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Novel Technology Reduces Water Usage 44% While Increasing Drilling Efficiency in the Permian Basin

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Abstract

Significant improvements in drilling efficiency (10 - 40% reduction in well times) and water usage (44% reduction) were seen following the introduction of a Clear Water Drilling Fluid (CWDF) and a Drilled Solids Stripping Unit (DSSU). First introduced in the Barnett Shale in 2006, this technology has been used on over 1,000 wells drilled in the Permian Basin between 2008 and 2011. The water conservation benefits of this technology became increasingly important during the drought conditions in 2011, conditions which are expected to continue through 2012.

CWDF is a solids-free fluid containing soluble inhibitors which, when combined with the use of the stripping unit, results in significantly reduced volumes of fresh water and brine used during the drilling operation. The result is fewer loads transported to location and a reduction in waste disposal costs. Additional benefits include a reduction in location size, longer bit life, longer pump and liner life, and less safety and environmental exposure.

This paper reviews the performance of the CWDF and DSSU combination. Average drilling hours and total well times were reduced by up to 40%. Fresh water usage was reduced by 44% and brine reductions were 73%.

Introduction

The Permian Basin is located in West Texas and the adjoining area of southeastern New Mexico. It covers an area approximately 250 miles wide X 300 miles long (75,000 square miles) across 17 counties in Texas and 4 in New Mexico. The first evidence of oil or gas in the areas was discovered when farmers and ranchers drilled water wells to water their crops and livestock because surface water was almost nonexistent. From the first commercial discovery in the early 1920s, the Permian Basin has grown to where it is acknowledged as the largest inland petrochemical complex in the United States, with large investments in petrochemical refineries and plants[1]. In 2011, 280 million barrels (bbls) of oil were produced from the West Texas Basin, along with 1.17 trillion cubic feet of gas[2]. With over 3,600 wells continuing to be drilled in the Basin[3] every year, many exploiting the newer technologies of horizontal drilling and hydraulic fracturing, the area is important to the energy independence of the United States.

In 2011, over 390 rigs were drilling in the Permian Basin in West Texas, with another 70 rigs drilling in SE New Mexico. Approximately 80% of the 3,600 Permian Basin wells drilled last year were drilled into the Wolfberry structure (the Wolfcamp and the Spraberry formations). Average well times are 20 to 25 days with an average depth of 11,000 feet. The approximate well cost is \$1.6 to \$1.7 million including drilling and completion.

Formations and Wellbore Geometry

In the Permian Basin, the Red Beds are sedimentary rocks, which typically consist of sandstone, siltstone, and shale that are predominantly red in color due to the presence of ferric oxides. The Red Beds extend from surface to a depth of approximately 1,300 feet. Below that are relatively benign formations including the Rustler, Salado, Yates, Grayburg, San Andres, Clearfork, Spraberry, Wolfcamp, Cisco and Canyon. Below these formations, the Strawn, Atoka and Barnett shale are encountered. These shale formations contain highly reactive smectite clays. The primary production zones are the Wolfcamp, Spraberry, Strawn and Atoka. Figure 1 shows the general stratigraphy for the Permian Basin.

Well Geometry and Fluid Systems

Figures 2 and 3 show the typical casing set points for the wells drilled in the Permian Basin. Most of the wells are drilled using the two casing string design (Figure 2). Surface casing is typically set at approximately 300 feet with the production casing at approximately 11,000 feet. The surface casing shoe is drilled out with brine. The brine is displaced with a fresh water gel mud around 6,000 feet. The density is kept as low as possible while drilling through the Spraberry formation where fluid losses are a common problem. Density is maintained below 8.9 pounds per gallon (ppg) using the dump-and-dilute technique which requires large amounts of fresh water. Approximately 1,000 to 1,500 feet above the programmed well depth, polyanionic cellulose (PAC) and starch are added to the drilling fluid for drilling the Atoka Shale.

