

## **Produced Water - the Unlikely Hero of the Permian Basin**

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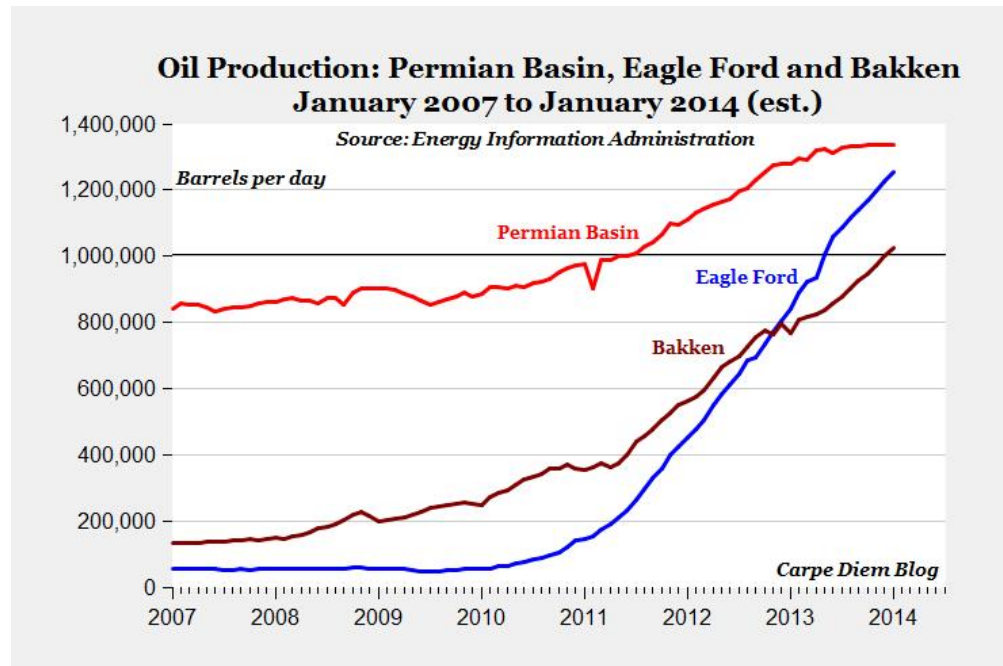
### Introduction

Produced water (PW) has traditionally been viewed as a byproduct of oil and gas development. Over the past decade onshore unconventional oil and gas development has forced the industry to reevaluate how it looks at PW. Some of Texas' greatest new onshore oil developments are in areas that have extremely stressed fresh water supplies. When looking for a reliable source of water for hydraulic stimulation the energy producers have begun to use water that has little or no value to competitive interests, including impaired water and brackish water. This paper will look at several examples where industry has gone a step further and has resorted to using PW as the base fluid for new hydraulic stimulations. The old way of thinking about PW focused on disposal. The new way of thinking about PW involves combining disposal, blending and recycling. The Permian Basin offers some unique examples of how PW can often be the solution to help energy producers meet their water needs.

The state of Texas has helped remove barriers to the beneficial re-use of PW. The new RRC recycling rules were introduced in March 2013 and HB 2767 (Phil King) was signed into law on May 29/13. HB 2767 allows recycled water liability to be transferred away from the generator of the PW. PW is no longer strictly a liability - in many cases it can become an asset.

## 1.0 Permian Basin

A recent Wall Street Journal article proclaims “U.S. Oil Prices Fall Sharply as Glut Forms on Gulf Coast<sup>1</sup>.” Where did the oil come from?



