This presentation premiered at WaterSmart Innovations

watersmartinnovations.com
“Making Water Fracable”

Hydraulic Fracturing Solutions

Powered by FracSTAR

“Industry leaders in safety and innovation!”
“Making Water Fracable”

How do you make water “Fracable” if you never look at the water?
Conventional Water Usage Model

Fresh Water

Fracturing of Well

Well Flowback Water → Salt Water Disposal

Well Produced Water
The fracturing process uses an average of 230,000 barrels / 9,660,000 gallons of water per well. If only 6 wells are located on a pad, 1,380,000 barrels / 57,960,000 gallons of water per 6 well pad.

Shale gas fields need many more wells than conventional fields. This illustration shows expansion of a single well to 12 wells from two well pads a half-mile apart within the same square-mile area.

(Images courtesy of frackingboom.com)
U. S. Land Working Rig Count

- July 23-24 2014
- NCH Water Reuse Workshop
- CONFIDENTIAL
The average well takes 14 days to complete.

890 active drill rigs running for a year will drill 23,203 wells per year.

These wells would consume 5,336,690,000 Barrels / 224,140,980,000 Gallons of Water each year.
No sand, no water, no frac

No frac will take place unless the sand is on hand to complete the stages that are scheduled during a 24hr period.

By the same measure, if there is no water to carry the sand (Proppant) into the formation, there will be NO FRAC.

Water is the most important medium, and part of the Frac. It’s the safety, the rinse (Flush) and the carrier of the sand that holds the formation open to let the oil and gas escape.
Water delivery systems to location

- Pumped through pipes that can travel for many miles with no treatment of bacteria
- Trucking
How is water currently used?

- Water for at least one stage, and/or the number of stages to be completed for the first 24hrs, is on hand at location.
- Most locations have a set of working tanks to hold a minimum amount of water that is needed to start the fracturing process.
- The amount of water is considered a safety feature should a loss of water being delivered to the frac. As a safety an amount of water will be needed to flush the sand from the pumping equipment and the casing to avoid a screen out.
Water Storage

Does the bacteria count go up, down or stay the same?
Working Frac Tanks (4) = 2,000 Bbl.'s / 80,000 Gal. of Water

Sand Storage Tanks (3) (Sand Kings)

Sand Trucks Delivering Sand (3) (1 per Sand Kings)

Frac Van (Control Center)

Horse Power (Pumps)

Blender / Hydration Unit Mixes Sand / Water / Chemicals

Well Heads

Reuse Water 55,000 Bbl.'s 2,310,000 Gal.
Test Pit for first Frac Simulation

Test Pit for Chlorine Dioxide ClO₂
Impenentation for Fracing
50,000 Barrels / 2,100,000 Gallons

1) Run continuous ClO₂ generation
2) Maintain ClO₂ residual at 2 Points:
   A1 & A2) Point-#1 at Effluent from manifold
   B1 & B2) Point-#2 at Effluent of Pipping

Run for 10 hours at 100 BPM in each 10'' Pipe
<table>
<thead>
<tr>
<th>Date</th>
<th>Stage</th>
<th>A1 ClO₂ Res.</th>
<th>A2 ClO₂ Res.</th>
<th>Average ClO₂ Res.</th>
<th>ClO₂ Res</th>
<th>ClO₂ Res</th>
<th>Average ClO₂ Res</th>
<th>Source (Coming Into Unit)</th>
<th>SRB (col/ml)</th>
<th>APB (col/ml)</th>
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<td>Sample #1 @ Pump #1</td>
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Genesis Trailer

- 24’ Bumper Pull trailer
- 10’ Armadillo Trailer
- 2 Armadillo Lines with NO blending capabilities
- Treat 238 bbls/min
- 456 Points of measurement
- Measures Armadillo Lines and frac tank \( \text{ClO}_2 \) residual, conductivity, pH, and pressure
- Web based
- PID/PLC Control
### Test #2 Frac #1

#### 120,000 Barrel Pit

<table>
<thead>
<tr>
<th>Date</th>
<th>Stage</th>
<th>Inlet Manifold to the Working Tanks</th>
<th>Treated Samples at Blender</th>
<th>Untreated Water Cultures</th>
<th>Source (Coming Into Unit)</th>
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<tr>
<td></td>
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<td>Amadillo #1</td>
<td>Amadillo #2</td>
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<td>SRB (col/ml)</td>
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<td>2.90</td>
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### Test #2 Frac #1

#### 120,000 Barrel Pit

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<thead>
<tr>
<th>Date</th>
<th>Stage</th>
<th>Working Frac Tanks</th>
<th>Frac Tank #1</th>
<th>Frac Tank #2</th>
<th>Frac Tank #3</th>
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Source water was high in bacteria

- 9 Stage Frac Test results of Prefrac Bacteria Counts
  - SRB’s @ 109 (1,000,000,000 cfu/ml) (9 bottles turned)
  - APB’s @ 104 (10,000 cfu/ml) (4 bottles turned)

9 Stage Frac Research 12-22-09

After Stage #3 Best and Worst Frac Tanks

Test results of Bacteria Counts
SRB’s @ <100 (less than 1 cfu/ml) !!!!
APB’s @ <100 (less than 1 cfu/ml) !!!!
IN ALL TANKS!!!