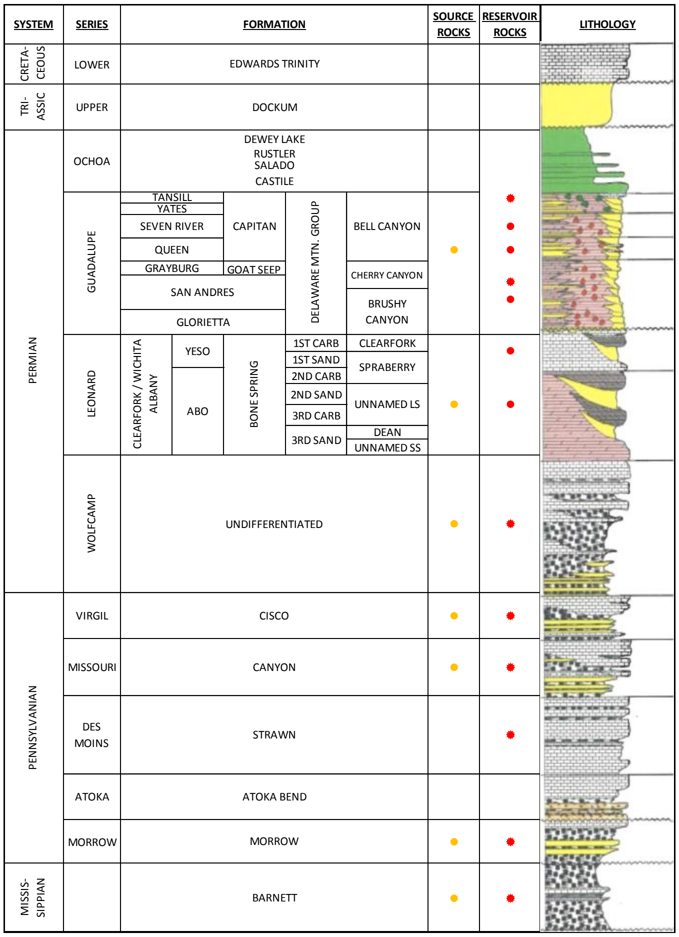

Figure 1: Permian Basin Stratigraphic Chart

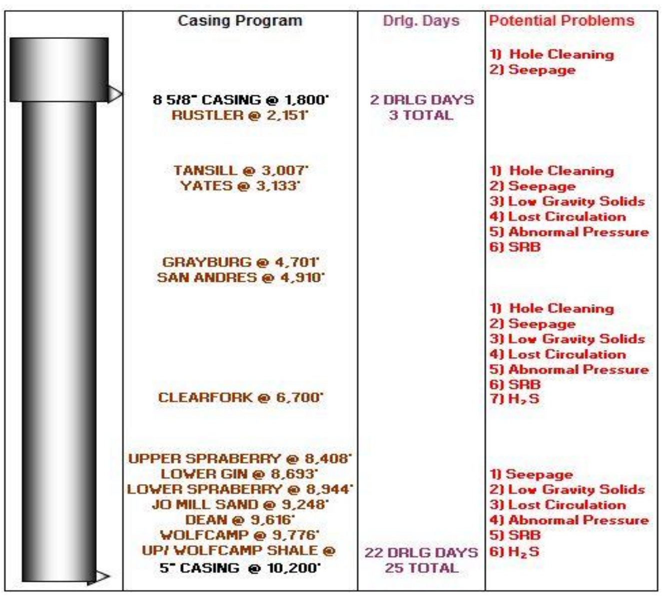

Figure 2: Diagram of Typical 2-String Wolfberry Well

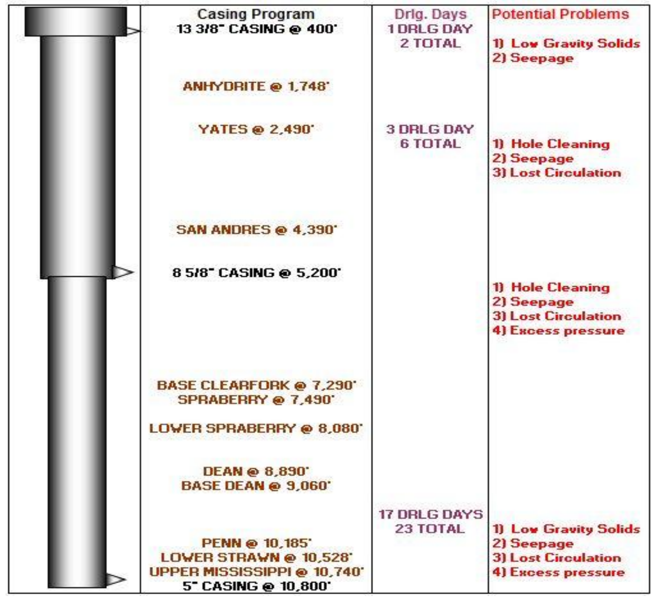

Figure 3: Diagram of Typical 3-String Wolfberry Well

Lost circulation is a major problem in the 2-string wells when the buildup of solids in the mud and longer exposure to salt stringers increases the density and breaks down formations. This increases well costs as time is taken to combat the problem and large quantities of lost circulation material (LCM) are consumed. To prevent these problems, some operators use the three casing string well design shown in Figure 3. The surface hole and production hole sections are drilled with fresh water while the intermediate is drilled with brine. While drilling the final 1,000 feet of both the intermediate and production hole sections, PAC and starch are added to the fluid.

Solids Control

Little or no solids control equipment is used when drilling with fresh water or brine. Large earthen pits that provide long settling times to remove the drilled solids are common. These pits, typically covering 75,000 sqft and holding approximate 25,000 bbls of water, allow the solids to settle out of the fluids while traveling around a three-leg design, commonly called a “horseshoe” pit.

These large earthen pits have the perceived benefit of being low cost since the wells require no mechanical solids control equipment while drilling. However, there are large costs associated with pit construction, the large volumes of the fluids used to fill them (cost of the fluid and the transportation to location), disposal of end volumes (disposal cost plus associated transportation costs) and finally the costs associated with the reclamation of the pits.

When bentonite or polymer muds are used, conventional solids control equipment, such as shakers, de-sanders, de-silters and centrifuges are required. Since none of these devices, except the shakers, process more than 25 to 50% of the whole mud system, solids will build up in the drilling fluid system and the only way to control density is to dump and dilute the fluid. The costs associated with this dump and dilute strategy include purchasing the fluid, trucking the dilution fluid to location, construction of storage pits for the dumped mud, transportation and disposal of dumped volume, and the chemicals required to achieve the desired mud properties in the new fluid. Additionally, solids settle out in the rig mud tanks and approximately 9 hours per well are spent on cleaning the rig tanks at the end of each well.