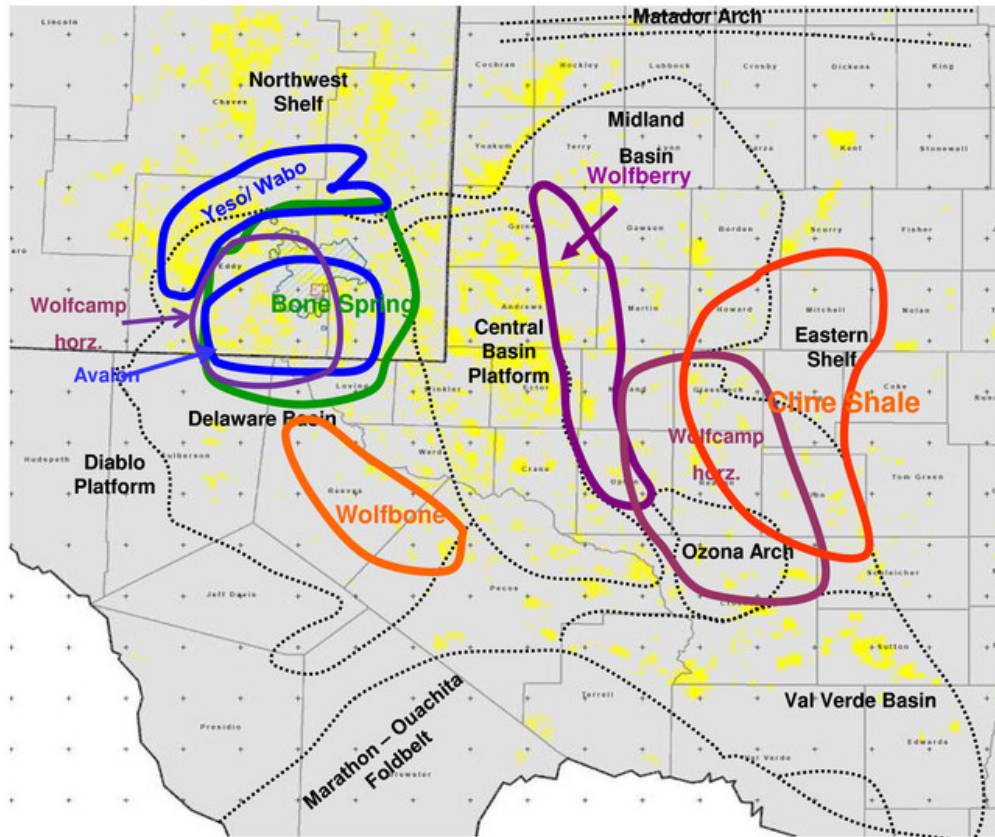
The new domestic supply is largely due to unconventional oil development in areas like the Eagle Ford (south Texas), Bakken (North Dakota), Utica Shale (Ohio) and of course the Permian Basin (west Texas). All of these developments are driven by advances in long-lateral horizontal drilling coupled with multi-stage hydraulic fracturing.

This paper will focus on the Permian Basin. The Permian Basin is approximately 260 miles by 300 miles and covers roughly 86,000 square miles in west Texas and New Mexico. According to Pioneer Natural Resources, the Spraberry field in the Permian Basin contains an estimated 50 billion barrels of oil equivalent which makes it the largest U.S. oil field and the second largest oil field in the world<sup>2</sup>.

<sup>1</sup> Wall Street Journal, December 7, 2013.

<sup>2</sup> [www.pxd.com/operations/permian-basin](http://www.pxd.com/operations/permian-basin)

The Permian Basin is a unique area in that there are multiple overlapping formations in the region (refer to map below)<sup>3</sup>.



The key problem with the Permian lies with the availability of water. The entire western half of Texas relies on groundwater which is diminishing due to a lack of adequate recharge to the aquifers. There are no sizable natural rivers or lakes as backup. This is a serious issue for the entire state of Texas – so much so that Proposition 6 was recently passed to allow \$2bn from Texas' Economic Stabilization Fund to be diverted into helping solve Texas water issues.

Development of the Permian using long lateral multi-stage hydraulic fracturing will require an enormous volume of water (many wells are planning for 300,000bbl+ per frac). The oil is there, but is the water?

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<sup>3</sup> March 2013 OXY Presentation

(<http://www.sec.gov/Archives/edgar/data/797468/000079746813000013/hwconference2013presentatio.htm>)

## 2.0 Water Sources

The development of the potential oil reserves in the Permian Basin spells US energy independence. The prize is huge and the technology exists – the key to unlocking the resource potential is water.

