FourWorld
CAPITAL MANAGEMENT

Flotek: Drilling Down to Zero

FourWorld Capital Management LLC ("FourWorld") is an SEC registered investment advisor based in New York, New York. The views expressed in this research paper represent the opinions of FourWorld. As of the publication date of this presentation, FourWorld, and FourWorld managed accounts, have a direct or indirect short position in Flotek Industries Inc. ("Flotek") stock, and therefore stand to realize significant gains in the event that the price of Flotek stock declines. Following publication of this presentation, we intend to continue transacting in the securities covered herein, and we may be long, short, or neutral at any time hereafter regardless of our initial recommendation. The consulting firms hired by FourWorld, and referenced in this paper, are receiving a fee that is based on the performance of FourWorld's positions in Flotek stock, and, independent of FourWorld, may have a direct or indirect short position in Flotek stock.

Summary

Flotek Industries Inc. ("FTK", "Flotek" or the "Company") is primarily a supplier of specialty chemicals to oil and gas exploration and oilfield service companies. Flotek began trading on the NYSE in 2007 under the ticker "FTK". Flotek's "crown jewel" and primary driver of revenue and profitability is their suite of "Complex-nano Fluid®" products ("CnF") used primarily by operators engaged in hydraulic fracturing in the United States. FTK markets CnF as the industry leading suite of superior, environmentally responsible surfactants that significantly enhances oil production from horizontal well completions. Flotek claims oil production uplift of 30-70%,[1] states that operators have cost themselves $70 billion in revenue in Texas plays alone by not using CnF,[2] and touts an independent study claiming production uplift of nearly 60% for wells using the product.[3]

FourWorld has analyzed the independent reports issued by Flotek, conducted a series of studies analyzing the efficacy of CnF and performed in-depth due diligence of the Company. To assist in our analysis, FourWorld hired RK Trading LLC ("RK Trading") and Sylvania LLC ("Sylvania"), two Houston based consulting firms with substantial experience in horizontal completions and performance measurement. Our primary conclusions are as follows:

- **The independent studies commissioned by Flotek were based on incomplete data and failed to consider key variables in the oil production process.**
- **The impact of CnF on well productivity is indistinguishable from zero when using a full data set.**
- **Flotek has experienced 85% attrition of CnF end users (i.e. oil and gas operators) over the last four years.**
- **All other things being equal, if CnF were repriced to the level of other generic surfactants, revenues would fall $60-90 million per annum (2016 estimated total revenue is $297 million) and adjusted EBITDA would be negative $50-$80 million per annum (2016 estimated adjusted EBITDA is $12.5 million).**

[1] Flotek press release dated February 23, 2015.

[2] *"Operators have lost revenue potential of $70 billion; yes, billion with a B from not using CnF in their wells in just the Eagle Ford and Permian basins alone."* John Chisholm, FTK Chairman and CEO, Johnson Rice & Company Energy Conference. September 28, 2015. Transcript from Bloomberg.

[3] Flotek press release dated January 27, 2016.

Background Information

Hydraulic Fracturing, Surfactants and Complex nano-Fluids ("CnF")

In the process of hydraulic fracturing ("fracking"), a well is drilled, casings and liners (i.e., pipes) are cemented into place and then perforated with directional explosives or opened through tiny ports. Fracturing fluids are then pumped down the well under extreme pressure to crack open the rock, which allows oil to flow out. Fracturing fluids are roughly 99.5% sand and water and 0.5% specialty chemicals. CnF is a specialty chemical known as a surfactant. It is used with a concentration of roughly 1.3 gallons of CnF per thousand gallons of water (0.13%). Surfactants are used to reduce surface tension (e.g., soaps and detergents are common surfactants). Generic surfactant products are manufactured by the likes of Baker Hughes (BHI) and NalcoChampion and sold to oil and gas operators by companies like Halliburton (HAL) and Schlumberger (SLB) at prices in the $3 to $6 per gallon range, with gross margins of 15 to 20%. This is in stark comparison to the price of CnF, which Flotek sells for $12-15 per gallon (2-4x generic products) with gross margins over 40%. FTK sells CnF directly to operators via the Flotek Store and also distributes products through service providers (i.e., HAL, BHI, SLB), who generally repackage CnF and sell it to operators under a white labelled trade name (i.e., product name, such as HAL's "OilPerm FMM-2" and "GasPerm 1100" or BHI's "Flo-back Prime").

Flotek's History, Business Segments and CnF Reliance

According to the Company's 2016 Annual Report, Flotek was originally incorporated in British Columbia in 1985. In 2001, Flotek moved the corporate domicile to Delaware and completed a reverse merger with Chemical and Equipment Specialties Inc. ("CESI"), including a 120 to 1 reverse stock split, creating an OTC traded company (OTCBB: "FLTK") with a market cap of approximately $15 million. In 2003, the Company "purchased what would become the CnF technology for about $100,000 and a few thousand shares of Flotek's stock"[4] (Flotek's stock price in 2003 was $0.30 to $0.50 with a market cap of $3 to $8 million). This would prove to be fortuitous timing, as over the next ten years, CnF would grow to become the "flagship of Flotek's technology portfolio" as the fracking boom took off in the United States. On the brink of collapse in 2009, FTK issued new equity (at $1.27 per share) and restructured its debt, including the exchange of a $36 million convertible note and a new $40 million term loan. Since completing its restructuring in early 2010, FTK's stock price (and market capitalization) has gone from $1.27 ($30 million) to a high of $32.66 ($1.75 billion) on June 19, 2014, to its current price of $13.18 ($747 million) as of December 2, 2016.[5]

Flotek has four business units, the largest and most profitable of which is Energy Chemistry Technologies ("ECT") which primarily sells specialty chemicals (mostly CnF) to the oil and gas industry at gross margins over 40%. The table below shows key statistics by segment.

[4] John Chisholm, Chairman and CEO of Flotek on the Q4 2014 Flotek earnings call. Transcript from Bloomberg.
[5] Stock price and market capitalization figures based on Company 10-Ks and Bloomberg data.

(In $ Millions)	Q4 2015 12/31/2015	Q1 2016 03/31/2016	Q2 2016 06/30/2016	Q3 2016 09/30/2016	LTM 09/30/2016
Energy Chemical Technologies					
Revenue	50.3	44.7	43.4	45.0	**183.4**
Operating Income	10.9	8.0	7.6	6.2	**32.7**
Gross Profit	21.2	18.8	17.7	18.2	**75.8**
Gross Margin	—	*42.0%*	*40.7%*	*40.4%*	***41.3%***
Consumer and Industrial Chemical Technologies					
Revenue	13.6	19.1	20.7	19.3	**72.7**
Operating Income	2.0	3.4	2.7	2.4	**10.5**
Gross Profit	3.5	5.0	4.1	4.2	**16.7**
Gross Margin	—	*26.3%*	*19.6%*	*21.6%*	***23.0%***
Drilling Technologies					
Revenue	10.3	6.5	6.4	7.2	**30.3**
Operating Income	(2.8)	(41.0)	(1.6)	(0.9)	**(46.3)**
Gross Profit	3.3	1.0	2.2	2.9	**9.5**
Gross Margin	—	*15.9%*	*34.8%*	*40.4%*	***31.2%***
Production Technologies					
Revenue	2.9	2.0	1.9	2.1	**8.9**
Operating Income	(1.2)	(5.4)	(1.3)	(1.1)	**(9.0)**
Gross Profit	0.2	0.1	(0.0)	0.1	**0.4**
Gross Margin	—	*5.4%*	*-0.7%*	*4.8%*	***4.4%***
Corporate and others					
Revenue	0.0	0.0	0.0	0.0	**0.0**
Operating Income	(11.0)	(11.0)	(10.1)	(10.9)	**(43.0)**

Source: Bloomberg

ECT is FTK's primary driver of revenue and profit. For the last twelve months ("LTM") ended September 30, 2016, ECT generated 62% of consolidated revenue, 74% of consolidated gross profit, and $32.7 million of income from operations versus a consolidated loss of $55.1 million (includes a $40.4 million write-down in inventory and long-lived assets for the Drilling Technologies and Production Technologies segments in Q1 2016). CnF currently represents approximately 70% of ECT sales. We understand that CnF is actually responsible for a higher percentage of sales, as lower margin products are bundled with CnF and sold as a package.

The Consumer and Industrial Chemical Technologies ("CICT") unit primarily sells chemical products to the flavor and fragrance industries at a gross margin of approximately 22% and is the only other significant contributor to revenue and profit. For the twelve months ended September 30, 2016, CICT generated 25% of consolidated revenue, 16% of consolidated gross profit and $10.5 million of income from operations. FTK's other two business units, Drilling Technologies and Production Technologies, combined account for less than 15% of consolidated revenue and had a loss from operations of $55.3 million. FTK has stated they "continue to consider a wide range of options" for these businesses that are "less essential" as they evolve "to an enterprise with a more acute focus on chemistry technology, primarily in the energy arena."[6]

[6] Flotek Q3 2016 earnings call and the Flotek presentation at the IPAA OGIS Conference in San Francisco on September 27, 2016. Transcripts from Bloomberg.

By all measures, Flotek is heavily reliant on the success of CnF. If CnF were repriced to the top of the range for generic surfactants ($6 per gallon, which we estimate is $2 per gallon below the manufacturing cost of CnF), at current CnF sales volume, ECT revenues (all other products being equal) would drop by $60 to $90 million per annum.[7] This revenue loss would result in an estimated adjusted EBITDA of negative $50-$80 million and a consolidated operating loss of $80 to $100 million per annum. With SG&A plus R&D at approximately $105 million per annum, we have seen no evidence that would lead us to believe that Flotek could cut enough expenses to offset this loss of revenue. The table below shows key financial statistics by quarter since Q4 2015 and estimates for FY 2016 from Bloomberg.

Flotek Industries Inc (FTK US) - Adj Highlights

In Millions of USD Period ending	Q4 2015 12/31/2015	FY 2015 12/31/2015	Q1 2016 03/31/2016	Q2 2016 06/30/2016	Q3 2016 09/30/2016	Q4 2016 Est 12/31/2016	FY 2016 Est 12/31/2016
Market Capitalization	**612.5**	**612.5**	**393.8**	**711.6**	**824.4**		
- Cash & Equivalents	2.2	2.2	2.5	3.8	3.5		
+ Preferred & Other	0.4	0.4	0.4	0.4	0.4		
+ Total Debt	50.5	50.5	61.2	64.9	42.6		
Enterprise Value	**661.1**	**661.1**	**452.9**	**773.0**	**863.8**		
Revenue, Adj	**77.0**	**334.4**	**72.3**	**72.3**	**73.7**	**78.4**	**296.6**
Growth %, YoY	*-38.1*	*-25.6*	*-12.2*	*-16.9*	*-16.2*	*1.7*	*-11.3*
Gross Profit, Adj	**28.1**	**115.1**	**24.9**	**23.9**	**25.4**	**27.6**	**101.8**
Margin %	*36.5*	*34.4*	*34.5*	*33.1*	*34.4*	*35.3*	*34.3*
EBITDA, Adj	**2.4**	**19.2**	**-1.8**	**14.9**	**-1.1**	**0.6**	**12.5**
Margin %	*3.1*	*5.7*	*-2.4*	*20.5*	*-1.5*	*0.7*	*4.2*
Net Income, Adj	**-1.4**	**-0.2**	**-4.2**	**7.1**	**-3.0**	**-1.9**	**-2.0**
Margin %	*-1.8*	*-0.1*	*-5.8*	*9.7*	*-4.1*	*-2.4*	*-0.7*
EPS, Adj	**-0.03**	**-0.01**	**-0.08**	**0.13**	**-0.05**	**-0.04**	**-0.04**
Capital Expenditures	**-9.4**	**-20.5**	**-4.2**	**-4.7**	**-2.7**	**-3.0**	**-14.6**
Free Cash Flow	**-0.5**	**6.2**	**-10.8**	**-1.5**	**-0.2**	**-2.9**	**-15.4**

Source: Bloomberg

FTK's financial position can not withstand a $60 to $90 million revenue hit

Readers should consider whether Flotek is viable under these conditions.

Bronte Capital Report, SEC Inquiry and the Flotek Special Technical Committee

In November of 2015, Bronte Capital Management Pty Ltd ("Bronte") questioned production data that FTK used in its marketing materials. Bronte pointed out that production data generated from FTK's FracMAX™ software (FracMAX™ was Flotek's patented iPad application used as a sales tool to demonstrate the impact of CnF) was inconsistent with official production data from the State of Texas. Bronte showed that the official production data for the non-CnF wells were reduced by 40% before comparing with CnF wells, resulting in the misleading conclusion that CnF

[7] FTK's presentation at the Jefferies 2016 Energy Conference showed CnF volume of 2.5 million gallons in Q3 2016. Repricing from $12-15 per gallon to $6 per gallon equates to a drop of $15 to $22.5 million per quarter in CnF sales, or $60 to 90 million per annum.

wells significantly outperformed non-CnF wells.[8] After conceding the data error highlighted by Bronte (which raised material questions about the efficacy of both CnF and FracMAX™ as a data management tool), FTK formed a Special Technical Committee ("STC") of the Board to handle, among other things, a related SEC inquiry and to evaluate the performance of CnF. The last mention of FracMAX™ by the Company was at an industry conference in April 2016, when John Chisholm stated "we continue to make progress on a new version of the Company's proprietary measurement software and expect to discuss progress on FracMax 2.0 in the future."[9]

To our knowledge, Flotek has never released the names of the Special Technical Committee members. FTK's January 19, 2016, press release stated the STC was to consist of five **independent** members of the Board of Directors.[10] FTK's Board of Directors has seven members, including John Chisholm, the Chairman and CEO of Flotek. We note that Mr. Ted Brown joined FTK's Board as an **independent** member in November 2013, when he was also a senior executive at Noble Energy Inc. ("NBL"). Since 2008, Mr. Brown was responsible for the northern region of NBL's US division, which included the Denver-Julesburg Basin ("DJ Basin") in Colorado, until he retired from NBL on January 31, 2015. According to FTK's website, Mr. Brown continues to serve on the Executive Committee of the Colorado Oil & Gas Association. A later statement by John Chisholm on the July 27, 2016, Q2 earnings call stated that the STC was "made up of folks inside Flotek and outside Flotek." Interestingly, the only member of the STC that we can find publicly disclosed is a hedge fund manager specializing in micro-cap stocks, who is not on the FTK Board of Directors. His membership was disclosed in a footnote of the selling stockholders table from the August 2016 registration statement for shares offered just weeks earlier in a private placement (at a 5% discount).[11]

Following the Bronte disclosure, the STC hired MHA Petroleum Consultants, LLC ("MHA") primarily to assist in its charge of independently validating the effectiveness of CnF. MHA was tasked with reviewing CnF's performance in the DJ Basin in Colorado, the Permian Basin in Texas and New Mexico, and the Eagle Ford in Texas.

The "Independent" MHA Reports

Flotek released MHA's first study addressing the performance of CnF in the DJ Basin on January 27, 2016, and released two studies analyzing the influence of CnF on Texas completions on July 27, 2016. In each case, MHA compared the productivity of wells completed with CnF to the productivity of wells completed without CnF in the same geographic area, i.e. a simple control

[8] Bronte Capital report entitled "Flotek: a plea for accuracy" available at http://brontecapital.blogspot.com/.

[9] Flotek presentation at the IPAA OGIS in New York on April 12, 2016. Transcript from Bloomberg.

[10] "The Company's Board of Directors subsequently formed a Special Committee consisting of five independent members of the Board of Directors to conduct an independent review of the issues as well as any other relevant issues that may arise in connection with the shareholder litigation or SEC inquiry." Flotek Press Release, January 19, 2016. Available on company website.

[11] Flotek Industries, Inc. prospectus dated August 11, 2016, p.5 (footnote 11). Available at www.sec.gov.

study. MHA provides the following explanation of their evaluation strategy in their study of the DJ Basin (bold emphasis added):[12]

> "In a study such as this, **there are numerous additional factors, beyond the presence or absence of the CnF additive, which will have an influence on the productivity of a given horizontal well relative to other similar wells.** These include factors such as the length of the horizontal well, the thickness of the reservoir, the geologic formation into which the well was drilled, the ratio of gas and oil in the produced fluid, the size and design of the hydraulic stimulation, and the date during which the well was completed. While it was not possible to completely remove the influence of these other factors from our analysis and to isolate completely on the impact of using CnF, **it is the opinion of MHA that by segregating our evaluation into the three focus areas, the analysis was predominately centered on the effect that CnF had on well productivity.** This is because generally, within a specific focus area, drilling occurred during the same time period, **wells were drilled utilizing similar lateral lengths**, the ratio of produced gas and oil was relatively consistent, reservoir thickness did not vary significantly, and **the development was confined to a small number of operators helping to minimize variations in hydraulic fracture design and implementation.**"

According to the explanation above, MHA relied on spatial and temporal proximity among completions - as well as sample size - to mitigate the influence of factors that are known to affect the productivity of horizontal completions. **Our research indicates that this approach produces highly misleading results. There is significant variation in lateral length and location-specific field productivity in the populations of wells located in the three focus areas of the DJ Basin. A study that considers the influence of these key variables indicates that the impact of CnF on well productivity is indistinguishable from zero. By omitting these key factors, we believe any study would overstate the efficacy of CnF.**

Within the DJ Basin, MHA considered three focus areas ("Area 1," "Area 2," and "Area 3"), and concluded that CnF uplift, calculated using "the most meaningful comparison parameter…the normalized 12-month cumulative oil volume per foot of gross perforated interval,"[13] to be 46.9% in Area 1, 18.3% in Area 2, and inconclusive in Area 3 (MHA concluded Area 3 was "inconclusive" because two performance measures were negative and two were positive, as seen in the table).

[12] MHA study entitled "Effectiveness of CnF on Improving Horizontal Well Performance Greater Wattenberg Area – DJ Basin; Colorado," p.4., January 25, 2016.

[13] MHA study entitled "Effectiveness of CnF on Improving Horizontal Well Performance Greater Wattenberg Area – DJ Basin; Colorado," p.6., January 25, 2016.

MHA Conclusions – DJ Basin Study[14]

Percent Gain of CNF (Niobrara Horizontal Wells Only)						
Focus Area	CNF Well Count	Non-CNF Well Count	Improvement in Average first 12-month oil production	Improvement in Average first 12-month oil production per foot of gross perforated interval	Improvement in Average Oil EUR	Improvement in Average Oil EUR per foot of gross perforated interval
Area 1	105	122	10.0%	46.9%	19.2%	58.4%
Area 2	348	123	7.4%	18.3%	12.1%	27.6%
Area 3	251	184	-2.7%	9.8%	-12.1%	1.4%

Since MHA itself determined that Area 3 was inconclusive, we focused our analysis on Area 1 and Area 2. As stated in the MHA report, the classification of wells MHA used to arrive at these estimates was based on the FracFocus data base.

FracFocus

FracFocus.org ("FracFocus") is the national hydraulic fracturing chemical registry and is widely accepted by the industry as a standard source for finding chemical data on oil and gas wells (Flotek and MHA use this as a primary data source). The site provides a public database that includes information about chemicals used in 25 states and over 117,000 wells.[15] Each well in the US is assigned an API number. Operators are required to report chemicals used in the well's fracture treatment on a state by state basis by API number.[16] With a list of API numbers and a list of CnF trade names (i.e. product names), a user can distinguish wells completed with CnF from wells that did not use CnF. A small subset of wells don't report trade names but list actual chemicals, which can also be used to identify CnF. For purpose of our analysis, wells that used a product identical in chemical identical in chemical make-up to Flotek's patented makeup are treated as CnF.

State Government Agencies: Production and Well Design Data

Production data and the length of the gross production interval (the part of the wellbore that is fracked) ("GPI") are also publicly available from the state authorities by API number. This makes it possible to calculate oil production per foot GPI, the standard output metric in the fracking industry. In Colorado, GPI and production data can be found or calculated using Colorado Oil & Gas Information Services ("COGIS"), which is the Colorado state database run by the Colorado Oil & Gas Conservation Commission ("COGCC"). We, like MHA, combined data from FracFocus with data from COGIS to conduct control studies on the efficacy of CnF in Area 1 and Area 2 of the DJ Basin.[17] MHA did not provide enough information to perfectly replicate their study, so we pulled

[14] MHA study entitled "Effectiveness of CnF on Improving Horizontal Well Performance Greater Wattenberg Area – DJ Basin; Colorado", p.1., January 25, 2016.

[15] While reporting lags vary by state and operator, the overall average reporting time frame is 79 days from the fracking end date according to the FracFocus website. We found the larger operators in the major oil producing states tend to report more promptly.

[16] 23 states have mandatory reporting on FracFocus and Wyoming and New Mexico require disclosure but do not make the use of FracFocus mandatory; however, we have found that most operators use FracFocus as a best practice and therefore also report heavily on FracFocus in New Mexico and Wyoming.

[17] MHA sourced this data through IHS Enerdeq Browser, which sources its data from COGIS.

data for wells completed from November 1, 2012 when FracFocus 2.0 – which improved data consistency and quality – was introduced. We required at least 12-months of production[18] to be included in our study, which means the latest well start date in our data set is in mid-2015 with 12 months of production that went into mid-2016.

We also used FracFocus to conduct end user / operator usage studies across all reported wells, both horizontal and vertical, in all major oil producing regions in the US. FracFocus allowed us to analyze CnF usage (by month) for all operators in the US over the past four years (since November 1, 2012). We also ran the same study using only horizontal well completions.

FourWorld's Conclusions

1. **The independent study of the DJ Basin commissioned by Flotek used an incomplete list of CnF trade names.**

   - As shown in the table above, the MHA data set in Area 1 and Area 2 consisted of 698 wells that met MHA's 12-month production criteria. FTK provided MHA with a list of CnF trade names to use to identify which wells use CnF products. Our data set in Area 1 and Area 2 consisted of 604 wells with acceptable production data in Area 1 and Area 2. [19,20] In our sample, **we find seven trade names we believe are CnF products vs the five provided to MHA by Flotek for the DJ Basin study**. The two missing trade names are "OilPerm FMM-1" and "FDP-S1007-11". Additionally, we found a small number of wells listed in FracFocus under a partial trade name, "OilPerm." All three are white labeled products from Halliburton (HAL). The 2 missing trade names and the partial trade name accounted for 132 wells, or 22%, of the 604 wells in our data set.[21]

   - OilPerm FMM-1 accounted for the largest number of misclassified wells at 97 out of 132. OilPerm FMM-1 is one of Halliburton's suite of Formation Fluid Mobility Modifiers (FMM). A list of the ten FMM product variations disclosed on the Halliburton website are detailed in Appendix C. The Material Safety Data Sheet (MSDS) available from Halliburton for each FMM variation discloses its chemical components and concentrations. Five of the ten FMM variations contain citrus terpenes with the CAS no. 68647-72-3 or CAS No. 94266-

[18] Some wells have "shut-in" months during which oil production is halted. These are reported as shut-in by the operator to COGIS and labeled as shut-in by COGIS in their downloadable files. We allow for one shut-in month in the first 12 months of production data. So a well could have 11-months of production plus a shut-in month and still be a valid well. We normalize all wells to 12 months to mitigate the effect of a shut-in month. Our data set of 604 wells has a total of 68 (11%) "shut-in" wells. Please see Appendix F for API's and sample data for the 604 wells.

[19] FourWorld identified 676 wells in Area 1 and Area 2 with a start date after November 1, 2012. The wells from Encana Oil & Gas Inc and PICO Niobrara LLC, a total of 6 wells, were removed due to the insignificant sample size and lack of any non-CnF wells from them to compare to (they were CnF wells only). 37 wells were removed for lack of sufficient production history. 29 wells were removed because they were not in the Niobrara formation, a filter applied by MHA. For all assumptions used to compile our filtered data set, please see Appendix E

[20] MHA stated that the length of the gross perforated interval (GPI) was readily available for only 76% of the wells included in their analysis, which implies 24% of well GPI data was missing from their averaging calculations. The FourWorld data set has GPI data for all 604 wells.

[21] There were more than eight trade names present in Area 1 and Area 2, but the wells failed to meet the filters for our final valid data set, so there is a chance MHA misclassified additional wells.

47-4 that are unique to CnF products.[22] OilPerm FMM-1 is one of the five FMM variations containing citrus terpenes, as is OilPerm FMM-2, which is a CnF trade name that Flotek provided to MHA, as noted in the MHA study. Both FMM-1 and FMM-2 have the same concentration of citrus terpenes (5-10%) listed on their respective MSDS sheets. [23]

- FDP-S1007-11 is also a Halliburton product and showed up in 30 of the 132 misclassified wells. While FDP-S1007-11 did not show up in the list of trade names that Flotek provided to MHA for the DJ Basin study, it was supplied by Flotek to MHA in the Texas reports published just six months later.
- OilPerm is the general name for a family of Halliburton surfactant products. OilPerm has a number of variants, some of which contain CnF (evidenced by the presence of citrus terpenes) and some of which do not. It is likely that the operator left off the specific OilPerm variant indicator (e.g., OilPerm "B", OilPerm "FMM-1") when reporting to FracFocus. However, the presence of citrus terpenes on the FracFocus file indicates this is one of the OilPerm variants containing CnF. Without knowing to look for "OilPerm" and the presence of citrus terpenes, it is possible to misclassify these CnF wells as non-CnF wells. "OilPerm" showed up in 5 wells in our 604 well data set.
- If the same percentage of misclassified wells in our data set were misclassified in the MHA data set for Area 1 and Area 2 of the DJ Basin, then **MHA would have misclassified approximately 153 of the 698 wells**. This is significant because MHA's entire analysis was based on a simple comparison of production for wells tagged as using CnF and wells tagged without using CnF. As we demonstrate later in this report, correcting the trade names affects the results in a very meaningful way.

Area 1 and Area 2 Wells by Trade Name (All Operators)

Trade Name	Supplier	Well Count	% of Total
OilPerm B	Halliburton	150	24.8%
GasPerm 1100	Halliburton	102	16.9%
*OilPerm FMM-1	Halliburton	97	16.1%
OilPerm FMM-2	Halliburton	48	7.9%
*FDP-S1007-11	Halliburton	30	5.0%
DWP-937	CWS	6	1.0%
*OilPerm	Halliburton	5	0.8%
StimOil FBA M	Flotek	4	0.7%
Total CnF Wells		**442**	**73.2%**
Total Non-CnF Wells	-	162	26.8%
Grand Total		**604**	**100%**

**Trade names that were not provided to MHA by Flotek.*

- The operator with the most wells that used CnF products with the missing trade names was Noble Energy (NBL). We note Ted Brown, the Noble executive responsible for fracking

[22] A CAS number is a unique numerical identifier assigned by Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature. CAS numbers are disclosed in FracFocus and MSDS files.
[23] The MSDS files for OilPerm FMM-1 and FMM-2 are available in Appendix D.

operations in Colorado when most of the wells in the study were fracked, is an independent member of the FTK Board of Directors.[24] 66 of the 323 Noble wells (20.4%) in our Area 1 and Area 2 data set had CnF trade names that were missing from the trade name list in MHA's DJ Basin study. The MHA study states, "MHA was provided with a listing of CnF trade names from Flotek."[25] This implies that either FTK did not provide MHA with all of the CnF trade names in the DJ Basin, or Flotek did not know the trade names for the products causing the largest disparity (OilPerm FMM-1 and FDP-S1007-11) despite having the former head of NBL's DJ Basin operations on its Board of Directors. It is worth noting that Flotek provided MHA with three other Halliburton CnF products in Area 1 and Area 2 (OilPerm B, GasPerm 1100, OilPerm FMM-2).[26] The following table shows NBL wells by trade name in our Area 1 and Area 2 data set and highlights the missing trade names comprising over 20% of all NBL wells.

Area 1 and Area 2 Wells by Trade Name (Noble Only)

Trade Name	Supplier	Well Count	% of Total
GasPerm 1100	Halliburton	96	29.7%
OilPerm B	Halliburton	80	24.8%
*OilPerm FMM-1	Halliburton	63	19.5%
OilPerm FMM-2	Halliburton	48	14.9%
*FDP-S1007-11	Halliburton	3	0.9%
Total CnF Wells		**290**	**89.8%**
Total Non-CnF Wells	-	33	10.2%
Grand Total		**323**	**100.0%**

**Trade Names that were not provided to MHA by Flotek.*

[24] According to Flotek, the STC consists of five independent members of the Board of Directors. The Board has seven members. John Chisholm is not an independent member of the board and is not on the STC, therefore leaving just six possible choices, of which five were chosen.

[25] MHA study entitled "Effectiveness of CnF on Improving Horizontal Well Performance Greater Wattenberg Area – DJ Basin; Colorado", p.4., January 25, 2016.

[26] CnF trade names can be compiled by analyzing publicly available information. Sylvania compiled a list of over 20 CnF trade names by analyzing publicly available information across all major oil basins.

2. **Production data used by MHA contained discrepancies**

- Sylvania identified numerous wells with missing monthly production reports (MPR) during the process of collecting and analyzing production data. 62 wells (10.3%) of the 604 wells that made it into our filtered data set, completed by three out of the five operators represented in the data, had at least 1 month missing MPR in the first 12 months of well production. NBL had the highest number and percentage of missing reports.

Operator	Total Wells	Wells Missing MPR	% of Total Wells
Noble	323	57	17.7%
Bonanza Creek	93	4	4.3%
Carrizo	31	1	3.2%
Bill Barrett	43	0	0.0%
Whiting	114	0	0.0%
Total:	**604**	**62**	**10.3%**

- Sylvania worked with the COGCC to identify wells with missing monthly production reports (MPR) and resolve discrepancies. MHA may not have included those wells in its sample or it would have had wells with missing production. This is a potential explanation of the minimal variation that we observe between the results reported by MHA and the results that we report by applying MHA's methodology to what we believe is a reliable and significant sample set.

3. **An objective evaluation of the evidence shows that the impact of CnF on well productivity is indistinguishable from zero**

- Two perspectives incorporating all of the evidence produced to date concerning the relationship between production and the use of CnF lead to the same conclusion: The measurable impact of CnF on production cannot be distinguished from zero.
  - First, a simple contingency table that incorporates two features of Weld County completions (location and length of the well) reveals the flaw in the methodology employed by MHA that led to the conclusion that CnF use is associated with increased production;
  - Second, a careful evaluation of our data, using visualization and widely accepted statistical tools, indicates that horizontal well productivity in Weld County is related to location, well depth, the length of the well bore, and the amount of sand and water used in completions, but is not related to CnF use.

A corrected list of trade names affords a different view of DJ Basin completions

- The relationship between CnF use and well productivity in the DJ Basin as reported by MHA and estimated by FourWorld is described in the table below. Our estimates of

production are very close to the estimates presented by MHA when we use the list of trade names provided to MHA by Flotek, suggesting that differences between our results and MHA's results are not due to production data. The correction produces a moderate revision in the relationship between production and CnF use in Focus Area 1, and a larger revision in Focus Area 2.

- The t-statistic associated with corrected estimate of improvement in Focus Area 1 is 7.08, while the corresponding statistic in Focus Area 2 is 0.38. The first difference is meaningful using any reasonable measure of performance, while the second is not. We focus the balance of this summary on Focus Area 1. Analysis of production data from both Focus Areas is presented in the White Paper from RK Trading and Sylvania, available on the FourWorld website and attached herein as Appendix H.

Focus Area 1	**CnF Wells**	**Non CnF Wells**	**Improvement**
MHA Report	16.6	11.3	5.3
MHA Method, Our Sample	16.3	11.0	5.3
Corrected, Our Sample	15.3	10.7	4.6

Focus Area 2	**CnF Wells**	**Non CnF Wells**	**Improvement**
MHA Report	**11.0**	**9.3**	**1.7**
MHA Method, Our Sample	11.7	9.6	2.1
Corrected, Our Sample	10.9	10.6	0.3

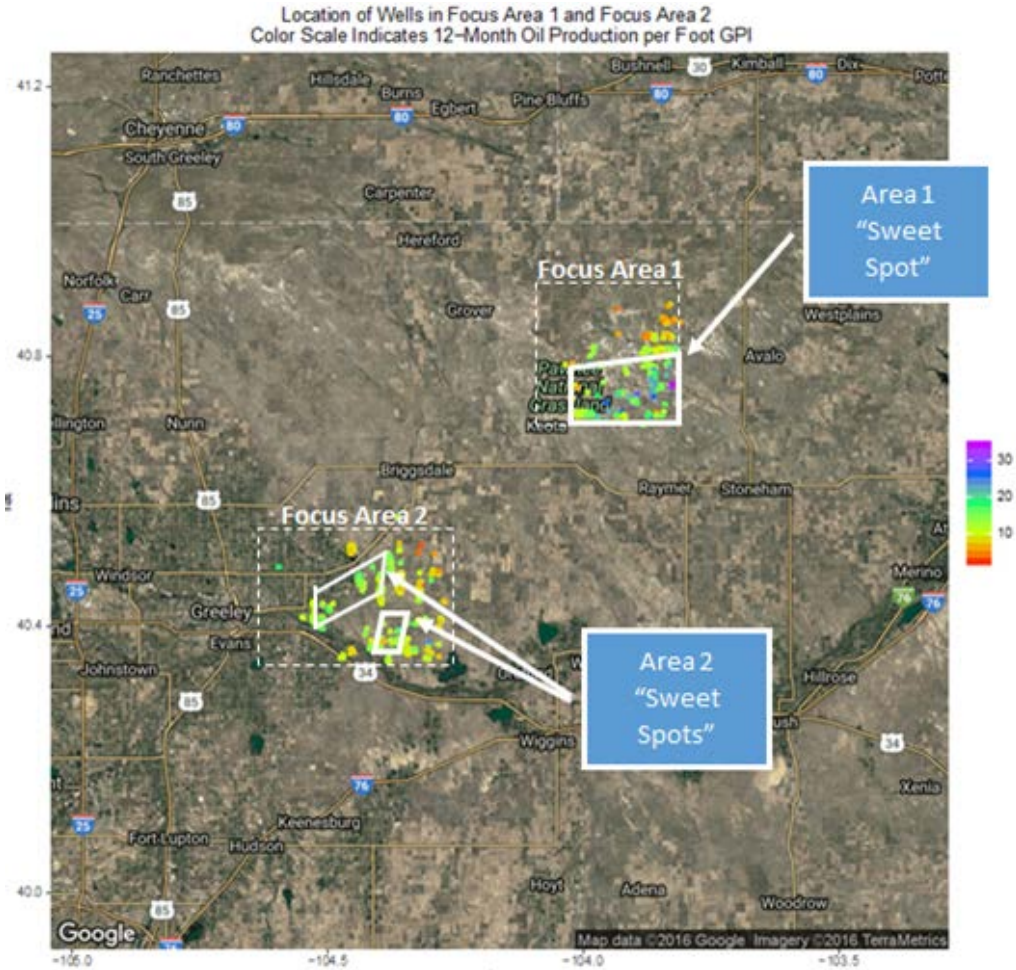
18.3% uplift becomes 2.8% in Area 2

<u>The problems with the MHA Weld County study are easy to see and suggested by MHA's own commentary</u>

- MHA's explanation of their evaluation strategy in their study of the DJ Basin describes numerous factors that influence production. The table below focuses on two: the length of the horizontal completion and the location where a well is drilled. Visual inspection of a color-coded map for well productivity reveals "sweet spots" in both Focus Areas.[27] We concentrate on Focus Area 1 below, but note that the conclusions reached are consistent for Focus Area 2 as well. The sweet spot in Focus Area 1 has production that is 7.2 BBLs per foot GPI (73 percent) larger than anywhere else in the field.[28]

[27] We identified the sweet spots by inspecting the map for the location of super-productive wells, then confirmed that the productivity could not be attributed to other features of the completion, including operator, GPI, sand, water or the use of CnF. The GAM picked out these same locations, located on a SW-NE azimuth in both Focus Areas. Two sweet spots were identified in Focus Area 2 on roughly the same azimuth as in Focus Area 1 sweet spot. These are separate as there is very little overlap among operators in Focus Area 2 production, unlike Focus Area 1. The gap in Focus Area 2 separates NBL's operations from those of Bonanza Creek. See White Paper for detail. Including the sweet spot as an explanatory variable enhances the precision of our estimates, but is in no sense critical to our judgement about the efficacy of CnF.