Regulatory Environment

New Mexico has a "pit rule"[4], which encourages the use of "closed loop" drilling practices. The pit rule requires all fluids used while drilling be contained (pits, if used, must be lined) and all of the waste generated must be disposed of on the drill site in accordance with strict guidelines or at an authorized offsite disposal facility.

Texas does not require permits for temporary mud circulation pit construction[5] and the regulations do not specifically encourage nor discourage the use of closed loop drilling systems. Consequently most locations use the large earthen pits described above. These pits, containing drilling wastes, are left open on all locations after drilling operations are completed. The wastes in these pits, including drilling fluids, drill cuttings, and rig wash are left exposed for evaporation for up to one year. If the chlorides content is above 6,100 mg/liter, the cuttings must be dewatered within 30 days and the pit back filled within one year.

Water Usage

Since 2008, the cost of fresh water increased from $0.50 to $2.00/bbl and the price of saturated brine has climbed from $1.50 to $6.00/bbl. More importantly, the state of Texas has been under severe drought conditions for the past year, and the water supply is a major concern. Municipalities are closely monitoring and in some cases are limiting the supply of fresh water for drilling operations because the aquifers are depleting rapidly. Municipalities are trying to ensure their citizens have adequate fresh water for general household and municipal requirements.

Richard Morton, City Manager of Odessa stated in a meeting with Q'Max representatives on January 10, 2012, that, *"Unless there is a significant amount of rainfall to raise the levels of the area lakes that provide water to Odessa, the City of Odessa would be restricting its residents' water use this spring and summer to winter levels."* That would mean little to no watering of lawns and possibly allowing for the watering of trees only in the Odessa city limits. Odessa is taking the additional step of not issuing any new commercial water use permits to customers located outside of the city limits.

