# FRACTURE STIMULATION OF THE MORROW FORMATION WITH CROSSLINKED METHANOL: CASE HISTORIES

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## ABSTRACT

In recent years several papers have been written on the merits of fracture stimulation with crosslinked methanol. While crosslinked methanol has been available to the industry since the late 1980's, only in recent years has it been successfully and routinely utilized in the Permian Basin.

This paper will discuss the fluid system, with focus on recent system refinements, while special attention will be paid to the development of standard procedures implemented to ensure methanol is pumped safely. An overview of the reservoirs where crosslinked methanol has been applied successfully, along with treatment parameters, will be discussed. Finally, a production study of case history wells relative to offset Morrow producers will be reviewed.

## INTRODUCTION

Crosslinked methanol has been available as a stimulation fluid since the late 1980's. However, widespread usage in the continental United States has not been the case. The lack of extensive usage is due to a multitude of reasons and related perceptions. Crosslinked methanol will never take the place of standard water-based fracture fluid systems due to their wide application range and relative low cost. Standard foam fluids have a long history of success and provide certain advantages that can only be realized by energized fluid systems. Oil-based fluids, emulsions, water-based crosslink fluids, linear fluids, and more recently non-gelled water fluids have all found areas of application where they may claim supremacy. Crosslinked methanol is no different in that it too has found niche applications where it is proving to be the fluid of choice, and where relative results are undeniable. One of these applications at present is the Morrow formation of Southeast New Mexico. It is not suggested that all Morrow wells be stimulated only with crosslinked methanol. Quite the contrary, it is in some Morrow formations that exhibit certain reservoir characteristics that crosslinked methanol has found success. Like any fluid system, crosslinked methanol is no "silver bullet." All fluid systems should be applied with reservoir parameters and treatment goals in mind. Crosslinked methanol simply provides another choice, and another tool, when addressing a reservoir for a potential fracture stimulation treatment. Reservoir parameters should always be the driving force behind fracture stimulation design and subsequent fluid selection.

## CROSSLINKED METHANOL FLUID SYSTEM & APPLICATIONS

Methanol as a stimulation fluid has long been a respected application in the oil industry. Historically, methanol has been used in remedial applications, and in most cases it has been used to take advantage of its low surface tension properties. The surface tension properties of pure methanol have been measured in the laboratory at 22.6 dynes/cm, relative to fresh water at 72.7 dynes/cm. Another application of methanol is to prevent the introduction of water to supposed water sensitive formations during stimulation or workover operations.

The crosslinked methanol fluid system applied to the case history wells, which are the subject matter of this paper, is a simplistic fluid system in its construction. The biggest problem associated with methanol fluid systems has been in the hydration of the base polymer. To overcome this challenge, the subject fluid system uses a derivatized hydroxypropyl guar or HPG polymer. The derivatized polymer has a greater affinity to methanol than do standard polymers. Even though this polymer will hydrate in methanol, it requires loadings in the 50 ppt range to provide enough polymer to create adequate crosslink sites for the creation of a stable fluid when crosslinked. Even with the derivatized polymer some water is still required in the system. The current crosslinked methanol formulation requires a 4 percent water phase to ensure complete polymer hydration. Once hydration is achieved, the system is crosslinked with an organo-metalic crosslinker. The crosslink time can be delayed and controlled by adjustments to the system buffer. Breaking of the crosslinked methanol system post treatment is accomplished with conventional ammonium persulfate (AP) breakers. AP breakers react quickly in methanol fluid systems. Due to this fast reaction rate, controlled breaks are achieved with controlled release AP breakers. The reaction rate of the breaker may be slowed, and the ensuing break of the fluid system may then be controlled with relative ease. An example of the fluid viscosity generated and the controlled system break can be examined in Table 1. The data series labeled 'blank" in Table 1 indicates a fluid with no breaker added to the system, and provides a good example of the ultimate viscosity that can be generated by the system. The viscosity is approximately 500 cp. at 40 $^{-1}$sec on a Fann-50 rheometer. Upon examination of Table 1, one may surmise the effect of various breaker loadings, and the subsequent control of the break time when combinations of controlled release and non-encapsulated breakers are used.