[28] See Table 5.3.1 in the White Paper for details.



The data also indicates that doubling the length of a lateral well in Focus Area 1 from 3,500 ft to 7,000 ft decreases expected production by 2.8 BBLs per foot GPI. The tables below partition the Focus Area 1 data based on these two variables.

Table 1: Production and CnF Well Count by Location and GPI

	Inside Sweet Spot	Outside Sweet Spot
GPI > 6,000 ft	15.7 (0 / 7)	8.9 (30 / 111)
GPI < 6,000 ft	17.1 (97 / 118)	13.3 (18 / 31)

The majority of CnF wells were completed in the sweet spot with a GPI length below 6000 feet (97 out of 145 CnF in Area 1)

The lower left cell of Table 1 indicates that short laterals (average of 3,700 feet) in the sweet spot produced an average of 17.1 BBLs per ft GPI. The top right cell of Table 1 indicates that long laterals outside of the sweet spot yielded an average of 8.9 BBLs per foot GPI. The numbers in parentheses indicate the number of wells in each group that were completed with CnF and the number of overall wells in the group.

- Table 1 indicates that wells treated with CnF are disproportionately represented in the left column and the lower left cell. **Our evidence indicates that these wells were likely to be productive because of their location and length, and not because the wells were treated with CnF.**

Table 2: CnF Uplift by Location and GPI

	Inside Sweet Spot	Outside Sweet Spot
GPI > 6,000 ft	NA	0.04
GPI < 6,000 ft	-0.72	-1.91

CnF did not show any uplift once you correct for operator, well length and location

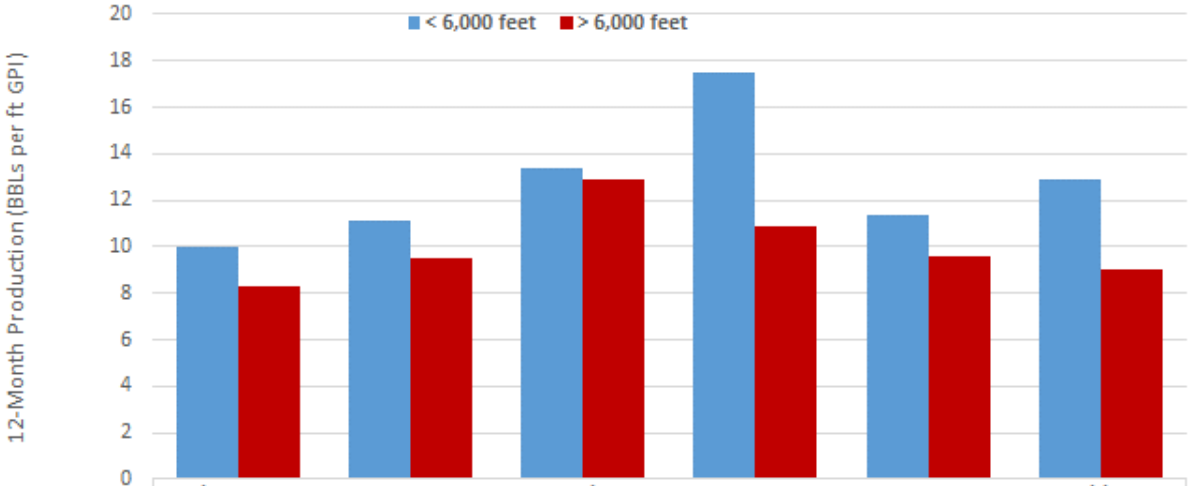
- Another view of the data is presented in Table 2 above. The table calculates the uplift associated with CnF use for each type of well, first by operator (i.e., NBL, WHI, CRZO), then averaged across operators. The results indicate that CnF showed no outperformance in either location at either lateral length.[29] In other words, using the largest subsection from the table (the 118 wells located inside the sweet spot that are under 6,000 feet), if you calculate the difference in production in CnF wells versus non-CnF wells for each operator and then average the results, **CnF wells underperformed non-CnF wells** by 0.72 BBLs per ft GPI, or approximately -4.2%. **Across operators in either Focus Area 1 or Focus Area 2, the results are the same: the uplift associated with using CnF is noise, with a mean of zero.**

- The charts bellow illustrate that shorter wells are more productive (BBLs per foot GPI) than longer wells for every operator, that wells in the right location are more productive for every operator, and that the influence of CnF on performance is random when considered operator-by-operator, by operator and well length, or by operator and location. The rows and columns of the table above represent systematic influences. *The distribution of CnF use throughout the table is "noise", with no measurable influence on production*. (Note: names marked with an asterisk in a graph mean that a difference is statistically significant.)

[29] The upper left cell is empty because we don't have the CnF, non-CnF pairs required to populate it.

Production vs GPI

Long Wells are Less Productive than Short Wells for Every Operator

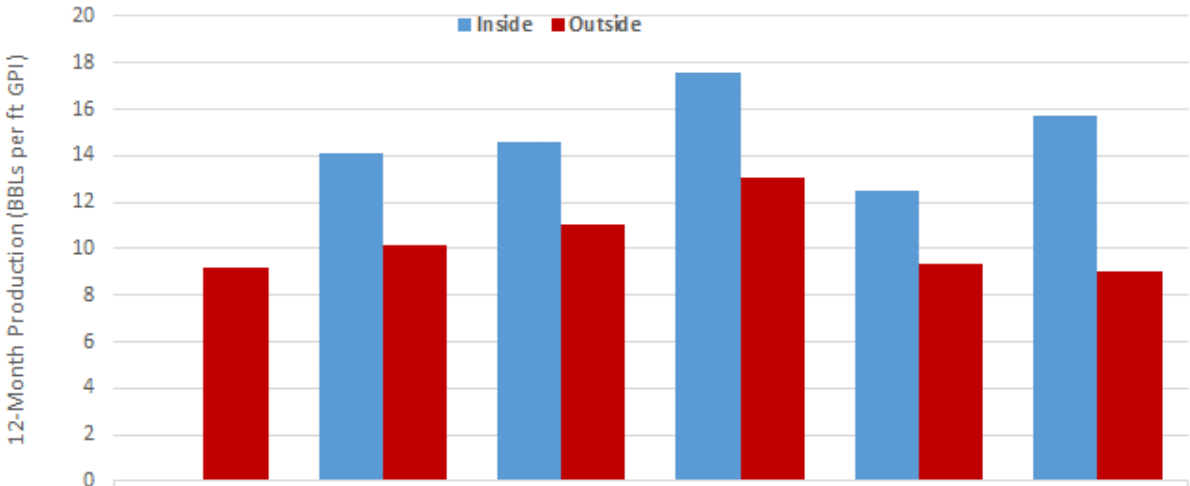


	Bill Barrett	Bonanza Creek	Carrizo	Noble (Area 1)*	Noble (Area 2)*	Whiting*
< 6,000 feet	10.0	11.1	13.4	17.5	11.4	12.9
> 6,000 feet	8.3	9.5	12.9	10.9	9.6	9.0
Uplift	1.7	1.6	0.5	6.6	1.8	3.9

Shorter wells are more productive than longer wells for **every** operator

Production vs Location

Sweet Spot Wells are More Productive for Every Operator

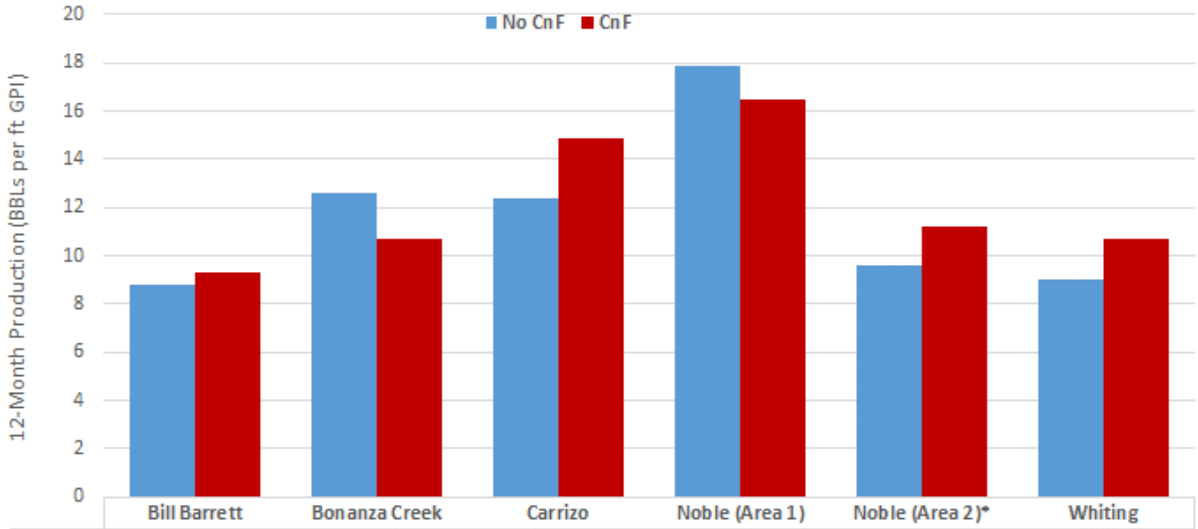


	Bill Barrett	Bonanza Creek*	Carrizo*	Noble (Area 1)*	Noble (Area 2)*	Whiting*
Inside	-	14.1	14.6	17.6	12.5	15.7
Outside	9.2	10.1	11.1	13.0	9.4	9.0
Uplift	-	3.9	3.5	4.6	3.1	6.7

Sweet spot wells are more productive for **every** operator

Production vs CnF

Performance is Random Across Operators



	Bill Barrett	Bonanza Creek	Carrizo	Noble (Area 1)	Noble (Area 2)*	Whiting
No CnF	8.8	12.6	12.4	17.9	9.6	9
CnF	9.3	10.7	14.9	16.5	11.2	10.7
Uplift	0.5	(1.9)	2.5	(1.4)	1.6	1.7

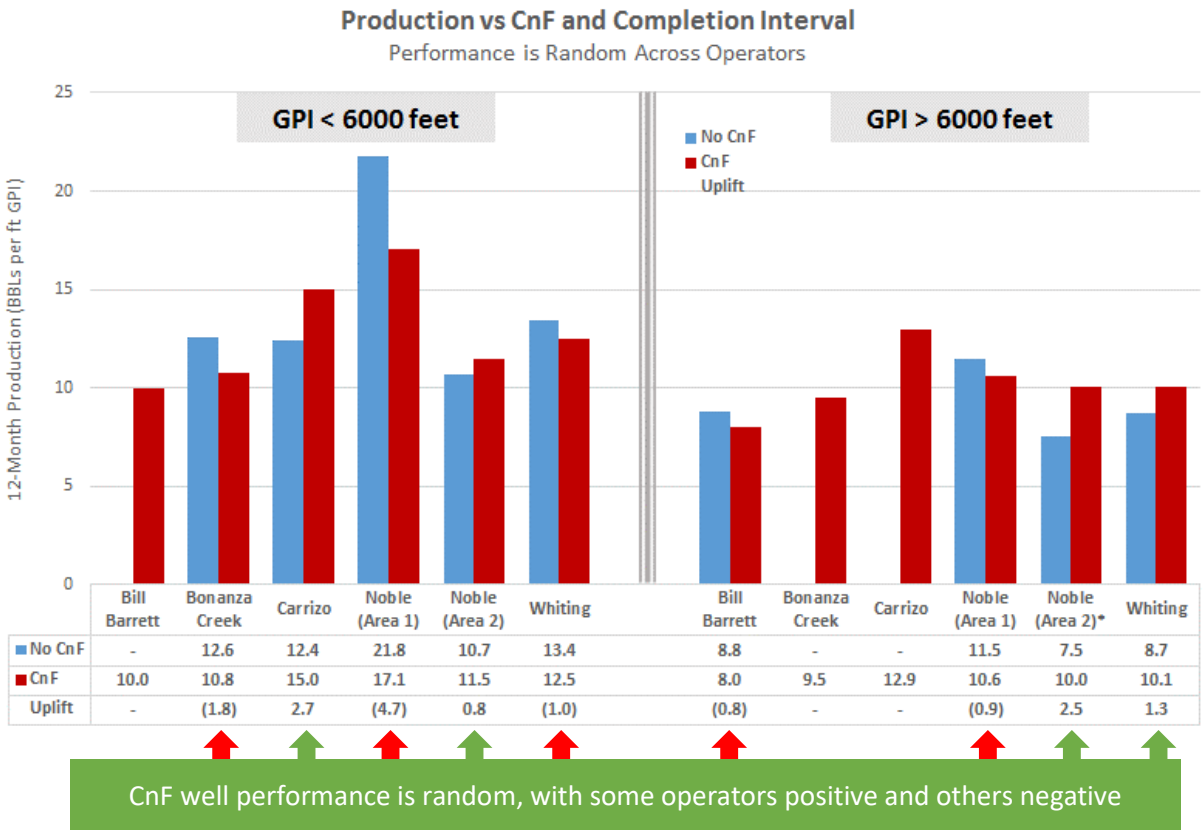
CnF well performance is random, with some operators positive and others negative

Production vs CnF and Location

Performance is Random Across Operators

	Bill Barrett	Bonanza Creek	Carrizo	Noble (Area 1)	Noble (Area 2)	Whiting*	Bonanza Creek*	Carrizo	Noble (Area 1)	Noble (Area 2)	Whiting
No CnF	8.8	10.5	11.0	12.6	10.0	8.4	16.1	13.2	22.1	7.7	15.7
CnF	9.3	10.1	11.3	13.2	9.3	10.7	13.3	16.7	17.2	12.7	-
Uplift	0.50	(0.40)	0.30	0.60	(0.70)	2.30	(2.80)	3.50	(4.90)	5.00	-

CnF well performance is random, with some operators positive and others negative



The White Paper from RK Trading and Sylvania develops a model of well productivity motivated by these observations. Fundamental relationships are identified through statistical comparisons similar to those presented above. The relationships are tested with econometric models, some of which make it possible to consider detail inside of the sweet spot. In every model, the estimated contribution of CnF to production is less than 1 BBL per ft GPI (typically less than 0.5 BBLs per ft GPI) and not statistically different from zero. CnF has no measurable impact on production.

Key results for Focus Area 1 are summarized in the table below. In the table, Impact is the variation in production due to the influence of a variable, measured in BBLs per ft GPI. Variables are listed in order of their estimated influence on production.[30] All of the variables marked as being statistically significant in the table have parameter estimates that reject the null hypothesis of zero influence on production at 1 percent or better. Three of the four flagged as being statistically significant reject the null hypothesis at 1/10 of 1 percent.[31] The one variable in the table that has no measurable influence on production is CnF.

[30] Average production in Focus Area 1 is 13.2 BBLs per ft GPI, ranging from 3.2 BBLs to 34.0 BBLs.

[31] For those who may have forgotten the meaning of statistical significance, the chance of observing any one of these parameter estimates in a world where there is no true relationship between the test variable and production is less than 0.001, or one-in-one thousand.

Parameter Estimates for the GAM for Focus Area 1			
Variable	**Impact**	**Significant**	**p-value**
Location (latitude and longitude)	10.0	Y	10^{-14}
Sand and Water	6.0	Y	0.01
Operator – Noble	4.4	Y	<0.001
GPI	2.8	Y	< 0.001
CnF	-0.4	N	0.53

- By far the most important variable identified by the analysis is location in the field. Productivity along the fringe of Focus Area 1 is less than productivity in the heart of the developed area by ~10 BBLs per ft GPI. The test statistic associated with location rejects the null hypothesis at 10-14. The sweet spot identified by the econometric model is consistent with what you see when you simply look at a map of production.
- The second most important variable is the joint influence of sand and water, which explains production variation of as much as 6 BBLs per ft GPI. The test rejects the null hypothesis at 1 percent. This estimate is consistent with data reported throughout the industry.
- Operator identity is next on the list. Noble's wells produced an average of 4.4 BBLs per ft GPI more than Carrizo wells, once we account for the influence of all other variables on production. The test statistic rejects the null at 1 percent. Whiting also outperforms Carrizo, by an estimated 1.3 BBLs per ft GPI, but the difference is not statistically significant.
- Doubling GPI (lateral length) from 3,500 ft to 7,000 ft decreases expected production by 2.8 BBLs per ft GPI. The test statistic rejects the null hypothesis at 1 percent.
- **The one variable included in the model which had no measurable impact on production is CnF.**

Summary of Results for All Models and Methodologies

The tables below summarize the results of all of the methodologies presented above, as well as the estimated contribution of CnF to production, once you account for the influence of well characteristics on production in Focus Area 1 and Focus Area 2.

Summary of CnF Performance by Study in Focus Area 1

Methodology	CnF Wells	Non CnF Wells	Improvement
MHA Report	16.6	11.3	5.3
MHA Method, Our Sample	16.3	11.0	5.3
Corrected Trade Names, Our Sample	15.3	10.7	4.6
Predicted by well characteristics	15.2	10.7	4.5

The perceived improvement seen by the methodology used by MHA is explained by well characteristics other than CnF.

- The MHA report states that CnF use is associated with an uplift in Focus Area 1 production of 5.3 BBLs per ft GPI, or 46.9% (first row of the table). Our data set yields the same result if we use the methodology employed by MHA and the list of CnF trade names that Flotek provided to MHA (second row). Expanding the list of CnF trade names (which we believe to be more accurate) and applying MHA's methodology to our data produces estimated uplift of 43%, or 4.6 BBLs per foot GPI (third row). The robust regression and GAM methodologies employed by our consultants indicate that well characteristics (operator, location, GPI, sand and water) explain 4.5 BBLs out of the 4.6 BBLs per foot GPI improvement observed in Focus Area 1 (last row).
- The table below summarizes the estimated contribution of CnF to 12-month production per ft GPI for the different regression and GAM approaches. The estimated contribution of CnF using these models is between -0.40 and 0.10 BBLs per ft GPI, or -3.7% to 1.0%, in Focus Area 1.

Estimated Contribution of CnF to Production in Focus Area 1

Methodology	Variables	CnF Uplift (BBLs)	Percent Uplift
Robust Regression	Operator, GPI	0.10	1.0%
Robust Regression	Operator, GPI, Location, Sand, Water	-0.35	-3.3%
GAM	Operator, GPI, Location, Sand, Water	-0.40	-3.7%

Summary of CnF Performance by Study in Focus Area 2

Methodology	CnF Wells	Non CnF Wells	Improvement
MHA Report	11.0	9.3	1.7
MHA Method, Our Sample	11.7	9.6	2.1
Corrected, Our Sample	10.9	10.6	0.3
Predicted by Well Characteristics	10.9	10.5	0.4

Correcting the trade names reduced the uplift to just 3%, but even this outperformance is explained by well characteristics other than CnF.

- The MHA report states that CnF use is associated with an uplift in Focus Area 2 production of 1.7 BBLs per ft GPI, or 18.3% (first row). Using the methodology employed by MHA and the list of CnF trade names provided by Flotek to MHA on our data set produces a similar result of 21.9% (second row). Applying the methodology employed by MHA to our data set but expanding the list of CnF trade names reduces the estimated uplift to just 2.8%, or 0.3 BBLs per foot GPI (third row). The robust regression and GAM methodologies employed by our consultants indicate that well characteristics (operator, location, GPI, sand and water) explain substantially all of the improvement in Focus Area 2 (last row).

- The table below summarizes the estimated contribution of CnF to 12-month Focus Area 2 production per ft GPI for the different regression and GAM approaches.

Estimated Contribution of CnF to Production in Focus Area 2

Methodology	Variables	CnF Uplift (BBLs)	Percent Uplift
Robust Regression	Operator, GPI	-0.20	-1.9%
Robust Regression	Operator, GPI, Location, Sand, Water	-0.16	-1.5%
GAM	Operator, GPI, Location, Sand, Water	-0.08	-0.8%

- The estimated contribution of CnF using these models is between -0.08 and -0.20 BBLs per ft GPI, or -1.2% to -0.8%, in Focus Area 2.
- RK Trading and Sylvania document the stability of these models, on an operator-by-operator basis and across locations, and demonstrate that the conclusions are not sensitive to either the way that a model is specified or the definitions of key variables, including production.
- A similar approach is applied to data from the Permian Basin. The results all say the same thing: the estimated impact of CnF on production cannot be distinguished from zero.[32]

4. <u>85% of CnF end users (i.e. oil and gas operators) have stopped using the Flotek product in horizontal and vertical well completions</u>

- We conducted a detailed study of operators who have used CnF with data from FracFocus. Operators purchase CnF products either directly from FTK, or from service providers (e.g. HAL, BHI, SLB) who purchase CnF from the Company, repackage it, and sell it as part of their well completion services. When studied at the operator level, the magnitude of the end user turnover appears significantly higher than the Company suggests in recent disclosures. We observe that many large operators with ample resources to test different well completion fluid systems are no longer using CnF in their wells.

Readers should consider the circumstances under which a large, sophisticated operator, who continues to frack new wells, would stop using CnF.

Our independent list of CnF trade names[33] allows us to identify 334 operators who used CnF ("Total CnF Operators") in at least one well completion since November 1, 2012.[34] For this study, we included both horizontal and vertical well completions in order to capture as many operators

[32] We encourage you to read the full econometric studies in the White Paper from RK Trading and Sylvania available on the FourWorld website and attached herein as Appendix H.
[33] A list of the top ten most common trade names is provided in Appendix C.
[34] As noted previously, we include both horizontal and vertical completions in order to capture as many customers of CnF as possible and give Flotek the benefit of the doubt in our study.

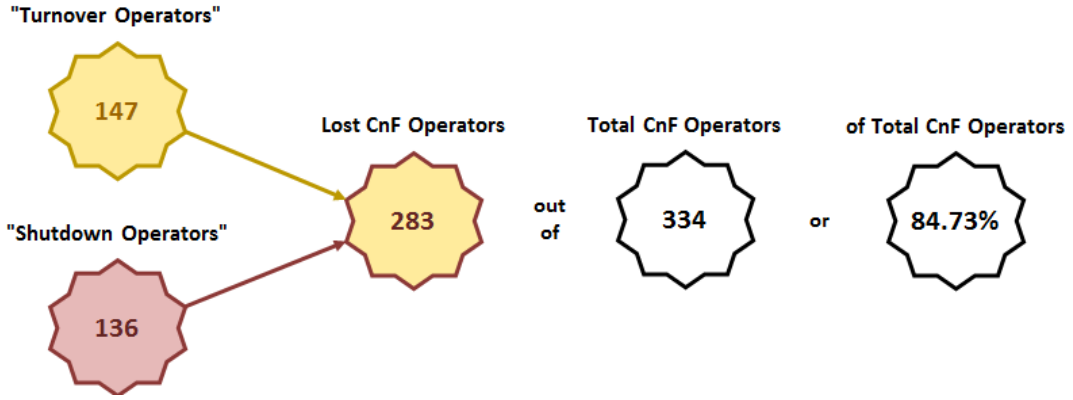
and well completions using CnF as possible. (We also conducted a study using only horizontal wells that shows the same trends and a higher attrition rate. This study is summarized at the end of this section). We are able to look through the service providers (HAL, SLB, etc.) to the operators by using FracFocus. Based on Flotek's statements at conferences and earnings calls, we believe the Company relies on Flotek Store data for their customer metrics and does not look through service providers to the ultimate consumers of their products – providing only a partial picture of CnF end users.

We classify the operators in our study into the following groups:

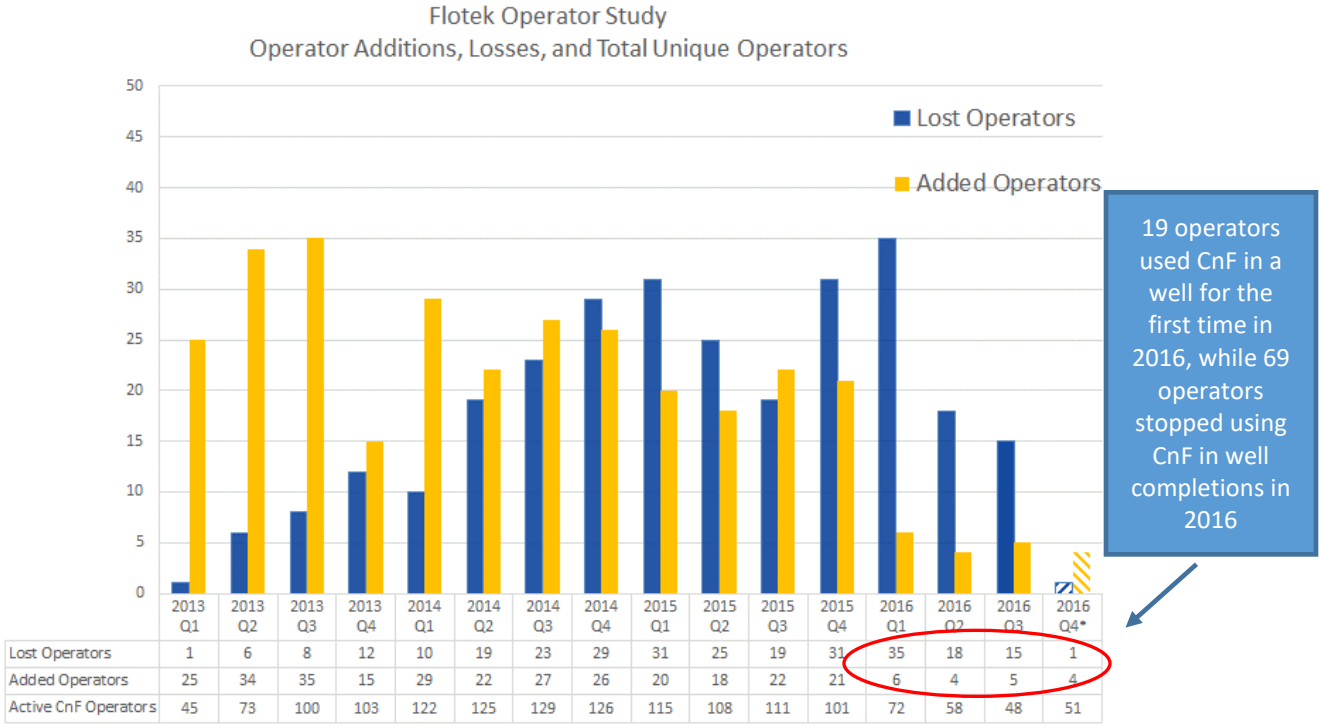
- **"Active CnF Operators"**: operators who completed any well within 180 days of November 16, 2016 (the end date of the study) AND used CnF in a well within 90 days of their last well. These operators have active well completion operations and are still using CnF.
- **"Shutdown Operators"**: operators who have not completed a wells since May 20, 2016 (180 days before the study period end) but used CnF in a well within 90 days of completing their last well. These operators were still using CnF when they ceased fracking operations, either by choice, bankruptcy, or some other reason.
- **"Turnover Operators"**: operators who have not used CnF within 90 days of their last well, regardless of whether they are still fracking today or not. These operators decided to stop using CnF in their wells.

Based on the methodology listed above, we conclude that 84.7% (283 out of 334) of the operators who have used CnF since November 1, 2012, stopped using the product in their wells. The customer classifications are as follows:

- **51 (15%) are "Active CnF Operators"** that are currently completing wells and using CnF in at least one of them.
- **147 (44%) are "Turnover Operators"** that used CnF in a well, but then completed additional non-CnF wells at least 90 days later without using CnF in a well again. We interpret this to mean they chose to stop using the product in well completions.
- **136 (41%) are "Shutdown Operators"** that used CnF in a well but then ceased all fracking operations within 90 days. We interpret this to mean they may have stopped using CnF for a reason other than the product itself. Nonetheless, these are lost volumes and revenues for Flotek.



- According to our study, Flotek can claim only 51 **"Active CnF Operators",** which is 15% of the total end users who used CnF over the last four years. Of these 51 unique operators, we calculate that the top 3 (Pioneer, Noble, and PDC Energy) currently account for greater than 75% of total CnF sales volumes and revenues. This is supported by research analyst reports that put the top two customers at greater than 50% and the top three customers at greater than 75% of total 3Q 2016 CnF sales[35], though we note that analysts' reports generally include HAL in the top two customers, where our study looks through service providers like HAL to the end operators (i.e. NBL). It is well known that PXD is FTK's largest customer.[36] We understand that FTK recently gave PXD a volume based pricing discount. It is clear that FTK has a severe customer concentration problem; a loss of any of these key customers would be material to Flotek.
- The chart below illustrates customer additions and losses per quarter, according to our study, and clearly demonstrates the significant customer losses Flotek has sustained over the last four years.



	2013 Q1	2013 Q2	2013 Q3	2013 Q4	2014 Q1	2014 Q2	2014 Q3	2014 Q4	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2016 Q1	2016 Q2	2016 Q3	2016 Q4*
Lost Operators	1	6	8	12	10	19	23	29	31	25	19	31	35	18	15	1
Added Operators	25	34	35	15	29	22	27	26	20	18	22	21	6	4	5	4
Active CnF Operators	45	73	100	103	122	125	129	126	115	108	111	101	72	58	48	51

**Q4 2016 data is incomplete due to FracFocus reporting lag*

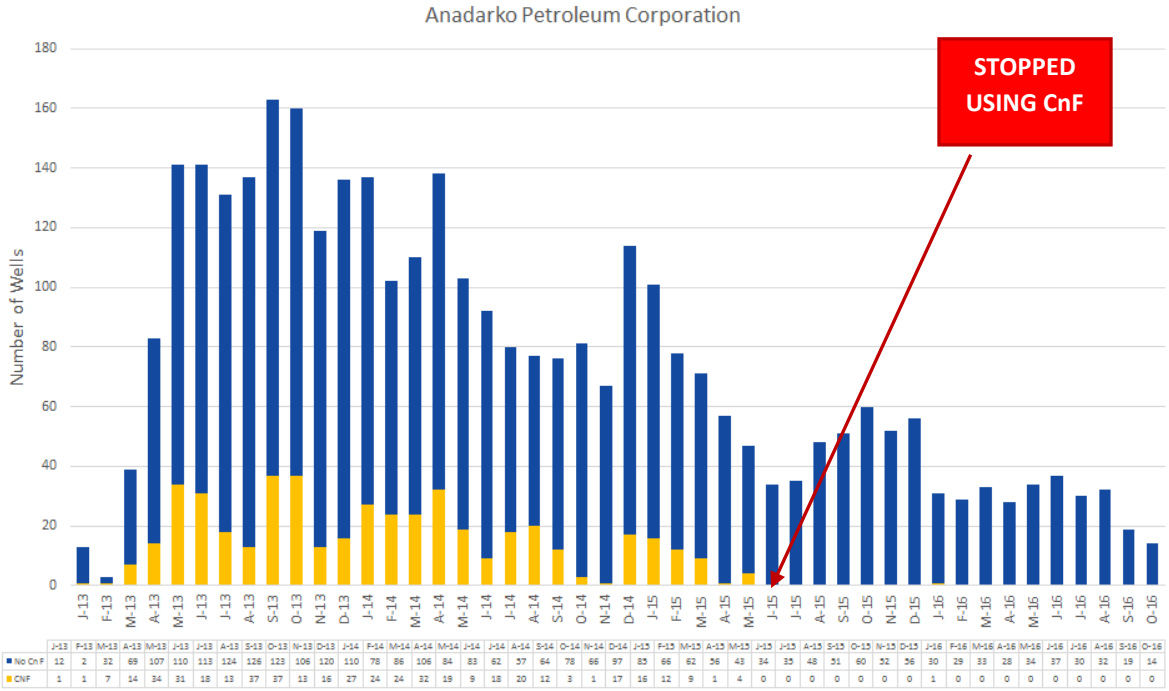
- In order to get a more complete picture of CnF end users, we utilized FracFocus to analyze the CnF usage history of individual operators. **<u>We find that Anadarko (APC), Chesapeake (CHK), EOG Resources (EOG), Devon (DVN), Aera Energy, and ConocoPhillips (COP), among many others, have discontinued the use of CnF in their wells. This means that</u>**

[35] Source: IBERIA Capital Partners reports. Coker & Palmer reports.

[36] "I also want to take a moment to congratulate Scott Sheffield, Chairman and Chief Executive at Pioneer Natural Resources on his pending retirement. Scott has been a personal friend and a key supporter of Flotek, something for which I will be forever grateful." John Chisholm, Flotek's Q3 2016 earnings call.

six of the top ten operators in FracFocus (ranked by total well count since November 1, 2012) stopped using CnF in their well completions. We think this is important because these operators have the resources to conduct their own studies.