Figure 4 shows the drilling pads for a small section of Ector County. The crescent in the upper central part of the large photo is part of the city of Odessa. The second photo shows a "Section" of 16 pads. The open "double horseshoe" pit that can be clearly seen in the third photo measures approximately 250 feet by 200 feet. In 2011 there were over 3,000 of these pits constructed in the Permian Basin. Each was filled with water used in the drilling process and ultimately reclaimed.

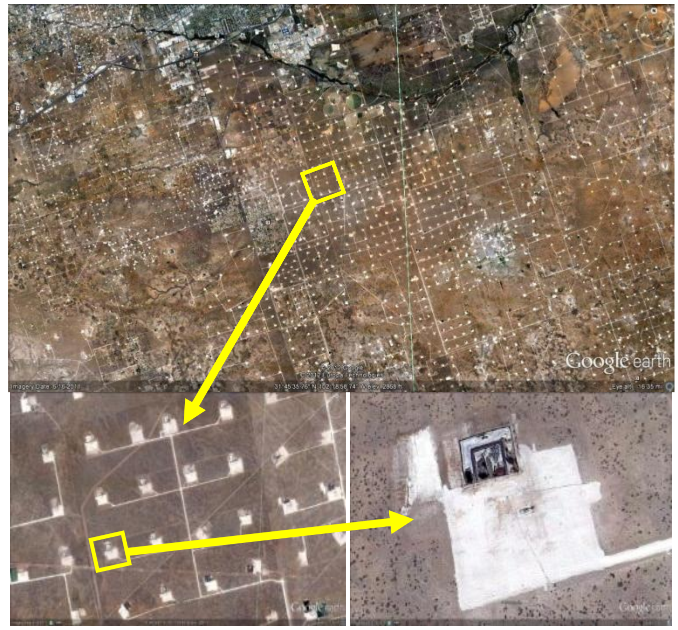

Figure 4: Arial View of Ector County

The typical West Texas well with earthen pits uses between 25,000 and 35,000 bbls of fresh water. For comparison, in New Mexico an average well uses 10,000 to 18,000 bbls when using the closed loop systems. The amount of water used depends upon the type of equipment and the fluid management procedures employed. To put the water usage into perspective, if one considers that approximately 400 rigs are working in the West Texas today, there is between 10 and 14 million barrels of water at drill sites today. On an annual basis, that is approximately 90 to 120 million bbls of water used in the drilling operation. Based upon the New Mexico experience, the use of closed loop drilling systems would reduce this by approximately 50%.

Some landowners have heard of the water conservation practices and regulations implemented in New Mexico and would like to see similar drilling practices and regulations adopted in Texas. These landowners expect that the use of closed loop systems will aid in the preservation of water reserves and are encouraging the operators to use closed loop systems while drilling on their land.

Reclamation and Disposal

The costs associated with the use of closed loop drilling practices in New Mexico impact the total well cost by approximately $30,000 to $145,000 per well. This includes the cost of solids control equipment, de-watering, transportation and disposal at approved sites. These costs are offset by savings on the construction and reclamation of large pits and the reduction in the cost of water and associated transportation. Table 1 is a compilation of typical cost data from three operators showing fluids related costs for typical wells in Texas using conventional pits and a typical well in New Mexico using a closed loop system. The costs have been broken down into Fixed Costs and Variable Costs. The Fixed

Costs are relatively independent of well depth while the Variable Costs are directly related to well depth.