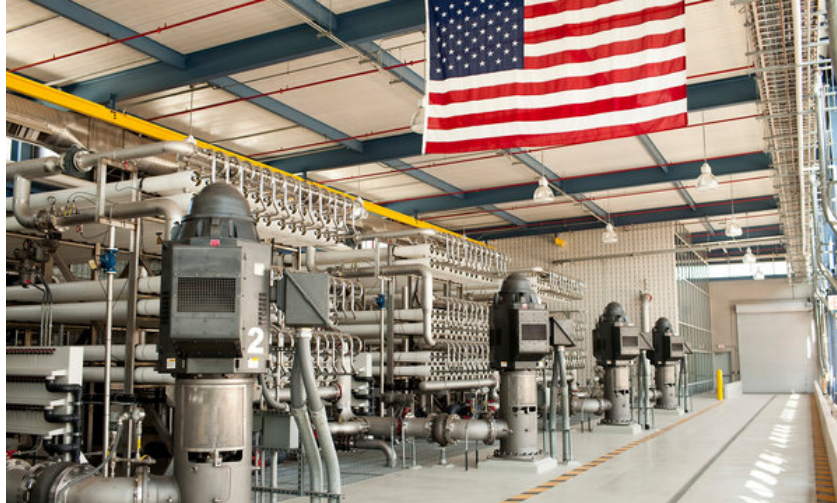
Freshwater is available to varying degrees throughout the Permian Basin, however competition for the resource is becoming intense. Municipalities like Midland, Odessa and San Angelo are struggling to identify where they will get water to meet their current needs and additional water to meet their projected growth. Demand for municipal water in Texas is projected to rise from 4.9 million acre-feet (2010) to 8.4 million acre-feet by 2060<sup>4</sup>.

Desalination of brackish water is being seriously considered by municipalities as part of the solution. El Paso led the way by recently building the \$91M Kay Bailey Hutchison desalination plant, which is capable of supplying 27.5 million gallons of water a day<sup>5</sup>. For now the desalination plant remains on standby and its capacity is rarely used, however the city felt it had to have a contingency plan. The State Water Plan envisions Texas deriving 3.4% of its 2060 water needs from desalination (currently <1% is from desalination). With projected population growth factored in, meeting the 2060 water needs will require a massive investment into desalination to meet the 3.4% target.

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<sup>4</sup> RRC website (<http://www.rrc.state.tx.us/about/faqs/wateruse.php>)

<sup>5</sup> [http://www.nytimes.com/2012/06/10/science/earth/turning-saltwater-from-earth-and-sea-into-drinking-water.html?\\_r=0](http://www.nytimes.com/2012/06/10/science/earth/turning-saltwater-from-earth-and-sea-into-drinking-water.html?_r=0)