Thompson et.al.[1] documented the use of $CO_2$ with crosslinked methanol in western Canada during the late 1980's. While methanol is routinely pumped in conjunction with $CO_2$, the chemistry associated with the current crosslinked methanol system will not tolerate $CO_2$ and is therefore not recommended. The system's incompatibility with $CO_2$ should not be a limiting issue due to the fact that the boiling point of methanol is lower than that of most formation temperatures encountered. Since it is soluable in methane, a small percentage of the methanol will be recovered as a liquid, the remainder being produced in the post fracture gas flow.

Crosslinked methanol can be utilized to stimulate any low permeability and/or low bottom hole pressure well. It was thought that the best application for crosslinked methanol in the Permian Basin would be in older wells or depleted Morrow reservoirs. This application was later proven and documented by Malone[2]. It was not until the case history wells had been treated in this study that the fluid was proven successful on new and relatively undamaged Morrow reservoirs. The system was introduced in Argentina in 1992, and has since been pumped on over 200 wells'. There are several reasons that crosslinked methanol should be considered for use in fracturing applications. These may include low bottom hole pressure wells, reservoirs containing an abundance of smectite or other swelling or migrating type clays, and finally reservoir rocks that exhibit a tendency to retain treating fluids. In studies by Bennion, et.al. [4,5,6] the concept of aqueous phase trapping has been reviewed in detail. This phenomenon deals with both the initial aqueous phase saturation, which is the initial average fractional portion of the pore space which is occupied by water, and the irreducible aqueous phase saturation. Often the initial aqueous phase saturation is not necessarily equal to the irreducible aqueous phase saturation. Aqueous phase trapping has the potential for severe productivity reductions when the difference between initial and true irreducible water saturation is great. This ultimately leads to adverse relative permeability effects caused by the presence of a high immobile fluid saturation, which in turn yields poor stimulation fluid flowback, and subsequent economic hydrocarbon production rates that are not commercial.

The miscibility of methanol in water is also an important factor when considering methanol as a fracturing fluid. Due to the miscibility of methanol in water, the post fracture flow-back process can potentially decrease the water saturation near wellbore to below original irreducible saturation values thereby increasing gas permeability. This phenomenon has been observed both in wells stimulated with crosslinked methanol in Argentina[3] and in the case histories to be reviewed in the Permian Basin.

## PRACTICAL **SAFETY** PROCEDURES

The pumping of hazardous fluids is a standard practice in the oil & gas industry. An example of the hazardous materials that have been used historically during well completions may include such fluids as refined oils, formation condensates, crude oils, acids (HCL, HF, Formic, etc...), alcohol, petroleum products (fuels), and liquefied gases. All of these fluids are designated as hazardous, and each presents its own unique set of challenges. However, with the proper planning, each can be pumped in such a manner as to avoid risk of injury to personnel. Such is the case with methanol. Practical safety precautions should be put in place during the planning stages of the treatment, and these precautions must be adhered to without exception during the mixing and pumping of a crosslinked methanol treatment.

The flash point of methanol is 53 °F, thus requiring the vapors to be contained during all phases of the operation. Containment of vapors becomes one of the main priorities during a crosslinked methanol treatment. When mixed with air and contacted by an ignition source the vapor, not the liquid, will ignite. The containment of these vapors requires a $CO_2$ blanket be placed over the methanol fluid at all times. The $CO_2$ vapor serves to segregate the methanol vapor from an oxygen source required for ignition. During a crosslinked methanol treatment the frac tanks used for holding methanol are placed 150 feet or more from the wellhead, and are modified to accommodate a $CO_2$ blanket during the mixing and pumping of the methanol. The downhole blender is also modified to allow a $CO_2$ vapor to cover the fluid passing through the tub during the treatment. All equipment deck engines are equipped with spark arrestors. Spray manifolds containing water are placed on the downhole pump plungers to keep them cool during pumping in order to eliminate a potential ignition source. Metal covers in the stay rod area of the pump are installed to prevent spray, a potential source of methanol vapor, should a pump packing leak. All suction and discharge hoses are wrapped to ensure a spray of mist does not occur should a hose rupture. All equipment is grounded during the treatment to eliminate the potential for static spark.

Only brass hammers are allowed on any location that utilizes methanol as part of the completion fluid.

