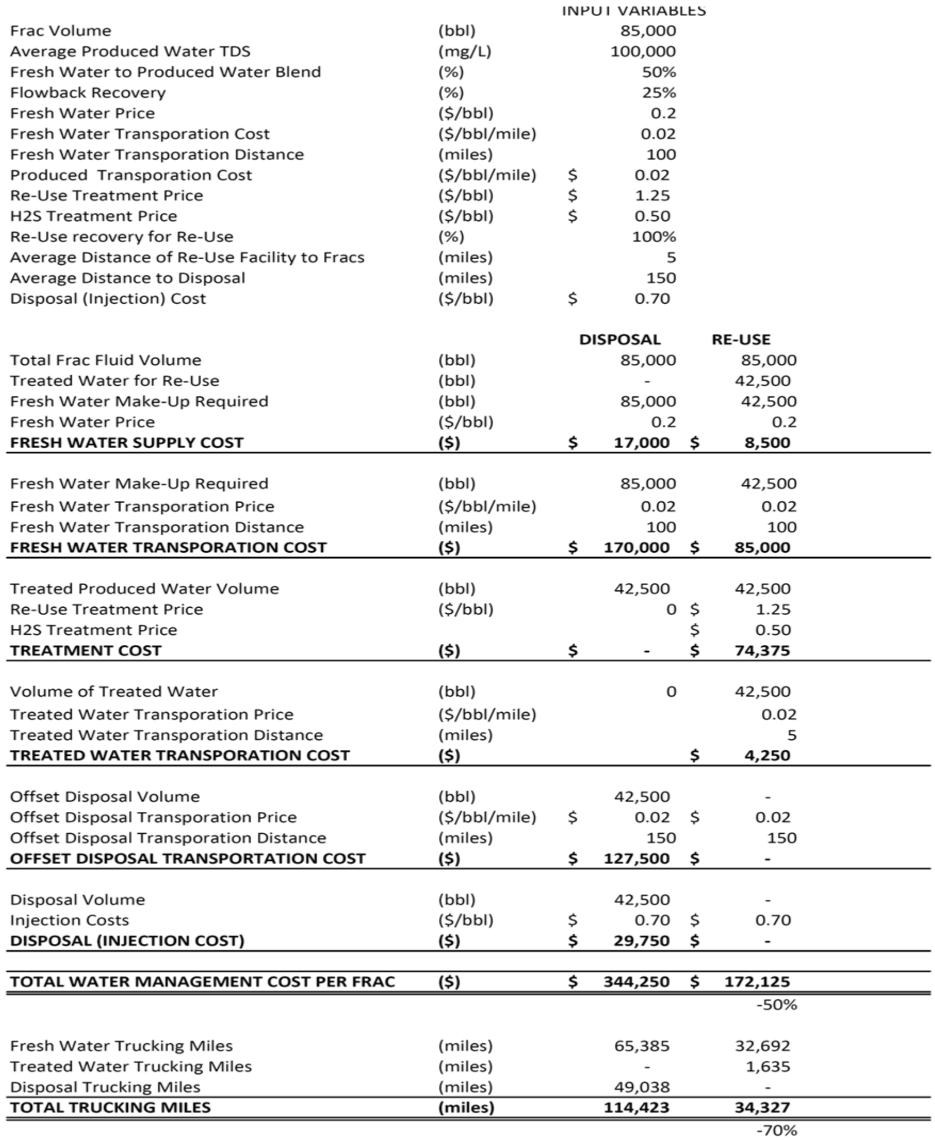


Figure 4: Re-Use Scenario Process Flow Diagram



COMPONENT			INFLUENT	EFFLUENT	REMOVAL	SPEC
Sodium	Na	(mg/L)	33,900.0	34,200.0	-0.9%	
Potassium	K	(mg/L)	828.0	824.0	0.5%	
Magnesium	Mg	(mg/L)	1,370.0	1,240.0	9.5%	
Calcium	Ca	(mg/L)	5,460.0	5,000.0	8.4%	
Strontium	Sr	(mg/L)	145.0	143.0	1.4%	
Barium	Ba	(mg/L)	0.27	0.20	25.1%	
Iron	Fe	(mg/L)	51.5	0.1	99.7%	< 10
Chloride	Cl	(mg/L)	61,200.0	61,800.0	-1.0%	< 85000
Sulfate	SO4	(mg/L)	1,740.0	1,720.0	1.1%	
Bicarbonate	HCO3	(mg/L)	476.0	396.0	16.8%	< 1000
Carbonate	CO3	(mg/L)	-	-		
Silica	SiO2	(mg/L)	20.3	2.1	89.5%	
Total Dissolved Solids	TDS	(mg/L)	105,191.1	105,325.5		
Total Suspended Solids	TSS	(mg/L)	220.0	0.9	99.6%	
Turbidity		(NTU)	110.0	0.4		< 10
pH		(SU)	7.47	7.75		6 to 8

