History of Horizontal Drilling in the Tyler Formation, North Dakota

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Introduction

The Tyler Petroleum System of North Dakota has cumulatively produced over 84 million barrels of oil during the past 50+ years (ND Oil & Gas Division, 2011). With peak production during the late 1970s (Nordeng, 2011), the Tyler Formation has been primarily developed using conventional vertical-well technology to target lenticular oil-bearing sand bodies in southwestern North Dakota (fig. 1).

Between 2001 and 2007, Upton Resources drilled four horizontal Tyler wells (plus one attempted horizontal re-entry) in southwestern North Dakota. Three of these wells have produced a combined total of over 555,000 barrels of oil and are all still actively producing. In addition to Upton Resources', two other horizontal Tyler wells have been attempted, neither of which had significant production from their horizontal laterals. The success of these seven horizontal Tyler wells varied significantly. This article examines the history and methodology of horizontal drilling in the Tyler Formation to date.

History of Horizontal Drilling in the Tyler Formation

The first horizontal Tyler well was Axem Resources' Tracy Mountain #12-36H drilled in the southern portion of the Fryburg field during July 1992 (fig. 2, top right corner). Tracy Mountain #12-36H had two lateral legs of 866 ft. and 1,805 ft. in length, which targeted an oil-productive sand interval but instead went through a variety of lithologies, including sandstone, limestone, and shale (the longer lateral encountered more sand than the first). The initial production (IP) of Tracy Mountain #12-36H was a minimal 32 barrels (BBLS) of oil, 37 BBLS of water, and negligible gas, and had monthly production of over 1,000 BBLS of oil for the first few months. However, production tapered off and the well was converted into a water injector after cumulatively producing 10,456 BBLS of oil and 1,544 BBLS of water.

The first economically successful horizontal Tyler well was Upton Resources' Federal #2-13, drilled in the Tracy Mountain field in September 2001. Federal #2-13 consisted of a ~3,000 ft. lateral drilled into the productive Tyler sand interval of the Tracy Mountain field and had an IP of 194 BBLS of oil and has a running