Numerous other precautions are taken during a standard crosslinked methanol treatment. Prior to any methanol treatment it is recommended that the operating company representatives meet with the service company weeks in advance of the treatment to discuss the operation in order to identify all potential vapor and ignition sources on location. **A** plan to address each of these potential vapor and ignition sources should be implemented. As with any non-aqueous fluid, human exposure should be eliminated where possible. If a plan is created, and adherence to the plan is not compromised, it has been demonstrated that methanol can be pumped safely and successfully.

## STUDY AREA

The study involved four wells in Lea County, New Mexico within the Wilson and Ojo Chiso fields. The fields are located approximately 25 miles southwest of Hobbs, New Mexico. All of the wells are completed in the Morrow formation at depths between 12,700 and 13,100 feet. The Morrow reservoir throughout the study area is generally characterized as tight gas sandstone.

The Morrow formation in Southeast New Mexico can exhibit several characteristics that must be understood in order to maximize ultimate production. One of these is the Morrow's apparent extreme sensitivity to water. This characteristic often manifests itself in areas where permeability is low. In reality this sensitivity is associated more with the tight nature of the reservoir rock, and the corresponding capillary pressure issues that develop when water is placed into the porosity matrix. Often following a water-based or acidic Treatments, the reservoir pressure is insufficient to overcome these capillary forces and the wells will show evidence of damage. To minimize these effects, operators routinely add methanol, low surface tension surfactants, nitrogen, or carbon dioxide to HCl acid and water-based treating fluids. The four wells drilled in the study area fall into this category. They tend to have porosity of less than 12 percent and effective permeabilities less than 1 md.

Offset hydraulic fracture stimulations in the area of the study wells consist of foam fracturing treatments. Foams are typically used in an effort to reduce the amount of water placed on the formation during stimulation, thereby minimizing the amount of water that can become trapped in the porosity matrix due to capillary forces. Studies of the offset treatments showed that the foams used in treating the Morrow were linear foams, thus they were limited with respect to the viscosities achieved. A significant number of those fracture treatments were unable to place more than 3 ppg proppant into the formation, and some of the treatments were unable to place even 3 ppg proppant. Due to these factors, crosslinked methanol was chosen as a better all-around fluid for future completions in the study area. Crosslinked methanol provided a fluid with greater apparent viscosity in order to achieve maximum fracture width development for the placement of proppant, and further limited the amount of water placed on the formation during the fracturing process.

## STUDY WELL #1 – OUTLAND STATE UNIT #1Y

The first well treated with crosslinked methanol in the study area contained a single Morrow pay of 46 net feet. The zone was fracture stimulated down a 3 ½" tubing string set in a 4 ½" liner. The treatment placed 29,000 pounds of 20/40 mesh intermediate strength ceramic proppant staged from 0.5 pound per gallon (ppg) to 3 ppg. A subsequent 4-point test calculated the absolute open flow of the reservoir to be 26,000,000 scfd.

During the first 180 days of production well #1 produced 1,011,000 mscf. Comparing 180-day production of the immediate offset wells fracture stimulated with foams showed the average production of those wells to be 89,000 mscf. The best offset well produced 254,000 mscf in the same time period. This translates into an improved production of 1,100 percent for the crosslinked methanol frac versus the average offset well treated with foam.

## STUDY WELL #2 – STATE 'R' #2

The second crosslinked methanol treatment was performed on two Morrow pay sections totaling 52 feet of net pay. The zones were fracture stimulated down a 3 ½" tubing string set in a 4 ½" liner. The treatment placed 32,000 pounds of 20/40 mesh high strength ceramic proppant staged from 1 ppg to 3 ppg. **A** post frac build-up performed on the zones indicated the created fracture half length to be 145 feet with a proppant pack conductivity of 1,400 md-ft. The absolute open flow of the reservoir was calculated to be 13,000,000 scfd from this reservoir containing 0.21 md of permeability with a BHP of 7205 psi.

Well #2 produced 601,000 mscf in the first 180 days of production versus 83,000 mscf for the average 180-day production of the fracture stimulated offset wells. In this case the production following the crosslinked methanol fracture treatment was over 700 percent greater than the average offset well.

## STUDY WELL #3 – BELL LAKE UNIT #22

The third well treated five Morrow stringers over a gross interval of 50 feet. Together they contributed 32 net feet of pay averaging 1.3 md of permeability and 5402 psi BHP. The zones were fracture stimulated down a 3 ½" tubing string set in a 4 ½" liner. The treatment placed 34,000 pounds of 20/40 mesh high strength ceramic proppant staged from 1 ppg to 4 ppg.