- Of the 4 remaining operators from the top ten in FracFocus, XTO Energy (XTO) used CnF in less than 5% of wells since Q1 2013, Apache Corp (APA) used it in a single well in September 2016 for the first time in over a year, but has not used it any wells reported since.[37] Occidental Petroleum (OXY) showed no wells using CnF after November 2015 until using it just three times in 2H 2016 for a purpose, it appears, other than enhanced oil recovery in a horizontal fracturing completion.[38] The remaining operator in the top ten is Pioneer (PXD), who uses it regularly and is Flotek's largest customer, accounting for approximately 30 - 40% of CnF revenues.
- Over the study period, the attrition in CnF end users is 84.7%, or 283 Lost Operators out of 334 Total CnF Operators.
- Removing Shutdown Operators (136) from Total CnF Operators (334) implies a turnover in CnF end users of 74%, or 147 of 198 non-Shutdown Operators.
- Below is a sample chart for Anadarko from our study. For customer charts covering the top 20 operators by number of well completions, see Appendix G.



[37] This well appears to a vertical well (total water volume of 157k gallons) in Oklahoma. APA had not used CnF in 15 months and used it in only 14 wells out of 2,087 wells since November 1, 2012. Furthermore, APA has not used CnF in subsequent wells, including wells in Texas.

[38] These wells are vertical wells with an average total water volume under 100k gallons. Estimated CnF volume is 250 gallons and estimated revenue is approximately $3000 for all three wells combined.

Lost Operator Study – Horizontal Wells Only – Summary of Results

- When we restrict the study outlined above to horizontal well completions only (defined as well completions with a total base water volume reported to FracFocus over 500,000 gallons[39]), the attrition rate increases to 87.4%.
- Eliminating vertical wells from the study reduces the number of Total CnF Operators from 334 to 183, which implies 151 operators (45%) only used CnF in vertical well completions. In total, these 151 operators completed 837 vertical wells that used a total of 64.6 million gallons of water, according to FracFocus data. For comparison 64.6 million gallons is less than the water consumed by just 4 PXD wells in 2016. **The revenue opportunity from an average vertical well is just a fraction of an average horizontal well, since CnF is used in proportion to water volume. Assuming a generous loading factor of 1.5 gallons of CnF per 1,000 gallons of water and a price of $15 per gallon for CnF, the wells from these 151 operators would have represented $1.5 million in total revenue to Flotek.**
- For the 183 operators who completed a horizontal well with CnF since November 1, 2012, we conclude that 87.4% (160 out of 183) of them stopped using the product in their wells. The customer classifications are as follows:
    - **23 (13%) are "Active CnF Operators"**
    - **98 (54%) are "Turnover Operators"**
    - **62 (34%) are "Shutdown Operators"**
- In addition to the 6 operators mentioned in the more general study above, 3 (XTO, APA, OXY) of the remaining 4 operators in the top ten are deemed Turnover Operators, if you eliminate vertical wells from the study. XTO's last horizontal well completion using CnF was in January 2015. The 67 wells XTO completed with CnF since then were all vertical completions and used a total of 14.7 million gallons of water, which is less than the water used in a single PXD well. For comparison, the average Pioneer CnF well used 16.9 million gallons of water in 2016.[40] OXY and APA have not used CnF in a horizontal well completion since February 2015 and May 2015, respectively, according to our study of FracFocus data. Only PXD remains as an Active CnF Operator ranked in the top ten by total well count since November 1, 2012.
- Over the study period, the attrition in CnF end users is 87.4%, or 160 Lost Operators out of 183 Total CnF Operators.
- Removing Shutdown Operators (62) from Total CnF Operators (183) implies a turnover in CnF end users of 81%, or 98 of 121 non-Shutdown Operators.

---

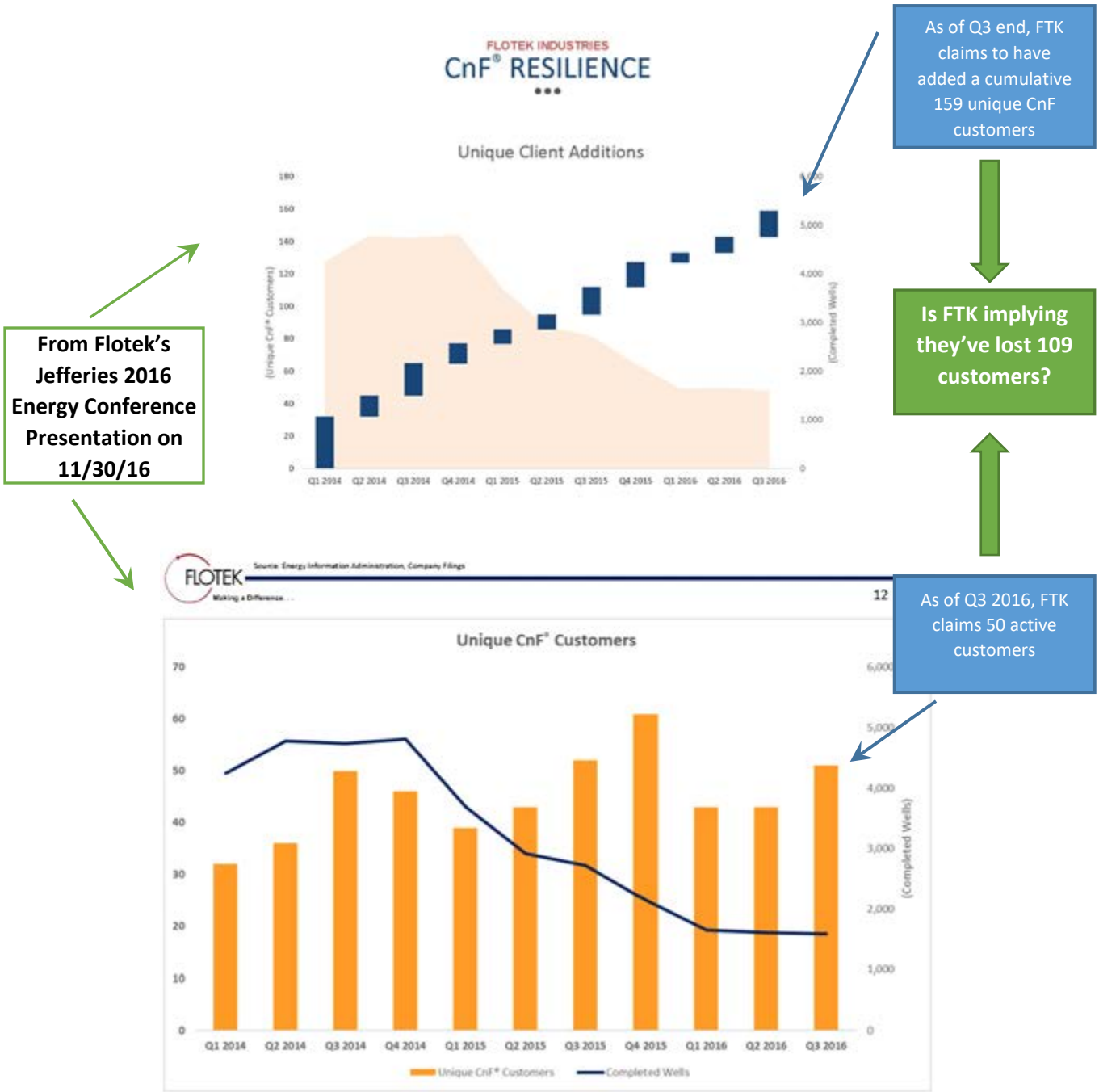
[39] We use a conservative assumption of 0.5 million gallons of water to determine a vertical well from a horizontal well. For comparison, the average well, in our database of over 70k from FracFocus, used 4.2 million gallons of water - ranging from 2.7 million gallons in 2014 to 7.3 million in 2016. Pioneer uses over 16 million gallons of water on average per horizontal well completion in 2016, as shown in the water usage section of this paper.

[40] See the table entitled "Water Usage in CnF Wells (based on FracFocus)" in the water usage section of this paper for more detail.

Readers should consider, if a horizontal well completion costs approximately $5 to 8 million and CnF costs approximately $0.01 to $0.03 million per well completion (depending upon CnF loading concentration and water usage), the likelihood of whether any of these sophisticated operators would stop using CnF if they realized any material uplift in oil production.

5. <u>We believe FTK's statements about new CnF customers ignores the quality of the customer base and masks the number of large operators who have chosen to stop using CnF in well completions.</u>

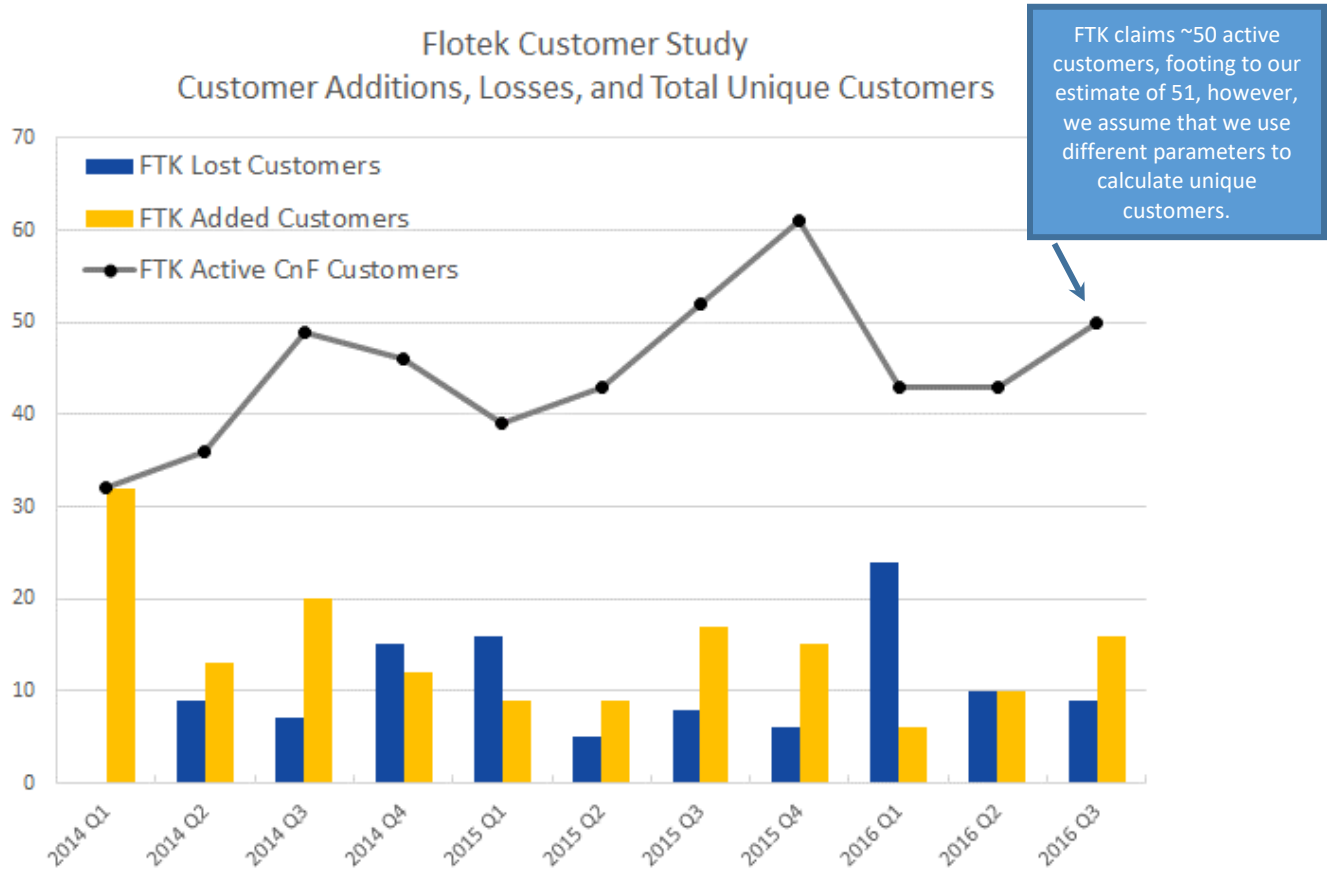
- Flotek is touting new CnF customers while ignoring customers they have lost. For example, at the Jefferies 2016 Energy Conference in Houston on November 30, 2016, John Chisholm stated, "We continue to see market penetration from our core CnF chemistries…we believe the second half of 2016 provides additional opportunities for growth. We have added more new customers in the third quarter compared to the second quarter and compared to the first quarter of 2016. Furthermore, Chisholm adds, "adoption [of CnF chemistries] has quickened [in 2016] and will continue to do so into 2017." In the company's 3Q 2016 earnings presentation, John Chisholm stated "the base of CnF users broadened meaningfully in the third quarter."
- Our study of CnF end users using FracFocus shows that Flotek's stated customer additions and number of total customers are not an accurate measure of the quality of the customer base. We demonstrate that FracFocus may be used to identify a transition from high quality, high revenue potential operators to much smaller, low revenue potential operators. As highlighted previously, our study using FracFocus data shows 19 operators tried CnF in at least one well in 2016, however 69 operators stopped using CnF in well completions by our definition. As we discuss below, we see similar customer turnover trends using FTK's own data.
- The charts below from FTK's presentation at the Jefferies 2016 Energy Conference illustrate unique CnF customer additions and total CnF customers within the Flotek Store, by quarter.



- Flotek claims they have added 159 unique customers since Q1 2014. They also claim to have approximately 50 current customers. We find no evidence that Flotek explained what happened to the other 109 customers, who represent 69% of the unique CnF customers since 2014 (recall our operator study using FracFocus showed end user attrition of approximately 85% since November 1, 2012). Flotek also states the 159 added customers is "clearly understated" because "distributors… continue to purchase CnF that is sold to potentially dozens of additional customers. For example, Halliburton, a major customer for years, likely provides the chemistry to a cluster of customers that are not

captured in this count".[41] These customers are not reflected in FTK's numbers because FTK does not look through service providers (distributors like HAL, SLB, BHI) to the end user of the product, the operator. In our view, it is much more likely that a service provider could be experiencing high levels of churn of CnF end users, but FTK would not be including this in their calculations; all FTK sees is the service provider or what has been sold through the Flotek store. Our customer study uses FracFocus data reported at the operator level. Our study shows FTK 256 CnF operators stopped using CnF in well completions since Q1 2014 versus the 109 lost customers implied in FTK's presentation materials.

- Although Flotek does not highlight customer losses in their presentation, their own "Unique CnF Customers" chart implies significant customer losses each quarter. The chart below shows the customer additions per quarter claimed by Flotek, but adds the customer losses implied from the "Unique CnF Customers" claimed by Flotek. It appears that Flotek may be aware that they have been losing more customers than they have been adding recently, despite public statements indicating otherwise. FTK claims that their data does not look through service providers, which may be masking the true number of operators who have been completing new wells without using CnF.



[41] John Chisholm at the IPAA OGIS San Francisco Conference on September 27, 2016. Transcript on Bloomberg.

- According to Flotek's own numbers, the company lost approximately 43 customers in 2016 but only gained about 32. Based on our conclusions, we believe Flotek should have presented their total customers to shareholders as we do in the chart above. We question Flotek's claim that "the adoption pace [of CnF] was quickened and should continue to do so into 2017."[42]

Readers should consider the effect on Flotek sales if the Company reported the number of operators who previously fracked wells with CnF but no longer use the product in subsequent completions.

- We cannot directly connect Flotek's statements on customer additions to our operator study due to FracFocus reporting latency and the diminished view of operator use from Flotek using only Flotek Store data. But FracFocus data through Q3 2016 does show that the 19 operators who used CnF for the first time in 2016 did so in a **total of 50 wells** out of the 285 they completed in 2016.[43] The 69 operators that we conclude stopped using CnF in their wells in 2016, cumulatively completed 1,476 wells this year.

Flotek Unique New CnF Operator Additions - 2016

Operator	CnF Wells	2016 Wells	Total Wells	First CnF Start Date	Last CnF Start Date	Days Since CnF Used*	Days Since Last Well Start
Midstates Petroleum Company	19	40	383	2/23/2016	8/20/2016	88	24
Bluefin Resources LLC	5	5	5	4/19/2016	8/16/2016	92	92
Land and Natural Resource Development, Inc	4	4	4	1/11/2016	3/2/2016	259	259
Clayton Williams Energy, Inc.	2	7	187	8/21/2016	8/30/2016	78	51
Parsley Energy Operations, LLC	2	69	465	3/8/2016	8/25/2016	83	30
Murphy Exploration and Production USA	2	38	509	7/28/2016	7/28/2016	111	19
East Cheyenne Gas Storage, LLC	2	2	2	10/13/2016	10/24/2016	23	23
Green Century Exploration & Production, LLC	2	3	25	6/30/2016	11/3/2016	13	13
Alta Mesa Services, LP	2	46	95	3/23/2016	5/5/2016	195	14
Tapstone Energy	1	24	76	8/23/2016	8/23/2016	85	16
PPC Operating Company LLC	1	3	72	10/10/2016	10/10/2016	37	37
ABARTA Oil & Gas Co., Inc.	1	2	2	4/12/2016	4/12/2016	218	218
COBRA OIL & GAS CORPORATION	1	1	40	10/4/2016	10/4/2016	43	43
Tanos Exploration II, LLC	1	14	34	4/18/2016	4/18/2016	212	29
Gulf Pine Energy	1	3	3	1/13/2016	1/13/2016	308	53
Three Rivers Operating Co III LLC	1	1	1	9/26/2016	9/26/2016	51	51
Valence Operating Company	1	10	72	11/2/2016	11/2/2016	14	14
PayRock Energy, LLC	1	12	36	1/29/2016	1/29/2016	292	163
M. E. Operating and Services, Inc.	1	1	1	9/8/2016	9/8/2016	69	69
Total/Average	50	285	2012	6/12/2016	7/19/2016	120	64

*Days elapsed = End of Sample Period (11/16/2016) - Last CnF Start

All 19 new operators completed 2,012 wells combined since 11/1/12. Anadarko, who stopped using CnF, alone completed 3,459 wells during the same time period.

- Of these operators, only four – Clayton Williams, Midstates Petroleum, Murphy Exploration and Parsley Energy – have fracked more than 100 wells of any kind since FracFocus 2.0 was introduced. Clayton Williams, Murphy and Parsley used CnF in just two wells each. As the table above shows, Midstates used CnF in 19 out of 40 wells so far this year, but has not fracked a well with CnF since August 2016. Over the study period of almost 4 years, Midstates fracked a total of 383 wells of any type. In comparison, Anadarko, who stopped using CnF in their wells, completed 3,459 wells over the study period and has already fracked 297 wells this year. As discussed above, we believe the lack of broader acceptance outside the top three operators and the repeated loss of end

[42] John Chisholm, FTK Q3 2016 Earnings call. Transcript from Bloomberg.

[43] Per data from the FracFocus database, the revision date indicated by FracFocus was November 16, 2016.

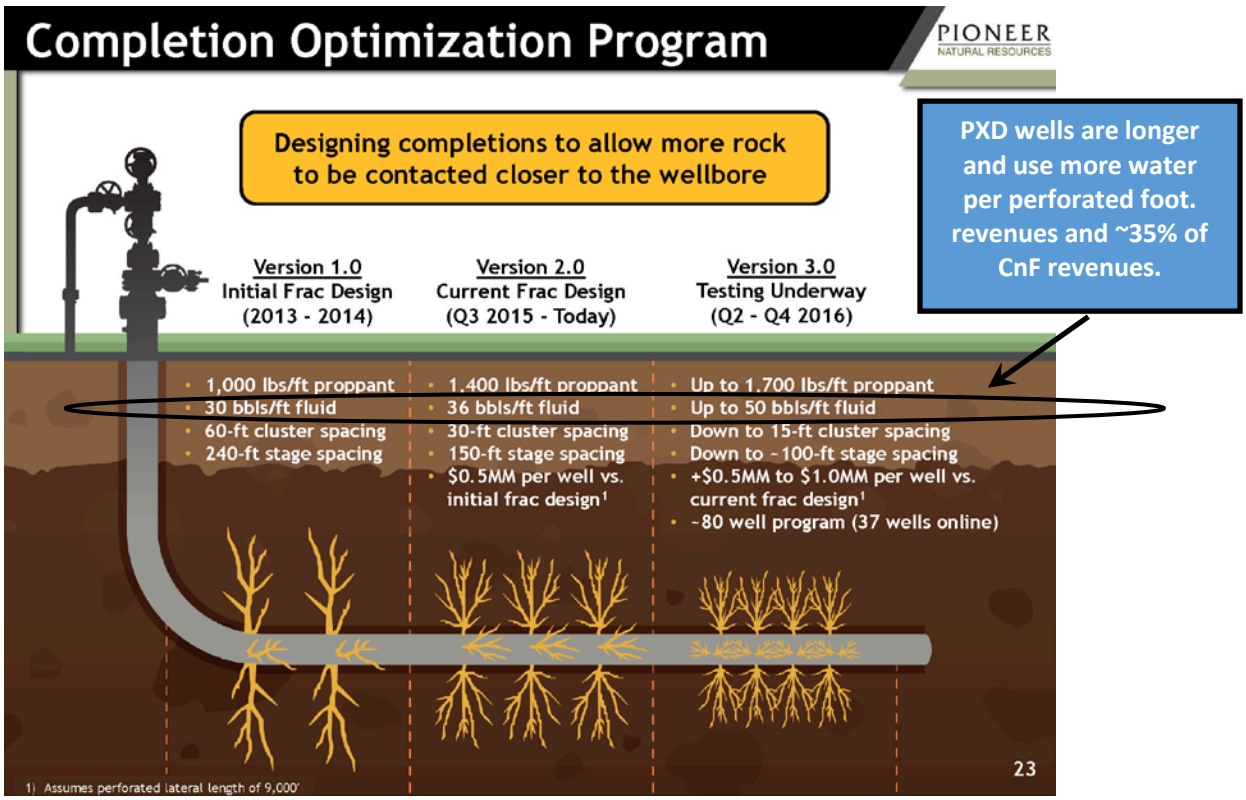
users with sufficient resources to test the efficacy of CnF is preventing FTK from adding large customers that could move the needle.

- We believe the revenue potential from the customers being added by FTK is minimal and FTK's statements regarding meaningful client additions and accelerating adoption are misleading.

Readers should consider whether high end-user turnover has resulted in the loss of higher revenue potential operators, leaving the Company exposed to severe customer concentration risks.

6. <u>Increased water volume in modern fracking completions has masked the substantial loss of the end users of CnF products.</u>

- Water usage in fracking has increased immensely in the past few years (i.e., sophisticated operators are pushing more and more frac fluids into horizontal completions). As noted above, CnF is used in proportion to water (typically in concentrations of 1.0 - 1.5 gallons per thousand gallons of water). Consequently, as a handful of existing customers rollout enhanced well designs that call for much larger water volumes, CnF usage rises by default, which, we believe, has helped mask the losses in CnF volumes from the large churn of end users.
- To illustrate this, the slide below is from Pioneer's Q3 2016 earnings presentation, which shows PXD uses 67% more water per foot of perforated lateral length in 2016 (version 3.0) wells than 2013-2014 (version 1.0) wells. At the same time, the lateral length of PXD's wells has increased by up to 2,000 feet since 2013. This means PXD wells are using up to 20 million gallons of water today versus fewer than 9 million gallons just 2-3 years ago.



- Using the FracFocus database, we calculated the total amount of water used in CnF wells by all operators, the top 3 CnF users each year, all CnF users outside the top 3, as well as Pioneer and Noble individually (two of FTK's largest end users) from 2014 to 2016. The table below summarizes the results.

Wells using CnF fell 41% YOY

CnF is not seeing broadening adoption

Concentration of Top 3 growing immensely

CnF well count and portion of well count for Outside Top 3 plummeting

PXD and **NBL** water usage, water per well and portion of total CnF well count all growing.

Water Usage in CnF Wells (based on FracFocus data)

		All Operators	Top 3 Operators		Outside the Top 3		Pioneer (PXD)		Noble (NBL)	
Year				*% All*		*% All*		*% All*		*% All*
2014	Water (gallons)	5,789,628,066	2,234,947,448	*39%*	3,554,680,618	*61%*	4,764,396	*0%*	1,007,820,550	*17%*
	CnF well count	2,321	559	*24%*	1,762	*76%*	2	*0%*	259	*11%*
	Avg gal/well	2,494,454	3,998,117		2,017,412		2,382,198		3,891,199	
	Operator count	186	3		183		1		1	
2015	Water (gallons)	6,172,580,331	3,967,835,740	*64%*	2,204,744,592	*36%*	2,427,898,569	*39%*	1,076,855,571	*17%*
	CnF well count	1,347	512	*38%*	835	*62%*	212	*16%*	176	*13%*
	Avg gal/well	4,582,465	7,749,679		2,640,413		11,452,352		6,118,498	
	Operator count	170	3		167		1		1	
2016*	Water (gallons)	6,784,154,952	5,526,085,411	*81%*	1,258,069,541	*19%*	3,386,159,633	*50%*	1,472,543,826	*22%*
	CnF well count	791	469	*59%*	322	*41%*	200	*25%*	131	*17%*
	Avg gal/well	8,578,850	11,777,676		3,911,908		16,897,004		11,257,980	
	Operator count	85	3		82		1		1	

**annualized from 10 to 12 months except for Operator count. 2016 data through approx 10/31/16 due to FracFocus reporting latency.*

- We observe the following:
  - Total gallons of water used in CnF wells grew less than 10% a year while the number of CnF wells fracked fell by 40% per year during the same period. This implies the average CnF well used 2.5 million gallons of water in 2014, but used 8.6 million gallons in 2016, **a 244% increase in water usage per CnF well in just two years**.
  - The top 3 CnF end users in 2016 (PXD, NBL, PDCE) accounted for 60% of the CnF well count and used over 80% of the total water used in CnF wells. This composition is dramatically different than just two years ago, when the top 3 end users (NBL, APC, PDCE) accounted for only 24% of the CnF well count and used just 39% of the total water used in CnF wells. It is worth noting that APC (a top 3 user in 2014) stopped using CnF in May 2015. **Based on well count and water usage, the customer footprint seems to have contracted, further concentrating in just a few, very large customers**.
  - The average PXD CnF well used almost 17 million gallons of water in 2016, up 48% from the year before. The same trend is seen for NBL. **PXD alone now accounts for half of the total water used in CnF wells. That figure is 72% when you combine PXD and NBL**.
  - CnF end users outside of the top 3 accounted for 40% of the CnF well count, consumed only 19% of the total water volume, and used just 3.9 million gallons of

water per CnF well, implying this group consists of primarily smaller operators trying the product in very few, less sophisticated well designs.

- On November 30, 2016, John Chisholm stated, **"Even in the worst cyclical downturn in our lifetime, Flotek's chemistry business has held its own, continued to grow and is poised for even greater growth in the months ahead..."** "Over the past three years, in an environment more conducive to contraction than expansion, **Flotek has added over 150 unique clients to its chemistry client base**…"[44]
- Flotek claims that the resilience of CnF is evidenced by consistent annual sales volumes and revenues since 2014. Company disclosures show CnF volumes and revenues were approximately 7.7 million gallons ($130 million) in 2014, 9 million gallons ($115 million) in 2015 and 9.5 million gallons ($120 million) forecast in 2016.[45] On the surface, the consistent total water volume per annum used in CnF wells seems to support this claim. However, the composition of that water usage tells a much different story.
- We question whether the "resilience" claimed in Flotek's presentations is due to the broadening CnF customer base as Flotek claims, or is simply a result of the 2-3x increase in water volume required by modern fracking completions from a three existing customers, who now account for the majority of CnF wells and use over 80% of all the water.

See the enclosed appendices for additional detail, modeling assumptions and support for these conclusions, along with a white paper from industry experts RK Trading and Sylvania. These materials are also available at the FourWorld website.

Disclosure: FourWorld reached out to MHA Petroleum and Flotek, but calls and electronic communications were not returned.

[44] Jefferies 2016 Energy Conference. Transcript and presentation from Bloomberg.
[45] Jefferies 2016 Energy Conference. Transcript and presentation from Bloomberg.

Legal Disclaimer

FourWorld Capital Management LLC ("FourWorld") is an SEC registered investment advisor based in New York, New York. FourWorld provides investment advisory services focused on tax, legal and regulatory event driven investing. The views expressed in this research presentation ("Presentation") represent the opinions of FourWorld and/or certain affiliates and the investment funds it manages that hold shares in Flotek Industries Inc. ("Flotek").

This Presentation is for informational purposes only, and it does not have regard to the specific investment objective, financial situation, suitability or particular need of any specific person who may receive this Presentation, and should not be taken as advice on the merits of any investment decision. This Presentation expresses our research opinions, which we have based upon interpretation of certain facts and observations, all of which are based upon publicly available information and FourWorld analysis, and all of which are set out in this Presentation.

Use FourWorld's research is at your own risk. You should do your own research and due diligence, with assistance from professional financial, legal and tax experts, before making any investment decision with respect to securities covered herein. FourWorld disclaims any and all liability as to the completeness or accuracy of the information and for any omissions of material facts. FourWorld disclaims any obligation to correct, update or revise this Presentation or to otherwise provide any additional materials. Neither FourWorld nor any of its affiliates makes any representation or warranties of any kind – whether express or implied – as to the accuracy, timeliness, completeness of the information contained herein and the recipient agrees and acknowledges that it will not rely on any such information.

As of the publication date of this presentation, FourWorld (possibly along with or through our members, partners, affiliates, employees, and/or consultants) along with our subscribers and clients have a direct or indirect short position in Flotek stock, and therefore stand to realize significant gains in the event that the price of Flotek stock declines. Following publication of this presentation, we intend to continue transacting in the securities covered herein, and we may be long, short, or neutral at any time hereafter regardless of our initial recommendation. All expressions of opinion are subject to change without notice, and FourWorld does not undertake to update this report or any information contained herein. FourWorld, subscribers and/or consultants shall have no obligation to inform any investor or viewer of this report about their historical, current, and future trading activities. The consulting firms hired by FourWorld, and referenced in this paper, are receiving a fee that is based on the performance of FourWorld's positions in Flotek stock, and, independent of FourWorld, may have a direct or indirect short position in Flotek stock.

FourWorld may buy or sell or otherwise change the form or substance of any of its investments in any manner permitted by law and expressly disclaims any obligation to notify any recipient of this Presentation of any such changes. There may be developments in the future that cause funds managed by FourWorld to engage in transactions that change the beneficial and/or economic interest in Flotek.

The opinions expressed in this report are not investment advice nor should they be construed as investment advice or any recommendation of any kind. Any investment involves substantial risks, including complete loss of capital. Any forecasts or estimates are for illustrative purposes only and should not be taken as limitations of the maximum possible loss or gain. You should assume these types of statements, expectations, pro forma analyses, estimates, and projections may turn out to be incorrect for reasons beyond FourWorld's control.

This Presentation may contain, or incorporate by reference, forward-looking statements which reflect FourWorld's views with respect to, among other things, future events and financial performance. Forward-looking statements are subject to various risks and uncertainties and assumptions. There can be no assurance that any idea or assumption herein is, or will be proven, correct. If one or more of the risks or uncertainties materialize, or if FourWorld's underlying assumptions prove to be incorrect, the actual results may vary materially from outcomes indicated by these statements. Accordingly, forward-looking statements should not be regarded as a representation by FourWorld that the future plans, estimates or expectations contemplated will ever be achieved.

The securities or investment ideas listed are not presented in order to suggest or show profitability of any or all transactions. There should be no assumption that any specific portfolio securities identified and described in this Presentation were or will be profitable. Under no circumstances is this Presentation to be used or considered as an

offer to sell or a solicitation of an offer to buy any security, nor does this Presentation constitute either an offer to sell or a solicitation of an offer to buy any interest in funds managed by FourWorld. Any investment in the FourWorld funds is speculative and involves substantial risk, including the risk of losing all or substantially all of such investment.

Appendix A – White Paper from RK Trading and Sylvania, LLC

The following is a White Paper from RK Trading and Sylvania LLC entitled *"Well Productivity, Completion Design and CnF: Horizontal Wells in Weld County, CO"*

Well Productivity, Completion Design and CnF
Horizontal Wells in Weld County, CO

November 30, 2016

Richard Jefferis
RK Trading
Houston TX

Nik Tsirigotis
Sylvania, LLC
Houston TX

The authors of this paper will receive a fee that is based on the performance of an investment managed by FourWorld Capital Management LLC, a New York based hedge fund, in Flotek stock and may also have an independent position in that stock.

Abstract

We consider the relationship between oil production and completion parameters for a set of 604 horizontal wells located in Weld County, Colorado. We document statistically significant relationships between production and location, the length of the well bore, TVD, and the amount of sand and water used in a completion, and demonstrate that the use of CnF, a proprietary flowback surfactant, has zero marginal impact on production in the sample considered here. This property of CnF is apparent in simple regressions incorporating only operator identity and the length of the wellbore, and estimated consistently by a sequence of models that introduce additional variables related to production. The variables with the largest impact on production are, in order of magnitude, location, the amount of sand and water used in a completion, operator identity and length of the well bore. Model R2 are in the range of 50 percent to 70 percent.

1.0 Summary

We present a framework for measuring the productivity of horizontal oil well completions, which account for a significant and increasing fraction of US oil production, and use data from FracFocus (an industry data base) and state drilling records to characterize the influence of geology and completion design on well productivity. Direct comparisons, regression analysis and Generalized Additive Models ("GAM's") allow us to measure the relationship between production and explanatory variables that we identify through visualization. These include the gross fractured length, total vertical depth, and location of the wellbore, as well as the amount of sand and water used to complete the well. We use the models to investigate the influence of Complex nano-Fluid ("CnF"), an additive that is incorporated into fracturing fluids, on well productivity.

FracFocus is an important source of information about fracturing fluid systems used in horizontal well completions. Twenty-three states and the Federal BLM either require or recommend that operators who develop horizontal wells report the content of fracturing fluids to FracFocus.[1] The database describes the amount of different materials present in the frac fluid, expressed as a percentage of total frac fluid mass, including sand, water, and chemical additives. Combining the data from FracFocus with information about well characteristics from state completion and production records affords a profile of individual well productivity that is linked to well characteristics.