After Stage #6 All Frac Tanks #1 to #4

Test results of Bacteria Counts
SRB’s @ <100 (less than 1 cfu/ml) !!!!
APB’s @ <100 (less than 1 cfu/ml) !!!!
IN ALL TANKS!!!

Produced Samples 100 Barrels 1-1-10 and 1025 Barrels 1-2-10

Test results of Post TERRAfrac Bacteria Counts
SRBS @ <10^0 (less than 1 cfu/ml) !!!!
APBs @ <10^0 (less than 1 cfu/ml) !!!!

In Produced Water After 100 Barrels & 1025 Barrels !!!
1025 Barrels Sample had a ClO2 Residual of 0.23ppm!!
and Chlorides of >18,000ppm
<table>
<thead>
<tr>
<th>Date</th>
<th>Stage</th>
<th>Inlet Manifold to the Working Tanks</th>
<th>Treated Samples at Blender</th>
<th>Untreated Water Cultures Source (Coming Into Unit)</th>
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</thead>
<tbody>
<tr>
<td>Filling Tanks</td>
<td>Sample #1 @ Inlet Armadillo #1</td>
<td>Amadillo #1</td>
<td>Amadillo #2</td>
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Alpha 1 & Alpha 2 Trailers

- 42’ Gooseneck Trailer
- Two 10” Armadillo lines and a 6” produced water line
- 6” Produced line blends up to 30/bpm into each Armadillo line
- Able to treat 240 bpm
- 712 Points of measurement
- Measures armadillo lines and frac tank ClO2 residual, conductivity, pH, and pressure
- Web based
- PID/PLC Control
- Water treatment test lab
- Supplies its own power through a generator
- Eye wash / safety shower

- Average to blender will approach, but not exceed 5PPM because set 5PPM as max per this test and research.

- Able to maintain residual available to blender at steadier rate

- Rapidly respond and adjust to variation

- Produced water introduces high variability into system
Stage 2A Review – Software Calibration

Residual

-Responding to Inorganic and Organic Demand in the water

Flow

-Further calibration of “software” required to smooth out our response

-Initial ramp impact
Stage 3A pH at Frac Tanks

Stage 2B pH at Frac Tanks

Stage 3B pH at Frac Tanks
FracSTAR is a custom built proprietary hardware and software package to integrate points of measurement used in the TerraFrac process. It allows for the blending and treatment of water used in the fracturing process. FracSTAR models the water 100 times per second and can predict the bio-demand to control the blends of reuse and recycled waters.
The TERRA trailer is a mobile water treatment plant/process that treats water using Chlorine Dioxide (ClO₂) to remove all bacteria from water used in hydraulic fracturing. The FracSTAR technology operates in real-time, with 1,489 points of continuous measurements with a proprietary custom built operating system at flow rates of over 345 barrels per minute (BPM). The FracSTAR system is the safest, most advanced form of water treatment using Chlorine Dioxide (ClO₂) that has ever been developed for hydraulic fracturing.
The TERRA unit was built to follow the same on-pad model as horsepower; first equipment on location and last off. Every drop of water used in the fracturing of an oil & gas well will flow through the TERRA trailer process.

The FracSTAR mobile frac water treatment process was built around water use during the hydraulic fracturing process. It can process large volumes of water, at high velocities, and deliver a 99.99999999% bacteria kill.
The TERRA trailer has three separate water inlets:

- Armadillo line #1 is a 10” fresh water inlet 142.00 BPM / 6,000 GPM
- Armadillo line #2 is a 10” fresh water inlet 142.00 BPM / 6,000 GPM
- Produce Water is a 6” waste water inlet 59.00 BPM / 2,500 GPM
The TERRA trailer replaces the traditional water transfer distribution manifold. This is to insure that all water passes through the FracSTAR process so that every drop of water is not only measured, but treated. The FracSTAR process can treat between 4 and 8 working tanks.
Recycle / Reuse Blending
Into Armadillo Line #1 & #2

Recycle / Reuse Treatment
Isolated Non-Blended

Armadillo Line #2

Armadillo Line #1
The TERRA trailer has nine separate outlets.