Production after 180 days was 688,000 mscf for the third well. The best offset produced 223,000 mscf during the same period. Total offset production to well #3 averaged 132,000 mscf for the first 180 days. Production from this well was over 500 percent greater than the average offset well.

## STUDY WELL #4 – OW STATE #1

The fourth well was unique in that it produced naturally for 10 months prior to fracturing with crosslinked methanol. The well was initially completed in three Morrow sands spanning a gross interval of 196 feet. The upper Morrow contained 12 feet of net pay, the middle Morrow contained 34 feet of net pay, and the lower Morrow had 8 feet of net pay. Production testing however indicated that only the upper and lower Morrow intervals were contributing significantly to the overall production. Log information, as well as build-up data, indicated that the middle Morrow sand contained considerably lower permeability than the other two intervals. It was determined that if the middle zone was to contribute it would require fracture stimulation. The three zones were treated together down 5 ½" casing at a pump rate of 50 bpm. Radioactive tracers were incorporated into the treatment in order to verify the position of the proppant placement. The crosslinked methanol stimulation placed 52,000 pounds of 20/40 mesh high strength ceramic proppant staged from 1 ppg to 3.5 ppg. **A** subsequent log of the radioactive tracers confirmed that a majority of the treatment had been placed in the larger middle Morrow pay interval.

Post frac production from the forth well indicated that the fracture stimulated middle Morrow interval did not contribute significantly to an increase in overall well production. Following 90 days of post frac production the well made 104,000 mscf. In the 90 days preceding the fracture treatment the well had made 75,000 mscf. The average production of the offset wells was 151,000 mscf over the same time period.

## OFFSET STUDY COMPARISON

Post frac production from each of the case history wells were tracked and compared to the offset producers surrounding the case history wells. Mapping software was utilized and queries set up to identify all surrounding Morrow producers. Once all the surrounding Morrow producers were identified, the Morrow wells that were completed naturally or without fracture stimulation were eliminated from the study group as the ultimate goal was to compare stimulation techniques. The first 90-dayand 180-day production history of the wells were then compared. The results of this study are contained in the maps and tables numbered 2-9.

## CONCLUSIONS

1. It has been shown over multiple treatments that crosslinked methanol can be pumped in such a manner as to reduce risk to personnel and equipment. When pre-job planning is implemented as a standard practice and adherence to subsequent job safety plans are not compromised, crosslinked methanol can and has been pumped successfully and safely.

2. Crosslinked methanol has proven its effectiveness in stimulating low permeability reservoirs that have been deemed water sensitive, and in most cases has proven to be superior in this application relative to conventional fluid systems.

3. Crosslinked methanol is not a "fix-all silver bullet" for all reservoirs. However, it is a proven fracture fluid that should be seriously considered when reservoirs with low permeability and low bottom hole pressure are identified as hydraulic fracture stimulation candidates.