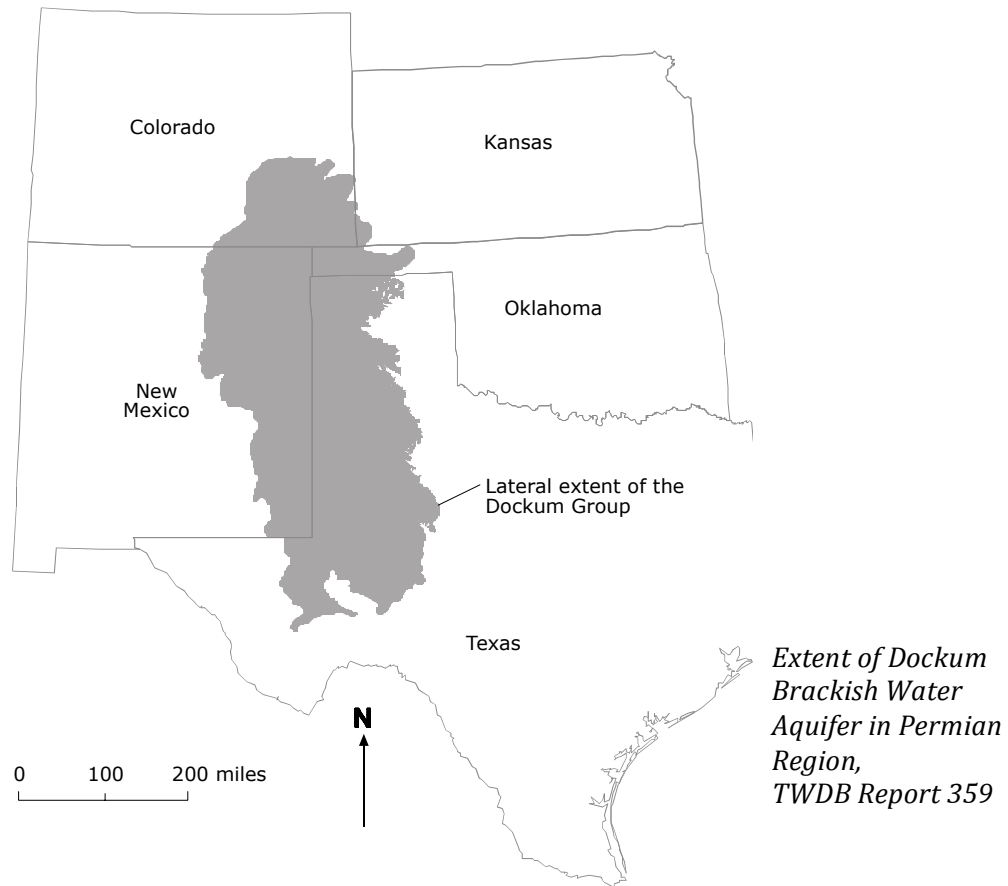
*Kay Bailey  
Hutchison  
Desalination Plant,  
El Paso TX*

Brackish water (5,000mg/L TDS to 30,000mg/L TDS) is relatively abundant in the Permian region, predominantly from the Dockum Aquifer, however this water cannot be viewed as a “free resource”. Many of these brackish water formations have minimal, if any, recharge and will deplete quickly if drawn upon heavily. There is additional concern from hydro geologists regarding the potential for infiltration between fresh and brackish water formations. By drawing too heavily on brackish water there is potential to impact freshwater layers above if the hydrogeology is not properly understood beforehand. Keep in mind that municipalities in west Texas are already looking at the brackish water as forming part of their future supply as well.

Texas Water Development Board (TWDB) Report 359 states “We estimate that the total amount of water available in the entire Dockum aquifer in Texas is approximately 185 million acre-feet. Of this amount, approximately 109 million acre-feet contains TDS of less than 5,000mg/L. However, not all of this water is readily available for withdrawal. In fact, the measured aquifer parameters suggest that the aquifer cannot provide large quantities of water. The confined parts of the aquifer receive little recharge, and any water withdrawn from these areas will essentially mine the aquifer.”<sup>6</sup>

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<sup>6</sup> Texas Water Development Board – Report 359 “The Groundwater Resources of the Dockum Aquifer in Texas” by Robert G. Bradley P.G., and Sanjeev Kalaswad, Ph.D., P.G. December 2003. Page 53.



When more extreme options such as piping in water from other regions (i.e.: east Texas) are examined, it becomes apparent just how big Texas really is. The pumping costs (energy and infrastructure) involved are mind-boggling, not to mention the fact that many of these areas are not prepared to have their water be diverted willingly to west Texas<sup>7</sup>.

So freshwater is not a long term solution for Permian development unless a new source can be identified. Brackish water may be a short-term solution, however pressure will increase as municipalities and others look to this supply for their needs.

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<sup>7</sup> Cadillac Desert: The American West and Its Disappearing Water, Revised Edition. By Marc Reisner, Penguin Books, June 1993

What remains for water resources is somewhat surprising. Since the Permian Basin is an old production field there is a considerable volume of produced water in the region. David Burnett from Texas A&M University estimates, based on 2002 data, that the Permian Basin generates roughly 400 million gallons (9.5 million bbls) of PW per day<sup>8</sup>. This wastewater has traditionally been sent to deepwell disposal, however producers are starting to look at this as a resource rather than a waste. The focus of this paper is to examine how Permian Basin produced water can be beneficially re-used for the development of new wells. The waste that nobody wanted, existing produced water, may be a critical part of the solution for developing the resources of the Permian Basin going forward.