The rapid development of the horizontal completion industry in the US has been associated with an evolution in completion design, as operators and service companies learn through trial and error about the productivity of well design features. The data employed here, investor materials from different operating companies and engineering literature all suggest the rapid evolution of completion designs. A recent Centennial Resources SEC filing indicates the significance that operators attach to completion parameters.

> *We have an evolving completion strategy that involves methodical adjustments of parameters, experimentation with different designs on adjacent locations with similar rock characteristics, and constant monitoring and re-evaluation of results … Our current base completion design is a hybrid fracture stimulation, a combination of slickwater and cross-linked gel, targeting approximately 150 foot stage length, 50 feet cluster spacing, 40 barrels of fluid per foot of lateral length and 1600 – 1900 lbs of white sand per foot of lateral length.*[2]

Our objective is to identify and measure the relationship between well productivity and both control parameters that may be influenced by an operator, and exogenous variables that describe the environment where a completion occurs. We are able to observe only a fraction of

---

[1] Coverage of the data base is described in Kate Konschnik and Archana Dayalu, *HF Chemicals Reporting: Summary of Frac Focus Data Analysis*, Harvard Law School, Septmber 29, 2015.
[2] Centennial Resources S1 (IPO) filing dated June 22, 2016 p 93.

the information that is incorporated into a completion design (more about this later). Our measurement strategy exploits the fact that wells completed at a particular point in time, in a given location, by a particular operator are likely to share many characteristics that are not observable to a third party. This strategy makes it easier to identify the influence of variables that we can observe.

The evaluation of well productivity that is discussed here uses data from Weld County, Colorado, which is located in the DJ Basin. We use information about well location and total vertical depth, which represent lithology (i.e. properties of the rock), as well as design features including the length of the wellbore, and the amount of sand and water used in the completion, to develop a model that explains between 50 percent and 70 percent of the observed variation in output from a set of 604 wells. The relationships that we identify are consistent with intuition, as well as information reported by third parties about factors that influence horizontal well productivity.

We use this analytical framework to measure the influence on well productivity of one specific completion design feature that is within the control of the well operator. Complex nano-fluid or CnF is a flowback surfactant that is used to enhance the flow of oil from horizontal wells. Materials distributed by Flotek, who manufactures and distributes the product, allege that the use of CnF can increase output from horizontal completions by 30 – 70 percent.[3]

We demonstrate that the measurable contribution of CnF to well productivity in our sample of 604 wells in the DJ Basin is zero. This result is consistent across locations and operators.

In one sense, our results conflict with conclusions about the influence of CnF on production reported by MHA Petroleum Consultants of Denver, who were hired by Flotek to evaluate the efficacy of CnF. MHA asserted in a report to the Flotek Board, delivered January 25, 2016, that "The results presented demonstrate that for Focus Areas 1 and 2, the wells which used the CnF additive showed a significant increase in both 12-month and ultimate oil production productivity parameters".

We resolve the apparent inconsistency between our results and the results presented by MHA by appealing to two features of the MHA study. One is that MHA appears to have used a faulty "key" to interpret the data in FracFocus, which identifies chemical additives included in frac fluids using trade names (e.g. "StimOil"), but does not indicate whether those products contain CnF.[4] MHA interpreted the information in FracFocus using a key that was supplied to MHA by

---

[3] Press release dated February 23, 2015. "Our data suggest that a remediation or restimulation treatment of a well using a tailored CnF chemistry design can reinvigorate production by 30-70% and, in some cases, return the well to its original production profile. More important, it can do so at a fraction of the cost of drilling and completing a new well".

[4] It is also possible to identify products containing CnF using CAS identifiers associated with specific citrus terpenes.

Flotek.[5] We have compiled independently a list of trade names for products that we believe incorporate CnF, which is materially different from the list of trade names that was supplied to MHA by Flotek. The difference in the content of the two lists affects the conclusions about the relationship between production and the use of CnF in Weld County completions.[6]

Even if we agreed with MHA that a particular group of wells treated with CnF were more productive than another group of wells not treated with CnF – which is bound to be true in some cases – we would still have cause to consider carefully a claim that "the use of the CnF additive *made a significant difference in well performance* when compared with wells in the same vicinity that did not use CnF".[7] We illustrate the second source of discrepancy between our results and those reported by MHA with an example that is developed more fully below.

Completion intervals in the sample of 604 wells examined here range from 2108 feet to 9612 feet. Long completions are less productive than short completions for every operator in every location, independent of whether the wells were completed with CnF.[8] The production data in the first column of Table 1.0.1 indicate that short completions treated with CnF underperform short completions that were not treated with CnF by 1.0 BBL of production per ft of gross perforated interval ("GPI") during their first 12 months of operation. The data in the second column of the table indicate that the relationship between CnF use and productivity is a mirror image among long completions. The gain associated with using CnF is positive in one case and negative in the other.

Table 1.0.1: CnF Use, Completion Length and Production[9]

	Short	Long	Average
No CnF	13.8 (N = 61)	8.8 (N = 101)	10.7 (N = 162)
CnF	12.8 (N = 365)	9.8 (N = 77)	12.3 (N = 442)
Gain	-1.0 (N = 426)	1.0 (N = 178)	1.6 (N = 604)

[5] MHA Report dated January 25, 2016 pp 4 -5.
[6] The list of trade names reported by MHA and our alternate list of trade names are presented in Appendix A.
[7] MHA report to the Flotek Board titled "Effectiveness of CnF on Improving Horizontal Well Performance: Permian Basin, Texas and New Mexico", dated July 22, 2016. Emphasis added.
[8] Production increases with the length of the lateral, but production per foot of gross perforated interval declines.
[9] Short wells have completion intervals of less than 6,000 ft. Production is cumulative 12-month output per foot of gross perforated interval. This is a standard measure of performance, used both here and in the MHA report.

The situation is quite different when we look across the columns. The cost of moving from short completions to long completions is 5.0 BBLs per ft GPI in the first row and 3.0 BBLs per ft GPI in the second row. Moreover, the column differences are associated with t-statistics of at least 6.18, while the largest t-statistic for a row difference is 1.83.

There is of course no reason to expect that CnF performs differently in long completions and short completions. The message in Table 1.0.1 is rather a caution about generalizing from a simple comparison. Our analysis indicates that the relationship between production and the length of the completion interval is consistent, measurable and statistically significant across operators and locations. The marginal performance of wells treated with CnF is random, on average equal to zero and not statistically different from zero. These properties of the data are apparent in Table 1.0.1, and in a simple regression involving nothing more than operator identity, the length of the completion interval and CnF use. The same properties are estimated consistently in more sophisticated models that address other characteristics of production.

The data in the last column of Table 1.0.1 suggest that CnF improves performance because the marginal penalty associated with longer completions happens to be greater in the top row of the table, which represents wells not treated with CnF, than in the bottom row of the table for this sample of wells. Evidence presented below (see Table 5.1.1, for example) indicates that this feature of Table 1.0.1 is a result of influences other than the presence of CnF in frac fluid.

The length of the completion interval plays an important but not definitive role in explaining observed variations in well productivity. Location, operator identity, well depth and the application of sand and water in the fracturing process also explain observed variations in production. Our conclusions about "what matters" – location, operator, well depth, length of the wellbore, sand and water but not CnF - are not sensitive to the definition of production, sample size or the way that we measure explanatory variables or their influence. Simple comparisons, visualizations of production and completion parameters, and various econometric models all lead to the same conclusion.

These results generalize beyond Weld County. We demonstrate that data presented by MHA in a series of three reports to the Flotek board provide evidence of nothing more than a random relationship between well productivity and the use of CnF when evaluated with standard statistical tools. The application of our analytical tools to a group of 120 wells completed in the Bone Spring formation in the Permian Basin indicates that the marginal impact of CnF on production is zero there as well.

2.0 The MHA Reports

MHA delivered three reports on the relationship between horizontal well productivity and CnF use to the Flotek board between January 2016 and July 2016. The three studies address the relationship between CnF use and well performance in the Weld County, CO section of the DJ Basin, the Eagle Ford play of South Texas, and the Permian Basin of West Texas. In each

case, MHA identified a set of geographic Focus Areas, and compared the average cumulative 12-month production from a group of wells treated with CnF to the average cumulative 12-month production from a group of wells not treated with CnF.

MHA did not offer any assessment of statistical reliability in any of its studies. We have computed t–statistics and p-values using data taken directly from the three reports. The evidence presented in Table 2.1 indicates that producer experience with CnF documented by MHA is consistent with random behavior, if we treat the results from each Focus Area as a single trial.

Table 2.1: Summary of Evidence Presented By MHA[10]

Play	Number of Focus Areas	Number of CnF Wins	Average Gain	t-statistic	p-value
DJ Basin, Colorado	3	3	26.2	2.22	0.16
Eagle Ford, Texas	15	6	15.6	0.82	0.43
Permian, Texas	14	8	4.1	0.49	0.63
Total	32	17	11.5	1.16	0.25

Specifically, the 17 cases of outperformance in 32 trials that is described in the last row of Table 2.1 are what one would expect from a coin toss. None of the t-statistics reported in the table would lead to a rejection of the null hypothesis of zero outperformance in a clinical trial. The 11.5 percent average gain associated with CnF use that is described in the last row of the table reflects one observation with 263 percent outperformance based on 6 wells in the Eagle Ford play of South Texas. If we omit that observation - the next biggest gain for any Focus Area sample is 58 percent – average outperformance declines from 11.5 percent to 3.2 percent. The t-statistic for overall outperformance declines to 0.58, which is associated with a p-value of 0.57. Median outperformance is 3.0 percent for the sample as a whole, which is very close to mean outperformance measured without the single outlier.

We would interpret the collective evidence offered by MHA to indicate that the appropriately measured average difference in production between wells completed with CnF and wells completed without CnF is 3.2 percent, *which cannot be distinguished from zero*. This would NOT be viewed as evidence indicating that wells treated with CnF produce more oil than wells not treated with CnF in any conventional interpretation of the data.

[10] The performance metric employed in Table 1.1 is 12-Month Production per foot of Gross Perforated Interval, which MHA characterizes as the most informative production metric considered in its reports. The Number of Cases statistic in the table incorporates only Focus Areas where production data were available. A larger number of Focus Areas were considered in the Texas studies, but the candidate wells did not have

3.0 The Weld County Data

3.1 FracFocus

FracFocus.org ("FracFocus") is the national hydraulic fracturing chemical registry. It is a public database that is the industry-standard reference for materials used to fracture oil and gas wells. Twenty-three states and the Federal BLM either require or recommend that operators who hydraulically fracture wells report the composition of frac fluids to FracFocus, which currently contains records describing more than 100,000 completions.[11]

We use FracFocus to measure several completion parameters. One is the amount of water used in the completion, which affects both the delivery of sand to the fracture and the amount of pressure applied to the source rock. The unit of measure adopted here is gallons of water per foot of gross perforated interval or GPI. We also use FracFocus to identify the concentration of sand in the fracturing fluid, measured as a fraction of the overall mass of the frac fluid. Water volume and sand concentration are widely recognized as exerting a strong influence on well productivity.

FracFocus also allows us to identify chemical additives used in the frac fluid, which typically make up less than 1.0 percent of the frac fluid by mass. 91 percent of the wells in our sample incorporate CMHPG, CMC, or CMG. These additives are used to increase the viscosity of the frac fluid, allowing sand to be held in suspension while it is transported from the surface to the fracture.

Our final use of FracFocus is to determine whether a particular well was completed with CnF, which is a flowback solvent / surfactant marketed by Flotek. Additives incorporated into frac fluids are typically described in FracFocus by their trade names (e.g. “OilPerm B” or “Stimoil FBA M”), which do not indicate whether that additive contains CnF. To determine which wells contain CnF, we require a list of trade names. MHA listed five trade names in their report to the Flotek board dated January 25, 2016. We have identified an additional three trade names that were associated with the completions in our sample. All of these are listed in Appendix A.

Each well in the US is assigned a unique API number, which is referenced in the FracFocus record and may be used to link different sources of information.

3.2 Production Data

We identified a set of candidate wells using the methodology described by MHA. The Colorado Oil and Gas Conservation Commission (“COGCC”) maintains a set of records for wells completed

[11] Wyoming and New Mexico have mandatory disclosure rules but do not require operators to use FracFocus. We have found that disclosure to FracFocus in these jurisdictions is nonetheless routine.

in that state, using a system known as COGIS. Our samples for Focus Area 1 and Focus Area 2, where MHA developed the results used to support its claim of superior performance for wells treated with CnF, were created by identifying all horizontal wells fractured in those locations during the period beginning November 1, 2012 and ending June 30, 2015.[12] The start date corresponds to the release of FracFocus 2.0, which marked a significant increase in the quality of the FracFocus database. The end date is determined by the requirement that 12 months of production data be available as of the cut-off date for this study.

The raw oil production data extracted from COGIS were examined for discrepancies. For each candidate well, we visually inspected the monthly production profile for obvious data entry errors. We also identified missing production reports, and checked water volumes reported by COGIS and FracFocus for discrepancies, then followed up with COGCC to resolve conflicts. This exercise yields a set of 604 wells completed in the Niobrara formation. 267 of the wells are located in Focus Area 1. 337 wells are located in Focus Area 2.

MHA did not provide the API numbers for the wells used in its studies, or the dates that delimit its sample. We are therefore unable to identify exactly the overlap between our data and their data. But both the method of construction and the correspondence in summary statistics that is documented below suggest a high degree of overlap.

Production statistics reported here are total 12-month oil production per foot GPI, adjusted for days online.[13] To be included in the sample, a well would have to produce in at least 11 of the 12 months in question. If a well is shut in for part of a month, adjusted production is calculated as Adjusted = Raw*(NDays/Actual Days) where NDays is the number of calendar days in that month. The estimated production for each calendar month is then normalized to 365 / 12 days. If a well was shut-in for a full month, production for the missing month is set equal to the average of the other 11 months. All of the results reported here were reproduced using raw data as well as adjusted data. Our conclusions are not sensitive to the definition of production, or the time horizon used to measure production.[14]

The location of wells in Focus Area 1 and Focus Area 2 are described in Figure 3.2.1. Operators of the 267 wells located in Focus Area 1, which is to the northeast in the figure, are Carrizo (31),

---

[12] MHA obtained its production data from IHS, which accesses COGIS. Focus Area 1 and Focus Area 2 correspond to particular township and range locations that are described in the MHA report. Candidates for our sample include all wells completed in those locations during the time period specified in the text.

[13] The use of this metric is consistent with MHA's view that "the most meaningful productivity parameters calculated in our analysis were the two parameters which were expressed in terms of the ratio of oil volume to the gross perforated interval length in the horizontal well (barrels per foot)". Report dated January 25, 2016, p 4.

[14] All of the tables from this report, calculated using raw production for wells with a full 12 months of production data, are available from the authors.

Noble (122) and Whiting (114). Focus Area 2, located to the southwest, contains wells operated by Bill Barrett (43), Bonanza Creek (93) and Noble (201).

Figure 3.2.1

3.3 Discrepancy in the List of Trade Names

As noted above, the analysis presented by MHA in its January 2016 report to the Flotek Board of Directors is based on a list of trade names that we believe to be incomplete. The 5 trade names used by MHA and our alternate list of 8 trade names are presented in Appendix A. The difference in classification schemes results in the reassignment of 23 percent of the wells in the sample from the non-CnF group of wells to the group of wells completed with CnF. The impact of this reassignment on the relationship between average production and CnF use is presented in Table 3.3.1 and Table 3.3.2.

Table 3.3.1: 12-Month Production and CnF Use in Focus Area 1

Focus Area 1	CnF Wells	Non CnF Wells	Improvement
MHA Report	16.6	11.3	5.3
MHA Method, Our Sample	16.3	11.0	5.3
Corrected, Our Sample	15.3	10.7	4.6

Table 3.3.2: 12 Month Production and CnF Use in Focus Area 2

Focus Area 2	CnF Wells	Non CnF Wells	Improvement
MHA Report	11.0	9.3	1.7
MHA Method, Our Sample	11.7	9.6	2.1
Corrected, Our Sample	10.9	10.6	0.3

In both cases, reclassification reduces the observed difference in production between wells completed with CnF and completions that did not involve CnF. The impact of the reclassification is greater for wells located in Focus Area 2 than for wells located in Focus Area 1. With our classification, wells located in Focus Area 1 that were treated with CnF yielded an incremental 4.6 BBLs (43 percent) of oil per foot of GPI during the first 12 months of production. Wells completed with CnF in Focus Area 2 outperformed the wells that did not use CnF by 0.3 BBLs (3 percent) of oil per foot of GPI. The observed difference in Focus Area 1 is associated with a t-statistic of 6.91, while the difference in Focus Area 2 is associated with a t-statistic of 0.38.

The evidence in Table 3.3.1 and Table 3.3.2 suggests that our sample of wells resembles closely the group of wells analyzed by MHA. In both Focus Areas, we calculate uplift associated with CnF use that is similar to what MHA reported if we use the same list of trade names. The evidence presented in Table 3.3.2 implies that MHA would have reported a gain of 3 percent from CnF use in Focus Area 2, instead of the 18 percent that was reported, had they used the proper key.

The relationship between CnF use and production in the revised data as documented in these tables is consistent with the overall pattern reported by MHA, in that a simple comparison of output suggests that CnF is linked to increased production in one case but not the other. We view this situation as an invitation to "look under the hood".

4.0 Interpreting the Data

4.1 CnF Use and Production

Our sample of 604 wells from the DJ Basin exhibits evidence of a random relationship between CnF use and well productivity, consistent with our interpretation of the overall evidence presented by MHA. This characteristic of the data is illustrated in Table 4.1.1 and Figure 4.1.1.

Figure 4.1.1

The uplift in production from the use of CnF suggested by the differences in Table 4.1.1 and Figure 4.1.1 are positive in three cases, negative in two cases and break-even in the last. Only one difference is statistically significant at the five percent level: 184 wells completed by Noble using CnF in Focus Area 2 outperformed 163 completions that did not involve CnF by 1.7 BBLs per ft GPI. (This is documented in the last row of the table.) Noble had a different experience in Focus Area 1, where 106 wells completed with CnF underperformed 16 wells completed without CnF by 1.4 BBLS per ft GPI.

If we increase the threshold probability used to determine statistical significance from 5 percent to 10 percent, we identify two cases with a gain of 1.7 BBLs per ft GPI and one with a loss of 1.9 BBLs per ft GPI. Overall, the performance documented in the table and the figure is consistent with sampling variation.

Table 4.1.1: CnF vs Production by Operator (N completions in parenthesis)

	CnF	No	Difference	t-statistic	p-value
Carrizo	14.9 (N = 12)	12.4 (N = 19)	2.5	1.51	0.15
Noble I	16.5 (N = 106)	17.9 (N = 16)	-1.4	0.73	0.48
Whiting	10.7 (N = 27)	9.0 (N = 87)	1.7	1.78	0.08
Bill Barrett	9.3 (N = 36)	8.8 (N = 7)	0.5	0.57	0.57
Bonanza Creek	10.7 (N = 77)	12.6 (N = 16)	-1.9	2.02	0.06
Noble II	11.2 (N = 184)	9.6 (N = 163)	1.6	2.10	0.05

4.2 Completion Interval Length and Production

The situation is different when we consider the relationship between production and the length of the gross perforated interval or GPI, as evidenced by Figure 4.2.1 and Table 4.2.1. Long wells are less productive than short wells for every operator in both Focus Areas. The t-statistic associated with the difference in mean production rejects the null hypothesis of equality at the 2 percent level in three of six cases, which are marked with an asterisk next to the operator's name in the graph. In two cases where it is not possible to reject the null – Carrizo and Bonanza Creek - we have only 1 and 3 long completions, respectively.

Figure 4.2.1

The evidence in Table 4.2.1 and Figure 4.2.1 is not dispositive, but it all points in the same direction and is consistent with the notion that longer completions are less productive than short completions in this sample. Measurements based on econometric models that treat GPI as a continuous variable, which are presented below, sustain this view. That evidence is stronger statistically, even on an operator-by-operator basis, because we don't throw away information by partitioning the data into cells, as is the case in Table 4.2.1. A negative relationship between GPI and production per foot of GPI for DJ Basin wells has been documented elsewhere using a much larger sample of completions.[15]

Table 4.2.1: GPI vs Production by Operator (N completions in parenthesis)

	GPI > 6,000	GPI < 6,000	Difference	t-statistic	p-value
Carrizo	12.9 (N = 1)	13.4 (N = 30)	0.0	NA	NA
Noble	10.9 (N = 15)	17.5 (N = 107)	6.6	10.76	< 0.01
Whiting	9.0 (N = 102)	12.9 (N = 12)	3.9	2.58	0.02
Bill Barrett	8.3 (N = 19)	10.0 (N = 24)	1.7	1.53	0.13
Bonanza Creek	9.5 (N = 3)	11.1 (N = 90)	1.6	1.43	0.27
Noble	9.6 (N = 38)	11.4 (N = 163)	1.8	3.10	< 0.01

4.3 Completion Length, CnF and Production

The perception of a random relationship between CnF use and production is enhanced if we go one step further and acknowledge the relationship between production and GPI when considering the impact of CnF on productivity. Table 4.3.1, Table 4.3.2, and Figure 4.3.1 all describe the relationship between CnF use and production by operator, contingent on completion length. The left panel of Figure 4.3.1 is associated with short wells, while the right panel is associated with long wells. There are 9 cases in the overall sample where a specific operator completed wells of roughly the same length, both with CnF and without CnF. Within this group, performance is random. Wells completed with CnF are more productive than other wells in 4 of 9 cases and less productive in 5 of 9 cases. In a single case – Noble completions of more than 6,000 ft GPI in Focus Area 2 – the data reject the null hypothesis of equal production, in favor of the alternative that wells treated with CnF are more productive, at a 5 percent level of significance. If we relax the test threshold to 10 percent, we are left with three cases of performance that is statistically different from zero. Two of these are negative.

Figure 4.3.1

Table 4.3.1: CnF Use and Production for wells with GPI < 6000 ft

	CnF	Else	CnF Uplift	t-stat	p-value
Carrizo	15.0 (N = 11)	12.4 (N = 19)	2.6	1.52	0.15
Noble I	17.1 (N = 97)	21.8 (N = 10)	-4.7	2.18	0.06
Whiting	12.5 (N = 7)	13.4 (N = 5)	-0.9	0.33	0.75
Bill Barrett	10.0 (N = 24)	NA N = 0	NA	NA	NA
Bonanza Creek	10.8 (N = 74)	12.6 (N = 16)	-1.8	1.96	0.06
Noble II	11.5 (N = 152)	10.7 (N = 11)	0.8	0.79	0.45

Table 4.3.2: CnF Use and Production for wells with GPI > 6000 ft

	CnF	Else	Uplift	t-stat	p-value
Carrizo	12.9 (N = 1)	NA	NA	NA	NA
Noble I	10.6 (N = 9)	11.5 (N = 6)	-0.9	1.21	0.25
Whiting	10.1 (N = 20)	8.7 (N = 82)	1.3	1.27	0.22
Bill Barrett	8.0 (N = 12)	8.8 (N = 7)	-0.8	0.85	0.41
Bonanza Creek	9.5 (N = 3)	NA	NA	NA	NA
Noble II	10.0 (N = 32)	7.5 (N = 6)	2.5	2.88	0.01

This simple look at the data suggests that increased GPI has a systematic, negative impact on well productivity while the marginal contribution of CnF to output is much more random. The perception is reinforced by the regression results presented in Table 4.3.3.[16] The regression model is Production ~ Operator + GPI + CnF. Operator effects are not reported in the table. The completion parameter estimates indicate that increasing the length of the completion interval by 1,000 ft decreases expected 12-month production by 1.30 BBLs per ft GPI in Focus Area 1 and 0.40 BBLs per ft GPI in Focus Area 2. The t-statistics associated with these

[16] The model is estimated in R using the robust regression function RLM, which implements an M-estimator that controls for outliers.

estimates, 6.94 and 3.99 respectively, indicate that the parameter values are significantly different from zero. The estimated uplift from using CnF is 0.10 BBLs per ft GPI in Focus Area 1 and -0.20 BBLs per ft GPI in Focus Area 2. Neither estimate associated with the uplift realized by using CnF is statistically significant.

Table 4.3.3: Regression Analysis of Production vs CnF and Completion Interval with Operator Control

Parameter	Focus Area 1	Focus Area 2
Number of Observations	267	337
Completion Interval (GPI)	-1.30	-0.40
t-statistic	6.94	3.99
CnF	0.10	-0.20
t-statistic	0.16	0.37

We demonstrate below that the regression models documented in Table 4.3.3 omit significant information about the source of variability in Weld County completion productivity. But the parameter estimates and message delivered by the test statistics endure. Doubling the completion interval from 4,000 ft to 8,000 ft, a phenomenon that we observe in the data, decreases expected production by ~ 1.5 – 5.0 BBLs per ft GPI. The measurable impact of CnF on production cannot be distinguished from zero, and is typically estimated at a fraction of 1 BBL per ft GPI.

5.0 Visualization of Production and Completion Parameters

5.1 Production and GPI

We develop more detailed results for Focus Area 1 and summarize our results for Focus Area 2. Focus Area 1 is more productive on average, more variable, and has a more balanced distribution of CnF use than Focus Area 2. This makes it a better candidate for analysis.

Figure 5.1.1 describes the relationship between GPI and production for firms operating in Focus Area 1.[17] These are the same data that are described in Table 4.2.1. We consider them again to highlight the relationship between production and GPI within the group of wells treated with CnF, and within the group of wells not treated with CnF. The graph also affords some additional perspective on the experience of individual operators.

Figure 5.1.1

[17] The number of firms included in the sample for a particular figure fluctuates with the identity of the variables that are included in the figure because of missing data. The most restrictive variable, in terms of the number of observations with available data, is typically TVD.

The most active operators in Focus Area 1 are Noble (122 wells) and Whiting (114 wells). Carrizo is a much smaller player (31 wells). There is a clear negative relationship between the length of the GPI (x-axis) and production per unit of GPI (y-axis) in wells completed by these operators. Long wells are less productive than short wells. The relationship holds within the group of wells that were completed with CnF (blue points) and within the group of completions that did not incorporate CnF (red points). It also holds for individual operators. Noble has wells at both ends of the GPI spectrum, although most of the Noble completions are shorter. The negative relationship between GPI and production per unit of GPI is also apparent within the group of wells completed by Whiting, which dominate the middle of the graph where 6000 ft < GPI < 8000 ft.

A significant feature of the data from Focus Area 1 is the range of observed production, which varies from 3.3 BBLs per foot GPI to 34.0 BBLs per foot GPI. The large range is not a consequence of a few outliers, although there is a "tail" at the upper range of production where 12-month productions exceeds 25 BBLs per ft GPI. It is rather evidence of a meaningful variation in the factors that influence production.

Table 5.1.1 describes the relationship between production and GPI for all wells in Focus Area 1, and for the subset of wells treated with CnF and the subset of wells not treated with CnF. The differences documented in the table are large and statistically significant in every case. For the group as a whole, a shift from completions of less than 6,000 feet (149 wells with average GPI of 3682 ft) to completions of more than 6,000 feet (118 wells with average GPI of 7171 feet) decreases production by 7.0 BBLs per foot GPI or 43 percent. A difference of this magnitude warrants consideration by both operators and third party observers attempting to understand production.

Table 5.1.1: GPI, CnF and Production for wells in Focus Area 1

	GPI < 6000	GPI > 6,000	Uplift	t-stat	p-value
All	16.3 (N = 149)	9.3 (N = 118)	7.0	12.92	< 0.01
CnF	16.6 (N = 115)	10.3 (N = 30)	6.3	7.96	< 0.01
Else	15.3 (N = 34)	8.9 (N = 88)	6.4	5.47	< 0.01

Neither operators nor CnF use are represented uniformly across the sample space described in Figure 5.1.1. But there are a meaningful number of observations in most of the cells that we have used to describe the data. Test statistics support the claim that long completions are less productive than short completions, for operators who completed wells in Focus Area 1, within the group of wells completed with CnF and within the group of wells not completed with CnF.

5.2 Production and TVD

A second feature of the production data from Focus Area 1 is illustrated in Figure 5.2.1.[18] Deeper completions tend to be less productive than shallow completions for both short wells and long wells. This is indicated by the fact that the colors in Figure 5.2.1 tend to become "hotter" (i.e. more red) as we move from left to right in the figure, for both short completions (at the bottom of the figure) and long completions (at the top of the figure). The interaction between completion length and TVD that is described in Figure 5.2.1 is related to location, although this is not apparent in the figure.

Figure 5.2.1

There are 33 wells in the sample with 12-month production in excess of 20 BBLs per ft GPI. Noble accounts for 27 of these, Whiting 4 and Carrizo 2. Nearly all of these wells appear in the lower left quadrant of Figure 5.2.1, which is associated with shorter completions at shallower depth. Three wells with production in excess of 20 BBLs per ft GPI had GPI > 6,000 ft. All were completed by Whiting.

5.3 Production and Location

The high productivity wells in Focus Area 1 that are discussed in the preceding paragraph share another common feature that is illustrated in Figure 5.3.1 and Figure 5.3.2. All of these wells are located within the polygon that appears in Figure 5.3.1.[19] The 125 wells located in the polygon had average 12-month production of 17.0 BBLs per ft GPI, while the 142 completions located outside of the polygon had average 12-month production of 9.8 BBLs per ft GPI. The 42 percent difference in production is associated with a t-statistic of 13.01.

Figure 5.3.1

A group of high production wells indicated by dark colors is apparent on a SW to NE azimuth within the Figure 5.3.1 polygon.[20] This same group of wells is identified in another manner in Figure 5.3.2. In the figure, residuals from the regression of Production on CnF and GPI, with an indicator variable to control for operator identity, are plotted against latitude and longitude. (This is the regression summarized in Table 4.3.3). The residuals, which represent variation in

---

[18] The sample size of 263 associated with Figure 5.2.1 is determined by the availability of TVD information.

[19] The polygon is defined by the location of completions with 12-month production in excess of 20 BBLS per ft GPI. Its vertices correspond to latitude {40.71, 40.71, 40.8, 40.80, 40.73} and longitude {-103.99, -103.81, -103.81, -103.84, -103.99}. We developed a specification using the convex of hull of points with yields of at least 20 BBLs per ft GPI, which produces the same results but is much more difficult to draw.

[20] Completions in the polygon tend to be short, but the GAM results and evidence in Table 1.1 indicate that there is a location effect independent of GPI.

production not accounted for by the length of the completion interval, the operator or CnF, show a clear location effect. We identify a productive trend with approximately the same azimuth in Focus Area 2.

The "sweet spot" that is described in Figure 5.3.1 and Figure 5.3.2 plays a big role in explaining the overall variation in Focus Area 1 production. We want to be sure that it is not a proxy for some other variable. Table 5.3.1 demonstrates that the sweet spot is not an operator effect. Completions in the sweet spot are much more productive than completions elsewhere in Focus Area 1 for every operator.

Table 5.3.1: Production vs Location and Operator

	Sweet Spot	No	Uplift	t-stat	p-value
Carrizo	14.6 (N = 20)	11.1 (N = 11)	3.5	2.60	0.02
Noble	17.6 (N = 98)	13.0 (N = 24)	4.6	4.36	< 0.01
Whiting	15.7 (N = 7)	9.0 (N = 107)	6.7	5.12	< 0.01

Table 5.3.2 demonstrates that the sweet spot is not a proxy for CnF use. Completions in the sweet spot are much more productive than completions elsewhere in Focus Area 1 if we restrict our attention to wells completed with CnF, or focus on completions that did not involve CnF.

Table 5.3.2: Production vs Location and CnF Use

	Sweet Spot	No	Uplift	t-stat	p-value
All	17.0 (N = 142)	9.8 (N = 125)	7.2	13.01	< 0.01
CnF	17.1 (N = 97)	11.6 (N = 48)	5.5	6.85	< 0.01
No	16.7 (N = 28)	8.9 (N = 94)	7.8	6.35	< 0.01

Table 5.3.3 demonstrates that the sweet spot is not a proxy for GPI. Completions in the sweet spot are much more productive than completions elsewhere in Focus Area 1, independent of whether we are considering long laterals or short laterals. There are relatively more short laterals in the sweet spot, but sweet spot wells are also much more productive than other wells within the set of long completions.

Table 5.3.3: Production vs Location and GPI

	Sweet Spot	No	Uplift	t-stat	p-value
GPI > 6000 ft	15.7 (N = 7)	8.9 (N = 111)	6.8	5.27	< 0.01
GPI < 6,000 ft	17.1 (N = 118)	13.3 (N = 31)	3.8	3.80	< 0.01

All of the differences documented in Table 5.3.1, Table 5.3.2 and Table 5.3.3 are large from an economic perspective and statistically significant. There is a clear location effect in the Focus Area 1 production data.

5.4 Production vs Sand and Water

Figure 5.4.1 describes the relationship between production and the concentration of sand in frac fluid. The relationship is noisy compared to the relationship between production and completion length or the relationship between production and location. But it is clearly not something that we should ignore. Figure 5.4.1 suggests an operator effect: The typical sand concentration in a Noble well exceeds that of a Whiting well. Wells completed by Noble with a sand concentration of less than 10 percent, which appear on the left edge of the graph, are less productive than those completed by Noble with a concentration of more than 10 percent, although the difference is small (0.2 BBLs per ft GPI) and not statistically significant. A similar statement applies to wells completed by Whiting.

Figure 5.4.1

Figure 5.4.2 describes the relationship among production, sand concentration and water volume. The production data have been filtered to remove the effects of location and GPI.[21] The dark points in the figure are the productive completions. These generally fall on a line indicating a tradeoff between water volume and sand concentration. A simultaneous increase in sand concentration and water volume is associated with increased production, as evidenced by the violet hexagons to the northeast of the line. The green hexagons southwest of the line indicate that decreasing water volume and sand concentration simultaneously causes production to fall.

Figure 5.4.2

Sand and water jointly explain production variation of 6 – 8 BBLs per ft GPI, which is more than any variable except location, but the relationship between these variables and production is not estimated precisely. (This statement is explained below when we consider GAM results). We suspect that this is due at least in part to the many features of the completion design that we

[21] "Production" in Figure 5.3.1 is the residual from a GAM projection of production onto latitude, longitude and GPI.

cannot observe. The pumping rate and density of perforations in the wellbore – see the quote from Centennial above - are two parameters that affect the interaction between frac fluid and the rock. Neither is observable to us. Introducing these variables into this framework would likely sharpen our insight.