## ACKNOWLEDGEMENTS

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Table 1

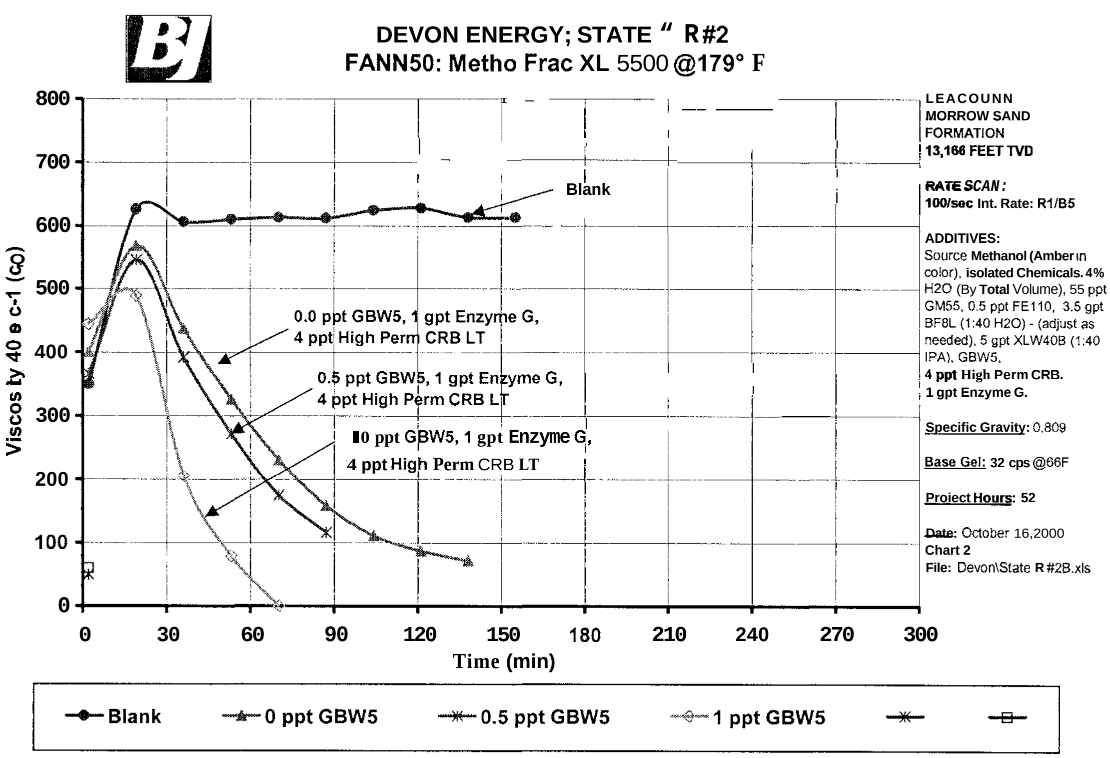

Table 2

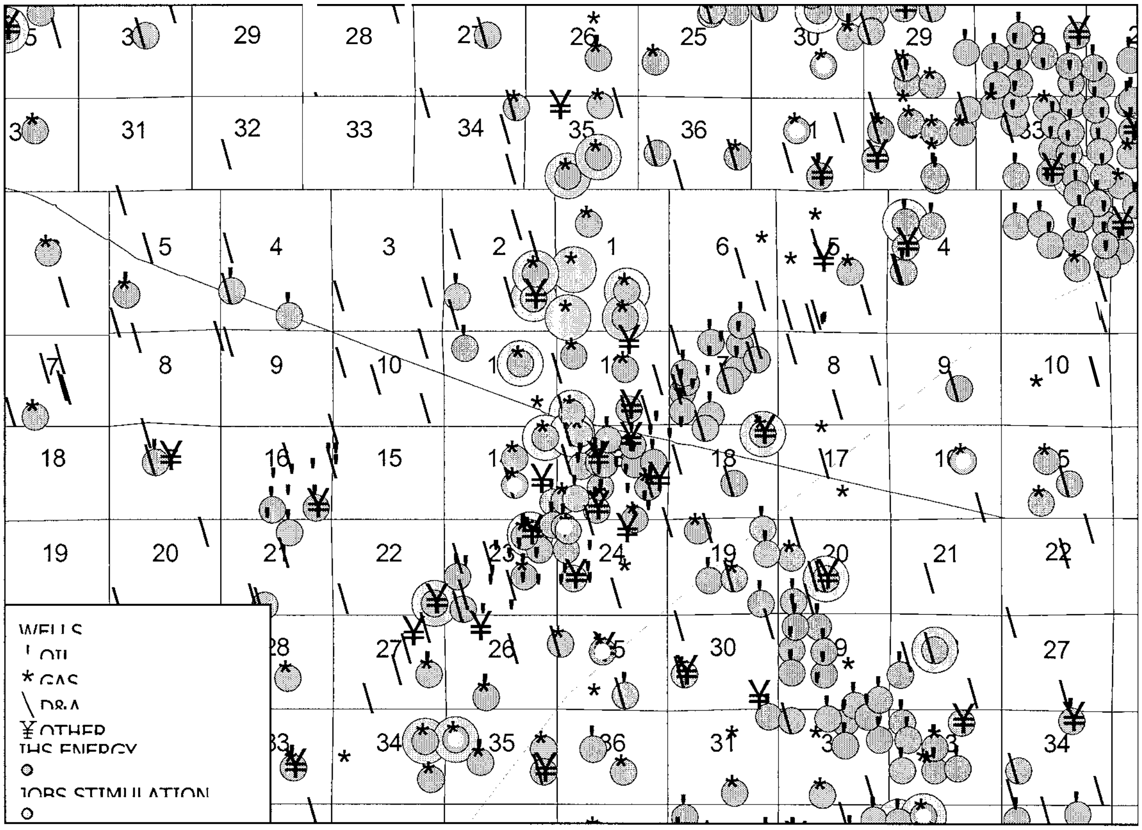

Table 3

| Well Name | 1st 180 Day Cums | | | Morrow Frac (Y/N |
|---|---|---|---|---|
| | Gas (MSCF) | Liquid (BO) | Water (BW) | |
| NM-State Gas CU No. 1 | 10233 | 0 | 0 | Y |
| South Wlsn DP State Corn No. 1 | 10828 | 195 | 920 | Y |
| State L Com No. 2 | 118884 | 455 | 200 | Y |
| Osudo PQ State Corn No. 1 | 62730 | 265 | 42 | Y |
| Badger 30 State No. 1 | 89437 | 533 | 71 | Y |
| Cuerno 4 State No. 1 | 130619 | 1113 | 79 | Y |
| Burgundy 20005 JV-P No. 1 | 39427 | 2043 | 36 | Y |
| Merchant 8700 JV-P No. 1 | 254259 | 1180 | 129 | Y |
| **Average of Offsets** | **89,552** | **723** | **185** | |
| **Outland State Unit No. 1Y** | **1,011,655** | **17,395** | **1,828** | |