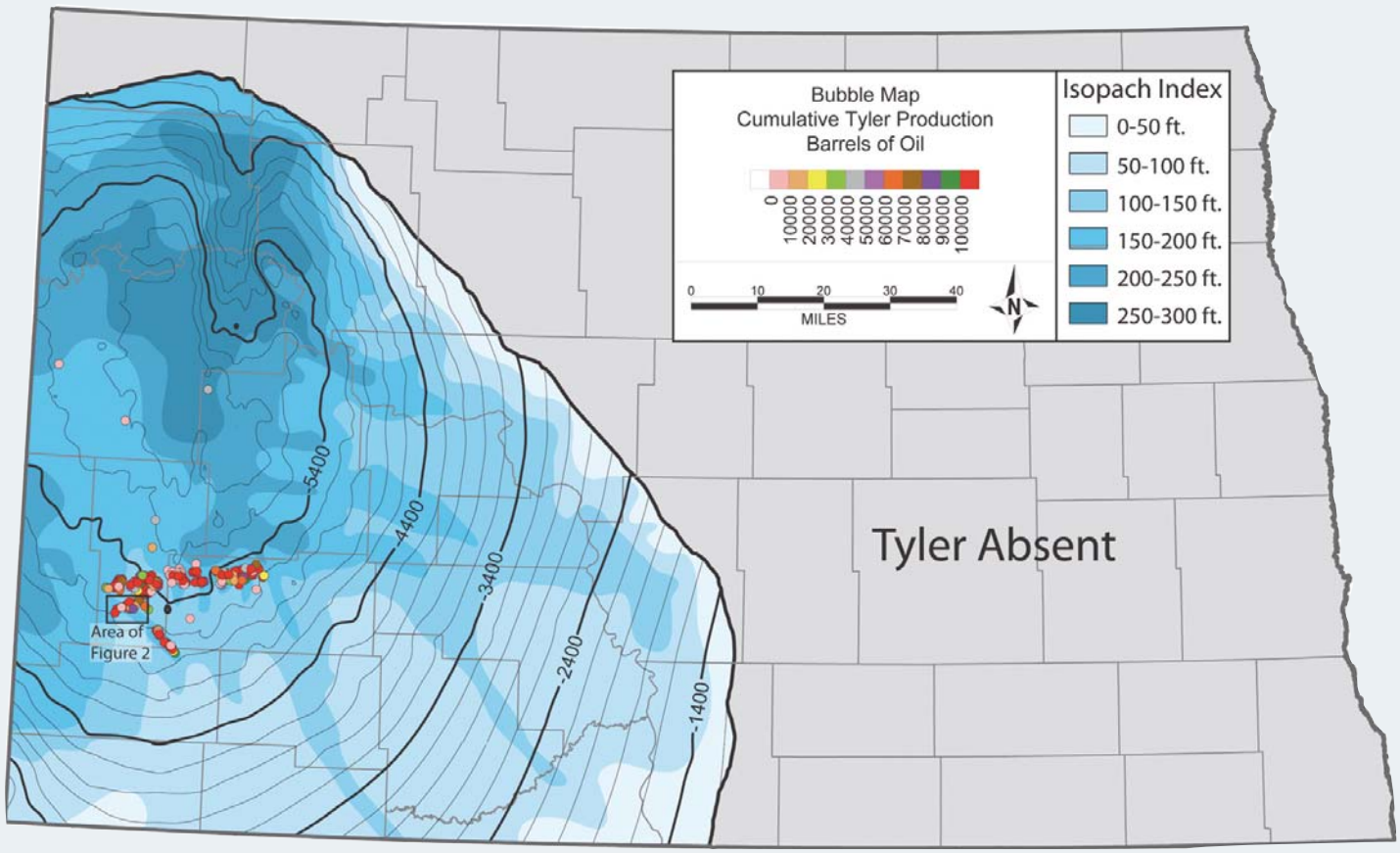

Figure 1. Structure contour (contour lines), isopach (background color), and production (colored circles) map of the Tyler Formation in North Dakota. The isopach (thickness) map is modified from Hastings (1990). The production data used is up to date through May 2011.

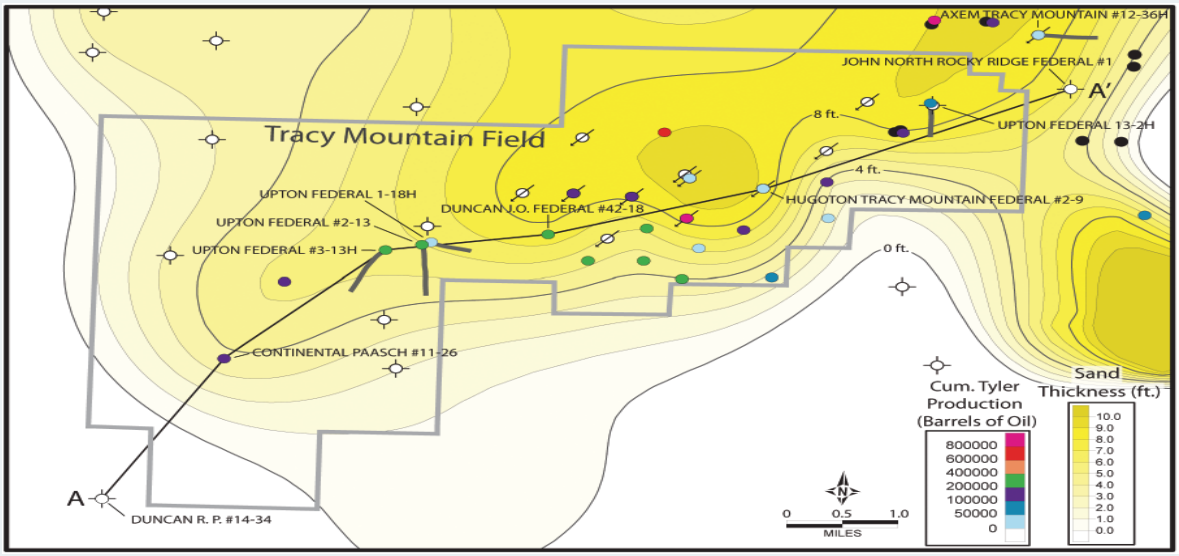

Figure 2. Field map of the Tracy Mountain field with cumulative Tyler production and the isopach of the productive sand interval. The production data used is accurate through May 2011. Figure 1 shows the approximate area and location of figure 2. A-A' shows the well locations and orientation of the figure 3 cross-section.

cumulative production of over 220,000 BBLS of oil. Upton Resources went on to drill three more horizontal Tyler wells, of which two have produced substantial amounts of oil and a third that was abandoned after limited production (table 1), plus one unsuccessful horizontal re-entry. To date, Federal #3-13H has been the most productive well (IP 262 BBLS oil, 40 thousand cubic feet (MCF) gas, and 8 BBLS water) producing over 280,000 BBLS of oil with limited water (fig. 3). Federal #3-13H is still producing 70-80 barrels of oil a day with limited water after 8+ years of production.