- Armadillo Line #1 has four 6” outlets
- Armadillo Line #2 has four 6” outlets
- Produce Water Line has one 6” outlet
All water being treated is plumbed to the sink in the Lab/Control Room to gather samples and run tests without the operator leaving the trailer.

Magnetic Stirrers
Under Counter

Sample Holders

Armadillo Inlet #1 (Untreated)
Armadillo Inlet #2 (Untreated)
Recycle/Reuse Inlet (Untreated)
ACL Sample (Treated)
Frac Tanks (Treated)
Safe environment that is controlled to insure safety and allow for maintenance and calibrations of sensors and meters
3 Dimensional modeling of the inorganic and biological demand of the water
FracSTAR can see the demand in real time, and therefore will always be able to keep the residual above the set point. One hundred readings every second, averaged per second. The data recorded is the highest value, lowest value, average value and actual value on the start of each minute.
FracSTAR controls the treatment process to insure that the water is properly treated and never below the set point. It learns the demand in real time.
FracSTAR measures and records the pH of the Water being used on the frac. It insures that the pH of the waters are not affected.
FracSTAR measures and records the conductivity of the water being used on the frac. It insures that the blends of the reuse and recycle waters are “fracable”
Field Evaluation Case Study

The FracStar control process will send information to two locations:
1) The frac van
2) Water Transfer and the working frac tanks
This information will be displayed on iPads,
Monitoring Equipment

Brine Tank
80% 0.0 Gallons 0.0 Barrels

Frac Tank #1
80% 0.0 Gallons 0.0 Barrels

Frac Tank #2
80% 0.0 Gallons 0.0 Barrels

Frac Tank #3
80% 0.0 Gallons 0.0 Barrels

Frac Tank #4
80% 0.0 Gallons 0.0 Barrels
Monitoring Equipment

- **Blender pH**: 0.00 pH
- **Blender ClO2**: 0.00 PPM
- **Blender TS 15/30**: 0 PPM
- **Blender Conductivity**: 0 PPM
- **Blender Chlorides**: 0 PPM
- **Total Frac Water Inlet**: 0.0 GPM, 0.0 PPM
- **Refractometer**: 40 PPM

- **Source #1**: 0.0 GPM, 0.0 BPM, 0.0 PSI
- **Source #2**: 0.0 GPM, 0.0 BPM
- **Source #1 & #2**: 0.0 GPM, 0.0 BPM
- **Produce Water**: 0.0 GPM, 0.0 BPM, 0.0 PSI
- **Produce Blending**: ON, 0%

- **Brine Tank**: 80 %, 0.0 Gallons, 0.0 Barrels, 0.00 pH, 0.00 PPM
- **Frac Tank #1**: 80 %, 0.0 Gallons, 0.0 Barrels, 0.00 pH
- **Frac Tank #2**: 80 %, 0.0 Gallons, 0.0 Barrels, 0.00 pH
- **Frac Tank #3**: 80 %, 0.0 Gallons, 0.0 Barrels, 0.00 pH
- **Frac Tank #4**: 80 %, 0.0 Gallons, 0.0 Barrels, 0.00 pH
Pre-treatment demand averaged $10^{12}$ APB’s and SRB’s.
After ClO₂ treatment
Iron Sulfide oxidized into SO₄ and Fe₃
SRB bacteria dead and floating on top of water like dead fish
10° APB’s and 10° SRB’s
Reusable water for the next frac
Before ClO$_2$ treatment

After ClO$_2$ treatment
FracSTAR Development Plan

- Total water management
- Zero water footprint
- Treatment concepts
- Stationary plants
- Blending and reuse on-the-fly development
Barium Sulfate Scale (BaSO4) with Iron (Fe3)

2” Diameter

¼” Buildup
Solids down in the formation

Inside Frac Tank #1

Inside Frac Tank #2

Inside Frac Tank #3

Inside Frac Tank #4

Oil-Wet Solids floating with Iron (Fe3)
Sand Down in the formation

Fig. 6—Representative images of 20/40-mesh ceramic proppant 30 min after introducing (a) Permian produced water, and (b) EC-treated Permian produced water at the flow rate of 100 mL/min.