Table 4

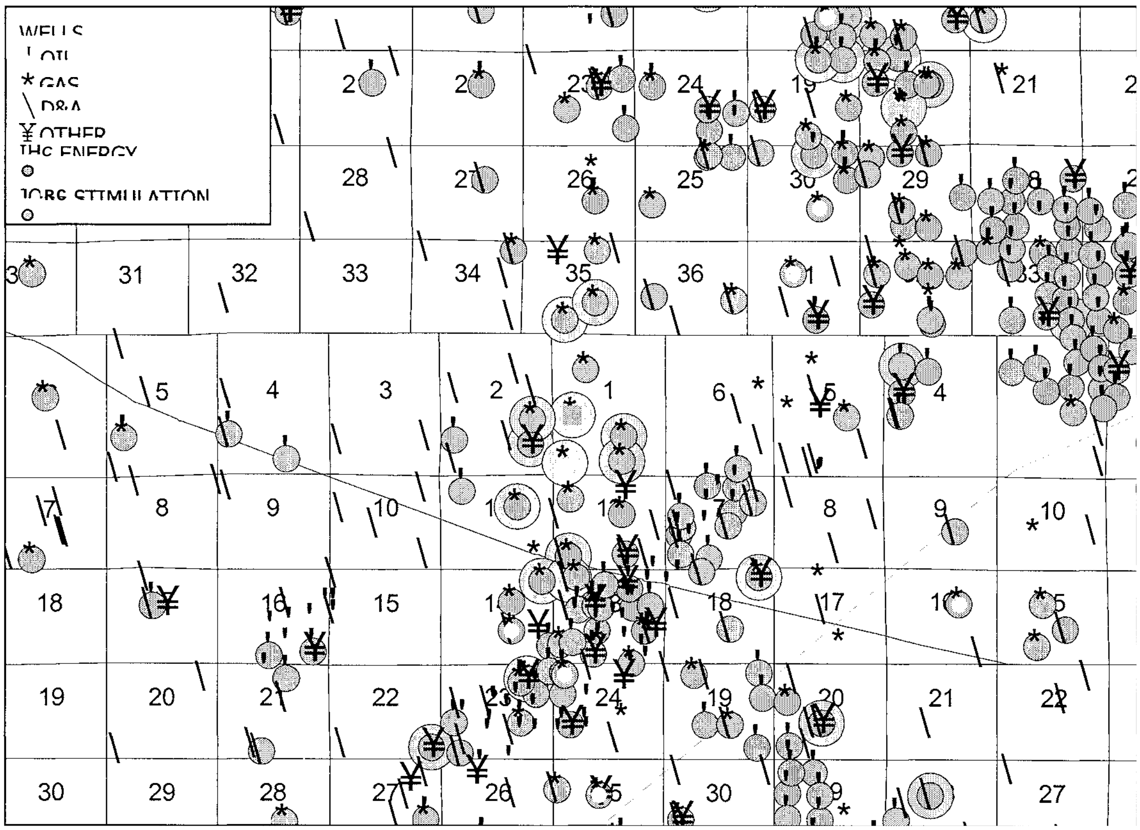

Table 5

| Well Name | 1st 180 Day Cums Gas (MSCF) | Liquid (BO) | Water (BW) | Morrow Frac (Y/N) |
|---|---|---|---|---|
| NM-State Gas CU No. 1 | 10233 | 0 | 0 | Y |
| Osudo State Corn No. 1 | 35503 | 0 | 0 | Y |
| South Wlsn DP State Corn No. 1 | 10828 | 195 | 920 | Y |
| State L Corn No. 2 | 118894 | 455 | 200 | Y |
| Osudo PQ State Com No. 1 | 62730 | 178 | 35 | Y |
| Badger 30 State No. 1 | 89437 | 533 | 71 | Y |
| Merchant 8700 JV-P No. 1 | 254259 | 1180 | 129 | Y |
| **Average of Offsets** | **83,126** | **363** | **194** | |
| **State R No. 2** | **601,444** | **6.083** | **465** | |