6.0 Production and Completion Parameters

The evidence presented above indicates that the productivity of wells completed in Focus Area 1 is related systematically to a number of completion characteristics. We have documented large, measurable, statistically significant relationships between productivity and GPI, and productivity and location. The visualizations suggest that TVD, sand and water are also related to well productivity. None of these factors has anything to do with CnF.

6.1 Regression Model

A direct and simple method for separating the influence of the different variables that are related to productivity is a linear regression. Parameters estimated from a robust regression model are presented in Table 6.1.1.[22] The estimates are consistent with both the visualizations and the tabular evidence presented above.

Table 6.1.1: Parameter Estimates from a Robust Regression Model of Focus Area 1 Production

Variable	Units	Estimate	t-statistic	p-value
Noble	Indicator	2.82	3.16	< 0.01
Whiting	Indicator	0.13	0.12	0.90
CnF	Indicator	-0.35	0.54	0.59
Sweet Spot	Indicator	2.86	3.08	< 0.01
TVD	100 ft	-0.07	1.58	0.11
GPI	1000 ft	-0.80	3.53	< 0.01
Sand	1 Percent of Frac Fluid	0.38	2.30	0.02
Water	100 gallons per ft GPI	0.28	1.70	0.09

The R2 of the regression is 51 percent for the group of 252 completions used in estimation.[23] The t-statistics indicate that the parameter estimates for Location (the sweet spot), GPI, and Noble are significantly different from zero at 1 percent. The parameter estimate for sand concentration is significant at 2 percent. Neither TVD nor water volume reject the null

[22] This is an M estimate as implemented in R through the RLM function. An operator effect is included in the model. The estimates for Noble and Whiting are relative to a Carrizo benchmark.

[23] The reported R2 is a pseudo-R2 for the M estimator. The sample size has been reduced to N = 252 because of the availability of location data, and our desire to use the same sample in the linear regression and the GAM.

hypothesis of zero explanatory power at 5 percent. The estimated impact of CnF use on production cannot be distinguished from zero.

Table 6.1.2: Production Variation Suggested by Parameter Estimates

			Production Shift	
Parameter	Significant?	Variation	BBLs per Ft GPI	Percentage of Mean
Noble	Y	NA	2.8	21
Whiting	N	NA	0.2	1
Sweet Spot	Y	NA	2.9	22
GPI	Y	3500 ft	2.8	21
TVD	N	500 ft	0.4	3
Sand	Y	4 percent	1.5	11
Water	N	600 gallons	1.7	13
CnF	N	NA	-0.4	-3

Table 6.1.2 describes the regression results in economic terms. For each input variable, we have specified a range of variation that is consistent with the data from Focus Area 1, and calculated the implied variation in output implied by the parameter estimates from the regression model. The production shift associated with variation in the underlying variable is presented in both absolute terms and relative to average Focus Area 1 production of 13.1 BBLs per ft GPI. We have flagged the parameter estimates that are statistically significant at 5 percent.

The regression results indicate that the parameters with the biggest impact on well productivity are location, GPI, and Noble, each accounting for a production swing of about 2.8 BBLs or 21 percent of average 12-month production. Sand concentration and water volume exert a weaker influence, around 1.7 BBLs each or 13 percent of average annual production. The other variables, including CnF, have no apparent relationship to production.

Noble accounts for the largest number of completions in both Focus Area 1 and Focus Area 2, and more than 50 percent of the completions in the overall data. The superior performance documented here is repeated in Focus Area 2, and suggests a benefit of experience.

6.2 Generalized Additive Model

The linear model is simple and transparent, but it ignores a considerable amount of information that is available to us. A Generalized Additive Model or GAM allows us to describe the relationship between production and location in much greater detail, model interactions

between completion parameters, and identify non-linear relationships.[24] The most important benefit of a GAM is a more refined description of the relationship between location and production than is available from the Sweet Spot polygon description that is illustrated in Figure 5.3.1. The GAM creates a topographical map with contours that represent the local variation in production that is apparent in Figure 5.3.2, allowing us to both quantify that phenomenon and sharpen our estimates of other parameters. The GAM also affords some insight into the joint influence of sand and water on production by allowing us to consider these variables jointly.

We have latitude and longitude information for 252 completions in Focus Area 1. The result of estimating a GAM with this data is described in Table 6.2.1. The "test statistic" presented in the table is a t-statistic in the case of the parameters for operator, CnF and GPI, and an F-statistic for parameters (tensors) representing location as defined by latitude and longitude, and the joint influence of sand and water.

Table 6.2.1: Parameter Estimates from a Generalized Additive Model of Focus Area 1 Production

Variable	Units	Estimate	Test statistic	p-value
Noble	Indicator	4.4	4.07	< 0.01
Whiting	Indicator	1.3	1.32	0.46
CnF	Indicator	-0.40	0.63	0.53
Location	NA	NA	7.65	10^{-14}
GPI	1000 ft	-0.80	3.58	< 0.01
Sand & Water	NA	NA	2.81	0.01

One notable feature of the estimates reported in the table is the stability of the parameters describing the influence of GPI and CnF on production. The estimates reported in Table 6.2.1 are strikingly similar to the regression estimates reported in Table 6.1.1 and Table 4.3.3. GPI has a statistically significant negative impact on production per ft GPI, which we estimate consistently at -0.8 BBLs per 1000 ft of completion interval in models that consider the role of other variables in production. The impact of CnF on production cannot be distinguished from zero, and is typically estimated at less than 1 BBL per ft GPI in absolute value.

A second notable feature of Table 6.2.1 is the magnitude of the test statistic for the location tensor, which explains considerably more variation than the "sweet spot" indicator variable used in the regression model. Latitude and longitude alone explain 54 percent of the observed variation in 12-month production per ft GPI. There has also been a notable increase in the estimated operator effect for both Noble and Whiting vs what we observe in the regression

[24] Generalized Additive Models are discussed in Simon Wood , Generalized Additive Models: An Introduction in R, 2006. We use the mgcv implementation in R to estimate the models presented here.

model, although only the Noble variable is statistically significant. Allowing production to vary within the sweet spot, where all three producers completed some wells (recall Table 5.3.1), results in a different perspective on operator efficiency.

Figure 6.2.1, Figure 6.2.2 and Figure 6.2.3 describe the relationship between production and location, using latitude and longitude instead of the sweet spot polygon. Figure 6.2.1 is presented exclusively to aid in the interpretation of the other two plots, and illustrate the amount of smoothing that was imposed in the estimation process to prevent over-fitting. The polygon created through visual inspection of the data has been imposed on the contour plot in Figure 6.2.2 and the hex plot in Figure 6.2.3. The difference between these two plots is that the contour plot represents the marginal impact of latitude and longitude on production while the hex plot illustrates the average relationship between production and those same variables.[25]

The GAM identifies the same sweet spot that we selected through visualization. The difference between the visualization and the contour plot is that the output data used to visually identify the sweet spot are unfiltered, whereas the data used to construct the contour plot have been corrected for other influences, such as GPI, CnF and any potential operator effect.

Figure 6.2.1 and Figure 6.2.2

The contours in Figure 6.2.2 and color scale in Figure 6.2.3 both indicate variation of ~10-12 BBLs per foot GPI between the heart of the sweet spot in the southeast of Focus Area 1 and the less productive areas on the northern fringe. The circular contour at the center of the polygon in Figure 6.2.2 is associated with incremental production of 6 BBLs per ft GPI. Each contour represents 2 BBLs per ft GPI of variation in 12-month production. This 10-12 barrel per foot GPI variation in production between the heart of the sweet spot and the northern and western fringes of Focus Area 1 is 3-4 X the variation associated with the sweet spot variable in the regression model, which treats all production within the sweet spot as a unit. Inspection of the raw data, using either Figure 6.2.2 or Figure 5.3.1, reveals a large number of wells on the N-S azimuth where these contours are located.[26] This feature of the contour plot is informed by a large number of observations.

Figure 6.2.3

The productive trend running from southwest to northeast is also apparent. One feature of the data revealed by Figure 6.2.1 and Figure 6.2.2 that is not apparent in the simple map presented in Figure 5.3.1 is a super-productive margin on the eastern boundary of the developed area. There is considerably less data here. We would require more observations to determine whether the effect is real.

---

[25] Figure 5.2.3 illustrates the same phenomenon in yet another manner.

[26] Both plots disguise a large number of wells completed in close proximity in the most productive part of the field.

A second term that represents the joint influence of sand and water is described in Figure 6.2.4. The tensor associated with these two variables generates an F-statistic of 2.81 that rejects the null hypothesis at 1 percent. The contours for sand and water illustrate the tradeoff between these two variables that is apparent in much of the horizontal completion data that we have considered, which includes other locations that are not discussed here. Each contour represents 1 BBLs per ft GPI of 12-month production. The range of variation that is described in the upper right quadrant of Figure 6.2.4 is 6 – 8 bbls per ft GPI, which is roughly double the combined influence of sand water suggested by the regression model as presented in Table 6.1.2. The R2 of a model containing only these two tensors is 66 percent.

Figure 6.2.4

The economic implications of the GAM are summarized in Table 6.2.2. The full model has an R2 of 68 percent. The GAM results are consistent with the linear regression model, the visualizations, and the basic statistics presented above.

Table 6.1.2: Production Variation Suggested by Parameter Estimates

			Production Shift	
Parameter	Significant?	Variation	BBLs per Ft GPI	Percentage of Mean
Noble	Y	NA	4.4	33
Whiting	N	NA	1.3	10
Sweet Spot	Y	NA	10-12	83
GPI	Y	3500 ft	2.8	21
Sand & Water	Y	4 percent	6-8	53
CnF	N	NA	-0.4	-3

TVD does not appear in Table 6.2.1 or Table 6.2.2, despite the strong relationship between TVD and production that is apparent in Figure 5.2.1. We tested for the influence of TVD, both independently and through the location tensor, and found no incremental effect. This is likely due to a lack of data, as we are able to observe an incremental contribution from TVD in the case of some operators when we check for stability by re-estimating the model on an operator-by-operator basis.

The GAM results may reflect some over-fitting, and their utility is constrained by features of individual fracs that are unobservable. The GAM results are nonetheless useful, in that they demonstrate the consistency of different approaches to estimation, and the stability of the parameters describing the relationship between production and GPI, and production and CnF. The primary determinant of well productivity is location, followed by completion parameters including GPI, sand and water. Individual operator effects are important. The use of CnF in frac fluid appears to be irrelevant.

6.3 Stability

We have devoted considerable effort to parsing the data in order to assure ourselves and the reader that the results presented here are not attributable to a few outliers or an important omitted variable. The robust regression model and GAM were computed operator-by-operator. The reduction in sample size reduces the precision of parameter estimates and the power of test statistics, but the results are consistent. There is a strong relationship between production and location, and a strong location between production and GPI, both of which are statistically significant.[27] We find no evidence in the data that CnF enhances production.

Visualizations (case studies) for the individual operators and additional analysis reveal some other features of interest. For example, TVD is able to explain meaningful variation in production for individual operators who complete wells in a more confined area. There is nothing in any data that we have considered which suggests that the sample considered here is anomalous.

7.0 Focus Area 2

The data from Focus Area 2 are different from the data from Focus Area 1 in several important respects. Production in Focus Area 2 is lower on average and much less volatile than production in Focus Area 1. The contrast is evident in Figure 7.0.1. In addition, the use of CnF is much more prevalent in Focus Area 2. 82 percent of our Focus Area 2 completions were treated with CnF, vs 56 percent in Focus Area 1. Finally, there is less geographical overlap in completions, which makes it more difficult to distinguish operator effects and location.

Figure 7.0.1

The structure of the data is consistent between the two fields, as evidenced by the GAM output that is summarized in Table 7.0.1. Location is the most important determinant of production. Latitude and longitude explain 30 percent of overall variation in Focus Area 2 production. The GAM contour plot picks out two production sweet spots that are apparent in the data, and describes variation of 8 BBLs per ft GPI between the most productive and least productive parts of the field. Productivity declines sharply on the margins of the field. The test statistic associated with the tensor that describes the location effect rejects the null hypothesis at 10^{-14}.

Longer completions are less productive than shorter completions. The estimated impact of a 1000 ft increase in GPI on production is 0.35 BBLs per ft GPI in Focus Area 2, which is about half the value of that parameter in Focus Area 1. The t-statistic associated with the GPI parameter estimate in the GAM is 3.18. Estimated parameter values are consistent across specificatons.

[27] Test statistics fail to reject the null for location and GPI in the case of Carrizo where N = 32.

Table 7.0.1: Parameter Estimates from a Generalized Additive Model of Focus Area 2 Production

Variable	Units	Estimate	Test statistic	p-value
Noble	Indicator	0.63	1.65	0.10
Bill Barrett	Indicator	2.42	2.75	0.01
CnF	Indicator	-0.15	0.30	0.76
Location	NA		6.40	10^{-12}
GPI	1000 ft	0.35	3.18	< 0.01
Sand & Water	NA		1.57	0.14

The sand and water contours have a reasonable appearance, and indicate variation of 5-6 BBLs per ft GPI, but are not statistically significant in their own right. This is likely a consequence of the fact that we observe less experimentation with input parameters in Focus Area 2, which has been in production for a much longer period of time than Focus Area 1. The presence of CnF in frac fluid has no measurable influence on production.

Bonanza Creek serves as the benchmark for the operator effect, which is smaller than what we observe in Focus Area 1. Regressions for individual operators give no hint of instability.

8.0 Closing the Loop

8.1 Intuition

The difference between the results presented here and the conclusions suggested by considering a sample average are summarized in Table 8.1.1, using data from Focus Area 1. The rows of the table correspond to completion length. The columns correspond to location, as represented by the sweet spot polygon. In each cell, we present average production for the type of well defined by the cell, the number of completions of that type in Focus Area 1, and the number of completions of that type that incorporate CnF. For example, the upper left cell indicates that 7 long completions carried out in the Focus Area 1 sweet spot had average 12-month production of 15.7 BBLs per ft GPI, and that none of those completions involved the use of CnF.

Table 8.1.1: Location, Completion Length, Production and CnF

	Sweet Spot	No
GPI > 6,000 ft	15.7 (0 / 7)	8.9 (30 / 111)
GPI < 6,000 ft	17.1 (97 / 118)	13.3 (18 / 31)

The feature of the data that produced the result documented by MHA in Focus Area 1 is found in the lower left cell. 97 of 118 short completions carried out in the sweet spot involved the use of CnF. These wells yielded an average of 17.1 BBLs of oil per ft GPI. Two-thirds of the wells in Focus Area 1 that used CnF were short completions in the sweet spot. The evidence presented in Table 5.1.1 indicates that the relative productivity of short wells should not be attributed to the use of CnF. The evidence presented in Table 5.3.2 indicates that the uplift associated with operating in the sweet spot is not attributable to CnF. The only reasonable interpretation of the evidence in Table 8.0.1, in light of the data considered here, is that wells treated with CnF in Focus Area 1 were productive because of their (short) completion length and where they were located.

Another view of the data, organized in a similar fashion, illustrates the same point. In Table 8.1.2, we have calculated the uplift associated with CnF use for each type of well, first by operator, then averaged across operators. Consider, for example, the -0.72 that appears in the lower left cell. We compute the average production difference between Noble wells completed with CnF and Noble wells completed without CnF, within the group of sweet spot completions with GPI < 6,000 ft. The exercise is repeated for Carrizo wells and Whiting wells. Averaging these gains produces the -0.72 BBLs per ft GPI reported in the table. Entries in the other cells are computed in a similar fashion. The upper left cell is empty because we don't have the CnF, non-CnF pairs required to populate it.

Table 8.1.2: Location, Completion Length, Production Uplift from CnF Use

	Sweet Spot	No
GPI > 6,000 ft	NA	0.04
GPI < 6,000 ft	-0.72	-1.91

The results of this exercise look similar on an operator-by-operator basis, carried out in Focus Area 1 or Focus Area 2.

8.2 Summary of Model Results

The ability of a GAM to predict production from wells treated with CnF using well characteristics that are independent of CnF is described in the bottom row of Table 8.2.1. The GAM predicts 12-month production of 15.2 BBLs per ft GPI for wells treated with CnF and 10.6 BBLs per ft GPI for wells not treated with CnF, vs observed values of 15.3 BBLs and 10.7 BBLs respectively, when CnF is excluded from the GAM.[28] The robust regression described in Table 6.1.1, which uses the sweet spot indicator variable rather than the more flexible GAM specification, yields fitted values of 15.2 BBLs per ft GPI and 10.2 BBLs per ft GPI when CnF is

[28] This is the model that is discussed in Section 6.2. Parameter estimates are presented in Table 6.2.1.

excluded from the regression. The robust regression described in Table 4.3.3 that uses only GPI and operator identity yields fitted values of 15.1 BBLs per ft GPI and 10.2 BBLs per ft GPI.

All of these models yield the same message as Table 8.1.1 about the variation in production between Focus Area 1 wells that were treated with CnF and comparison wells considered by MHA or us. Wells treated with CnF in Focus Area 1 were in fact more productive than comparable wells, but the difference in performance is explained by observable well characteristics rather than the presence of CnF in frac fluid.

Table 8.2.1: 12-Month Production and CnF Use in Focus Area 1

Focus Area 1	CnF Wells	Non CnF Wells	Improvement
MHA Report	16.6	11.3	5.3
MHA Method, Our Sample	16.3	11.0	5.3
Corrected, Our Sample	15.3	10.7	4.6
Predicted by well characteristics	15.2	10.7	4.5

The estimated marginal contribution of CnF to production from these different approaches to evaluation is summarized in Table 8.2.2. The first model indicates marginal uplift of 1 percent. The last three approaches all suggest –3 percent. None of the estimates is significantly different from zero.

Table 8.2.2: Estimated Contribution of CnF to 12-Month Production in Focus Area 1

Method	Variables	CnF Uplift
Robust Regression	Operator, GPI	0.10
Robust Regression	Operator, GPI, Location, Sand, Water	-0.35
GAM	Operator, GPI, Location, Sand, Water	-0.40
Compare and average	Operator, Location, GPI	-0.38

Comparable results for Focus Area 2 are presented in Table 8.2.3 and Table 8.2.4. A GAM that does not incorporate CnF predicts 12-month production of 10.9 BBLs per ft GPI for wells treated with CnF and 10.5 BBLs per ft GPI for wells not treated with CnF, vs observed values of 10.9 BBLs and 10.6 BBLs respectively. A robust regression that uses sweet spot indicator variables rather than the more flexible GAM specification yields fitted values of 10.4 BBLs per ft GPI for non-CnF wells and 10.9 BBLs per ft GPI for wells treated with CnF. A robust regression that incorporates only GPI and operator identity yields fitted values of 10.4 BBLs per ft GPI and 10.8 BBLs per ft GPI.

Table 8.2.3: 12 Month Production and CnF Use in Focus Area 2

Focus Area 2	CnF Wells	Non CnF Wells	Improvement
MHA Report	11.0	9.3	1.7
MHA Method, Our Sample	11.7	9.6	2.1
Corrected, Our Sample	10.9	10.6	0.3
Predicted by Well Characteristics	10.9	10.5	0.4

The marginal contribution of CnF to 12 Month production is estimated at ~-0.15 BBLs per ft GPI by the three regression specifications, and 0.54 BBLs per ft GPI by the simple "compare and average" approach that produces the results in Table 8.1.2.

Table 8.2.4: Estimated Contribution of CnF to 12-Month Production in Focus Area 2

Method	Variables	CnF Uplift
Robust Regression	Operator, GPI	-0.20
Robust Regression	Operator, GPI, Location, Sand, Water	-0.16
GAM	Operator, GPI, Location, Sand, Water	-0.08
Compare and average	Operator, Location, GPI	0.54

In all of these models, location, sand and water explain the vast majority of observed variation in production. As noted above, the R2 from GAM of Focus Area 1 production that involves only location is 54 percent. Adding sand and water increases the R2 to 66 percent. The incremental contribution of operator identity and CnF is to increase the model R2 to 68 percent.

Operator identity is linked closely to location: the R2 of the "stripped down" regression model that considers only operator identity is 48 percent. We are able to distinguish location from operator identify in Focus Area 1 using the GAM or a more more elaborate regression model only because Carrizo, Noble and Whiting operate in close proximity, with well locations that overlap.

The role of location, sand and water in the analysis presented here is to explain why MHA identified CnF uplift of 47 percent in Focus Area 1, and would have identified uplift of 3 percent in Focus Area 2 had they interpreted FracFocus correctly. The estimated impact of CnF on production is estimated consistently, independent of the other variables, even in the simple specification where we consider the role of the operator and the length of the perforated interval.

9.0 Conclusions

We believe that the results documented here are meaningful in at least two respects. One is that we are able to identify visually and measure econometrically relationships between production and completion parameters that are consistent across operators and locations. This aspect of the study is somewhat remarkable given the range of parameters that we cannot observe, which would certainly include stage length, cluster spacing and the pumping rate. We attribute our ability to extract information from the sample to the fact that many of these variables would have evolved only slowly during the time period in question. We can nonetheless see in the residuals from the econometric model a pattern that we interpret as evidence of a systematic search for optimal values of at least one unobservable parameter (residuals increase systematically from negative values to positive values in several different episodes).

The second meaningful feature of the results presented here is the consistent estimate that we obtain for the impact of CnF on production. A wide variety of models, implemented across locations and operators, produce estimated CnF slope coefficients that are less than 1 in absolute value and not significantly different from zero.

We contrast this stability with the conclusions suggested by a simple comparison of mean production across wells completed with CnF and without CnF, as documented by MHA. The interpretation of the data offered by MHA would suggest that CnF has a tremendous (42 percent) impact on well productivity in Focus Area 1, with only a slight (3 percent) impact on production in Focus Area 2, once we classify wells correctly. The lack of stability suggested by these parameters is evident in the other studies that MHA prepared for Flotek, which produce estimates of the relationship between CnF use and production that are essentially random.

The stability of our results extends to other locations. We have developed an analysis of well productivity in the Bone Spring formation of the Permian Basin, using the same approach implemented here, that identifies a systematic relationship between completion parameters and well productivity. That study also indicates that the incremental impact of CnF on well productivity is zero.

Appendix A
Trade Names for Additives Containing CnF

	Supplier	Number of Wells	MHA ?
OilPerm B	Halliburton	150	Y
GasPerm 1100	Halliburton	102	Y
OilPerm FMM-1	Halliburton	97	N
OilPerm FMM-2	Halliburton	48	Y
FDP-S1007-11	Halliburton	30	N
DWP-937	CWS	6	Y
OilPerm	Halliburton	5	N
StimOil FBA M	Flotek	4	Y
Total CnF		442	
Total Non-CnF		162	

RK Trading

Sylvania

White Paper Figures

November 30, 2016

Location of Wells in Focus Area 1 and Focus Area 2
Color Scale Indicates 12−Month Oil Production per Foot GPI

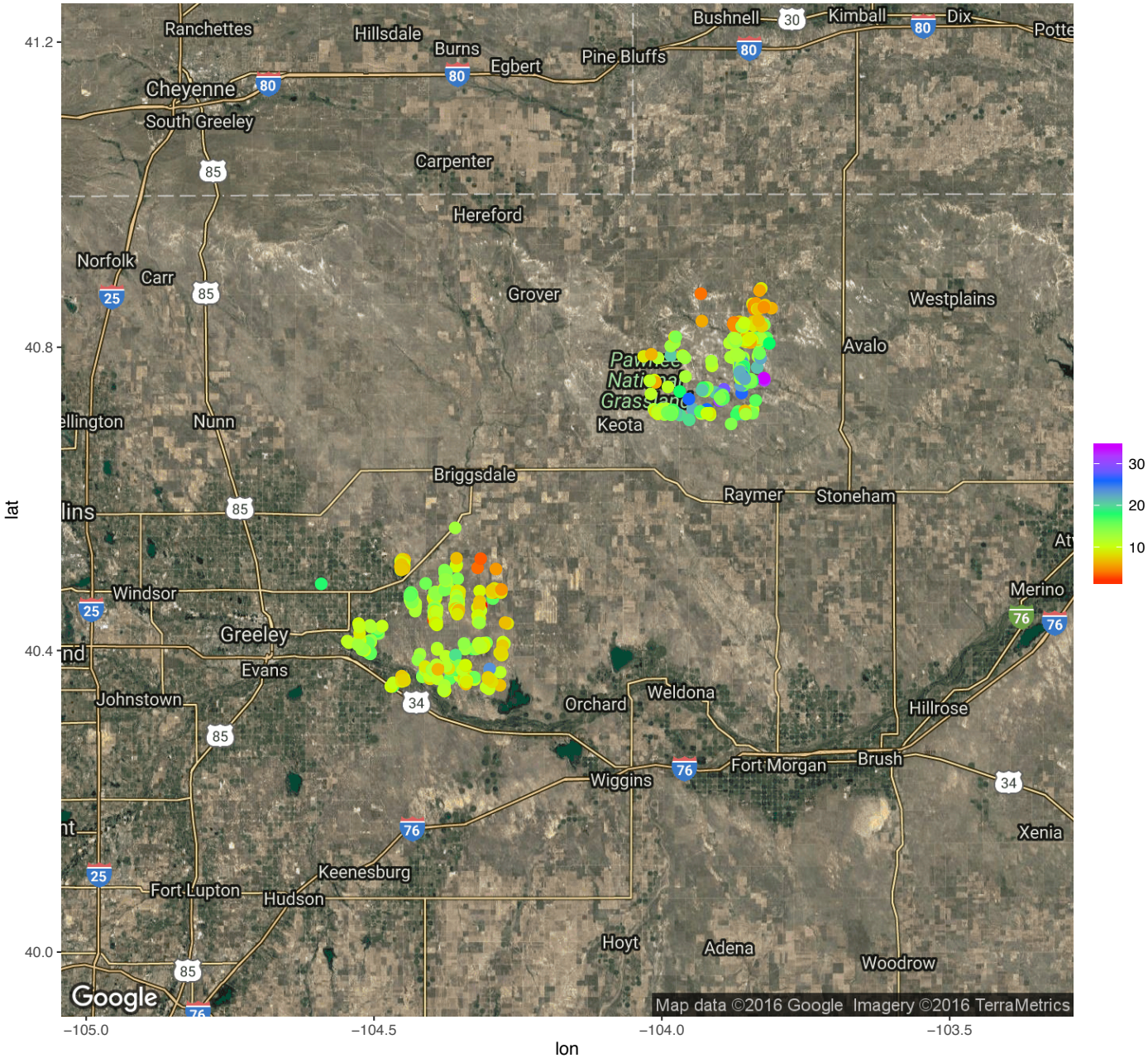


Figure 3.2. 1

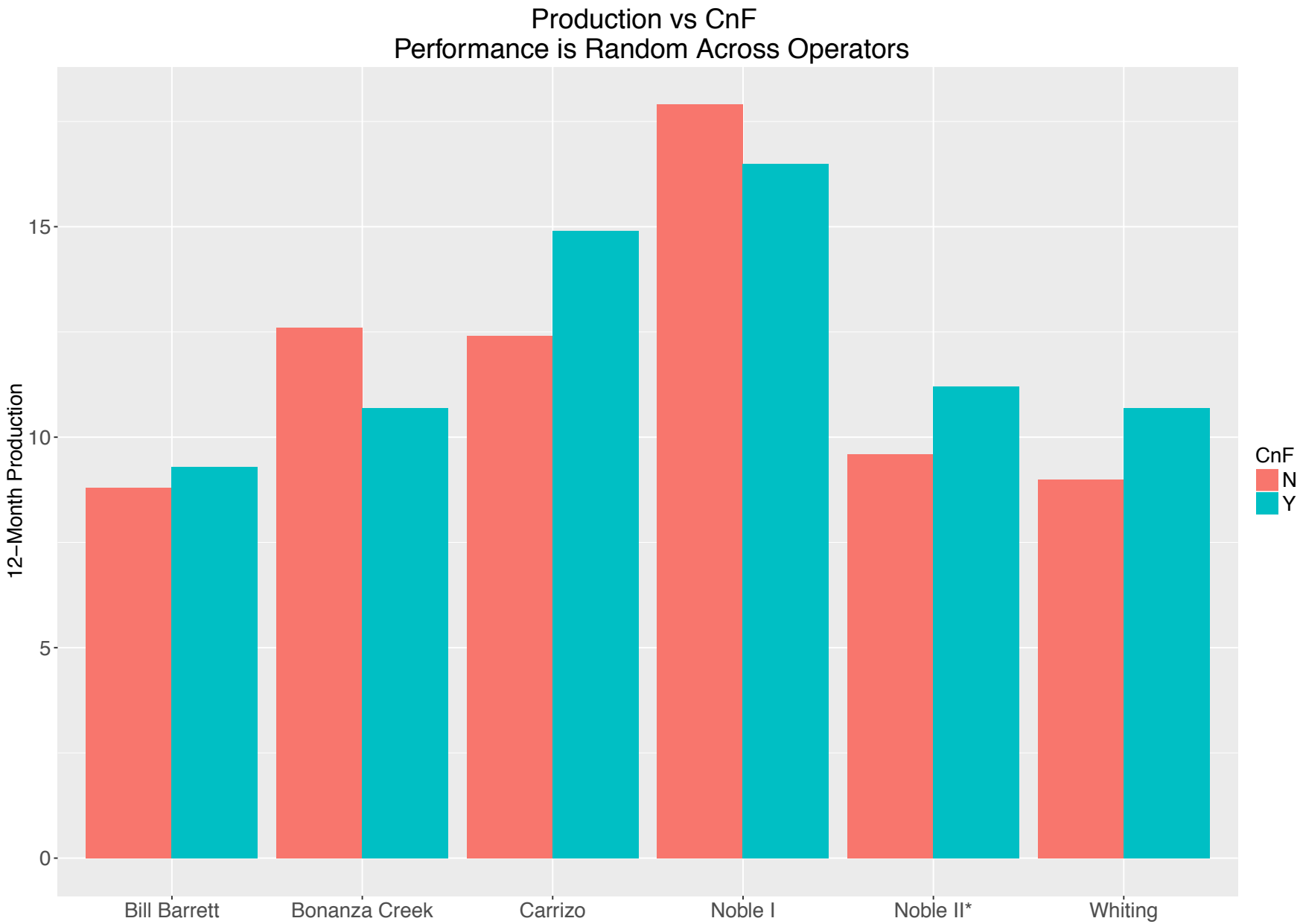

Production vs CnF
Performance is Random Across Operators
12–Month Production
0
5
10
15
Bill Barrett
Bonanza Creek
Carrizo
Noble I
Noble II*
Whiting
CnF
N
Y

Figure 4.1.1

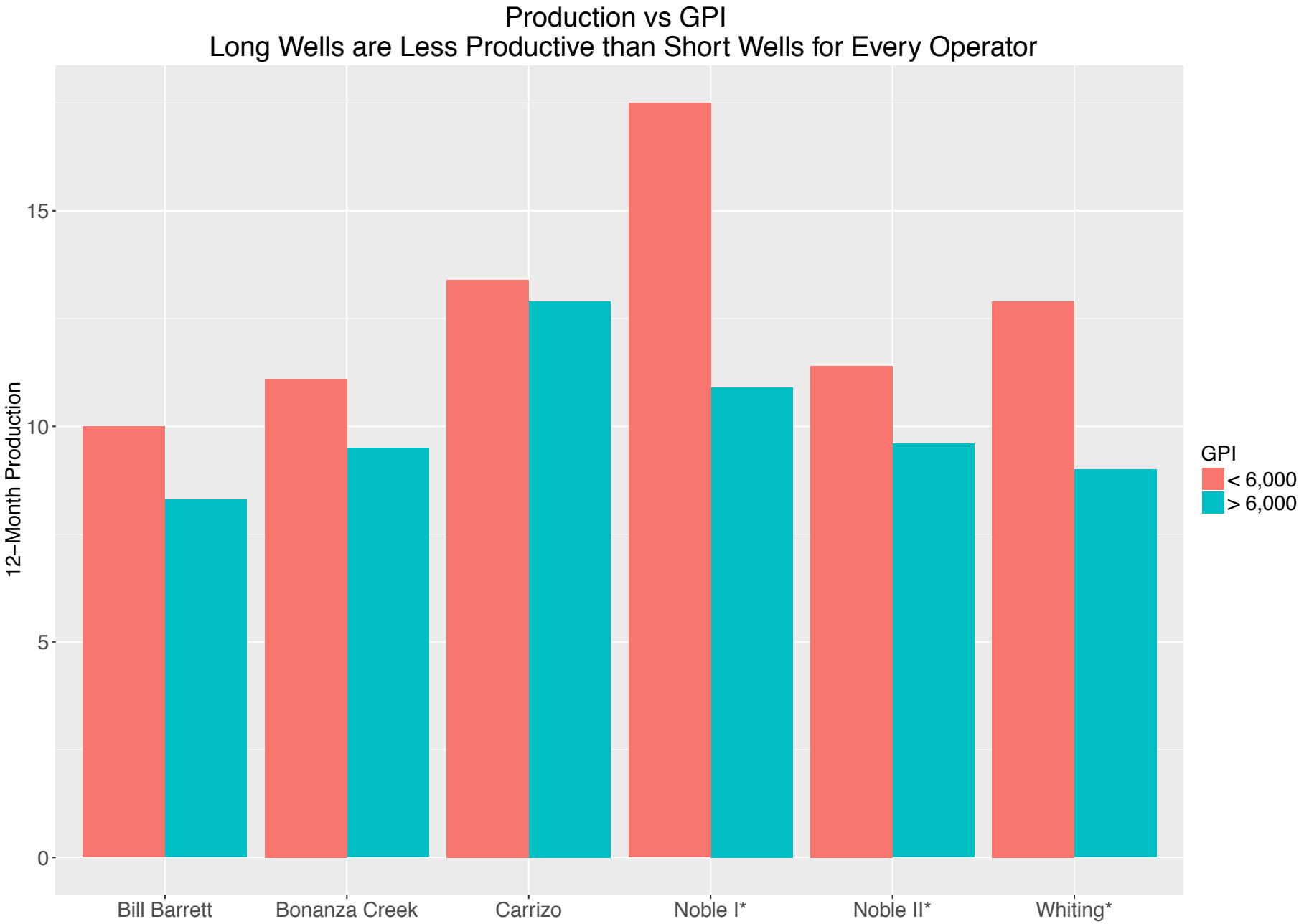

Production vs GPI
Long Wells are Less Productive than Short Wells for Every Operator
12–Month Production
0
5
10
15
Bill Barrett
Bonanza Creek
Carrizo
Noble I*
Noble II*
Whiting*
GPI
< 6,000
> 6,000