Fig. 7—Representative images of 20/40-mesh ceramic proppant 30 min after introducing (a) Marcellus produced water, and (b) EC-treated Marcellus produced water at the flow rate of 100 mL/min.
Reuse & Recycle Processes

- Treatment and isolation (non-blending processes)
- Centralized facility
- Mobile reuse & recycle

- The need to balance the water to make it fracable and remove:
  - TSS (Total Suspended Solids)
  - Soluble divalent cation’s and transition metals that will become insoluble
  - Oil and other TPH’s (Total Petroleum Hydrocarbons)
  - Bacteria (MOST IMPORTANT)
  - Do not put bacteria down hole and seed the formation
Three bottles turned = $10^3(1,000)$ CFU (Colony Forming Unit) Of SRB (Sulfate Reducing Bacteria)

Six bottles turned = $10^6(1,000,000)$ CFU (Colony Forming Unit) of APB (Acid Producing Bacteria)
Unconventional Water Reuse and Recycling Usage Model (Without Treatment)

- Fresh Water
  - Fracturing of Well
    - Well Flowback Water
      - Fracturing of Well
    - Well Produced Water
  - Salt Water Disposal
Hydraulic Fracturing Solutions
Powered by FracSTAR

“Industry leaders in safety and innovation!”
Continuous of operation for operators who want to recycle untreated flowback and produced water on-the-fly and let the pump service company's (Horsepower) control the blends/mixing.

The treatment program consists of oxidation to insure no bacteria, and the monitoring of pH residual in the post treated water.  

323+ wells  
23% Water reused & recycled  
17,086,700 barrels / 717,641,400 gallons of water reclaimed with an average disposal rate of $4.20 for disposal. The producer saved $71,764,140 in disposal cost.
This FracStar Dashboard takes into account the different waters and their make-up that would be blended with fresh waters to not affect the sand (proppant) chemistry. This helps to insure of no pressure increases and/or flow rate decreases going down hole during the fracturing process.

The FracSTAR Dashboard looks at the number of different water sources that would be used on the reuse and recycle process. FracStar allows different variables to be changed so the modeling and predictive changes to the treatment program can be established. This will ensure that the water is “fracable”
Specs for chemistry that will carry the sand (proppant). Variances that would affect the frac performance are identified.

FracStar was developed to micromanage the properties of the water to be used on the frac, and in the treatment of water that would be recycled and reused on the next frac. The Cation and Anions relationship must be considered in order to insure that the water is “fracable”.

<table>
<thead>
<tr>
<th>Reuse &amp; Recycle (Eagleford) - Treated Water Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
</tr>
<tr>
<td>Orr Ranch 1H</td>
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</tbody>
</table>
FracStar shows the limiting factor being hardness by 980.06 PPM. The water from this field would have to be used at a lower ratio to avoid the “fracablity” of the fluid.

The expense of removing the hardness by chemical and/or mechanical means would have to be deployed.
FracStar shows that the fluid could be used at greater ratios and not affect the “fracablity” of the fluid.

The spec variance models the water at 100% reuse and identifies the properties that must be diluted and/or treated to be remove.

| Location       | Date       | pH   | Spec Gravity (g/ccm) | TDS (mg/l) | H2S (mg/l) | CO2 (mg/l) | Resistivity | Barium (mg/l) | Calcium (mg/l) | Iron (mg/l) | Magnesium (mg/l) | Manganese (mg/l) | Potassium (mg/l) | Sodium (mg/l) | Strontium (mg/l) | Total Cations (mg/l) | Chloride (mg/l) | Carbonate | Bicarbonate | Sulfate | Boron | Total Anions (mg/l) | Calcite (% Saturation) | Calcite (lbs/1000 bbls) | Gypsum (% Saturation) | Gypsum (lbs/1000 bbls) | Barite (% Saturation) | Barite (lbs/1000 bbls) | Iron Hydroxide (% Saturation) | Iron Hydroxide (lbs/1000 bbls) |
|----------------|------------|------|----------------------|------------|------------|------------|-------------|--------------|---------------|---------------|-------------|-------------------|---------------------|-----------------|---------------|-------------------|------------------------|-------------|------------|-------------|---------|-------|------------------------|---------------------------|--------------------------|-----------------------|-----------------------|------------------------|------------------------|-----------------------------|---------------------------|
| Orr Ranch 9H   | 11/20/2013 | 6.9  | 1.092                | 129,585    | 1         | 14.67      | 0.079       | 0.1          | 10.400        | 2.69         | 2.147                  | 0.01                | 0                | 36,123       | 0               | 48,673              | 80,400                  | 0           | 110         | 402         | 0       | 80,912 | 2.39                  | 0.017                      | -119.11                 | 0.325                 | 0.017                 | -0.788                | 0.001                  | -0.001                  |
|                |            |      |                      |            |            |            |             |              |               |               |              |                   |                     |                 |               |                   |                       |             |            |             |        |        |                       |                            |                         |                       |                       |                         |                        |                          |
| Total Volume Per Day 2,500.00 |             |     |                      |            |            |            |             |              |               |               |              |                   |                     |                 |               |                   |                       |             |            |             |        |        |                       |                            |                         |                       |                       |                         |                        |                          |
| Total Volume of Resu 500.00 |             |     |                      |            |            |            |             |              |               |               |              |                   |                     |                 |               |                   |                       |             |            |             |        |        |                       |                            |                         |                       |                       |                         |                        |                          |
| Available Per Stage 45,000.00 |             |     |                      |            |            |            |             |              |               |               |              |                   |                     |                 |               |                   |                       |             |            |             |        |        |                       |                            |                         |                       |                       |                         |                        |                          |