Figure 5: An analysis of the average influent and effluent quality of the re-use facility



		INPUT VARIABLES
Frac Volume	(bbl)	85,000
Average Produced Water TDS	(mg/L)	100,000
Fresh Water to Produced Water Blend	(%)	50%
Flowback Recovery	(%)	25%
Fresh Water Price	($/bbl)	0.2
Fresh Water Transporation Cost	($/bbl/mile)	0.02
Fresh Water Transporation Distance	(miles)	100
Produced Transporation Cost	($/bbl/mile)	$ 0.02
Re-Use Treatment Price	($/bbl)	$ 1.25
H2S Treatment Price	($/bbl)	$ 0.50
Re-Use recovery for Re-Use	(%)	100%
Average Distance of Re-Use Facility to Fracs	(miles)	5
Average Distance to Disposal	(miles)	150
Disposal (Injection) Cost	($/bbl)	$ 0.70

		DISPOSAL	RE-USE
Total Frac Fluid Volume	(bbl)	85,000	85,000
Treated Water for Re-Use	(bbl)	-	42,500
Fresh Water Make-Up Required	(bbl)	85,000	42,500
Fresh Water Price	($/bbl)	0.2	0.2
FRESH WATER SUPPLY COST	**($)**	**$ 17,000**	**$ 8,500**
Fresh Water Make-Up Required	(bbl)	85,000	42,500
Fresh Water Transporation Price	($/bbl/mile)	0.02	0.02
Fresh Water Transporation Distance	(miles)	100	100
FRESH WATER TRANSPORATION COST	**($)**	**$ 170,000**	**$ 85,000**
Treated Produced Water Volume	(bbl)	42,500	42,500
Re-Use Treatment Price	($/bbl)	0	$ 1.25
H2S Treatment Price			$ 0.50
TREATMENT COST	**($)**	**$ -**	**$ 74,375**
Volume of Treated Water	(bbl)	0	42,500
Treated Water Transporation Price	($/bbl/mile)		0.02
Treated Water Transporation Distance	(miles)		5
TREATED WATER TRANSPORATION COST	**($)**		**$ 4,250**
Offset Disposal Volume	(bbl)	42,500	-
Offset Disposal Transporation Price	($/bbl/mile)	$ 0.02	$ 0.02
Offset Disposal Transporation Distance	(miles)	150	150
OFFSET DISPOSAL TRANSPORTATION COST	**($)**	**$ 127,500**	**$ -**
Disposal Volume	(bbl)	42,500	-
Injection Costs	($/bbl)	$ 0.70	$ 0.70
DISPOSAL (INJECTION COST)	**($)**	**$ 29,750**	**$ -**
TOTAL WATER MANAGEMENT COST PER FRAC	**($)**	**$ 344,250**	**$ 172,125**
			-50%
Fresh Water Trucking Miles	(miles)	65,385	32,692
Treated Water Trucking Miles	(miles)	-	1,635
Disposal Trucking Miles	(miles)	49,038	-
TOTAL TRUCKING MILES	**(miles)**	**114,423**	**34,327**
			-70%

Figure 6: Economic Comparison between Disposal and Re-Use Scenario

Figure 7: The Re-Use Facility Influent Water (Right) and Effluent Water (Left)

Figure 8: Photographs of the ROVER Re-Use Facility (Left and Right)

Conclusion

For many unconventional applications, appropriate selection of re-use technology enables the transformation of produced water from a liability into an asset. Chemical pre-treatment and clarification have been proven to be the most robust technology for the treatment of shale gas flowback and produced water for re-use. The ROVER is a fully contained mobile system, designed for easy integration into field water-management strategies, enabling the re-use of produced water for re-use. Depending on the application and re-use criteria, the ROVER makes an excellent stand-alone treatment system, or work in combination with other process modules (such as Oil Water Separation, Polishing Filtration, and MVR Evaporation). Scenarios with water supply and disposal challenges (generally associated with long transportation distances) benefit the most from re-use strategies from both an economic and environmental perspective. A re-use strategy with correct re-use treatment can provide a high level of control over the overall water management plan by reducing the dependency on water supply and disposal, reduce impact on the community and reduce environmental liability. In the case study evaluated in this paper, fresh water requirements were reduced by 50%, disposal was eliminated, total water management costs were reduced by 50% and total water trucking miles was reduced by 70%. These accomplishments enabled the producer to execute their development plan in a field that would have otherwise been limited by both water availability, while significantly reducing production cost at the same time.

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