Figure 4.2.1

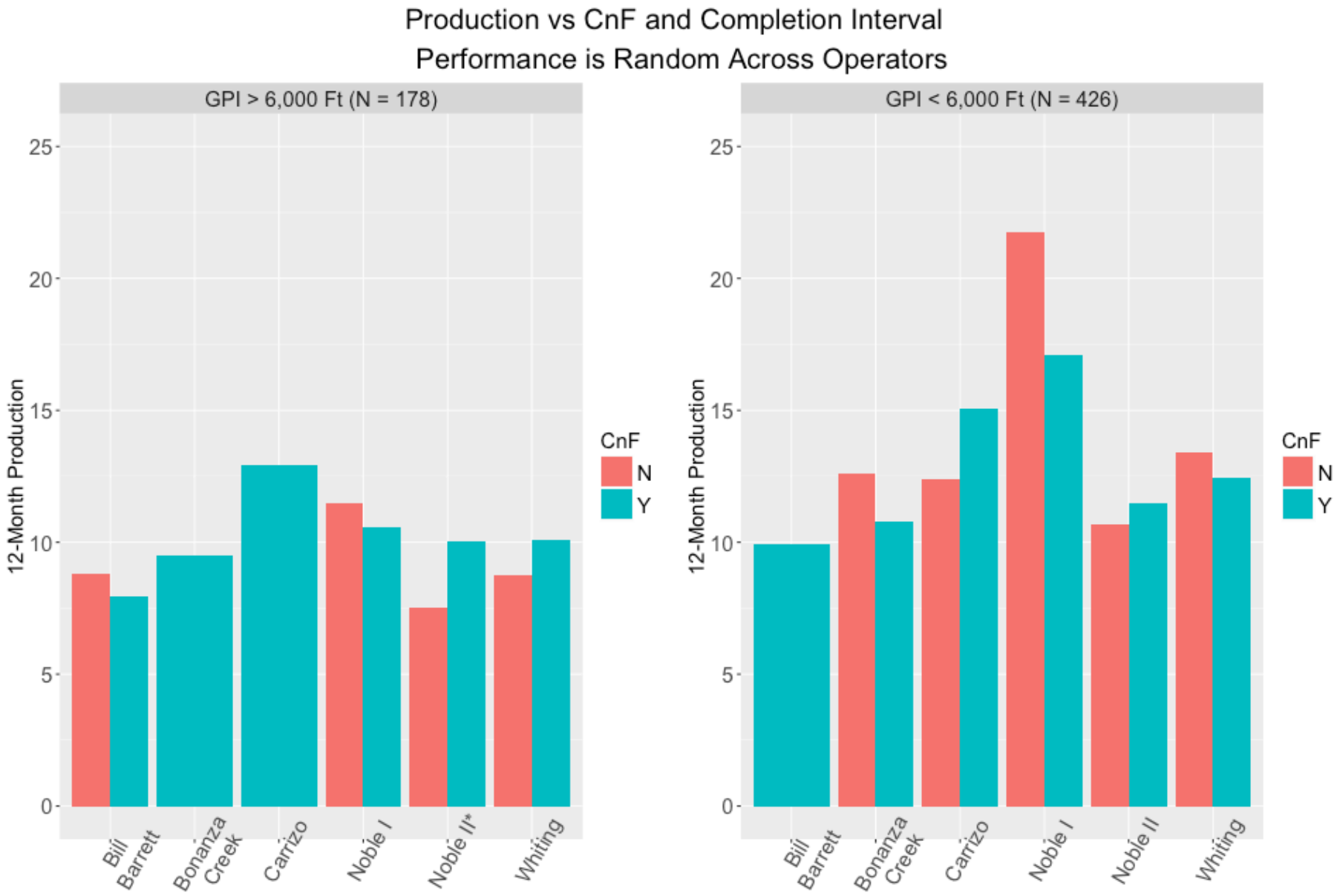

Production vs CnF and Completion Interval
Performance is Random Across Operators
GPI > 6,000 Ft (N = 178)
GPI < 6,000 Ft (N = 426)
12-Month Production
0
5
10
15
20
25
Bill Barrett
Bonanza Creek
Carrizo
Noble I
Noble II*
Noble II
Whiting
CnF
N
Y

Figure 4.3.1

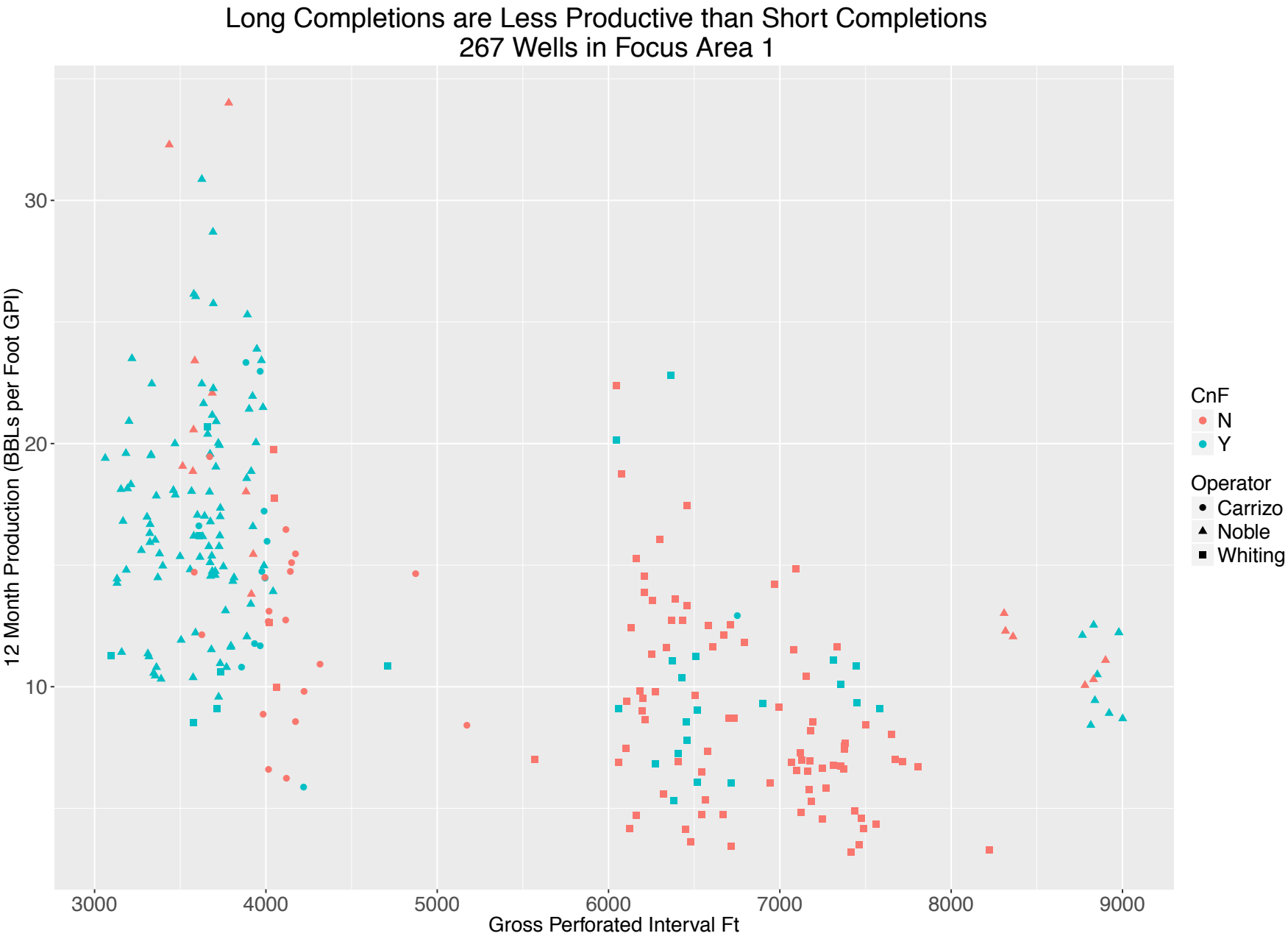

Long Completions are Less Productive than Short Completions
267 Wells in Focus Area 1
12 Month Production (BBLs per Foot GPI)
30
20
10
3000
4000
5000
6000
7000
8000
9000
Gross Perforated Interval Ft
CnF
N
Y
Operator
Carrizo
Noble
Whiting

Figure 5.1.1

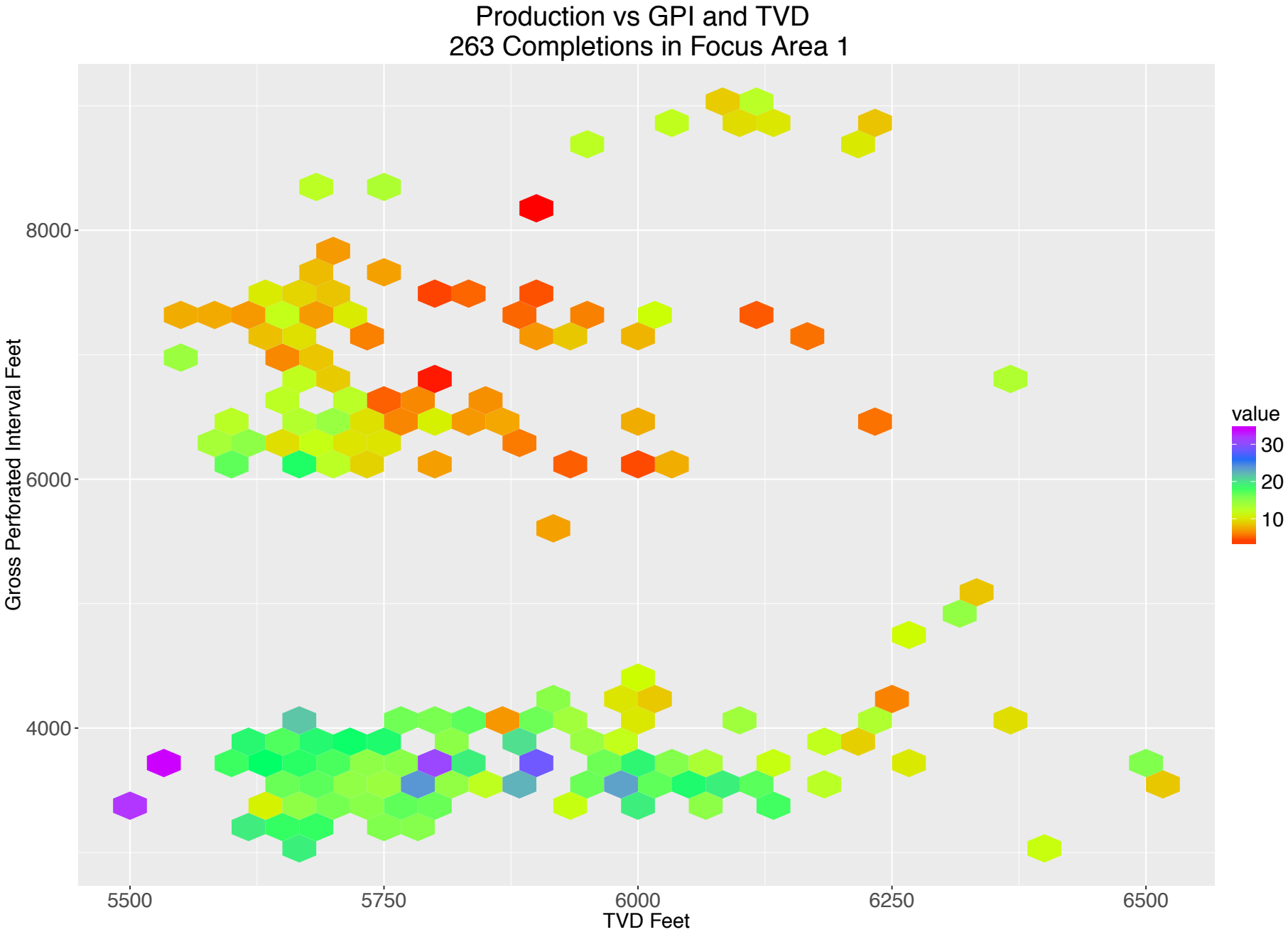

Production vs GPI and TVD
263 Completions in Focus Area 1
Gross Perforated Interval Feet
8000
6000
4000
5500
5750
6000
6250
6500
TVD Feet
value
30
20
10

Figure 5.2.1

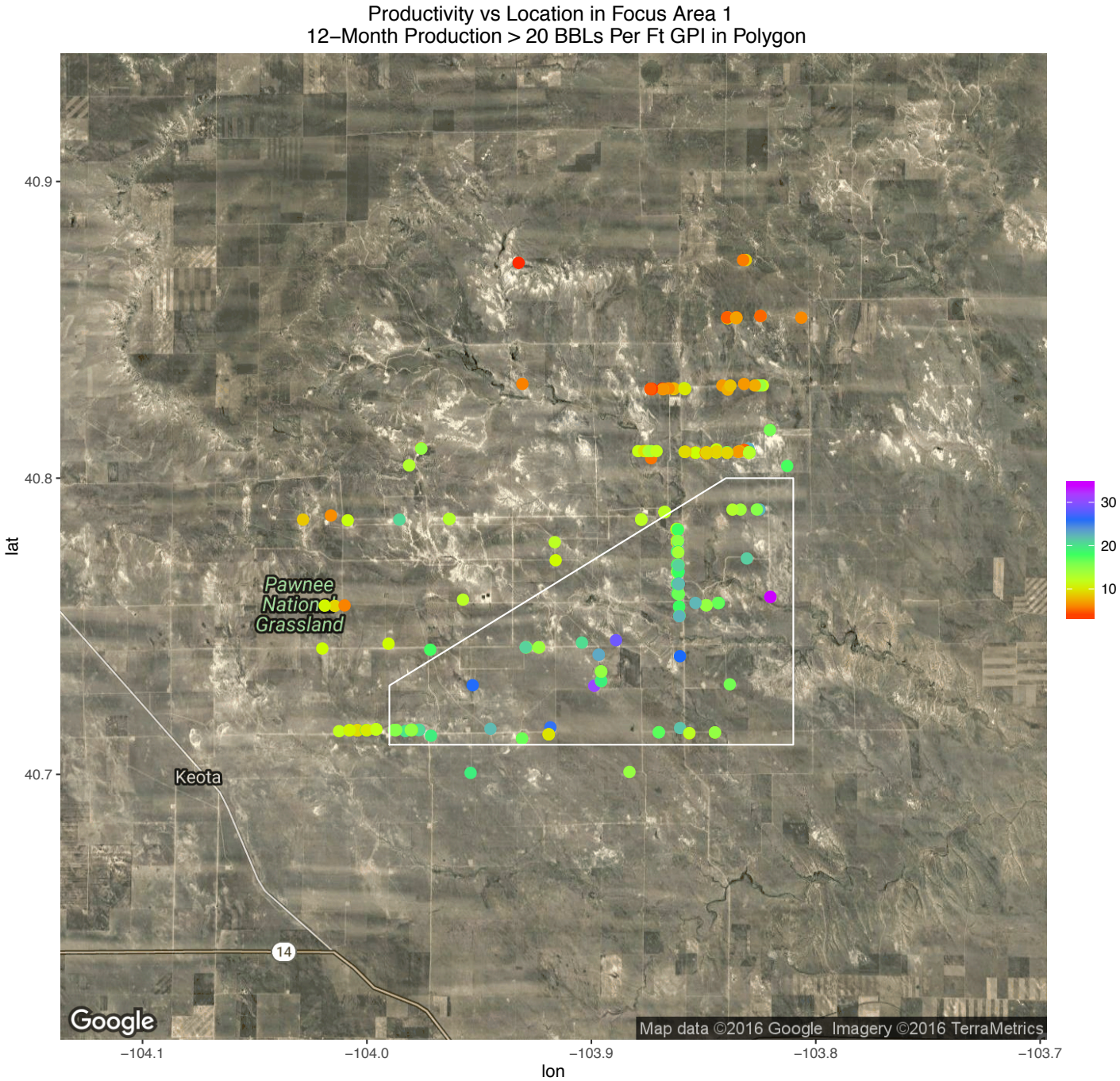

Productivity vs Location in Focus Area 1
12−Month Production > 20 BBLs Per Ft GPI in Polygon
40.9
40.8
40.7
lat
−104.1
−104.0
−103.9
−103.8
−103.7
lon
30
20
10
Pawnee National Grassland
Keota
14
Google
Map data ©2016 Google Imagery ©2016 TerraMetrics

Figure 5.3.1

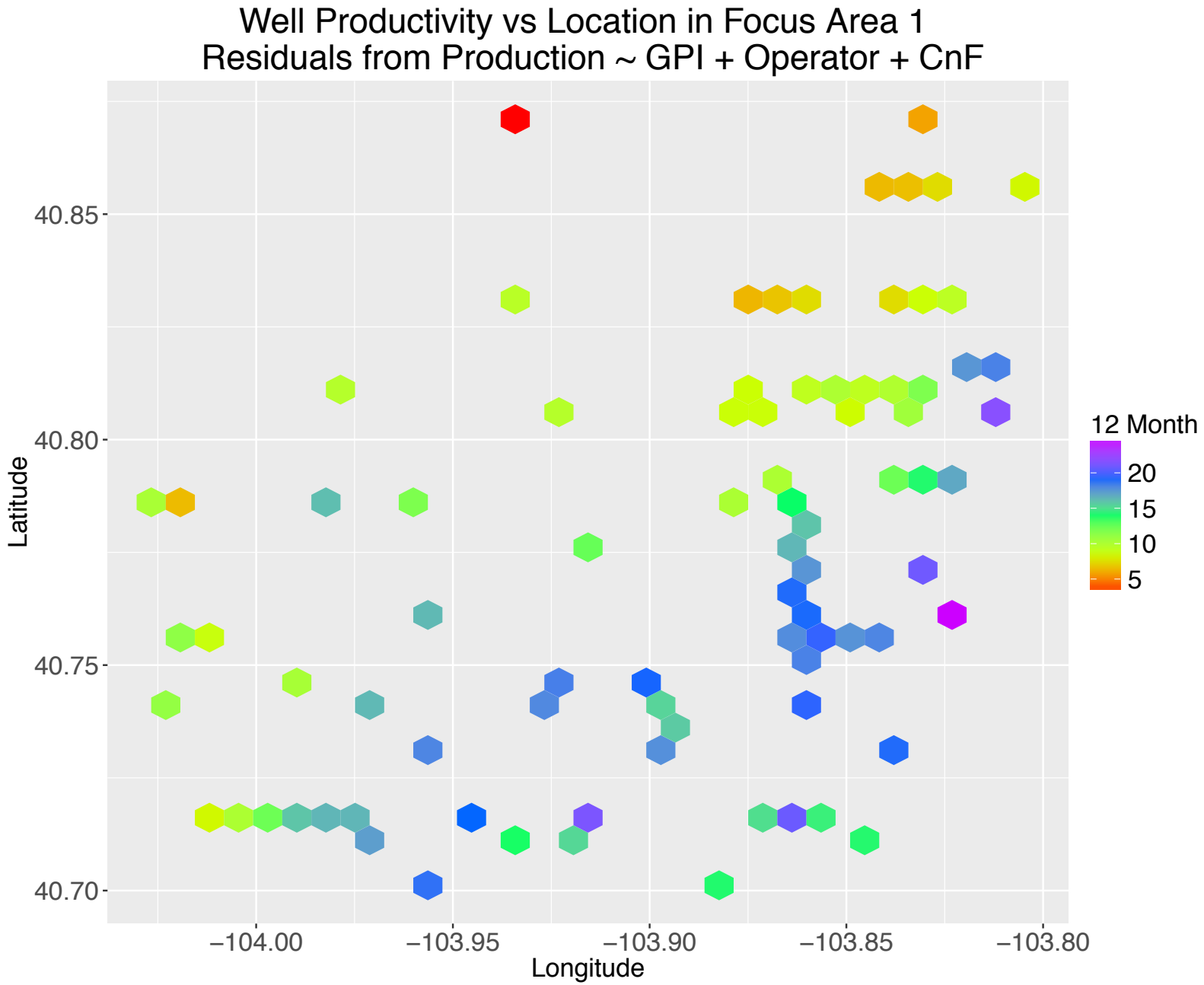

Well Productivity vs Location in Focus Area 1
Residuals from Production ~ GPI + Operator + CnF
Latitude
40.85
40.80
40.75
40.70
−104.00
−103.95
−103.90
−103.85
−103.80
Longitude
12 Month
20
15
10
5

Figure 5.3.2


Production vs Sand Concentration
267 Wells in Focus Area 1
12 Month Production (BBLs per Foot GPI)
30
20
10
7.5
10.0
12.5
15.0
17.5
Sand Concentration in Frac Fluid (Percentage Weight)
CnF
N
Y
Operator
Carrizo
Noble
Whiting

Figure 5.4.1

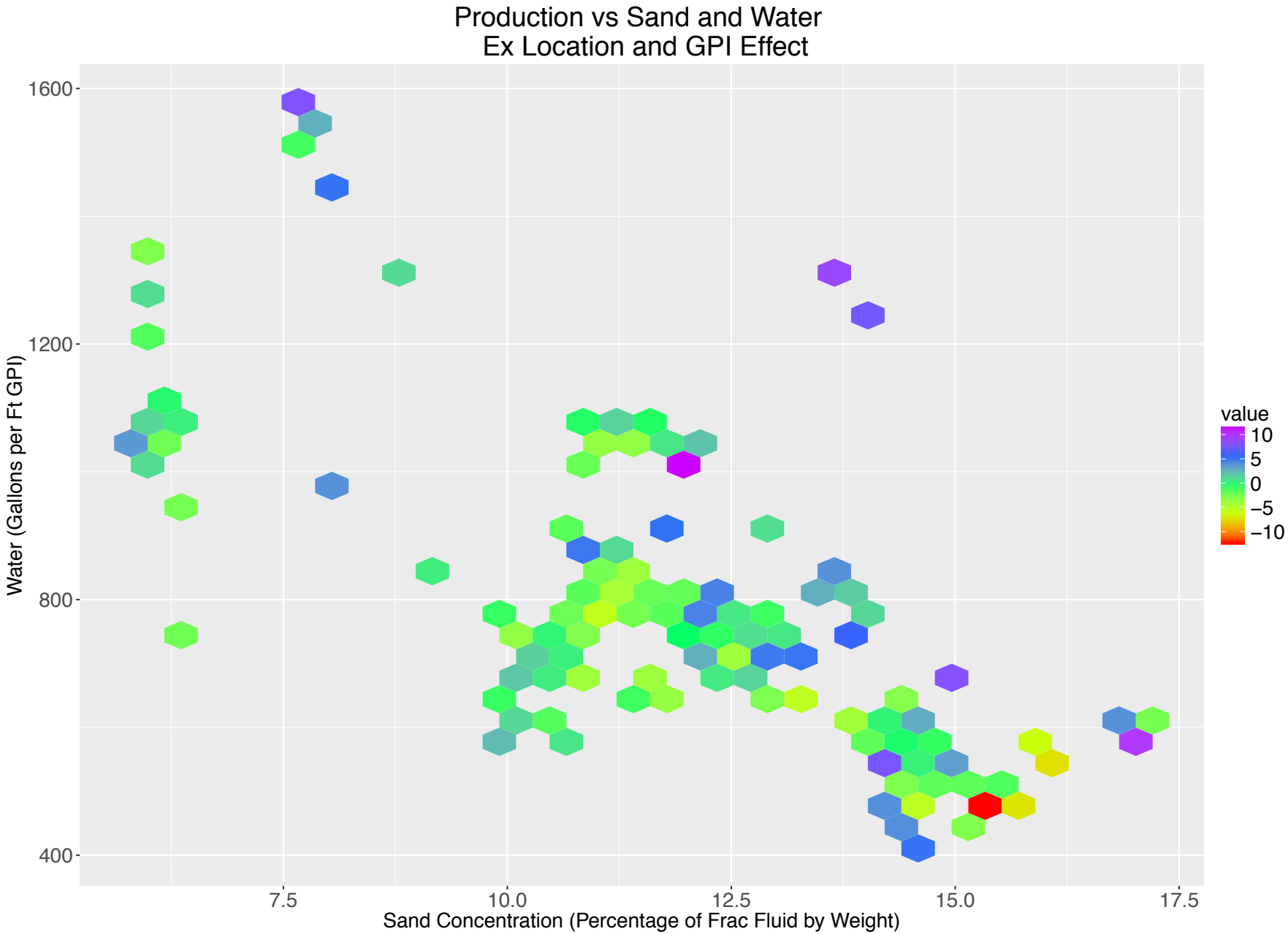

Production vs Sand and Water
Ex Location and GPI Effect
Water (Gallons per Ft GPI)
1600
1200
800
400
7.5
10.0
12.5
15.0
17.5
Sand Concentration (Percentage of Frac Fluid by Weight)
value
10
5
0
−5
−10

Figure 5.4.2

Location vs Production from the GAM

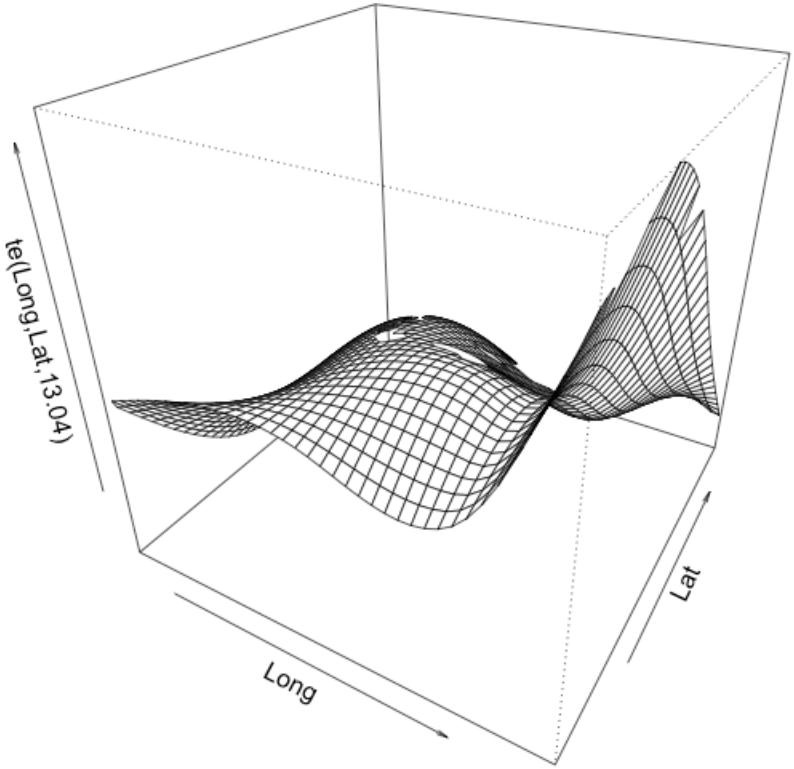


Figure 6.2.1

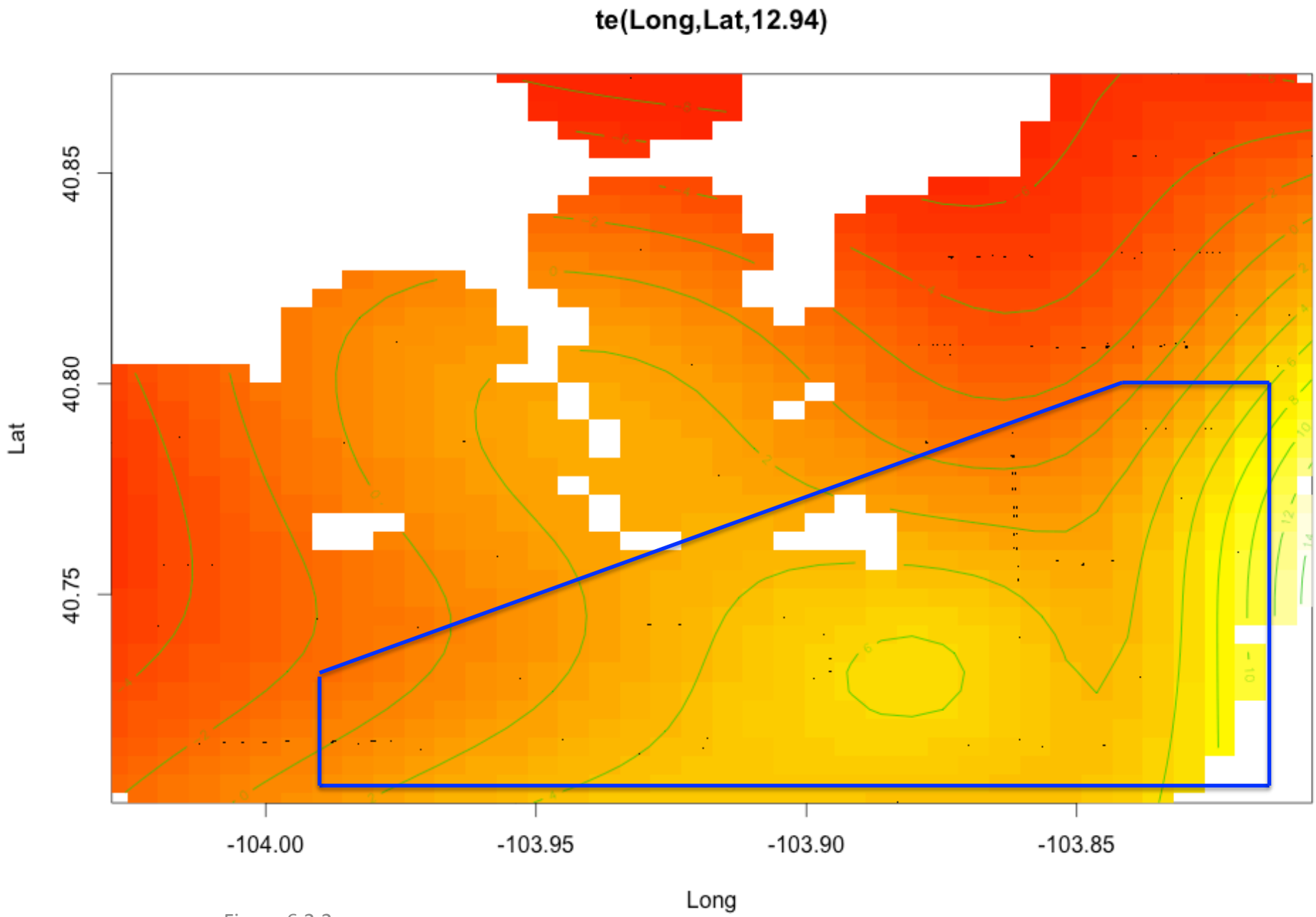

te(Long,Lat,12.94)
40.85
40.80
40.75
Lat
-104.00
-103.95
-103.90
-103.85
Long

Figure 6.2.2


Well Productivity vs Location in Focus Area 1
Productive Trend Runs SW to NE
40.85
40.80
40.75
40.70
Lat
−104.00
−103.95
−103.90
−103.85
−103.80
Long
12 Month
20
15
10
5

Figure 6.2.3

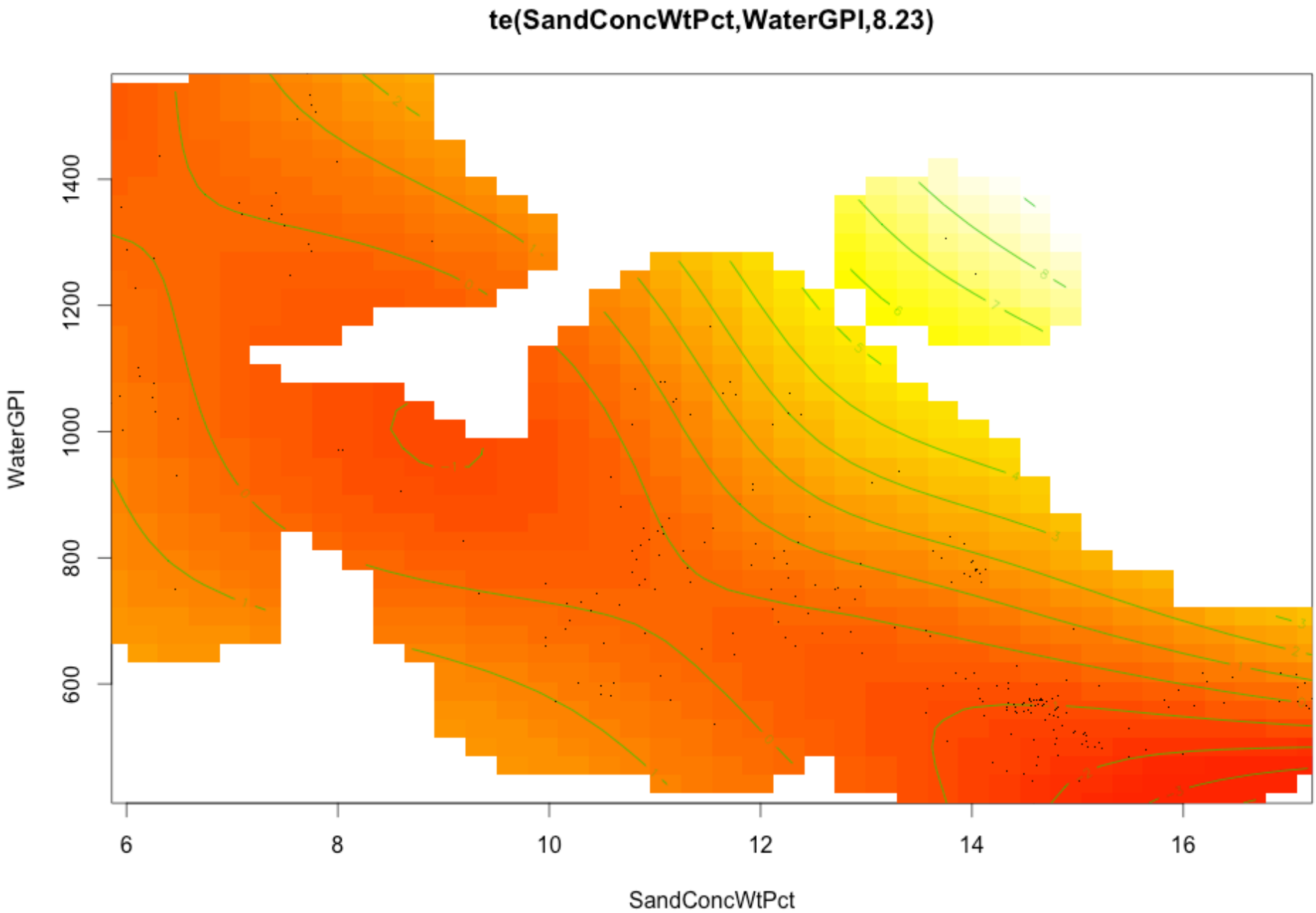

te(SandConcWtPct,WaterGPI,8.23)
WaterGPI
1400
1200
1000
800
600
6
8
10
12
14
16
SandConcWtPct

Figure 6.2.4

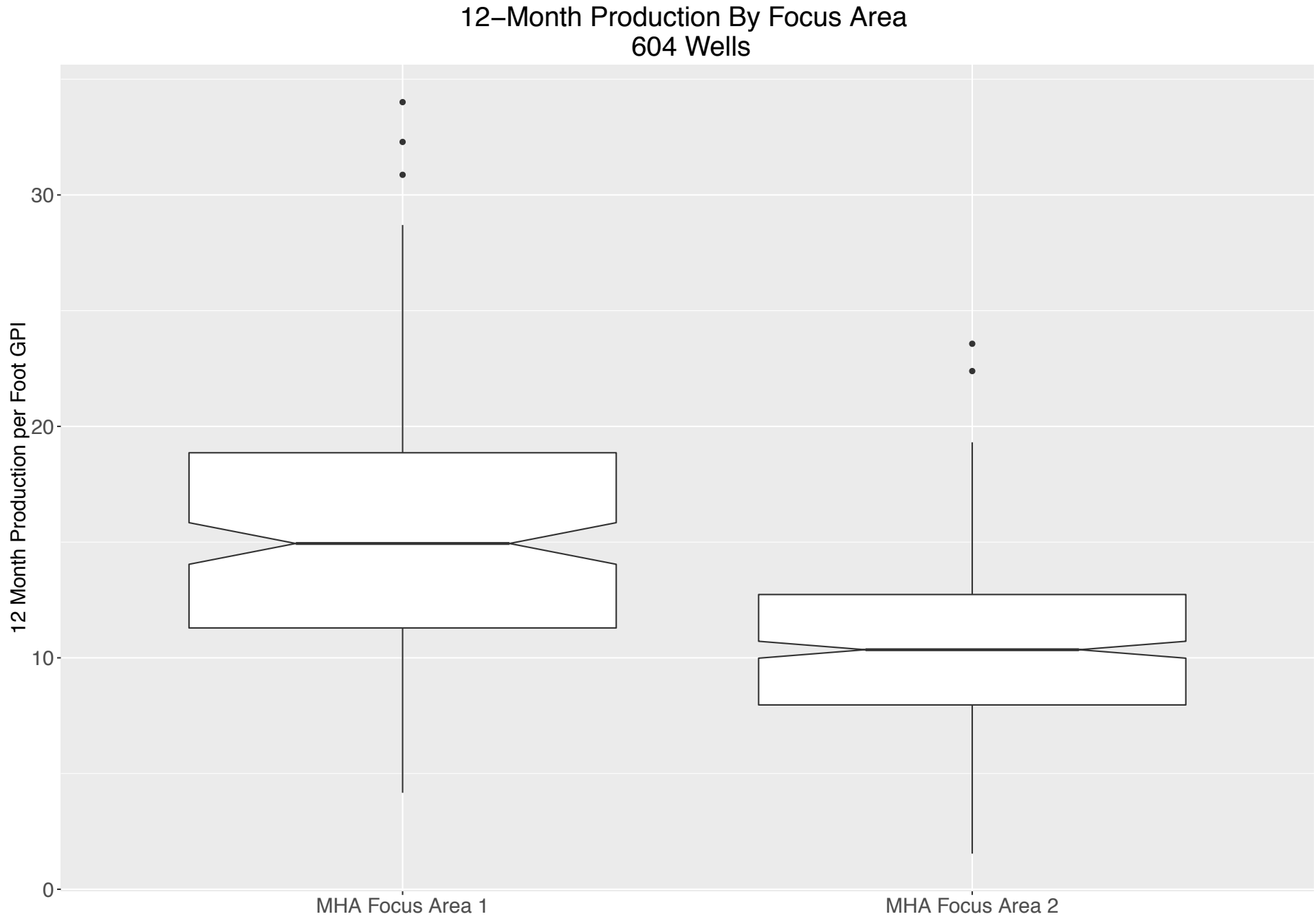

12−Month Production By Focus Area
604 Wells
12 Month Production per Foot GPI
30
20
10
0
MHA Focus Area 1
MHA Focus Area 2

Figure 7.0.1

Appendix B – Database Compilation

FourWorld compiled the master database by doing the following:

1. Downloaded all well data into Microsoft Access from FracFocus, following instructions outlined on the site (http://fracfocus.org/data-download).