### Resuse & Recycle (Eagleford) - Treated Water Comparison

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>Index</th>
<th>Untreated</th>
<th>Treated</th>
<th>EOG Specs (c)</th>
<th>Spec Variance</th>
<th>Dilution Value</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orr Ranch 9H</td>
<td>11/20/2013</td>
<td>pH</td>
<td>6.9</td>
<td>8.7</td>
<td>5.0 - 8.0</td>
<td>(0.700)</td>
<td>1,802.06</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Hardness (mg/l)</td>
<td>34,836</td>
<td>32,437</td>
<td>2,000</td>
<td>30,437.00</td>
<td>1,802.06</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Specific Gravity (g/ccm)</td>
<td>1.092</td>
<td>1.080</td>
<td>1.038</td>
<td>0.042</td>
<td>0.06</td>
<td>0.00</td>
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<td>TDS (mg/l)</td>
<td>129,585</td>
<td>113,724</td>
<td>120,000</td>
<td>(6,276.00)</td>
<td>6,318.00</td>
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<td>H2S (mg/l)</td>
<td>1</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>CO2 (mg/l)</td>
<td>14.67</td>
<td>2.33</td>
<td>2.330</td>
<td>0.13</td>
<td>0.00</td>
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<td>Resistivity</td>
<td>0.079</td>
<td>0.081</td>
<td>0.081</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Barium (mg/l)</td>
<td>0.1</td>
<td>0.01</td>
<td>10</td>
<td>(5.990)</td>
<td>0.00</td>
<td>0.00</td>
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<td>Calcium (mg/l)</td>
<td>10,400</td>
<td>9,280</td>
<td>1,000</td>
<td>6,280.00</td>
<td>515.56</td>
<td>0.00</td>
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<tr>
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<td>Iron (mg/l)</td>
<td>2.69</td>
<td>0.5</td>
<td>10</td>
<td>(5.500)</td>
<td>0.03</td>
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<td>Magnesium (mg/l)</td>
<td>2.147</td>
<td>2.245</td>
<td>1.200</td>
<td>1,045.00</td>
<td>124.72</td>
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<td>Manganese (mg/l)</td>
<td>0.01</td>
<td>0.01</td>
<td>10</td>
<td>(9.990)</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Potassium (mg/l)</td>
<td>0</td>
<td>0</td>
<td>1,000</td>
<td>(1,000.00)</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Sodium (mg/l)</td>
<td>36,123</td>
<td>30,824</td>
<td>36,000</td>
<td>(5,176.00)</td>
<td>1,712.44</td>
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<tr>
<td></td>
<td></td>
<td>Strontium (mg/l)</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>(10.000)</td>
<td>0.00</td>
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<td></td>
<td>Total Cations (mg/l)</td>
<td>48,673</td>
<td>42,349</td>
<td>42,349</td>
<td>42,349</td>
<td>2,352.72</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Chloride (mg/l)</td>
<td>80,400</td>
<td>69,600</td>
<td>70,000</td>
<td>(400.000)</td>
<td>3,866.67</td>
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<tr>
<td></td>
<td></td>
<td>Carbonate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Bicarbonate</td>
<td>110</td>
<td>988</td>
<td>1,000</td>
<td>(12.000)</td>
<td>54.89</td>
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<tr>
<td></td>
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<td>Sulfate</td>
<td>402</td>
<td>787</td>
<td>500</td>
<td>287.000</td>
<td>43.72</td>
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<tr>
<td></td>
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<td>Boron</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>(5.000)</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Total Anions (mg/l)</td>
<td>80,912</td>
<td>71,375</td>
<td>71,375</td>
<td>71,375</td>
<td>3,965.28</td>
<td>0.00</td>
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<tr>
<td></td>
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<td>Calcite (% Saturation)</td>
<td>2.39</td>
<td>339.87</td>
<td>2.39</td>
<td>339.87</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
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<td>Calcite (lbs/1000 bbls)</td>
<td>0.017</td>
<td>5.07</td>
<td>0.017</td>
<td>5.07</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
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<td>Gypsum (% Saturation)</td>
<td>0.325</td>
<td>0.607</td>
<td>0.325</td>
<td>0.607</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Gypsum (lbs/1000 bbls)</td>
<td>-119.11</td>
<td>-79.89</td>
<td>-119.11</td>
<td>-79.89</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Barite (% Saturation)</td>
<td>0.0693</td>
<td>0.0165</td>
<td>0.0693</td>
<td>0.0165</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Barite (lbs/1000 bbls)</td>
<td>-0.788</td>
<td>-3.353</td>
<td>-0.788</td>
<td>-3.353</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td></td>
<td>Iron Hydroxide (% Saturation)</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.00</td>
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<td>Iron Hydroxide (lbs/1000 bbls)</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.00</td>
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</tbody>
</table>
FracStar shows that this fluid could be used at greater ratios and not affect the “fracability” of the fluid.