After Upton Resources' early successes, a horizontal re-entry was attempted in the Fryburg field in August 2005. A ~400 ft. horizontal lateral was temporarily added to Westport Oil and Gas Company's SFTU #40-22. The horizontal lateral was noted to have several problems, including: a slow rate of penetration, a low angle of inclination upon entering the target zone (73° instead of the intended 85°), and drilling through more shale and less sand than planned. While SFTU #40-22 has produced over 110,000 BBLS of oil from the Tyler Formation, all production has been from the vertical portion of the well. The ~400 ft. lateral was deemed unsuccessful and was plugged and abandoned shortly after being drilled.

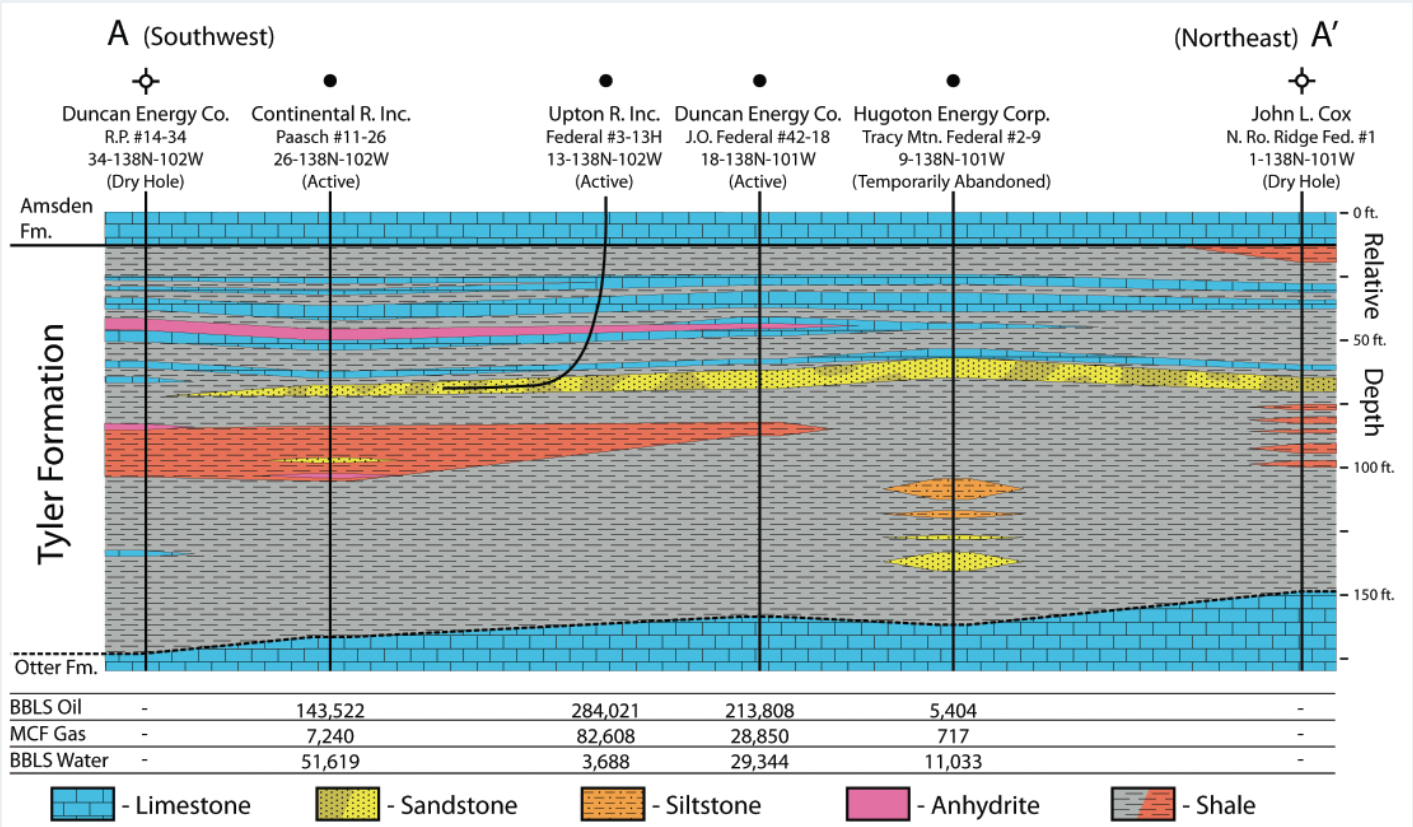

Figure 3. Stratigraphic cross-section of the Tyler Formation in the Tracy Mountain field. Cross-section was interpreted using wirelogs and the geologic reports from the well files. The near-continuous sand layer in the upper portion of the Tyler Formation is the oil-productive interval in the Tracy Mountain field. The darker colored sand areas represent non-pay zones of low porosity while the lighter colored sand areas represent pay zones with well-developed porosity (schematic representation). The curvature and length of Federal #3-13H's borehole is a schematic depiction.

The most recent horizontal Tyler well was Upton Resources' Tracy Mountain Federal 1-18H. Drilled during early 2007, Tracy Mountain Federal 1-18H was positioned relatively close to two of Upton Resources' earlier wells (fig. 2), but experienced drilling difficulties (reviewed later) and went on to produce significantly more water (53,256 BBLS) than oil (290 BBLS) before being abandoned. It is unknown to the author whether it was the failure of this last well or the onset of the Bakken-Three Forks play that ended (at least temporarily) Upton Resources' horizontal drilling of the Tyler Formation

Horizontal Drilling Techniques

Axem Resources' Tracy Mountain #12-36H, the first horizontal Tyler well, drilled two laterals into the upper Tyler sand (the same sand interval subsequently targeted by Federal #3-13H). Based on the geologic report, the first lateral (1,143 ft.) did not consistently stay within the targeted sand interval while the second lateral (2,298 ft.) did stay within the sand. The second lateral had a pre-perforated pipe casing and was perforated with both a stress frac and acid (table 1). The minimal production by Tracy Mountain #12-36H (table 1) may have been due to ineffective completion techniques, low porosity within the targeted sand interval, or both.