Table 1: Costs Associated with Drilling Fluids

	Operator		
	A	**B**	**C**
Location	Texas	Texas	New Mexico
Well Depth (feet)	11,000	11,000	8,000
Well Type	Vertical	Vertical	Vertical
Pit Design Regime	Conventional	Conventional	NM Pit Rule
Casing Program	3 string	2 string	2 string
DSSU	No	No	No
Fresh Water & Brine (bbls)	**25,000**	**30,000**	**17,000**
Fixed Cost			
Fluids Pit/Cuttings Storage	$ 27,000	$ 40,000	$ 36,000
Pit Reclamation	$ 30,000	$ 45,000	$ -
TOTAL Fixed Well Cost	**$ 57,000**	**$ 85,000**	**$ 36,000**
Variable Cost			
Fresh Water & Brine	$ 90,000	$ 105,000	$ 118,000
Drilling Mud Chemicals	$ 15,000	$ 50,000	$ 70,000
Cuttings & Fluid Disposal	$ 50,000	$ 60,000	$ 75,000
Equipment (Closed Loop)	$ -	$ -	$ 34,000
TOTAL Variable Well Cost	**$ 155,000**	**$ 215,000**	**$ 297,000**
Variable Well Cost/foot	**$ 14.09**	**$ 19.55**	**$ 37.13**
Total Fluids Related Costs	**$ 212,000**	**$ 300,000**	**$ 333,000**
Cost per foot	**$ 19.27**	**$ 27.27**	**$ 41.63**

The Fixed Costs include the costs of pit construction, cuttings storage and pit reclamation. The data shows that Fixed Costs are $20,000 to $50,000 lower for the closed loop system, savings that are primarily related to the elimination of the reclamation cost. The Variable Costs include the cost of water or brine (including the cost of the fluid and its transport cost), the cost of drilling fluid chemicals, the cost of disposal (disposal fees for fluids and cuttings including transport cost), and the cost of closed loop drilling equipment. The cost of disposal for the wells drilled with the closed loop system in New Mexico are generally higher than wells drilled with conventional pits since the cuttings are taken to an authorized disposal facility. However; if the cuttings are disposed of in a pit on location as allowed in Texas, the disposal costs will be similar. In general, closed loop drilling increases the total well cost by $30,000 to $145,000 depending upon well depth and duration.

Optimized Drilling Environment

Two main issues stand out regarding the conventional operation in the Permian Basin:

- the growing concern for water usage and its costs,
- the impact on the environment.

Closed loop systems clearly provide a reduction in water usage, however at an increased well cost. To address this issue, an innovative technology consisting of a “solids free” Clear Water Drilling Fluid (CWDF) and a drilled solids stripping unit, the “MudStripper™”, was developed. This system was first used in the Barnett Shale to reduce drilling cost through increased drilling performance. In the Barnett Shale, it reduced well times by over 40% and reduced drilling fluid volumes by 70%[6]. Based upon these results, the water saving application for the technology in the Permian Basin was recognized.

Drilling Fluid System

The CWDF, known as Q’Clear, is a versatile fluid that uses various salts and other additives to provide density and shale inhibition in solution. Brines containing salts such as calcium nitrate, calcium chloride, potassium chloride, formates or others are used to provide density and shale inhibition. The choice is dependent upon the application, cost of the salt and environmental regulations. In some instances, strict limits on chloride concentration on cuttings for disposal may restrict the use of chloride based salts. Fluid density is easily controlled within a range from 8.4 ppg to 10.5 ppg using brines.

Within the Permian Basin, drilling fluid properties must be adjusted to meet the needs of drilling in different geographic regions. In some areas, some shale inhibition is required; in other areas density is required, and the CWDF can be easily adjusted to meet these requirements. Fluid densities, of up to 10.5 ppg were used; the average density on these wells was 9.2 ppg.

Solids Control

Success with CWDF requires complete removal of the solids in the fluid on each circulation of the fluid. This is accomplished by removal of the large cuttings using coarse screens (24 to 40 mesh) on the shakers and then passing the underflow through the MudStripper™, the Drilled Solids Stripping Unit (DSSU). The DDSU is a patented solids control device where coagulants and flocculants are added to the fluid. As the fluid passes through a settling chamber, the flocculated solids settle out leaving the fluid clear of suspended solids. The solids from the DSSU are transferred by a positive displacement pump to either a small cuttings pit or portable solids collection tank. The DSSU is able to return the clear fluid to the active system with suspended solids content of less than 1%. The DSSU is designed to process flow rates up to 850 gal/min. In this application, the DSSU processes 100% of the flow from the rig pumps. The DSSU solids control device operates as a closed loop system.