The dilution value models the water at the planned percent of planned reuse, and identifies the properties that must be diluted and/or treated to remove. It also identifies if this water can be used in high concentrations without affecting the performance and the “fracability” of the treated water.

FracStar looks at the blend, and/or a composite of water that was blended prior to treatment. These results show what a 100% reuse and recycle water would look like, and the dilution factor when blended with other fresh waters.

This way knowing what the water will be after treatment helps control the quality of the finished product thereby insuring the performance and the “fracability” of the treated water.
Unconventional Water Usage Model (Centralized Treatment)

Fresh Water

Fracturing of Well

Well Flowback Water

Solids to Land

Well Produced

Oil Recovery

Salt Water Disposal

Treatment Facility

Fracturing of Well
Total Water Management Facility
Total Water Management Facility

Treatment process for flowback and produced waters

Flowback and produced water pump from mountains

Two Stage Filter:
Stage 1: 25 Micron
Stage 2: 10 Micron

FracSTAR process that all waters must flow through for blending and treatment

FracSTAR process blends treated flowback and produced into fresh water while treating the fresh Water for bacteria and scaling index's
This water was extremely turbid:
- SRB’s at $10^7$ CFU
- APB’s at $10^5$ CFU
- Iron Sulfide at 350 ppm
- H2S at 4 ppm
- pH at 5.8

**STARTED OUT AS FRESH WATER**
This water was not turbid and did not have H2S, Iron Sulfide and the pH was 7.2 going down hole

During the first 18 days of operation, 4,032 serial dilution bug bottles were used and 259 individual samples were taken from 18 different locations from within this operation to help adjust and develop the needed algorithmic equations and operational guidelines to achieve these goals in less than 30 days.

This water had some turbidity:
- SRB’s at $10^0$ CFU
- APB’s at $10^0$ CFU
- Iron Sulfide at 0 ppm
- H2S at 0 ppm
- pH at 6.5

**Treated REUSE and RECYCLE Water**
This water is not turbid and does not have H2S, Iron Sulfide and the pH was 7.5 going down hole with no SRB’s and or APB’s “FRACABLE WATER”
Treated REUSE and RECYCLE Water

This water is not turbid and does not have H2S, Iron Sulfide and the pH was 7.5 going down hole with no SRB’s and or APB’s “FRACABLE WATER”

This water had some turbidity:
- SRB’s at 10^0 CFU
- APB’s at 10^0 CFU
- Iron Sulfide at 0 ppm
- H2S at 0 ppm
- pH at 6.8

14 months of operation
48 wells
**99.10%** water reused & recycled
**6,873,408** barrels / **288,683,136** gallons of fresh water conserved
with an average disposal rate of **$4.20** for disposal the producer saved **$28,490,313.60** in disposal cost.
Unconventional Water Usage Model Mobile (Next to Frac)

- Fresh Water
  - Fracturing of Well
  - Well Flowback Water
    - Treatment Process
      - Fracturing of Well
      - Well Produced Water
        - Fracturing of Well
        - Salt Water Disposal
        - Oil Recovery
          - Solids to Land
Besides being very mobile it had to accomplish many goals to help make the Reuse and Recycle Project a successful and repeatable process certain KPI (Key Performance Indicators) had to be achieved.