Upton Resources' horizontal drilling techniques varied from that of Axem Resources (table 1). For each of their horizontal Tyler wells, Upton Resources intended to enter the same sand interval with an inclination of 85°, drill a ~3,500 ft. lateral, and produce from an open hole without hydraulic fracturing or acidizing. Success of each well hinged primarily upon the lateral staying within the target sand interval.

Two notable drilling-completion technique changes were made by Upton Resources. First, Upton Resources initially used a freshwater system to drill the horizontal Tyler lateral of Federal #2-13 (NDIC: 15209), but due to tight hole conditions and difficulty sliding the directional tools, they added a polymer to the fresh water halfway through drilling the lateral. After drilling, the lateral borehole was treated with enzymes to remove polymer mud. For their next horizontal Tyler well, Federal #13-13H (NDIC: 15261), the lateral borehole was drilled entirely using a freshwater polymer system and treated with enzymes. Second, the first horizontal well lateral, Federal #2-13, was left as an open hole with no liner or casing while later wells were reported to have 4 ½-inch liners throughout their horizontal laterals.

The success of Upton Resources' horizontal Tyler wells appears to be a function of how consistently the horizontal laterals were able to stay within the targeted sand interval. The laterals for both the Federal #2-13 and Federal #3-13H, and the second lateral for Federal 13-2H, were reported to have stayed within the targeted sand interval for ≥84% of the lateral's length. All three of these wells have produced significant quantities of oil (table 1). Federal 1-18H, the least productive well and an economic failure, was not able to consistently stay within the targeted sand interval. Instead, the geologic report for Federal 1-18H reported that the lateral penetrated both the overlying and underlying shales for much of the lateral's length. While oil shows (fluorescence and streaming cuts) were reported in most of the sand that the lateral passed through, the Federal 1-18H produced over 50,000 BBLS water and only 294 BBLS oil during its brief production history (table 1).