Waste Disposal

The solids output from the DSSU are discharged as dewatered cuttings with a density of approximately 14.5 ppg and as high as 17.5 ppg depending on the formations being drilled. The dewatered cuttings are collected in a cuttings bin or small cuttings pit and any free liquid that accumulates on top of the cuttings is pumped back to the receiving tank of the DSSU and reprocessed for return to the active system. In areas with zero discharge regulations, the dewatered cuttings can be transported by dump truck or in roll-off tanks as there is no free liquid.

Figure 5: DSSU

The CWDF is a low rheology fluid designed to maximize the efficiency of the DSSU. Since over 99% of the drill solids can be removed from the fluid on each circulation, the fluid can be recycled indefinitely from well to well. Also, since the fluid is always cleaned of drill solids, dilution is eliminated and the only volume that must be built on each well is the volume required for the new hole being drilled and to replace volume lost down hole through seepage, lost circulation and cementing operations. The DSSU dewaters the cuttings reducing the volume of fluid lost on the cuttings. (Figure 6)

Figure 6: Dewatered Cuttings Output from DSSU

Since most of the water and brine is reused on the next well, the waste disposal volume is significantly reduced on each well. Waste disposal volumes have been reduced by between 63% and 84% through the combination of fluid reuse, elimination of dilution and reduction of fluid on cuttings.

Water Usage

On average, the volume of fluid consumed per well dropped from 17,000 bbls in N.M. and 25,000 bbls in Texas bbls (Table 1) to approximately 5,700 bbls in N.M. and 3,500 bbls in Texas (Table 2). This is a 68% savings in water usage per well in N.M. and 84% savings in Texas. Table 2 shows the water volumes and fluids related costs on two wells drilled using CWDF and the DSSU, one well in Texas and one in New Mexico. The cost of water and brine decreased by $92,000 (Table 1) on a typical well, to approximately $12,500, a savings of 88%. As well, the cost of drilling fluid chemicals has been reduced from an average of $45,000 (Table 1) to $9,500, a 79% savings.

Table 2: Costs Associated CWDF

	Operator	
	D	E
Location	Texas	New Mexico
Well Depth (feet)	11,000	16,000
Well Type	Vertical	Horizontal
Pit Design Regime	Closed Loop	NM Pit Rule
Casing Program	3 string	3 string
DSSU	Yes	Yes
Fresh Water & Brine (bbls)	**3,500**	**5,700**
Fixed Cost		
Fluids Pit/Cuttings Storage	$ 18,000	$ 36,000
Pit Reclamation	$ 20,000	$ -
TOTAL Fixed Well Cost	**$ 38,000**	**$ 36,000**
Variable Cost		
Fresh Water & Brine	$ 10,850	$ 14,120
Drilling Mud Chemicals	$ 12,000	$ 7,000
Transport	$ -	$ -
Cuttings & Fluid Disposal	$ -	$ 80,000
Equipment (Closed Loop)	$ 55,000	$ 52,000
TOTAL Variable Well Cost	**$ 77,850**	**$ 153,120**
Variable Well Cost/foot	**$ 7.08**	**$ 9.57**
Total Fluids Related Costs	**$ 115,850**	**$ 189,120**
Cost per foot	**$ 10.53**	**$ 11.82**

Reclamation and Disposal

Referring to Tables 1 and 2, it should be recognized that in Texas, there were also significant savings in the Fixed Costs related to building and reclaiming the smaller cuttings pits vs. the large double horseshoe pits previously used. In New Mexico, the Fixed Costs were the same for using the CWDF and DSSU compared to using a conventional closed loop system. However, there are significant savings realized by less disposal related cost. The disposal cost using CWDF was $80,000 or $5.00/foot (16,000 foot horizontal well) compared to $75,000 or $9.38/foot (8,000 foot vertical well) using the conventional closed loop system. These savings are the result of a reduction in the number of roll off tanks required to transport cuttings to the disposal facility.

Accomplishments

The introduction of CWDF and DSSU technology has resulted in significant savings in water and brine usage as shown in the following graph (Figure 7).