- Oil Removal to <10 ppm
- Solids Removed with Turbidity < 20 NTU’s
- Solids Dewatered > 95% Total Influent Volume of Recovered
- Total Iron < 5 ppm
- pH >6.5 and <7.8
- No living SRB’s (Sulfate Reducing Bacteria)
- No Living APB’s (Acid Producing Bacteria)
- 30,000 BPD (Barrels Per Day) within 18 hrs
- No Spills !!!!!!
Process Through Put 30,000 Barrels Per Day in 18 Hours

Water Pumped to local Frac Location for treatment and blending with Fresh Water

Frac Tank #30-46 Influent

Polished Water #25-29

Solids Removal Storage

Section Three: TSS & Solids removal

Xchem Terra Process and Control Center

Section One: Oil Removal and Polishing

Isolation Valve
Oil Removal to <50 ppm
Mechanical and or Chemical
Oxidation and pH Adjustments

$\text{ClO}_2$, $\text{NaCO}_3$, $\text{NaOH}$, $\text{Ba}_2\text{Cl}$, Polymer
Solids Concentration with Polymers
Solids Removal is discharged into bins
Filtration & Polishing to reduce Post Precipitation
Filtration & Polishing Keep Solids Out of the Working Frac Tanks
### INFLUENT WATER FLOWBACK & PRODUCED H2O

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Days on RSW Pad</td>
<td>23.00</td>
</tr>
<tr>
<td>Total Barrels Treated</td>
<td>269,403.00</td>
</tr>
<tr>
<td>Total Gallons Treated</td>
<td>11,314,926.00</td>
</tr>
<tr>
<td>Total Pounds of Water Treated</td>
<td>102,859,466.30</td>
</tr>
<tr>
<td>Average Weight of Influent LBs/Gal</td>
<td>9.091</td>
</tr>
<tr>
<td>Average Weight of Enfluent LBs/Gal</td>
<td>9.086</td>
</tr>
<tr>
<td>Percent Total Water Weight Reduction</td>
<td>0.138%</td>
</tr>
</tbody>
</table>

### SLUDGE GENERATION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Barrels of Sludge Generated</td>
<td>30,774.86</td>
</tr>
<tr>
<td>Total Gallons of Sludge Generated</td>
<td>1,292,544.00</td>
</tr>
<tr>
<td>Total Pounds of Sludge Generated</td>
<td>11,779,082.73</td>
</tr>
<tr>
<td>Average Weight of Sludge LBs/Gal</td>
<td>9.11</td>
</tr>
</tbody>
</table>
### SOLIDS GENERATED FROM DECANING SLUDGE

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Barrels of Concentrated Sludge Generated</td>
<td>171.43</td>
</tr>
<tr>
<td>Total Gallons of Concentrated Sludge Generated</td>
<td>7,200.00</td>
</tr>
<tr>
<td>Total Weight of Concentrated Sludge in LBs</td>
<td>127,292.94</td>
</tr>
<tr>
<td>Average Weight of Haul Off LBs Per Gallon</td>
<td>17.68</td>
</tr>
</tbody>
</table>

### WATER RECOVERED FROM SLUDGE

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Barrels of Water Decanted from Sludge Generated</td>
<td>30,603.43</td>
</tr>
<tr>
<td>Total Gallons of Water Decanted from Sludge Generated</td>
<td>1,285,344.00</td>
</tr>
<tr>
<td>Average Weight of Recovered Water LBs/Gal</td>
<td>9.05</td>
</tr>
<tr>
<td>Percent Recovery of Water</td>
<td>99.443%</td>
</tr>
</tbody>
</table>
This Reuse and Recycle process when completed was successful in:

- Recovering over >99% of the water
- 1,100 Barrels of Oil
- **30,000 Barrels / 1,260,000 Gallons** of Sludge that was Decanted to <200 Barrels 8,400 Gallons of Solids
- 0 SRB Bacteria
- 0 APB Bacteria
- pH >6.8 and <7.5
- Two Stages completed with 100% Reuse & Recycled water (Fresh Water Pumps Failed)
- Average > 50% Reuse and Recycled Fracable Water

The water leaving the Reuse and Recycled Process was blended using FracStar on location with the untreated Fresh Water being treated for bacteria and a scale inhibitor being added on the fly. The layout of the process is shown below.
After the successes of the first mobile Reuse and Recycle treatment process the piloting of three more operations was approved and the summary of those processes was:

- **>850,000** Barrels of Reuse and Recycled Water Treated
- **>35,700,000** Gallons of Fresh Water Conserved
- **>1,800** Barrels of Oil Recovered
- **>85,000** Barrels of Sludge Generated that was dewatered to **< 450** Barrels of Disposal
- **>99%** water recovery
- Calcium and Sulfate Scaling Indexes were lowered by **>80%**
- **CO2 (Carbon Dioxide) Dissolved Gasses** removed by **>70%**
- No **H2S (Hydrogen Sulfide)**
- No **SRB’s (Sulfate Reducing Bacteria) going down hole**
- No **APB’s (Acid Producing Bacteria) going down hole**
- **pH > 6.85 and < 7.45**
Another development occurred throughout this process that led to another evolution in the development of Reuse and Recycle applications.