### 3.0 Produced Water Re-Use

The Permian Basin is a large area with multiple overlapping zones that were developed over decades. Technology for drilling and completing wells changed dramatically over this timeframe. As such, the Permian offers a wide range of produced water composition.

Some Permian PW has high H<sub>2</sub>S content<sup>9</sup>, making it a challenge to handle for safety reasons and also for potential corrosion issues. H<sub>2</sub>S is deadly in very small concentrations<sup>10</sup>, so any personnel involved in recycling must be aware of the dangers and be properly trained in H<sub>2</sub>S awareness. Fountain Quail has recycled Permian PW with H<sub>2</sub>S concentrations in excess of 200ppm. All of our operators in the Permian are required to wear H<sub>2</sub>S detectors, even if they do not expect H<sub>2</sub>S to be present.

The amount of Total Dissolved Solids (“TDS”) in the PW varies

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<sup>8</sup> “Potential for Beneficial Use of Oil and Gas Produced Water”, David Burnett, Texas A&M University

<sup>9</sup> H<sub>2</sub>S = Hydrogen sulfide

<sup>10</sup> OSHA considers H<sub>2</sub>S at or above 100ppm to be IDLH (Immediately Dangerous to Life and Health).

widely, with much of it averaging in excess of 100,000-120,000mg/L. The higher the TDS the more of a challenge it becomes to generate freshwater as %-recovery will decline with increasing TDS regardless of the technology used.

One big question operators face is “How much treatment is justified to meet the necessary water spec?” On the surface this is not a difficult question, except for the fact that there is not yet any agreed-upon specifications for what constitutes an acceptable frac fluid. The general consensus is that nobody wants to spend more than what is necessary to create an acceptable frac fluid.

There are risks to using PW as the base for frac fluid, including but not limited to the following:

- Downhole scaling.
- Solids/sludge deposition in containment. This is particularly exacerbated by treatment such as chloride dioxide (ClO<sub>2</sub>) and other “floc n’ drop” systems which instigate flocculation and cause solids to form in PW containment.
- Bacteria formation from sludge accumulation.
- Varying TDS levels in PW causing issues with cross-linking gels, etc.
- Potential liability from saltwater leaks during transfer and containment of fluid.

Many, if not all, of the risks above can be reduced or eliminated by applying varying levels of treatment to the produced water prior to re-use. The struggle remains to determine the proper balance between the cost of treatment and the offsetting increase in well performance (or reduction in liability).

#### 4.0 Recent Rule Changes

Regulators and legislators are under pressure to become more involved. Despite the relatively low volume of water used by the energy industry, hydraulic fracturing is an intense one-time use of water and this has drawn attention. The EPA is currently studying

hydraulic fracturing and is holding workshops and stakeholder discussions. The media has sensationalized the issue and environmental special interest groups have engaged, often with an agenda of stopping development at all costs.

#### 4.1 New RRC Recycling Rules

The Railroad Commission (RRC) opened up the recycling rules for review in 2011. Groups like the Texas Water Recycling Association ([www.txwra.org](http://www.txwra.org)) and energy producers met with the RRC staff to talk about improvements that could be made to encourage recycling. The new RRC recycling rules were adopted in March 2013. Highlights of the new rules include:

- Permit-by-rule. This allows operators to recycle their water without a permit.
- Multi-Lease. The old rules made a distinction between “on-lease” and “off-lease” recycling. This stipulation has been eliminated and the rules are now much simpler. Water can now be taken from multiple leases, co-mingled and be recycled for re-use.
- Multi-Operator. As long as the recycling operation is under the jurisdiction of an oilfield operator, water can be taken from different operators to be recycled and does not need to go back to the same energy company that generated the produced water.
- Special distinction for recycled distilled water. If PW is recycled back to freshwater standard using thermal distillation, then the RRC has allowed this recycled water to be handled as freshwater as long as it remains within the oilfield (i.e.: not discharged or used for purposed outside oilfield use). This special distinction was granted largely because of Fountain Quail’s 10-year track record with the RRC. During this period Fountain Quail recycled close to 1 billion gallons of PW back into distilled water (<100mg/L TDS).