2. Performed database processes in Microsoft Access for all FracFocus disclosures made after the introduction of FracFocus 2.0 to determine, query and organize:

    a) Terpene Wells: Each chemical recorded in FracFocus is designated with a unique Chemical Abstracts Service Number ("CAS Number"). CAS numbers are recorded in FracFocus for all chemicals used in each well. CAS numbers beginning with 68647 and 94266 indicate the presence of citrus terpene – the key ingredient included in all of Flotek's CnF products. Wells with CAS numbers beginning with 94266 or 68647 were found and labelled as potentially containing CnF.

    b) All Wells: Isolated all unique wells in the United States.

3. Exported Access query results to Excel and removed duplicates.

    a) Duplicate wells were defined as those with matching start date, API and total base water volume.

4. Screened terpene wells using a list of CnF trade names verified by Sylvania to verify the presence of CnF. Wells that contained citrus terpene but no Trade Name matching our list were further scrutinized and removed from our well database if no additional information indicating the presence of CnF was found.

    a) Downloaded FracFocus pdf file for all wells with ambiguous or generic trade names. For many of these wells, a corrected CnF trade name was found and added manually.

    b) Wells where a CnF trade name was unable to be found and chemicals indicative of CnF were not present were isolated and removed from our well database. These wells were not used in any study conducted by FourWorld.

    c) Trade names with typos were corrected to consolidate for analysis.

5. Downloaded the "All Production Reports Received by Year" data files from 2012 to 2016 from the COGCC website (http://cogcc.state.co.us/data2.html#/downloads) for all wells in Weld County CO, and combined with FracFocus data. Wells with missing production months were identified and rectified with COGCC.

Appendix C – CnF Trade Names

In order to find CnF wells, contents of all wells were screened against a list of trade names verified by Sylvania. The 10 trade names occurring most frequently within our list of CnF wells are included in Table 1.

This trade name list was created using the following sources:

1. MHA Reports: trade names provided by FTK to MHA
2. Material Safety Data Sheets ("MSDS"): these documents give detailed information about the nature of chemicals sold by chemical manufacturers. These documents must be made publicly available by chemical manufacturers, and can be found relatively easily on manufacturer (Halliburton) or MSDS aggregation websites. We determined which products contain CnF by comparing the contents listed on MSDS for white labelled products with those from MHA's CnF trade name list.
    - Table 2 lists Trade Names from Halliburton's suite of "OilPerm" products, and includes a column showing those we found to be CnF, which was determined using MSDS sourced from Halliburton's website.
3. CnF Patents: we compared white-labelled products with Flotek's patents for CnF. Per this analysis, Citrus Terpenes (CAS number 68647 or 94266) were found to be a good preliminary proxy for CnF.
4. FracFocus download and pdf files
    - Used to identify products containing citrus terpenes
    - Supplier information used to examine if 6 products supplied through Flotek, the Flotek Store, or CESI

Appendix C - Continued

Table 1

Top 10 CnF Trade Names		
Trade Name	Well Count	% Total
MA-844W	837	13.42%
OilPerm FMM-1	836	13.41%
GasPerm 1100	694	11.13%
OilPerm B	561	9.00%
Flo-Back Prime	430	6.90%
StimOil ENHF	330	5.29%
DWP-937	298	4.78%
FDP-S1007-11	294	4.71%
GasPerm 1000M	265	4.25%
StimOil FBA M	257	4.12%
Top 10 Trade Names	4802	77.00%
All Trade Names	6236	100.00%

Table 2

Halliburton Product Analysis

Product	Citrus Terpene CAS		CnF
	68647	94266	
OilPerm A	N	N	N
OilPerm B*	N	Y	Y
OilPerm FM-1	Y	N	Y
OilPerm FM-7*	Y	N	Y
OilPerm FMM-1	N	Y	Y
OilPerm FMM-2*	N	Y	Y
OilPerm FMM-3	Y	N	Y
OilPerm FMM-4	N	N	N
OilPerm FMM-5	Y	Y	I
OilPerm FMM-6	N	N	N
OilPerm FMM-7	N	Y	Y
OilPerm FMM-8	N	N	N
OilPerm FMM-9	N	N	N
OilPerm FMM-9-21	N	N	N
FDP-S1007-11*	N	Y	Y

*Trade Name identified by MHA as CnF

Inconclusive – Does not appear in any wells in FracFocus. Indicated application is a "wetting agent" (not a surfactant) on the MSDS sheet.

Appendix D – MSDS Sheets

The following pages include MSDS Sheets for Halliburton's OilPerm FMM-1 and OilPerm FMM-2

HALLIBURTON

SAFETY DATA SHEET

Product Trade Name: OilPerm FMM-1

Revision Date: 03-Jun-2015 **Revision Number:** 5

1. Identification

1.1. Product Identifier

Product Trade Name: OilPerm FMM-1
Synonyms: None
Chemical Family: Blend
Internal ID Code HM007597

1.2 Recommended use and restrictions on use

Application: Surfactant
Uses Advised Against No information available

1.3 Manufacturer's Name and Contact Details

Manufacturer/Supplier Halliburton Energy Services, Inc.
P.O. Box 1431
Duncan, Oklahoma 73536-0431
Emergency Telephone: (281) 575-5000

Prepared By Chemical Stewardship
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

1.4. Emergency telephone number

Emergency Telephone Number (281) 575-5000

2. Hazard(s) Identification

2.1 Classification in accordance with paragraph (d) of §1910.1200

Skin Corrosion / Irritation	Category 2 - H315
Serious Eye Damage / Eye Irritation	Category 2 - H319
Skin Sensitization	Category 1 - H317
Carcinogenicity	Category 2 - H351
Specific Target Organ Toxicity - (Single Exposure)	Category 2 - H371
Acute Aquatic Toxicity	Category 2 - H401
Chronic Aquatic Toxicity	Category 2 - H411
Flammable liquids.	Category 2 - H225

2.2. Label Elements

Hazard Pictograms

Signal Word Danger

Hazard Statements

H225 - Highly flammable liquid and vapor
H315 - Causes skin irritation
H317 - May cause an allergic skin reaction
H319 - Causes serious eye irritation
H351 - Suspected of causing cancer
H371 - May cause damage to organs
H401 - Toxic to aquatic life
H411 - Toxic to aquatic life with long lasting effects

Precautionary Statements

Prevention

P201 - Obtain special instructions before use
P202 - Do not handle until all safety precautions have been read and understood
P210 - Keep away from heat/sparks/open flames/hot surfaces. - No smoking
P233 - Keep container tightly closed
P240 - Ground/Bond container and receiving equipment
P241 - Use explosion-proof electrical/ventilating/lighting/equipment
P242 - Use only non-sparking tools
P243 - Take precautionary measures against static discharge
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P264 - Wash face, hands and any exposed skin thoroughly after handling
P270 - Do not eat, drink or smoke when using this product
P272 - Contaminated work clothing should not be allowed out of the workplace
P273 - Avoid release to the environment
P280 - Wear protective gloves/protective clothing/eye protection/face protection

Response

P303 + P361 + P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower
P337 + P313 - If eye irritation persists: Get medical advice/attention
P362 - Take off contaminated clothing and wash before reuse
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P333 + P313 - If skin irritation or rash occurs: Get medical advice/attention
P308 + P313 - IF exposed or concerned: Get medical advice/attention
P370 + P378 - In case of fire: Use water spray for extinction
P391 - Collect spillage

Storage

P403 + P235 - Store in a well-ventilated place. Keep cool
P405 - Store locked up

Disposal P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains

Substances	CAS Number
Ethanol	64-17-5
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0
Citrus, extract	94266-47-4
Isopropanol	67-63-0
Heavy aromatic petroleum naphtha	64742-94-5
Terpene hydrocarbon by-products	68956-56-9
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0
Naphthalene	91-20-3

2.3 Hazards not otherwise classified

None known

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - US
Ethanol	64-17-5	10 - 30%	Eye Irrit. 2A (H319) Flam. Liq. 2 (H225)
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	5 - 10%	Skin Irrit. 2 (H315) Eye Irrit. 2 (H319) Aquatic Acute 2 (H401)
Citrus, extract	94266-47-4	5 - 10%	Skin Irrit. 2 (H315) Eye Irrit. 2 (H319) Skin Sens. 1 (H317) Asp. Tox. 1 (H304) Aquatic Acute 1 (H400) Aquatic Chronic 2 (H411) Flam. Liq. 3 (H226)
Isopropanol	67-63-0	5 - 10%	Eye Irrit. 2 (H319) STOT SE 3 (H336) Flam. Liq. 2 (H225)
Heavy aromatic petroleum naphtha	64742-94-5	1 - 5%	STOT SE 3 (H336) Asp. Tox. 1 (H304) Aquatic Acute 2 (H401) Aquatic Chronic 2 (H411)
Terpene hydrocarbon by-products	68956-56-9	1 - 5%	Skin Irrit. 2 (H315) Eye Irrit. 2 (H319) Skin Sens. 1 (H317) Asp. Tox. 1 (H304) Aquatic Acute 2 (H401) Aquatic Chronic 2 (H411) Flam. Liq. 3 (H226)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	1 - 5%	Skin Irrit. 2 (H315) Eye Corr. 1 (H318) STOT SE 2 (H371) Aquatic Acute 1 (H400) Aquatic Chronic 1 (H410)
Naphthalene	91-20-3	0.1 - 1%	Acute Tox. 4 (H302) Carc. 2 (H351) Aquatic Acute 1 (H400) Aquatic Chronic 1 (H410) Flam. Sol. 2 (H228)

The exact percentage (concentration) of the composition has been withheld as proprietary.

4. First-Aid Measures

4.1. Description of first aid measures

Inhalation	If inhaled, move victim to fresh air and seek medical attention.
Eyes	Check for and remove contact lenses if present. In case of contact, or suspected contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention immediately after flushing.
Skin	In case of contact, immediately flush skin with plenty of soap and water for at least 15 minutes. Get medical attention. Remove contaminated clothing and launder before reuse.
Ingestion	Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

4.2 Most important symptoms/effects, acute and delayed

Causes skin irritation. Causes eye irritation May cause allergic skin reaction. Potential carcinogen. May cause damage to internal organs.

4.3. Indication of any immediate medical attention and special treatment needed

Notes to Physician	Treat symptomatically.

5. Fire-fighting measures

5.1. Extinguishing media

Suitable Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons

None known.

5.2 Specific hazards arising from the substance or mixture

Special Exposure Hazards

May be ignited by heat, sparks or flames. Use water spray to cool fire exposed surfaces. Closed containers may explode in fire. Decomposition in fire may produce toxic gases.

5.3 Special protective equipment and precautions for fire-fighters

Special Protective Equipment for Fire-Fighters

Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Use appropriate protective equipment. Wear self-contained breathing apparatus in enclosed areas.
See Section 8 for additional information

6.2. Environmental precautions

Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up

Isolate spill and stop leak where safe. Remove ignition sources and work with non-sparking tools. Scoop up and remove. Contain spill with sand or other inert materials.

7. Handling and storage

7.1. Precautions for Safe Handling

Handling Precautions
Ground and bond containers when transferring from one container to another. Avoid contact with eyes, skin, or clothing. Avoid breathing vapors. Avoid breathing mist. Wash hands after use. Launder contaminated clothing before reuse.
Hygiene Measures
Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities
Storage Information
Store away from oxidizers. Keep from heat, sparks, and open flames. Keep container closed when not in use. Terpene containing products should be stored in phenolic-lined metal, stainless steel, PET, or fluorinated plastic containers. Product has a shelf life of 24 months.

8. Exposure Controls/Personal Protection

8.1 Occupational Exposure Limits

Substances	CAS Number	OSHA PEL-TWA	ACGIH TLV-TWA
Ethanol	64-17-5	1000 ppm	STEL: 1000 ppm
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Not applicable	Not applicable
Citrus, extract	94266-47-4	Not applicable	Not applicable
Isopropanol	67-63-0	TWA: 400 ppm	TWA: 200 ppm STEL: 400 ppm
Heavy aromatic petroleum naphtha	64742-94-5	Not applicable	Not applicable
Terpene hydrocarbon by-products	68956-56-9	Not applicable	Not applicable
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Not applicable	Not applicable
Naphthalene	91-20-3	10 ppm	TWA: 10 ppm STEL: 15 ppm

8.2 Appropriate engineering controls

Engineering Controls Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation.

8.3 Individual protection measures, such as personal protective equipment

Personal Protective Equipment If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.

Respiratory Protection If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional.
Organic vapor respirator.
In high concentrations, supplied air respirator or a self-contained breathing apparatus.

Hand Protection Nitrile gloves. Impervious rubber gloves.
Skin Protection Rubber apron.
Eye Protection Chemical goggles; also wear a face shield if splashing hazard exists.
Other Precautions Eyewash fountains and safety showers must be easily accessible.

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State:	Liquid	**Color:**	Light amber
Odor:	Citrus	**Odor Threshold:**	No information available

Property Remarks/ - Method	Values
pH:	7.85
Freezing Point/Range	No data available
Melting Point/Range	No data available
Boiling Point/Range	No data available
Flash Point	17.5 °C / 63.5 °F PMCC
Flammability (solid, gas)	No data available
upper flammability limit	No data available
lower flammability limit	No data available
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	0.91
Water Solubility	No data available
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%)	No data available

10. Stability and Reactivity

10.1. Reactivity

Not expected to be reactive.

10.2. Chemical Stability

Stable

10.3. Possibility of Hazardous Reactions

Will Not Occur

10.4. Conditions to Avoid

Keep away from heat, sparks and flame.

10.5. Incompatible Materials

Iodine pentafluorethylene Strong acids. Strong alkalis. Strong oxidizers.

10.6. Hazardous Decomposition Products

Carbon monoxide and carbon dioxide. Oxides of nitrogen.

11. Toxicological Information

11.1 Information on likely routes of exposure

Principle Route of Exposure Eye or skin contact, inhalation.

11.2 Symptoms related to the physical, chemical and toxicological characteristics

Acute Toxicity

Inhalation May cause respiratory irritation. May cause central nervous system depression including headache, dizziness, drowsiness, incoordination, slowed reaction time, slurred speech, giddiness and unconsciousness.

Eye Contact Causes eye irritation.

Skin Contact Causes skin irritation. May cause skin defatting with prolonged exposure. May cause an allergic skin reaction.

Ingestion Irritation of the mouth, throat, and stomach. May cause abdominal pain, vomiting, nausea, and diarrhea. May cause central nervous system depression including headache, dizziness, drowsiness, muscular weakness, incoordination, slowed reaction time, fatigue blurred vision, slurred speech, giddiness, tremors and convulsions. Aspiration into the lungs may cause chemical pneumonitis including coughing, difficulty breathing, wheezing, coughing up blood and pneumonia, which can be fatal.

Chronic Effects/Carcinogenicity Repeated overexposure may cause liver and kidney effects.
The International Agency for Research on Cancer (IARC) has evaluated naphthalene and determined it to be a possible carcinogen to humans (Group 2B, based on sufficient evidence in experimental animals and inadequate evidence in humans).

11.3 Toxicity data

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Ethanol	64-17-5	7060 mg/kg (Rat) 10,470 mg/kg (Rat)	> 15,800 mg/kg (Rabbit) 17,100 mg/kg (Rabbit)	124.7 mg/L (Rat) 4h
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	> 5000 mg/kg (Rat) (similar substance)	> 2000 mg/kg (Rabbit) (similar substance)	> 6 mg/L (Rat) 4h (similar substance)
Citrus, extract	94266-47-4	> 5000 mg/kg (Rat)	> 5000 mg/kg (Rabbit)	> 1000 mg/kg (Mouse)
Isopropanol	67-63-0	4396 mg/kg (Rat) 5840 mg/kg (Rat) 3600 mg/kg (Mouse)	12,800 mg/kg (Rat) 12,870 mg/kg (Rabbit) 6280 mg/kg (Rabbit)	72.6 mg/L (Rat) 4h > 10,000 mg/L (Rat) 6h
Heavy aromatic petroleum naphtha	64742-94-5	> 5000 mg/kg (Rat)	> 2000 mg/kg (Rabbit)	> 4.778 mg/L (Rat) 4h
Terpene hydrocarbon by-products	68956-56-9	4400 mg/kg (Rat) (similar substance)	> 2000 mg/kg (Rat)	No data available
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	2000 - 5000 mg/kg (Rat) (Similar substance)	> 2000 mg/kg (Rabbit) (similar substance)	No data available
Naphthalene	91-20-3	490 mg/kg (Rat)	> 2000 mg/kg (Rabbit)	No data available

Substances	CAS Number	Skin corrosion/irritation
Ethanol	64-17-5	Not irritating to skin in rabbits.
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Causes moderate skin irritation. (similar substances)
Citrus, extract	94266-47-4	Causes moderate skin irritation. (Rabbit)
Isopropanol	67-63-0	Non-irritating to the skin (Rabbit)

Heavy aromatic petroleum naphtha	64742-94-5	Non-irritating to the skin (Rabbit)
Terpene hydrocarbon by-products	68956-56-9	Causes moderate skin irritation. (Rabbit)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Causes moderate skin irritation. (Rabbit)
Naphthalene	91-20-3	Non-irritating to the skin (Rabbit)

Substances	CAS Number	Eye damage/irritation
Ethanol	64-17-5	Causes moderate eye irritation. (Rabbit)
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Causes moderate eye irritation. (similar substances)
Citrus, extract	94266-47-4	Causes severe eye irritation.
Isopropanol	67-63-0	Causes severe eye irritation. (Rabbit)
Heavy aromatic petroleum naphtha	64742-94-5	Non-irritating to the eye (Rabbit)
Terpene hydrocarbon by-products	68956-56-9	Causes moderate eye irritation. (Rabbit) (similar substances)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Causes severe eye irritation which may damage tissue. (Rabbit)
Naphthalene	91-20-3	May cause mechanical irritation to eye. (human)

Substances	CAS Number	Skin Sensitization
Ethanol	64-17-5	Did not cause sensitization on laboratory animals
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Did not cause sensitization on laboratory animals (guinea pig) Patch test on human volunteers did not demonstrate sensitization properties (similar substances)
Citrus, extract	94266-47-4	May cause sensitization by skin contact
Isopropanol	67-63-0	Did not cause sensitization on laboratory animals (guinea pig)
Heavy aromatic petroleum naphtha	64742-94-5	Patch test on human volunteers did not demonstrate sensitization properties
Terpene hydrocarbon by-products	68956-56-9	May cause an allergic skin reaction. (mouse) (similar substances)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Patch test on human volunteers did not demonstrate sensitization properties
Naphthalene	91-20-3	Did not cause sensitization on laboratory animals (guinea pig)

Substances	CAS Number	Respiratory Sensitization
Ethanol	64-17-5	Did not cause sensitization on laboratory animals
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	No information available
Citrus, extract	94266-47-4	No information available
Isopropanol	67-63-0	No information available
Heavy aromatic petroleum naphtha	64742-94-5	No information available
Terpene hydrocarbon by-products	68956-56-9	No information available
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	No information available
Naphthalene	91-20-3	No information available

Substances	CAS Number	Mutagenic Effects
Ethanol	64-17-5	Not regarded as mutagenic.
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	In vitro tests did not show mutagenic effects In vivo tests did not show mutagenic effects. (similar substances)
Citrus, extract	94266-47-4	In vitro tests did not show mutagenic effects In vivo tests did not show mutagenic effects.
Isopropanol	67-63-0	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects.

Heavy aromatic petroleum naphtha	64742-94-5	In vitro tests did not show mutagenic effects In vivo tests did not show mutagenic effects.
Terpene hydrocarbon by-products	68956-56-9	In vitro tests did not show mutagenic effects
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	In vitro tests did not show mutagenic effects (similar substances)
Naphthalene	91-20-3	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects.

Substances	CAS Number	Carcinogenic Effects
Ethanol	64-17-5	Did not show carcinogenic effects in animal experiments
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	No information available.
Citrus, extract	94266-47-4	Did not show carcinogenic effects in animal experiments (similar substances)
Isopropanol	67-63-0	Did not show carcinogenic effects in animal experiments
Heavy aromatic petroleum naphtha	64742-94-5	Did not show carcinogenic effects in animal experiments
Terpene hydrocarbon by-products	68956-56-9	Did not show carcinogenic effects in animal experiments (similar substances)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Did not show carcinogenic or teratogenic effects in animal experiments (similar substances)
Naphthalene	91-20-3	Substances which should be regarded as if they are carcinogenic to man

Substances	CAS Number	Reproductive toxicity
Ethanol	64-17-5	Animal testing did not show any effects on fertility.
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Animal testing did not show any effects on fertility. Did not show teratogenic effects in animal experiments. (similar substances)
Citrus, extract	94266-47-4	Animal testing did not show any effects on fertility.
Isopropanol	67-63-0	No significant toxicity observed in animal studies at concentration requiring classification.
Heavy aromatic petroleum naphtha	64742-94-5	Animal testing did not show any effects on fertility. Did not show teratogenic effects in animal experiments.
Terpene hydrocarbon by-products	68956-56-9	Did not show teratogenic effects in animal experiments. (similar substances)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Not a confirmed teratogen or embryotoxin. (similar substances)
Naphthalene	91-20-3	Animal testing did not show any effects on fertility. Did not show teratogenic effects in animal experiments.

Substances	CAS Number	STOT - single exposure
Ethanol	64-17-5	No significant toxicity observed in animal studies at concentration requiring classification.
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Citrus, extract	94266-47-4	No significant toxicity observed in animal studies at concentration requiring classification.
Isopropanol	67-63-0	May cause headache, dizziness, and other central nervous system effects.
Heavy aromatic petroleum naphtha	64742-94-5	May cause disorder and damage to the Central Nervous System (CNS)
Terpene hydrocarbon by-products	68956-56-9	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Naphthalene	91-20-3	No data of sufficient quality are available.

Substances	CAS Number	STOT - repeated exposure
Ethanol	64-17-5	No significant toxicity observed in animal studies at concentration requiring classification.
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Citrus, extract	94266-47-4	No significant toxicity observed in animal studies at concentration requiring classification.

Isopropanol	67-63-0	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Heavy aromatic petroleum naphtha	64742-94-5	No significant toxicity observed in animal studies at concentration requiring classification.
Terpene hydrocarbon by-products	68956-56-9	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	No significant toxicity observed in animal studies at concentration requiring classification.
Naphthalene	91-20-3	No significant toxicity observed in animal studies at concentration requiring classification.

Substances	CAS Number	Aspiration hazard
Ethanol	64-17-5	Not applicable
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Not applicable
Citrus, extract	94266-47-4	Aspiration into the lungs may cause chemical pneumonitis including coughing, difficulty breathing, wheezing, coughing up blood and pneumonia, which can be fatal.
Isopropanol	67-63-0	Not applicable
Heavy aromatic petroleum naphtha	64742-94-5	Aspiration into the lungs may cause chemical pneumonitis including coughing, difficulty breathing, wheezing, coughing up blood and pneumonia, which can be fatal.
Terpene hydrocarbon by-products	68956-56-9	Aspiration into the lungs may cause chemical pneumonitis including coughing, difficulty breathing, wheezing, coughing up blood and pneumonia, which can be fatal.
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	Not applicable
Naphthalene	91-20-3	No information available

12. Ecological Information

12.1. Toxicity

Ecotoxicity Effects

Product Ecotoxicity Data

No data available

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Ethanol	64-17-5	No information available	LC50 > 100 mg/L (Pimephales promelas)	No information available	LC50 9268 - 14,221 mg/L (Daphnia magna) LC50 5012 mg/L (Ceridaphnia dubia) NOEC 9.6 mg/L (Daphnia magna)
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	EC50 (72h) 1.1 mg.L (Scenedesmus subspicatus) (similar substance) EC50 (72h) 22 mg/L (Scenedesmus subspicatus) (similar substance) EC50 (72h) 2.46 mg/L (Skeletonema costatum)	LC50 (96h) 4.5 mg/L (Brachydanio rerio) (similar substance) LC50 (96h) 2.9 mg/L (Oncorhynchus mykiss) (similar substance) LC50 (96h) > 2.5 mg/L (Scophthalmus maximus)	EC50 (3h) > 100 mg/L (Activated sludge) (similar substance)	EC50 (48h) 3.8 mg/L (Daphnia magna) (similar substance) EC50 (48h) 3.26 mg/L (Acartia tonsa)
Citrus, extract	94266-47-4	EC50 (72h) 20.41 mg/L (Skeletonema costatum)	LC50 (96h) >1000 mg/L (Scophthalmus maximus)	No information available	LC50 (48) 34.73 mg/L (Acartia tonsa) EC50 (48h) 0.577 mg/L (Daphnia magna)

Isopropanol	67-63-0	EC50 (72h) > 1000 mg/L (Desmodesmus subspicatus) EC50 (7d) 1800 mg/L (Scenedesmus quadricauda)	LC50 (96h) 9640 mg/L (Pimephales promelas) LC50 (7d) 7060 mg/L (Poecilia reticulata)	TT (16h) 1050 mg/L (Pseudomonas putida)	EC50 (48h) 13,299 mg/L (Daphnia magna) EC50 (24h) > 10,000 mg/L (Daphnia magna)
Heavy aromatic petroleum naphtha	64742-94-5	EC50 (72h) 7.8 mg/L (Pseudokirchneriella subcapitata)	LL50 (96h) 3.6 mg/L (Oncorhynchus mykiss) LC50 (96h) 357.7 mg/L (Scophthalmus maximus)	No information available	EL50 (48h) 1.1 mg/L (Daphnia magna) (similar substance)
Terpene hydrocarbon by-products	68956-56-9	ErC50 (72h) 4.779 mg/L (Pseudokirchnerella subcapitata) EC50 (72h) 63.59 mg/L (Skeletonema costatum)	LC50 (96h) 5.07 mg/L (Danio rerio) LC50 (96h) > 65 mg/L (Cyprinodon variegatus)	No information available	EL50 (48h) 1.4 - 2.7 mg/L (Daphnia magna) EC50 (48h) 155 mg/L (Acartia tonsa)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	EC50 (72h) > 3 mg/L (Pseudokirchnerella subcapitata) (similar substance)	LC50 (96h) 0.323 mg/L (Pimephales promelas) (similar substance)	EC50 (3h) 104 mg/L (Activated sludge) (similar substance)	EC50 (48h) 0.148 mg/L (Daphnia magna) (similar substance) NOEC (21d) 0.006 mg/L (Daphnia magna) (similar substance) NOEC (21d) 0.1 mg/L (Daphnia magna) (similar substance)
Naphthalene	91-20-3	EC50 (72h) 0.4 mg/L (Skeletonema costatum)	LC50 (96h) 1.6 mg/L (Oncorhynchus mykiss) NOEC (40d) 0.37 mg/L (Coho salmon fry)	IC50 (24h) 29 mg/L (Nitrosomonas)	EC50 (48h) 2.16 mg/L (Daphnia magna) NOEC (125d) 0.59 mg/L (Daphnia pulex)

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Ethanol	64-17-5	No information available
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	Readily biodegradable (96% @ 28d)
Citrus, extract	94266-47-4	Readily biodegradable (61% @ 28d)
Isopropanol	67-63-0	Readily biodegradable (53% @ 5d)
Heavy aromatic petroleum naphtha	64742-94-5	Readily biodegradable (58% @ 28d)
Terpene hydrocarbon by-products	68956-56-9	Readily biodegradable (83% @ 28d)
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	(58.7% @ 28d) (similar substances)
Naphthalene	91-20-3	Readily biodegradable (100% @ 7d)

12.3. Bioaccumulative potential

Substances	CAS Number	Log Pow
Ethanol	64-17-5	-0.32
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	2.63
Citrus, extract	94266-47-4	4.23
Isopropanol	67-63-0	0.05
Heavy aromatic petroleum naphtha	64742-94-5	2.9 - 6.1
Terpene hydrocarbon by-products	68956-56-9	5.7
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	2.1-3.4
Naphthalene	91-20-3	3.30

12.4. Mobility in soil

Substances	CAS Number	Mobility
Ethanol	64-17-5	No information available
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0	No information available

Citrus, extract	94266-47-4	KOC = 1300
Isopropanol	67-63-0	KOC = 1.5
Heavy aromatic petroleum naphtha	64742-94-5	No information available
Terpene hydrocarbon by-products	68956-56-9	No information available
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	No information available
Naphthalene	91-20-3	No information available

12.5 Other adverse effects
No information available

13. Disposal Considerations

13.1. Waste treatment methods

Disposal Method Disposal should be made in accordance with federal, state, and local regulations.
Contaminated Packaging Follow all applicable national or local regulations.