Horizontal versus Vertical Well Production

Tracy Mountain field (fig. 2) was discovered in 1992 when Duncan Energy Company's O'Connnell #1, a vertical well, encountered oil in a 7- to 8-foot sand interval in the upper portion of the Tyler Formation (fig. 3). To date, 28 vertical wells have been drilled in the field (including dry holes) with an overall average 148,353 cumulative BBLS oil per well (range: 0 to 806,170 BBLS) while the 4 horizontal wells have averaged a similar 144,930 BBLS oil per well (290 to 284,021+ BBLS). The question arises that if the overall vertical well production is similar to horizontal well production, why did Upton Resources spend more time and effort drilling horizontal wells instead of traditional vertical wells?

The oil-bearing sand interval within the Tracy Mountain field is reported to vary from being non-productive sand with "very poorly developed" porosity to an excellent, oil-productive reservoir with up to 12% porosity. Vertical wells that encountered sand intervals with "very poorly developed" porosity typically had a show of oil but were unable to economically produce oil.

Table 1. Table summarizing drilling information for each of the horizontal Tyler wells discussed in this article.

Well Name	Field	Inclination (deg)	Kickoff Depth (ft.)	TVD Target Depth (ft.)	Dogleg Severity (deg/100 ft.)	Lateral Length (ft.)	% of Lateral in Sand Target	Liner Used	Perf Record	Lateral Hole Diameter (in)	Cum Prod (BBLS Oil)	Wells Status
Tracy Mountain #12-36H	Fryburg	86.8	7360	7937	15.0	1143/2298	<50%/>50%	-	SF, A	7 7/8	10,456	AI
*STFU #40-22	Fryburg	73	7790	8014	32.6	349	<50%	?	-	?	>118,420	A
*Tracy Mountain Federal #12-2	Tracy Mtn	84.7	6931	7952	8.3	131	?	-	-	7 7/8	0	TA
Federal #2-13	Tracy Mtn	86	7662	8222.5	15.3	3063	85%	-	-	8 3/4	>211,000	A
Federal #3-13H	Tracy Mtn	89.6	7636	8223.5	15.3	2526	84%	4.5 in	-	6	>266,789	A
Federal 13-2H	Tracy Mtn	89.2	7138	7951	11.0	†1440	~100%	4.5 in	-	6	>70,000	A
**Tracy Mountain Federal 1-18H	Tracy Mtn	85.4	7727	8222.5	17.2	1577	<60%	4.5 in	-	6	290	AB

*Horizontal Re-entry: an unsuccessful lateral extension was added to an existing vertical well. The lateral extension was plugged and abandoned.
**Drilling was called on well due to tight hole conditions and fear of losing well. The target zone was estimated to be 4-6 ft. thick but ended up being only 2-4 ft. thick.
†2nd lateral drilled, 1st lateral hole collapsed.
Inclination - The angle (in degrees), in respect to the vertical borehole, of the horizontal lateral upon entering the target zone.
Kickoff depth - The depth at which drilling began to transition from vertical to horizontal.
Dogleg Severity - The rate of curvation as drilling transitioned from vertical to horiztonal.
Perf (perforation) Record - SF = stress frac, A = acid.
Well Status: AI = Active water injection well, A = active oil producing well, TA = Temporily abandonded well, AB = abandonded well.
Notes: 9 bits were used to drill well #15209's horiztonal lateral and 5 bits for well #15261. "Lateral Length" spans from target penetration to total measured depth.

A typical Tyler vertical well will often encounter only one sand pay zone, and if that sand interval is of low porosity then that well's production will likely not be very good. The advantage of a horizontal well is that a 3,000 ft. lateral may be able to drill through the zone of low porosity and into a high porosity zone (fig. 3). In addition, a horizontal well's lateral may penetrate several sand pay zones that were not initially interconnected, thereby increasing the wells' reserves, whereas a vertical well may only encounter one sand pay zone.