The RRC summarized their new rules by stating *“With the adoption of this rulemaking, the Commission sets up a regulatory framework in which recycling is a viable alternative to disposal, but allows the operators to make their own water and waste management decisions.”*

#### 4.2 HB 2767

The House and Senate unanimously approved HB 2767 and it was signed into law by Governor Perry. The bill was drafted by Representative Phil King in May 2013 to allow the liability for PW to be transferred to the owner when it is sold. Without this new law many energy producers preferred to have their PW go to a disposal well rather than be recycled for fear that they would have an ongoing liability if the PW, even recycled, remained above surface. The new law allows energy producers to sever their liability if the PW is recycled – the liability is passed to the recycler and ultimately to the purchaser/user of the recycled water.

#### 5.0 Saltwater or Freshwater?

The fundamental question in shale water management is whether the producer wants to deal with (1) saltwater, or (2) freshwater. Once this question is addressed the decisions going forward become much easier to deal with.

On the surface, the re-use of saltwater is a much lower cost alternative if it is practical. While the treatment options for saltwater are varied and generally low cost, the storage and handling of large volumes of saltwater can become very challenging. For example, in Texas the producer is required to have an H-11 approved pit to store large volumes of saltwater. The permitting and construction of such pits becomes significant for large volume fracs.

Recycling to a freshwater standard involves more expensive treatment to remove the dissolved solids (TDS) from the PW.

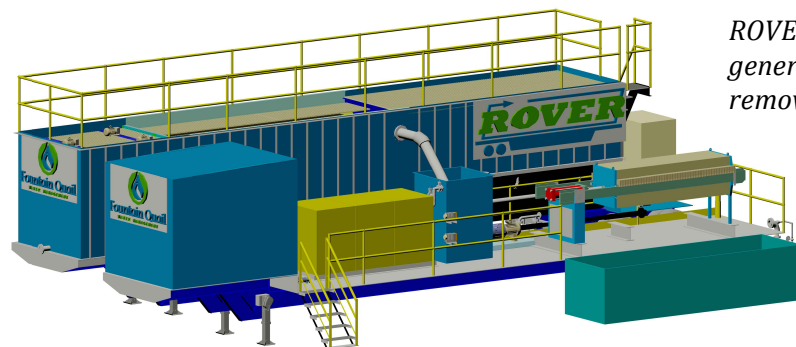
Fountain Quail has been recycling shale PW back to freshwater using NOMAD evaporator technology since 2004. Although the treatment cost is higher than for saltwater treatment, the logistics of storing and transporting the fresh (distilled) water become much easier if this path is selected.

Using freshwater eliminates the variability encountered when using saltwater. When saltwater is used the TDS of the brine will vary and this can pose a challenge for frac chemistry.

There is no right answer here and every producer needs to look at their own operation to determine if saltwater or freshwater is the preferred option.

## 6.0 Saltwater Case Study

Fountain Quail developed its ROVER mobile treatment system to generate clean brine from PW at the lowest possible price. The ROVER is a chemical flocculation/settling system that thickens and removes the solids as dry cake, leaving only clean brine (1-3 NTU) as product. It was designed by our engineers with the aim of being simple, rugged and easy to clean while simultaneously delivering consistent clean brine. The experience that led to the ROVER came out of a decade of trialing different technologies in shale PW treatment ahead of the NOMAD evaporator units in Texas.



*ROVER Treatment System generates clean brine and removes solids from PW.*

In this case the customer approached Select Energy Services for a complete water supply/containment/transfer solution for a well program in the Permian near NoTrees, TX. Select began to put together the necessary components but quickly realized that there would be no available water in the region on short notice. The only water found was PW from a nearby production battery. This PW had high H<sub>2</sub>S (~200ppm), suspended solids and iron which made it unacceptable for direct re-use.