Table 6

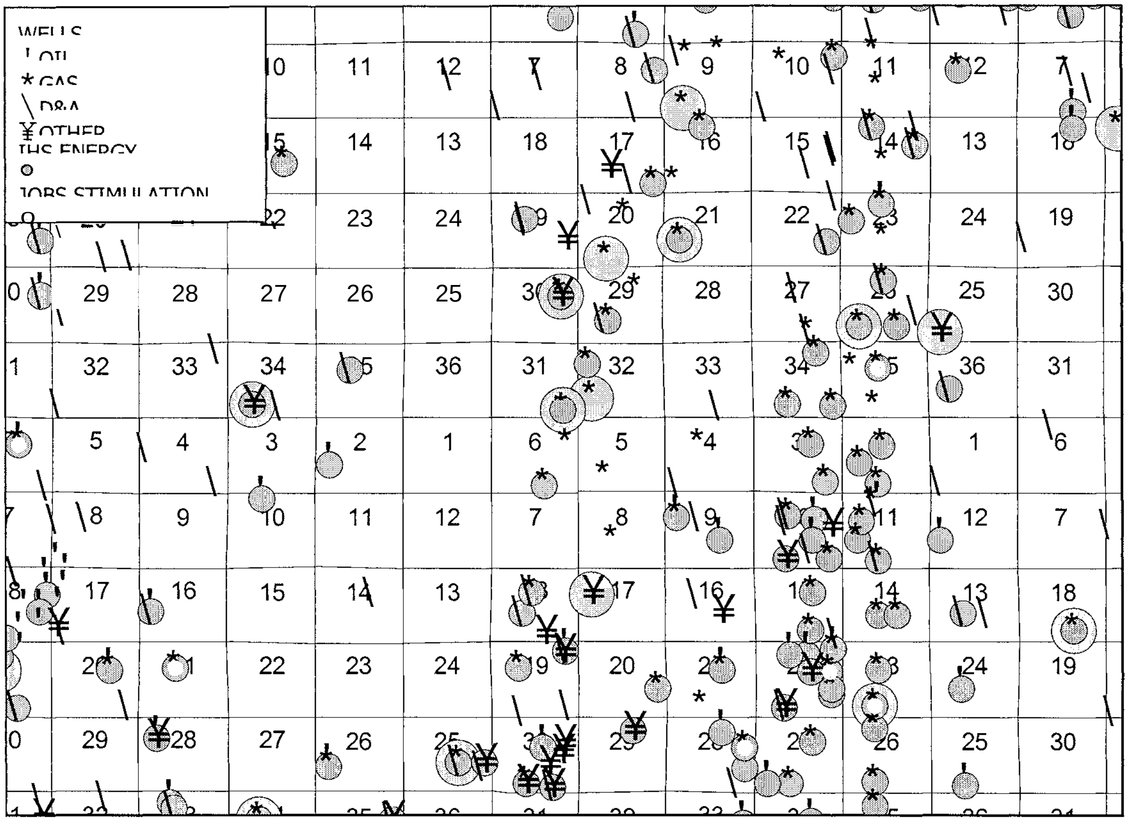

Table 7

| Well Name | 1st 180 Day Gas (MSCF) | 1st 180 Day Liquid (BO) | 1st 180 Day Water (BW) | Morrow Frac (Y/N) |
|---|---|---|---|---|
| Brinninstool U No. | 102,846 | 158 | 1,495 | Y |
| State 23 Com No. | 38,352 | 48 | 3,880 | Y |
| Pronghorn Unit No. 1 | 25,887 | 0 | 0 | Y |
| Antelope Ridge Unit No. | 20,387 | 19 | 1,721 | Y |
| Mddx FD B 8016 JV-P No. | 116,296 | 4,375 | 1,145 | Y |
| Curry State No. 4 | 19,499 | 350 | 0 | Y |
| Average of | 53,878 | 825 | 1,374 | |
| Bell Lake Unit No. 22 | 317,176 | 1,602 | 494 | |

Table 8

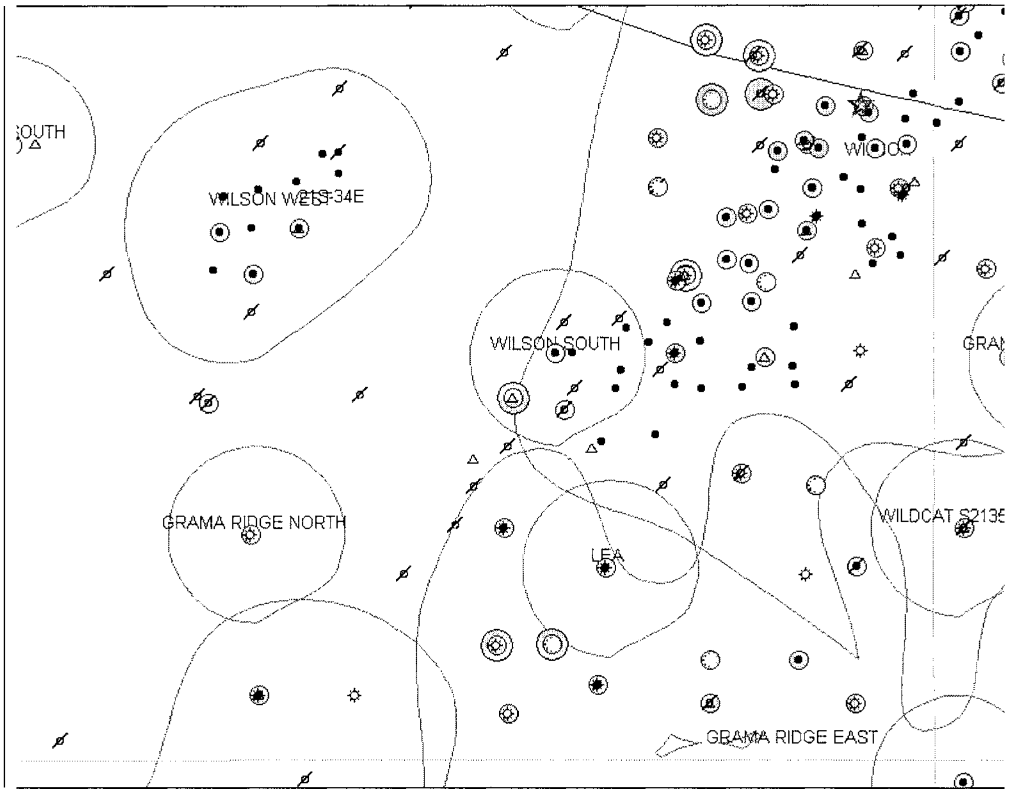


Table 9

| | 1st 90 Day Cums | | | Morrow |
|---|---|---|---|---|
| **Well Name** | **Gas (MSCF)** | **Liquid (BO)** | **Water (BW)** | **Frac (Y/N)** |
| Merchant 8700 JV-P No. 1 | 162772 | 748 | 131 | Y |
| South Wlsn DP State Corn No. 1 | 7407 | 195 | 326 | Y |
| State L Corn No. 2 | 77869 | 237 | 70 | Y |
| Burgundy 20005 JV-P No. 1 | 25143 | 1499 | 25 | Y |
| Corner Pocket '14' State No. 1 | 496383 | 4892 | 546 | Y |
| Getty '35' State Corn No. 2 | 136539 | 7444 | 0 | Y |
| **Average of Offsets** | **151,019** | **2,503** | **183** | |
| **O.W. State No. 1** | **104,091** | **1,408** | **1,729** | |