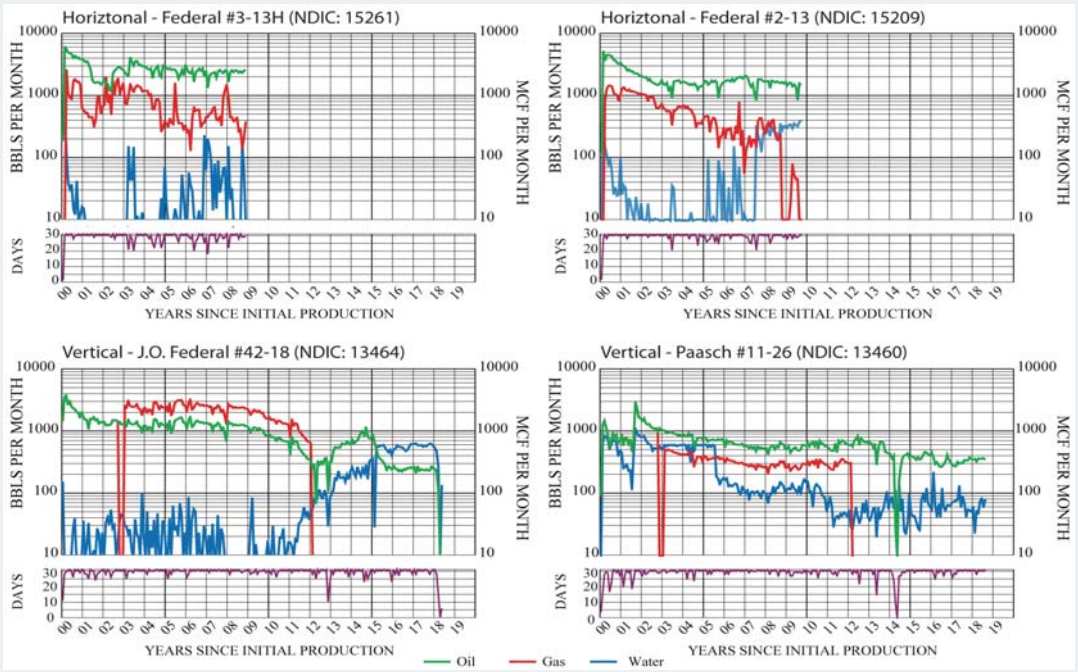

Figure 4. Monthly production diagrams comparing vertical versus horizontal well production in the western portion of the Tyler Mountain field. All four wells are shown and labeled in figures 2 and 3. Cumulative production information can be found in figure 3.

For example, the two more successful horizontal Tyler wells, Federal #3-13H and Federal #2-13, were drilled on the western side of Tracy Mountain field, where the productive sand interval thins to 0-6 ft. (fig. 2). Of the seven vertical wells drilled in the western side of the field, five (71%) were dry holes and two were successful wells that have both cumulatively produced ~140,000 BBLS of oil to date. Only one of the three horizontal wells in that area, Federal 1-18H, NDIC: 16526 (fig. 2), has been an economic failure. Also, comparing the production history of Federal #3-13H and Federal #2-13 to that of surrounding productive vertical wells (fig. 4 and table 2), the horizontal wells clearly out-produce the vertical wells. Overall, drilling a horizontal well instead of a vertical well seemingly decreases the chance of a dry hole and increases the well's productive capability.

Upton Resources' horizontal Tyler wells in the Tracy Mountain mark the first successful transition from conventional (vertical wells) to unconventional (horizontal wells) development for the Tyler Formation. Reexamination of Tyler oil fields that have been developed with vertical well technology, such as the Fryburg and Dickinson fields, may reveal numerous "dry holes" that encountered low-porosity pay zones that could be exploited with horizontal drilling.

In addition, the Tyler Formation has not been explored as an unconventional resource play. Our ongoing study of Tyler source rocks may reveal that the Tyler oil pool extends significantly beyond the Dickinson-Fryburg trend. Low porosity siltstone and limestone intervals in close vertical proximity to mature Tyler source rocks could be future horizontal well targets using multistage hydraulic fracturing recently developed for Bakken and Three Forks completions in the Williston Basin.

References

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Nordeng, S.H., 2011, Reviewing the resource potential of the Pennsylvanian Tyler Formation: Geo News, v. 38, no. 1, p. 21-25.

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Well Information			8 Year Cumulative Totals			
Name	NDIC	Well Type	Days	Oil (BBLS)	Water (BBLS)	Gas (MCF)
Paasch #11-26	13460	Vertical	2,825	82,970	42,116	5,817
J.O. Federal #42-18	13464	Vertical	2,847	140,160	2,093	20,654
Federal #2-13	15209	Horizontal	2,830	190,797	4,250	58,824
Federal #3-13H	15261	Horizontal	2,779	257,832	3,248	78,308

Table 2. Table showing the 8-year cumulative production total from the Tyler Oil Pool for select horizontal and vertical wells from the Tracy Mountain field. Well locations are shown in figure 2.