Select and Fountain Quail jointly offered a complete package for the customer involving the following:

- a) Set up a mobile ROVER recycling operation adjacent to the existing production battery.
- b) Recycle water, as needed, and place the clean brine into a 40,000bbl above ground containment. As the frac contractor used the clean brine more was recycled to meet their needs for the next stage.
- c) The recycled water had to be clean (1-3 NTU), with iron removed and H<sub>2</sub>S at non-detect.

The set-up is shown in the photo below. The production battery is in the background and the 40,000bbl containment for clean brine is in the foreground. The ROVER is setup in between.

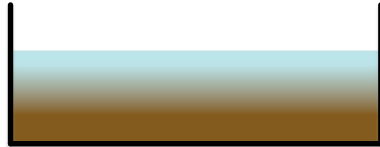


Removing solids from the PW before storing it in containment allows the following benefits:

- The entire volume of the containment is available for clean brine. If the solids were not removed ahead of time they could have taken up as much as 25% or more of the effective volume of the containment.

- Prevents expensive clean-up that would have resulted if solids/sludge were allowed to build up in the containment.
- Prevents new bacteria growth by eliminating the nutrient from the PW.

**1** Direct re-use or “floc-n-drop” into containment.



- Solids build up & reduce effective volume of containment.
- Bacteria blooms.
- Lower cost initially.
- Expensive clean-up.

**2** Remove solids prior to containment.



- Keep solids out of recycled water containment. 100% volume available for HF supply.
- Clean brine can be stored longer.



*Photos of water before (left) and after (right) ROVER treatment.*

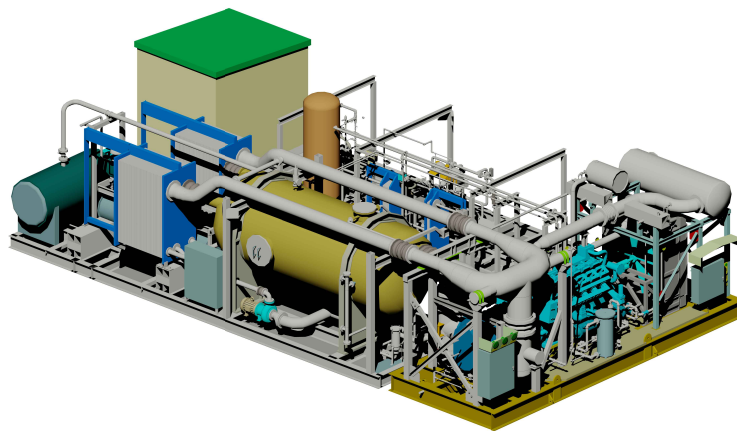
Fountain Quail Select (JV between Fountain Quail and Select Energy Services) jointly operated the recycling operation throughout several months at various locations in 2013. The customer intends to continue similar recycling in different parts of the Permian in 2014.

## 7.0 Freshwater Case Study

Most energy producers would prefer to use freshwater for hydraulic fracturing if it is readily available – it offers consistent composition and is easy to store and transport. There is also relatively low liability in the event of spills or other interaction with the environment (i.e.: birds landing in water pits or cattle drinking pit water). Any leftover water in pits can be left in place and transfer lines can simply be drained onto the ground (not the case for saltwater).

Treatment of PW to a freshwater standard can be a challenge, especially in high TDS water (the case for most of the Permian PW). The economics are helped if there is a beneficial re-use application, and thus value, for the residual concentrated brine left over, such as in the case study outlined below.

Fountain Quail uses a process-patented thermal evaporator called a NOMAD. These evaporators have been used successfully in Texas shale flowback/PW continuously since 2004. In fact, Fountain Quail was the first company to obtain a recycling permit with the RRC (no longer needed with new recycling rules). Devon Energy contracted for as many as 9 NOMAD units in the Barnett Shale. The NOMAD was developed to be rugged, efficient, easy to clean and easy to relocate. Each NOMAD is comprised of 3 skids that each fit on a standard lowboy trailer. The patented exchanger configuration allows the system to be very small, and more importantly, very easy to clean in this high fouling service.