This development however is tied to another upfront process which is significant in the ability to consume large volumes of water for Reuse and Recycle that helps reduce the need for additional fresh waters. In the application of the 4 Reuse and Recycle processes the FracStar application was being used for over a year to treat the fresh water being used in the Fracing Process. This had such a significant impact on the waters that were flowing back and being produced by the wells that the need for such a large mobile treatment process system was no longer needed and the footprint and speed of treatment evolved to a new level.

The on the fly Reuse and Recycle treatment process allows for the entire treatment process to occur on the frac pad and move with the pumping company. This also eliminates the risk of having a spill off location and on the ground due to a leaking or ruptured pipe.
Unconventional Water Usage Model (On Frac Pad) no Disposal

Fresh Water

Fracturing of Well

Well Flowback Water

Treatment at the Fracturing of

Well Produced

Solids to Land

Oil Recovery
Fresh Water 90% Recycled Water 18%

Fresh Water

Energen Guadalupe
90% Fresh
10% Brine
Untreated
pH = 8.44

Energen Guadalupe
90% Fresh
10% Brine
1.0m C1O2
C1O2 = 11.1 ppm
pH = 8.21
This Reuse and Recycle process is constantly running:

- Recovering over **>100%** of the water
- 700 Barrels of Oil
- Averages **7,785** Barrels / **326,970** Gallons of Recycled Water Every Day
- 0 SRB Bacteria
- 0 APB Bacteria
- pH >6.8 and <7.5

The this process has conserved **272,475** Barrels / **11,443,950** Gallons of Water to date.

The projected volumes conserved by end of 2014

**1,498,612** Barrels / **62,941,725** Gallons of Water
On another Reuse and Recycle process that was using 100% water flood water that had 1% to 2% Oil and >600 ppm H2S (Hydrogen Sulfide) and the presence of SRB and APB Bacteria which was to be 100% of the source water for a 13 Well Program. This water had to be treated to become Fracable and meet certain KPI (Key Performance Indicators) to insure the completion of the wells within the program which were:

- Turbidly <12 NTU’s
- <0 ppm H2S (Hydrogen Sulfide)
- No SRB Bacteria
- No APB Bacteria
- >15 ppm of ClO2 (Chlorine Dioxide)
- pH >6.5 and <7.5
- 100% Reuse Water (No Fresh Water)
- No Water to be disposed of 100% Reuse & Recycle

This process had some safety challenges and previous processes failed to deliver the volume of water to do a 100% Reuse and Recycle and the water quality was affecting the Frac Performance with pressure and flow rate issues. These wells were projected to deliver 65 to 85 BPD (Barrels Per Day) based on the previous results from the Reuse and Recycled program used last year. This very small foot print supplied the water for all 13 wells and allowed for the treatment process to take place on a single shift each day of operating.
This process was so successful in the treatment of waters used for Reuse and Recycle that a number of developments occurred that had never been seen before:

- The treated Reuse and Recycle Water had pump times of 45 to 55 minutes, which allowed for this fluid to be used on Horizontal Fracs and not just Vertical Frac’s
- Due to the length of the pump times and compatibility of the water with chemistry that was carrying the sand (proppant) down hole less Horsepower was needed to complete the wells (Major Cost Savings)
- The wells produced 75% to 100% more Oil than was projected (Major Money Maker) an increase from 75 BPD to 180 BPD

Due to these successes the implementation and use of the FracStar Process the expansion and development of this technology will help lead to the growth in Reuse and Recycle programs that will reduce the practice of disposing of water while consuming fresh water. With the enhanced well performance and major cost reductions in the implementation of Reuse and Recycle treatment programs the reduction and dependence on Fresh Water from the environment can start taking place.
To date over 170,000,000 Barrels / 7,140,000,000 Gallons of water treated.

Over 1,000 analysis consisting of complete water and bacteria analysis pre, during, and post frac.

7,200,000 Barrels / 302,400,000 Gallons of water treated last month

15,200,000 Barrels / 638,400,000 Gallons of water treated last quarter.

389,050 Barrels / 16,340,100 Gallons of water averaged everyday.

100,000,000 Barrels / 4,200,000,000 Gallons of water projected for this year

Making Water “Fracable”