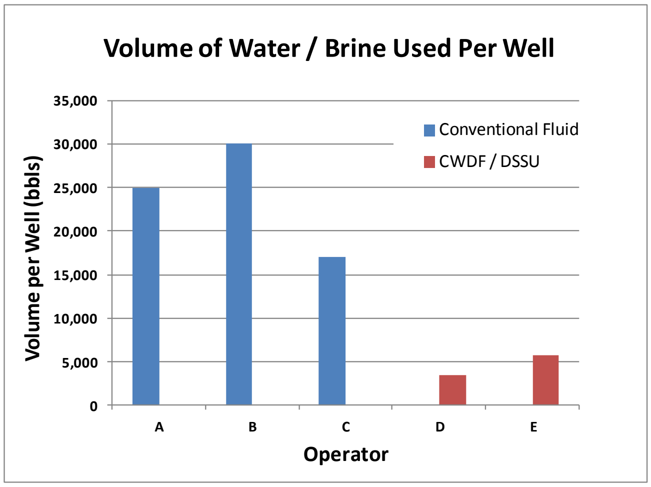

Figure 7: Volume of Water / Brine Used per Well

The reduction in water usage results in significant cost savings and puts is less demand on the water supply during a time of drought.

Figure 8 shows the impact of closed loop systems on the Fixed Costs related to pit construction and reclamation. Closed loop systems reduced the Fixed Costs by \$20,000 - \$50,000. Figure 9 shows the fluid related Variable Costs for the wells in Tables 1 & 2 as a cost per foot. The CWDF / DSSU provided the lowest cost per foot collectively by saving water, brine and drilling mud chemical maintenance costs.

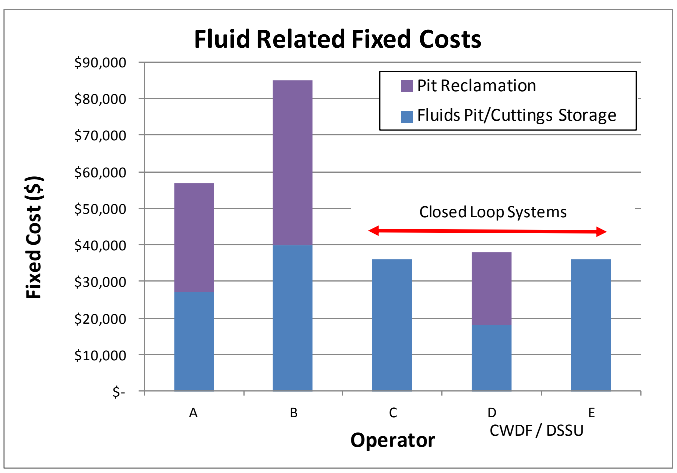

Figure 8: Fluid Related Fixed Costs

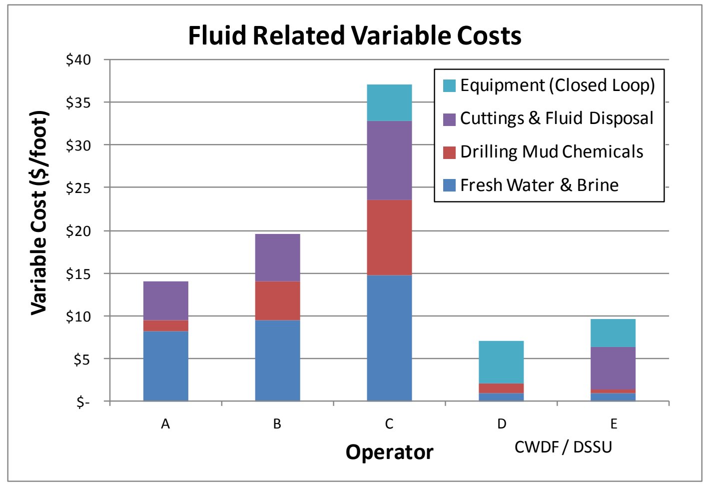

Figure 9: Fluid Related Variable Costs

Other Significant Benefits

In addition to the savings from water conservation and waste management, the use of the CWDF provides additional operational benefits including:

- HSE Benefits
  The reduced water usage results in fewer trucks on the road transporting fluids to and from the rig site. This reduces traffic resulting in lower risk of incidents and reducing the risk of spills.
- Reduced Well Times
  As in the Barnett Shale experience, well times have been reduced by up to 40%. This is primarily the result of faster drilling in the intermediate and production hole intervals and an elimination of problem time related to lost circulation.
- Longer bit life
  A review of offset bit records for West Texas indicated that, on average, there has been a 10% reduction in the number of bits used while running the CWDF/DSSU. In New Mexico, the number of bits used has been reduced by up to 50%. In many instances, the interval from the intermediate casing shoe to TD of the main production string has been drilled with one bit, an event that rarely happened in New Mexico before the introduction of the CWDF.
- Longer pump and liner life
  With conventional drilling fluids, pump liners were being changed every 3 wells. With CWDF, pump liners are lasting 4.5 wells. This is attributed to the elimination of suspended solids in the CWDF.

Conclusions

The introduction of the CWDF / DSSU technology in the Permian Basin has resulted in 44% savings in water usage while increasing drilling performance by 10% and up to 40%. The CWDF is reused and recycled from well to well. In contrast to conventional closed loop drilling systems that increase well cost, this technology reduces overall well cost while providing additional benefits.

In summary, CWDF in conjunction with the DSSU provides the following benefits:

- Recyclable drilling fluid (100% reuse from well to well)
- Elimination of dilution volume (99% of drill solids are removed from the fluid as the well is drilled so dilution is not required)
- Reduction in fluid on cuttings (drill solids are dewatered by the DSSU)
- Reduction in disposal volume (no fluid being dumped at the end of the well)
- 44% Reduction in water and brine volumes (volume reductions have been as high as 80% [Tables 1 and 2])
- Reduced cost of drilling fluids chemicals (elimination of dilution reduces chemical requirements)
- Closed Loop Solids Control
- Reduced location footprint (DSSU has a small footprint and the large circulation pits are eliminated)
- Increased ROP (elimination of drill solids and reduction in circulating density increases ROP)
- Reduction in down hole tool failures. (elimination of drill solids reduces abrasive wear on tools and equipment)
- Shale stability control (CWDF properties can be tailored to provide shale inhibition in solution)
- Extended bit life (10% improvement in bit life based upon review of offset bit records)
- Less wear and tear on mud pumps (pump liner life extended 50% [replace liners after 4.5 wells instead of 3])

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Nomenclature

bbls = barrels
CWDF = Clear Water Drilling Fluid
DSSU = Drilled Solids Stripping Unit
Mg/liter = milligrams per liter
MudStripper^{TM} = Q'Max Patented DSSU
ppg = pounds per gallon
ROP = Rate of Penetration
sqft = square feet
Q'Clear = Q'Max CWDF System

References

1. Charles D. Vertrees, "PERMIAN BASIN," Handbook of Texas Online http://www.tshaonline.org/handbook/online/articles/ryp02), accessed February 03, 2012. Published by the Texas State Historical Association.
2. Railroad Commission of Texas, "Oil & Gas Production Data Query" http://webapps.rrc.state.tx.us/pdq/generalreportaction.do
3. Railroad Commission of Texas, "Data and Statistics", "Drilling", "Monthly Drilling, Completion and Plugging Summaries" http://www.rrc.state.tx.us/data/drilling/drillingsummary/2011/annual2011.pdf
4. New Mexico Energy, Minerals and Natural Resources, Oil Conservation Division, Rule 19.15.17 NMAC. http://www.emnrd.state.nm.us/ocd/documents/20098-5currentrules-new17and39.pdf
5. Railroad Commission of Texas, Texas Administrative Code, Title 16: Economic Regulation, Part 1: Railroad Commission of Texas, Chapter 3: Oil and Gas Division, Rule 3.8: Water Protection. http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=16&pt=1&ch=3&rl=8
6. Gust, Douglas; Marquess, Scott; Dunham, Lane: AADE-2009-NTCE-09-04 "Case Study – Reducing Drilling Hours By Up To 54% In The Barnett Shale", presented at AADE 2009 National Technical Conference & Exhibition, New Orleans, LA., March 31 - April 2, 2009