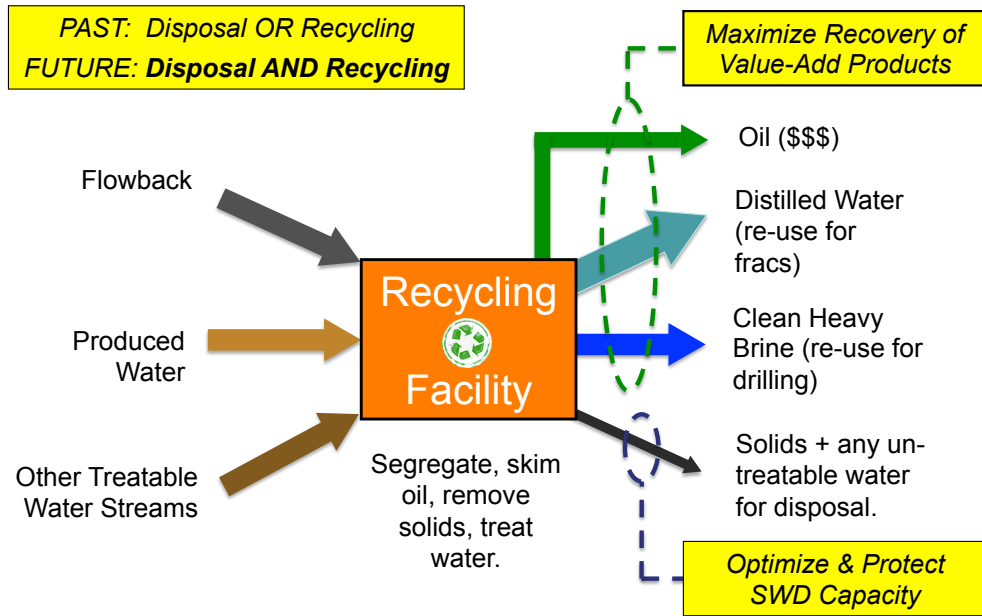
*NOMAD Treatment System generates pure distilled water and clean heavy brine for re-use.*

The producer in this case operates their own SWD injection well in a remote region of west Texas.

- Disposal is not an issue in this region, however freshwater is limited and the producer prefers using freshwater for hydraulic fracture stimulations.
- By using their own PW from their own SWD as the source water for a NOMAD installation the customer is becoming independent of groundwater.
- The NOMAD concentrate (9.8# clean brine) has value to the producer as a completions fluid and any excess concentrate can be sold to other producers in the region.
- Recycling their own PW also increases the longevity of the SWD injection well – less volume is injected and therefore the existing SWD can service far more production activity than previously.
- High solids early flowback used to be transported long distance to commercial SWD wells as the customer did not want this high solids water to compromise their SWD. This high TSS water can now be recycled rather than hauled away.
- Inevitably some oil goes down the SWD. By recycling this water any oil that gets past the standard gunbarrel separator will be recovered for the customer.

The installation involves pretreatment and 2 NOMAD units, with space to ultimately expand as more capacity is needed. The main source of energy is wellhead gas. Fountain Quail provides manpower for 24/7 operation and the customer now has access to both fresh (distilled) water and clean heavy brine (9.8#) at their central SWD facility.

This is an excellent example of combining recycling and disposal to maximize efficiency and the recovery of value-add products.



*2 NOMAD Permian Facility (8,000 bpd feed capacity).  
Feed (PW) containment in foreground, heavy brine containment in background.*

## 8.0 Summary

The Permian Basin offers a tremendous energy resource for our nation. Accessing water for long-lateral hydraulic fracture stimulations is a challenge today and competition for the remaining water in the region, including brackish water, will increase in the future. Starting with available, abundant PW and recycling this to either (1) clean saltwater, or (2) freshwater, offers a viable solution to help develop the Permian.