14. Transport Information

US DOT
UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Ethanol, Isopropanol)
Transport Hazard Class(es): 3
Packing Group: II
Environmental Hazards: Not applicable
NAERG: NAERG 128

US DOT Bulk
DOT (Bulk) Not applicable

Canadian TDG
UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Ethanol, Isopropanol)
Transport Hazard Class(es): 3
Packing Group: II
Environmental Hazards: Not applicable

IMDG/IMO
UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Ethanol, Isopropanol)
Transport Hazard Class(es): 3
Packing Group: II
Environmental Hazards: Not applicable
EMS: EmS F-E, S-E

IATA/ICAO
UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Ethanol, Isopropanol)
Transport Hazard Class(es): 3
Packing Group: II
Environmental Hazards: Not applicable

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code: Not applicable
Special Precautions for User: None

15. Regulatory Information

US Regulations

US TSCA Inventory	All components listed on inventory or are exempt.
EPA SARA Title III Extremely Hazardous Substances	Not applicable
EPA SARA (311,312) Hazard Class	Acute Health Hazard Chronic Health Hazard Fire Hazard
EPA SARA (313) Chemicals	This product contains toxic chemical(s) listed below which is(are) subject to the reporting requirements of Section 313 of Title III of SARA and 40 CFR Part 372: Isopropanol//67-63-0 Naphthalene//91-20-3 1,2,4-Trimethylbenzene//95-63-6
EPA CERCLA/Superfund Reportable Spill Quantity	EPA Reportable Spill Quantity is 2318 Pounds based on Naphthalene (CAS: 91-20-3).
EPA RCRA Hazardous Waste Classification	If product becomes a waste, it does meet the criteria of a hazardous waste as defined by the US EPA, because of: Ignitability D001
California Proposition 65	The California Proposition 65 regulations apply to this product.
MA Right-to-Know Law	One or more components listed.
NJ Right-to-Know Law	One or more components listed.
PA Right-to-Know Law	One or more components listed.

Canadian Regulations

Canadian DSL Inventory	All components listed on inventory or are exempt.

16. Other information

Preparation Information

Prepared By	Chemical Stewardship Telephone: 1-580-251-4335 e-mail: fdunexchem@halliburton.com
Revision Date:	03-Jun-2015

Reason for Revision SDS sections updated:
2

Additional information
For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key or legend to abbreviations and acronyms
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
ErC50 – Effective Concentration growth rate 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NIOSH – National Institute for Occupational Safety and Health
NTP – National Toxicology Program
OEL – Occupational Exposure Limit
PEL – Permissible Exposure Limit
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
UN – United Nations
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/
OSHA
ECHA C&L

Disclaimer Statement
This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

HALLIBURTON

SAFETY DATA SHEET

Product Trade Name: **OilPerm FMM-2**

Revision Date: 28-May-2015 **Revision Number:** 5

1. Identification

1.1. Product Identifier

Product Trade Name: OilPerm FMM-2
Synonyms: None
Chemical Family: Blend
Internal ID Code HM007587

1.2 Recommended use and restrictions on use

Application: Surfactant
Uses Advised Against No information available

1.3 Manufacturer's Name and Contact Details

Manufacturer/Supplier
Halliburton Energy Services, Inc.
P.O. Box 1431
Duncan, Oklahoma 73536-0431
Emergency Telephone: (1-866-519-4752 (US, Canada, Mexico) or 1-760-476-3962

Halliburton Energy Services
645 - 7th Ave SW Suite 2200
Calgary, AB
T2P 4G8
Canada

Prepared By Chemical Stewardship
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

1.4. Emergency telephone number

Emergency Telephone Number (281) 575-5000

2. Hazard(s) Identification

2.1 Classification in accordance with paragraph (d) of §1910.1200

Skin Corrosion / Irritation	Category 2 - H315
Serious Eye Damage / Eye Irritation	Category 1 - H318
Skin Sensitization	Category 1 - H317
Acute Aquatic Toxicity	Category 2 - H401
Chronic Aquatic Toxicity	Category 3 - H412
Flammable liquids.	Category 3 - H226

2.2. Label Elements

Hazard Pictograms

Signal Word Danger

Hazard Statements

H315 - Causes skin irritation
H317 - May cause an allergic skin reaction
H318 - Causes serious eye damage
H401 - Toxic to aquatic life
H412 - Harmful to aquatic life with long lasting effects
H226 - Flammable liquid and vapor

Precautionary Statements

Prevention

P210 - Keep away from heat/sparks/open flames/hot surfaces. - No smoking
P233 - Keep container tightly closed
P240 - Ground/Bond container and receiving equipment
P241 - Use explosion-proof electrical/ventilating/lighting/equipment
P242 - Use only non-sparking tools
P243 - Take precautionary measures against static discharge
P261 - Avoid breathing dust/fume/gas/mist/vapors/spray
P264 - Wash face, hands and any exposed skin thoroughly after handling
P272 - Contaminated work clothing should not be allowed out of the workplace
P273 - Avoid release to the environment
P280 - Wear protective gloves/protective clothing/eye protection/face protection

Response

P303 + P361 + P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower
P333 + P313 - If skin irritation or rash occurs: Get medical advice/attention
P363 - Wash contaminated clothing before reuse
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a POISON CENTER or doctor/physician
P370 + P380 + P375 - In case of fire, use water/water spray/water jet/carbon dioxide/sand/foam/alcohol resistant foam/chemical powder for extinction

Storage

P403 + P235 - Store in a well-ventilated place. Keep cool

Disposal

P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains

Substances	CAS Number
Isopropanol	67-63-0
Citrus, extract	94266-47-4
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary
Ethoxylated alcohols	Proprietary

2.3 Hazards not otherwise classified
None known

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - US
Isopropanol	67-63-0	10 - 30%	Eye Irrit. 2 (H319) STOT SE 3 (H336) Flam. Liq. 2 (H225)
Citrus, extract	94266-47-4	5 - 10%	Skin Irrit. 2 (H315) Eye Irrit. 2 (H319) Skin Sens. 1 (H317) Asp. Tox. 1 (H304) Aquatic Acute 1 (H400) Aquatic Chronic 2 (H411) Flam. Liq. 3 (H226)
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	1 - 5%	Acute Tox. 3 (H301) Skin Corr. 1C (H314) Eye Corr. 1 (H318) Aquatic Acute 1 (H400) Aquatic Chronic 1 (H410)
Ethoxylated alcohols	Proprietary	1 - 5%	Acute Tox. 4 (H302) Skin Irrit. 2 (H315) Eye Corr. 1 (H318) Aquatic Acute 1 (H400) Aquatic Chronic 3 (H412)

The exact percentage (concentration) of the composition has been withheld as proprietary.

4. First-Aid Measures

4.1. Description of first aid measures

Inhalation If inhaled, move victim to fresh air and seek medical attention.

Eyes Immediately flush eyes with large amounts of water for at least 30 minutes. Seek prompt medical attention.

Skin Wash off immediately with soap and plenty of water for at least 15 minutes while removing all contaminated clothing and shoes

Ingestion Get medical attention! If vomiting occurs, keep head lower than hips to prevent aspiration. Rinse mouth. Never give anything by mouth to an unconscious person. Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

4.2 Most important symptoms/effects, acute and delayed
Causes severe eye irritation which may damage tissue. Causes skin irritation. May cause allergic skin reaction.

4.3. Indication of any immediate medical attention and special treatment needed

Notes to Physician Treat symptomatically.

5. Fire-fighting measures

5.1. Extinguishing media

Suitable Extinguishing Media
Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons
None known.

5.2 Specific hazards arising from the substance or mixture

Special Exposure Hazards

Use water spray to cool fire exposed surfaces. Closed containers may explode in fire. Decomposition in fire may produce harmful gases. May be ignited by heat, sparks or flames.

5.3 Special protective equipment and precautions for fire-fighters

Special Protective Equipment for Fire-Fighters

Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Use appropriate protective equipment. Wear self-contained breathing apparatus in enclosed areas.
See Section 8 for additional information

6.2. Environmental precautions

Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up

Scoop up and remove. Contain spill with sand or other inert materials. Isolate spill and stop leak where safe. Remove ignition sources and work with non-sparking tools.

7. Handling and storage

7.1. Precautions for Safe Handling

Handling Precautions

Avoid contact with eyes, skin, or clothing. Avoid breathing vapors. Avoid breathing mist. Wash hands after use. Launder contaminated clothing before reuse. Ground and bond containers when transferring from one container to another.

Hygiene Measures

Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities

Storage Information

Store away from oxidizers. Keep from heat, sparks, and open flames. Keep container closed when not in use. Terpene containing products should be stored in phenolic-lined metal, stainless steel, PET, or fluorinated plastic containers. Product has a shelf life of 24 months.

8. Exposure Controls/Personal Protection

8.1 Occupational Exposure Limits

Substances	CAS Number	OSHA PEL-TWA	ACGIH TLV-TWA
Isopropanol	67-63-0	TWA: 400 ppm	TWA: 200 ppm STEL: 400 ppm
Citrus, extract	94266-47-4	Not applicable	Not applicable
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	Not applicable	Not applicable
Ethoxylated alcohols	Proprietary	Not applicable	Not applicable

8.2 Appropriate engineering controls

Engineering Controls Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation.

8.3 Individual protection measures, such as personal protective equipment

Personal Protective Equipment	If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.
Respiratory Protection	If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional. Organic vapor respirator. In high concentrations, supplied air respirator or a self-contained breathing apparatus.
Hand Protection	Nitrile gloves. Impervious rubber gloves.
Skin Protection	Rubber apron.
Eye Protection	Chemical goggles; also wear a face shield if splashing hazard exists.
Other Precautions	Eyewash fountains and safety showers must be easily accessible.

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State:	Liquid	**Color:**	Light yellow
Odor:	Citrus	**Odor Threshold:**	No information available

Property Remarks/ - Method	Values
pH:	4.5
Freezing Point/Range	-20.8 °C / -5.4 °F
Melting Point/Range	No data available
Boiling Point/Range	No data available
Flash Point	28.3 °C / 84 °F PMCC
Flammability (solid, gas)	No data available
upper flammability limit	6.1 %
lower flammability limit	0.7 %
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	0.9814
Water Solubility	Soluble in water
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%)	No data available

10. Stability and Reactivity

10.1. Reactivity

Not expected to be reactive.

10.2. Chemical Stability

Stable

10.3. Possibility of Hazardous Reactions
Will Not Occur

10.4. Conditions to Avoid
Keep away from heat, sparks and flame.

10.5. Incompatible Materials
Iodine pentafluorethylene Strong acids. Strong alkalis. Strong oxidizers.

10.6. Hazardous Decomposition Products
Carbon monoxide and carbon dioxide.

11. Toxicological Information

11.1 Information on likely routes of exposure

Principle Route of Exposure Eye or skin contact, inhalation.

11.2 Symptoms related to the physical, chemical and toxicological characteristics

Acute Toxicity

Inhalation May cause central nervous system depression including headache, dizziness, drowsiness, incoordination, slowed reaction time, slurred speech, giddiness and unconsciousness.
May cause respiratory irritation.

Eye Contact Causes severe eye irritation which may damage tissue.

Skin Contact Causes moderate skin irritation. May cause skin defatting with prolonged exposure. May cause an allergic skin reaction.

Ingestion Irritation of the mouth, throat, and stomach. May cause abdominal pain, vomiting, nausea, and diarrhea. May cause central nervous system depression including headache, dizziness, drowsiness, muscular weakness, incoordination, slowed reaction time, fatigue blurred vision, slurred speech, giddiness, tremors and convulsions.

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 0.1% are chronic health hazards.

11.3 Toxicity data

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Isopropanol	67-63-0	4396 mg/kg (Rat) 5840 mg/kg (Rat) 3600 mg/kg (Mouse)	12,800 mg/kg (Rat) 12,870 mg/kg (Rabbit) 6280 mg/kg (Rabbit)	72.6 mg/L (Rat) 4h > 10,000 mg/L (Rat) 6h
Citrus, extract	94266-47-4	> 5000 mg/kg (Rat)	> 5000 mg/kg (Rabbit)	> 1000 mg/kg (Mouse)
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	238 mg/kg (Rat) (similar substance)	> 2000 mg/kg (Rabbit) (similar substance)	No data available
Ethoxylated alcohols	Proprietary	2 g/kg (Rat) 1600 mg/kg (Rat) > 5000 mg/kg (Rat)	> 2000 mg/kg (Rat) 2500 mg/kg (Rabbit)	No data available

Substances	CAS Number	Skin corrosion/irritation
Isopropanol	67-63-0	Non-irritating to the skin (Rabbit)
Citrus, extract	94266-47-4	Causes moderate skin irritation. (Rabbit)
Alkyl hydroxyethyl benzyl ammonium chloride		Corrosive to skin (Rabbit) (similar substances)
Ethoxylated alcohols		May cause moderate skin irritation. (Rabbit)

Substances	CAS Number	Eye damage/irritation

Isopropanol	67-63-0	Causes severe eye irritation. (Rabbit)
Citrus, extract	94266-47-4	Causes severe eye irritation.
Alkyl hydroxyethyl benzyl ammonium chloride		Corrosive to eyes (Rabbit) (similar substances)
Ethoxylated alcohols		Risk of serious damage to eyes. (Rabbit) (similar substances)

Substances	CAS Number	Skin Sensitization
Isopropanol	67-63-0	Did not cause sensitization on laboratory animals (guinea pig)
Citrus, extract	94266-47-4	May cause sensitization by skin contact
Alkyl hydroxyethyl benzyl ammonium chloride		Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Ethoxylated alcohols		Did not cause sensitization on laboratory animals (guinea pig)

Substances	CAS Number	Respiratory Sensitization
Isopropanol	67-63-0	No information available
Citrus, extract	94266-47-4	No information available
Alkyl hydroxyethyl benzyl ammonium chloride		No information available
Ethoxylated alcohols		No information available

Substances	CAS Number	Mutagenic Effects
Isopropanol	67-63-0	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects.
Citrus, extract	94266-47-4	In vitro tests did not show mutagenic effects In vivo tests did not show mutagenic effects.
Alkyl hydroxyethyl benzyl ammonium chloride		In vitro tests did not show mutagenic effects In vivo tests did not show mutagenic effects. (similar substances)
Ethoxylated alcohols		In vivo tests did not show mutagenic effects. In vitro tests did not show mutagenic effects

Substances	CAS Number	Carcinogenic Effects
Isopropanol	67-63-0	Did not show carcinogenic effects in animal experiments
Citrus, extract	94266-47-4	Did not show carcinogenic effects in animal experiments (similar substances)
Alkyl hydroxyethyl benzyl ammonium chloride		No information available.
Ethoxylated alcohols		Did not show carcinogenic effects in animal experiments

Substances	CAS Number	Reproductive toxicity
Isopropanol	67-63-0	No significant toxicity observed in animal studies at concentration requiring classification.
Citrus, extract	94266-47-4	Animal testing did not show any effects on fertility.
Alkyl hydroxyethyl benzyl ammonium chloride		Animal testing did not show any effects on fertility. Adverse developmental effects were only observed at maternally toxic doses. (similar substances)
Ethoxylated alcohols		No significant toxicity observed in animal studies at concentration requiring classification.

Substances	CAS Number	STOT - single exposure
Isopropanol	67-63-0	May cause headache, dizziness, and other central nervous system effects.
Citrus, extract	94266-47-4	No significant toxicity observed in animal studies at concentration requiring classification.
Alkyl hydroxyethyl benzyl ammonium chloride		No information available
Ethoxylated alcohols		No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)

Substances	CAS Number	STOT - repeated exposure
Isopropanol	67-63-0	No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Citrus, extract	94266-47-4	No significant toxicity observed in animal studies at concentration requiring classification.
Alkyl hydroxyethyl benzyl ammonium chloride		No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)
Ethoxylated alcohols		No significant toxicity observed in animal studies at concentration requiring classification. (similar substances)

Substances	CAS Number	Aspiration hazard
Isopropanol	67-63-0	Not applicable
Citrus, extract	94266-47-4	Aspiration into the lungs may cause chemical pneumonitis including coughing, difficulty breathing, wheezing, coughing up blood and pneumonia, which can be fatal.
Alkyl hydroxyethyl benzyl ammonium chloride		Not applicable
Ethoxylated alcohols		No adverse health effects are expected from swallowing.

12. Ecological Information

12.1. Toxicity

Ecotoxicity Effects

Product Ecotoxicity Data

No data available

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Isopropanol	67-63-0	EC50 (72h) > 1000 mg/L (Desmodesmus subspicatus) EC50 (7d) 1800 mg/L (Scenedesmus quadricauda)	LC50 (96h) 9640 mg/L (Pimephales promelas) LC50 (7d) 7060 mg/L (Poecilia reticulata)	TT (16h) 1050 mg/L (Pseudomonas putida)	EC50 (48h) 13,299 mg/L (Daphnia magna) EC50 (24h) > 10,000 mg/L (Daphnia magna)
Citrus, extract	94266-47-4	EC50 (72h) 20.41 mg/L (Skeletonema costatum)	LC50 (96h) >1000 mg/L (Scophthalmus maximus)	No information available	LC50 (48) 34.73 mg/L (Acartia tonsa) EC50 (48h) 0.577 mg/L (Daphnia magna)
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	EC50(96h): 0.177 mg/L (Pseudokirchneriella subcapitata) (similar substance)	LC50(96h): 5-10 mg/L (Brachydanio rerio) (similar substance)	No information available	EC50(48h): 0.75 mg/L (Daphnia magna) (similar substance) NOEC(21d): 0.064 mg/L (Daphnia magna) (similar substance)
Ethoxylated alcohols	Proprietary	No information available	EC50 (48h) 0.39 mg/L (Ceriodaphnia dubia) NOEC (30d) 0.28 mg/L (Pimephales promelas) NOEC (16d) 0.16 mg/L(Lepomis macrochirus)	No information available	No information available

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Isopropanol	67-63-0	Readily biodegradable (53% @ 5d)
Citrus, extract	94266-47-4	Readily biodegradable (61% @ 28d)
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	Readily biodegradable (72% @ 28d)
Ethoxylated alcohols	Proprietary	Readily biodegradable

12.3. Bioaccumulative potential

Substances	CAS Number	Log Pow
Isopropanol	67-63-0	0.05
Citrus, extract	94266-47-4	4.23
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	No information available
Ethoxylated alcohols	Proprietary	3

12.4. Mobility in soil

Substances	CAS Number	Mobility
Isopropanol	67-63-0	KOC = 1.5
Citrus, extract	94266-47-4	KOC = 1300
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	No information available
Ethoxylated alcohols	Proprietary	No information available

12.5 Other adverse effects

No information available

13. Disposal Considerations

13.1. Waste treatment methods

Disposal Method Disposal should be made in accordance with federal, state, and local regulations.
Contaminated Packaging Follow all applicable national or local regulations.

14. Transport Information

US DOT

UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Isopropanol, Terpene Hydrocarbons)
Transport Hazard Class(es): 3
Packing Group: III
Environmental Hazards: Not applicable
NAERG: NAERG 128

US DOT Bulk

DOT (Bulk) Not applicable

Canadian TDG

UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Isopropanol, Terpene Hydrocarbons)
Transport Hazard Class(es): 3
Packing Group: III
Environmental Hazards: Not applicable

IMDG/IMO

UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Isopropanol, Terpene Hydrocarbons)
Transport Hazard Class(es): 3
Packing Group: III
Environmental Hazards: Not applicable
EMS: EmS F-E, S-E

IATA/ICAO

UN Number: UN1993
UN Proper Shipping Name: Flammable Liquid, N.O.S. (Contains Isopropanol, Terpene Hydrocarbons)
Transport Hazard Class(es): 3
Packing Group: III
Environmental Hazards: Not applicable

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code: Not applicable
Special Precautions for User: None

15. Regulatory Information

US Regulations

US TSCA Inventory All components listed on inventory or are exempt.

EPA SARA Title III Extremely Hazardous Substances

Substances	CAS Number	EPA SARA Title III Extremely Hazardous Substances
Isopropanol	67-63-0	Not applicable
Citrus, extract	94266-47-4	Not applicable

Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	Not applicable
Ethoxylated alcohols	Proprietary	Not applicable

EPA SARA (311,312) Hazard Class
Acute Health Hazard
Chronic Health Hazard
Fire Hazard

EPA SARA (313) Chemicals

Substances	CAS Number	Toxic Release Inventory (TRI) - Group I	Toxic Release Inventory (TRI) - Group II
Isopropanol	67-63-0	1.0%	Not applicable
Citrus, extract	94266-47-4	Not applicable	Not applicable
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	Not applicable	Not applicable
Ethoxylated alcohols	Proprietary	Not applicable	Not applicable

EPA CERCLA/Superfund Reportable Spill Quantity

Substances	CAS Number	CERCLA RQ
Isopropanol	67-63-0	Not applicable
Citrus, extract	94266-47-4	Not applicable
Alkyl hydroxyethyl benzyl ammonium chloride	Proprietary	Not applicable
Ethoxylated alcohols	Proprietary	Not applicable

EPA RCRA Hazardous Waste Classification
If product becomes a waste, it does meet the criteria of a hazardous waste as defined by the US EPA, because of:

Ignitability D001

California Proposition 65 The California Proposition 65 regulations apply to this product.

MA Right-to-Know Law One or more components listed.

NJ Right-to-Know Law One or more components listed.

PA Right-to-Know Law One or more components listed.

Canadian Regulations

Canadian DSL Inventory All components listed on inventory or are exempt.

16. Other information

Preparation Information

Prepared By Chemical Stewardship
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

Revision Date: 28-May-2015

Reason for Revision SDS sections updated:
2

Additional information
For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key or legend to abbreviations and acronyms
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
ErC50 – Effective Concentration growth rate 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NIOSH – National Institute for Occupational Safety and Health
NTP – National Toxicology Program
OEL – Occupational Exposure Limit
PEL – Permissible Exposure Limit
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
UN – United Nations
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/

Disclaimer Statement
This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

Appendix E – Analysis of DJ Basin

We compiled data for our analysis of the DJ Basin by doing the following:

1. Downloaded all horizontal well APIs for Weld County, CO, which contains all three MHA Focus Areas for their study of the DJ basin, using the "Facility Inquiry" tool on the COGCC website *(http://cogcc.state.co.us/data.html#/cogis)*

2. Identified the townships in MHA's Focus Area 1 ("FA1") and Focus Area 2 ("FA2") from the MHA Report dated January 25, 2016

    - FA1 consists of 4 townships: T9N-R59W, T10N-R59W, T9N-R58W, T10N-R58W

    - FA2 consists of 6 townships: T5N-R64W, T6N-R64W, T5N-R63W, T6N-R63W, T5N-R62W, T6N-R62W

3. Downloaded the entire FracFocus machine-readable database from the FracFocus website *(http://fracfocus.org/data-download)* and downloaded the pdf files for any wells in FA1 & FA2 not in the FracFocus machine-readable database download file *(https://fracfocusdata.org/DisclosureSearch/Search.aspx)*

4. Calculated the gross perforated interval (GPI) for all wells in FA1 & FA2 using the well information record from COGCC. Where GPI was not provided directly by COGIS, it was calculated using the methodology below. Any wells where GPI was unable to be calculated were omitted from our study (676 wells found with full GPI data).

    - GPI calculation is the result of "Liner BTM" or "PB Depth" subtracted from "Liner Top" or "Last Perf" data listed on COGIS

    - We calculate the difference between linear length and linear feet of GPI using the following methodology:

        1. To calculate the distance between the first perforation and liner top, subtract "Bottom of 1^{S} / Casing" from "Liner Top" or "Last Perf"

        2. To calculate the distance between the last perforation and liner bottom, subtract "Liner BTM" or "PB depth" from "Bottom of Liner"

        3. To find difference between liner length and linear feet of GPI sum values from 1 and 2 above

    - We calculate the average difference between linear length and linear feet for each operator, and subtract this value from liner length to get linear feet of GPI in instances where GPI is not provided on COGIS

5. Downloaded the "All Production Reports Received By Year" data files from 2012 to 2016 from the COGCC website *(http://cogcc.state.co.us/data2.html#/downloads)*

6. Identified wells in FA1 & FA2 with missing production months and rectified with COGCC

- For example, we identified 59 Noble Energy wells with at least 1 month production data missing. COGCC has since corrected and updated the database

7. Using the data collected above, we compiled a master data set with the chemical information from FracFocus and the production data / well information from COGCC for all Niobrara wells with at least 11 months of production data in the first 12 months of operation located in FA1 & FA2

    - FourWorld identified 604 Niobrara wells (listed in Appendix F) that meet our criteria in FA 1 & FA2. API numbers for these wells can be found in Appendix F. From a population of 676 wells, the following wells were removed:

        1. 37 wells with less than 11 months of production data
        2. 29 non-Niobrara wells (a constraint used in the MHA report)
        3. 6 wells belonging to two operators with no non-CnF wells: Encana Oil & Gas (5) and PICO Niobrara (1)

Appendix F – Well APIs with Sample Data and Maps

DJ Basin Analysis - 604 Total Well API's					
Area 1 - 267 Well API's					
05-123-33080-0000	05-123-37002-0000	05-123-37517-0000	05-123-37848-0000	05-123-38484-0000	05-123-38779-0000
05-123-33082-0000	05-123-37070-0000	05-123-37527-0000	05-123-37874-0000	05-123-38485-0000	05-123-38780-0000
05-123-33087-0000	05-123-37073-0000	05-123-37528-0000	05-123-37875-0001	05-123-38486-0000	05-123-38781-0000
05-123-33166-0000	05-123-37096-0000	05-123-37533-0000	05-123-37876-0000	05-123-38487-0000	05-123-38782-0000
05-123-33231-0000	05-123-37097-0000	05-123-37537-0000	05-123-37877-0000	05-123-38488-0000	05-123-38844-0000
05-123-33330-0000	05-123-37144-0000	05-123-37539-0000	05-123-37878-0001	05-123-38489-0000	05-123-38845-0000
05-123-33451-0000	05-123-37283-0000	05-123-37540-0000	05-123-37879-0000	05-123-38507-0000	05-123-38846-0000
05-123-33475-0000	05-123-37368-0000	05-123-37542-0000	05-123-37880-0000	05-123-38508-0000	05-123-38847-0000
05-123-33563-0000	05-123-37369-0000	05-123-37543-0000	05-123-37898-0000	05-123-38510-0000	05-123-38848-0000
05-123-33801-0100	05-123-37432-0000	05-123-37545-0000	05-123-37899-0000	05-123-38529-0000	05-123-38849-0000
05-123-33959-0000	05-123-37433-0000	05-123-37546-0000	05-123-37901-0000	05-123-38531-0000	05-123-38851-0000
05-123-33960-0000	05-123-37434-0000	05-123-37547-0000	05-123-37949-0000	05-123-38532-0000	05-123-38852-0000
05-123-34896-0100	05-123-37445-0000	05-123-37548-0000	05-123-37953-0000	05-123-38534-0000	05-123-38853-0000
05-123-34978-0000	05-123-37448-0000	05-123-37549-0000	05-123-37956-0001	05-123-38535-0000	05-123-38854-0000
05-123-35011-0000	05-123-37451-0000	05-123-37550-0000	05-123-37974-0001	05-123-38536-0000	05-123-38855-0000
05-123-36029-0000	05-123-37452-0000	05-123-37593-0000	05-123-37978-0000	05-123-38537-0000	05-123-38856-0000
05-123-36052-0000	05-123-37453-0000	05-123-37617-0000	05-123-37986-0000	05-123-38577-0000	05-123-39062-0000
05-123-36068-0000	05-123-37455-0000	05-123-37618-0000	05-123-37987-0000	05-123-38583-0000	05-123-39118-0000
05-123-36123-0000	05-123-37457-0000	05-123-37619-0000	05-123-37988-0000	05-123-38584-0000	05-123-39119-0000
05-123-36124-0000	05-123-37458-0000	05-123-37621-0000	05-123-37989-0000	05-123-38598-0000	05-123-39158-0000
05-123-36127-0000	05-123-37459-0000	05-123-37622-0000	05-123-37990-0000	05-123-38601-0000	05-123-39170-0000
05-123-36168-0000	05-123-37460-0000	05-123-37623-0000	05-123-37991-0001	05-123-38603-0000	05-123-39256-0000
05-123-36257-0000	05-123-37461-0000	05-123-37624-0000	05-123-37992-0000	05-123-38604-0000	05-123-39257-0000
05-123-36263-0000	05-123-37462-0000	05-123-37625-0000	05-123-38041-0000	05-123-38611-0000	05-123-39258-0000
05-123-36267-0000	05-123-37463-0000	05-123-37626-0000	05-123-38042-0000	05-123-38613-0000	05-123-39260-0001
05-123-36268-0000	05-123-37465-0000	05-123-37627-0000	05-123-38043-0000	05-123-38614-0000	05-123-39261-0000
05-123-36270-0000	05-123-37466-0000	05-123-37628-0000	05-123-38044-0000	05-123-38615-0000	05-123-39264-0000
05-123-36331-0000	05-123-37467-0000	05-123-37630-0000	05-123-38045-0000	05-123-38618-0000	05-123-39305-0000
05-123-36332-0000	05-123-37470-0000	05-123-37631-0000	05-123-38060-0000	05-123-38619-0000	05-123-39306-0000
05-123-36371-0000	05-123-37471-0000	05-123-37637-0000	05-123-38061-0000	05-123-38620-0000	05-123-39307-0000
05-123-36372-0000	05-123-37472-0000	05-123-37697-0000	05-123-38062-0001	05-123-38621-0000	05-123-39308-0000
05-123-36390-0000	05-123-37473-0000	05-123-37708-0000	05-123-38063-0000	05-123-38622-0000	05-123-39421-0001
05-123-36392-0000	05-123-37475-0000	05-123-37730-0000	05-123-38064-0001	05-123-38623-0000	05-123-39523-0000
05-123-36579-0000	05-123-37476-0000	05-123-37744-0000	05-123-38065-0001	05-123-38699-0001	05-123-39524-0000
05-123-36581-0000	05-123-37479-0000	05-123-37748-0000	05-123-38066-0000	05-123-38701-0000	05-123-39525-0000
05-123-36657-0000	05-123-37480-0000	05-123-37765-0000	05-123-38067-0000	05-123-38702-0001	05-123-39526-0000
05-123-36658-0000	05-123-37481-0000	05-123-37766-0000	05-123-38130-0000	05-123-38703-0000	05-123-39529-0000
05-123-36659-0000	05-123-37482-0000	05-123-37767-0000	05-123-38239-0000	05-123-38727-0000	05-123-39532-0000
05-123-36660-0100	05-123-37483-0000	05-123-37838-0000	05-123-38339-0000	05-123-38728-0000	05-123-39948-0000
05-123-36678-0000	05-123-37484-0000	05-123-37839-0000	05-123-38344-0000	05-123-38730-0001	05-123-40454-0000
05-123-36680-0000	05-123-37486-0000	05-123-37840-0000	05-123-38345-0000	05-123-38731-0000	05-123-40525-0000
05-123-36681-0000	05-123-37489-0000	05-123-37841-0000	05-123-38346-0000	05-123-38763-0000	05-123-40527-0000
05-123-36773-0000	05-123-37490-0000	05-123-37844-0000	05-123-38368-0000	05-123-38776-0000	
05-123-36951-0000	05-123-37493-0000	05-123-37845-0000	05-123-38369-0000	05-123-38777-0000	
05-123-36952-0000	05-123-37507-0000	05-123-37847-0000	05-123-38370-0000	05-123-38778-0000	

Appendix F - Continued

DJ Basin Analysis - 604 Total Well API's - Continued					
Area 2 - 337 Well API's					
05-123-30639-0000	05-123-36828-0000	05-123-37175-0000	05-123-37568-0000	05-123-38659-0000	05-123-39034-0000
05-123-33184-0000	05-123-36829-0000	05-123-37176-0000	05-123-37569-0000	05-123-38660-0000	05-123-39035-0000
05-123-34092-0000	05-123-36830-0000	05-123-37177-0000	05-123-37596-0000	05-123-38661-0000	05-123-39036-0000
05-123-34227-0000	05-123-36874-0000	05-123-37178-0000	05-123-37597-0000	05-123-38662-0000	05-123-39037-0000
05-123-35000-0000	05-123-36875-0000	05-123-37179-0000	05-123-37598-0000	05-123-38663-0000	05-123-39063-0000
05-123-35047-0000	05-123-36876-0000	05-123-37180-0000	05-123-37599-0000	05-123-38664-0000	05-123-39065-0000
05-123-35640-0000	05-123-36877-0000	05-123-37181-0000	05-123-37600-0000	05-123-38665-0000	05-123-39067-0000
05-123-35645-0000	05-123-36878-0000	05-123-37182-0000	05-123-37651-0000	05-123-38666-0000	05-123-39068-0000
05-123-35647-0000	05-123-36879-0000	05-123-37184-0000	05-123-37653-0000	05-123-38667-0000	05-123-39069-0000
05-123-35648-0000	05-123-36880-0000	05-123-37185-0000	05-123-37700-0000	05-123-38668-0000	05-123-39070-0000
05-123-35649-0000	05-123-36882-0000	05-123-37192-0000	05-123-37702-0000	05-123-38669-0000	05-123-39103-0000
05-123-35650-0000	05-123-36884-0000	05-123-37193-0000	05-123-37712-0000	05-123-38670-0000	05-123-39104-0000
05-123-35673-0000	05-123-36885-0000	05-123-37200-0000	05-123-37717-0000	05-123-38673-0000	05-123-39106-0000
05-123-35674-0000	05-123-36897-0000	05-123-37201-0000	05-123-37724-0000	05-123-38676-0000	05-123-39110-0000
05-123-35896-0000	05-123-36898-0000	05-123-37202-0000	05-123-37728-0000	05-123-38677-0000	05-123-39111-0000
05-123-36025-0000	05-123-36899-0000	05-123-37203-0000	05-123-37732-0000	05-123-38681-0000	05-123-39121-0000
05-123-36040-0000	05-123-36918-0000	05-123-37208-0000	05-123-37741-0000	05-123-38682-0000	05-123-39123-0000
05-123-36041-0000	05-123-36937-0000	05-123-37209-0000	05-123-37810-0000	05-123-38683-0000	05-123-39160-0000
05-123-36042-0000	05-123-37021-0000	05-123-37210-0000	05-123-37824-0000	05-123-38684-0000	05-123-39161-0000
05-123-36043-0000	05-123-37022-0000	05-123-37211-0000	05-123-37825-0000	05-123-38685-0000	05-123-39168-0000
05-123-36156-0000	05-123-37023-0000	05-123-37212-0000	05-123-38024-0000	05-123-38686-0000	05-123-39262-0000
05-123-36157-0000	05-123-37024-0000	05-123-37213-0000	05-123-38036-0000	05-123-38687-0000	05-123-39263-0000
05-123-36182-0000	05-123-37054-0000	05-123-37214-0000	05-123-38055-0000	05-123-38688-0000	05-123-39279-0000
05-123-36183-0000	05-123-37061-0000	05-123-37215-0000	05-123-38120-0000	05-123-38689-0000	05-123-39294-0000
05-123-36259-0000	05-123-37062-0000	05-123-37216-0000	05-123-38140-0000	05-123-38690-0000	05-123-39295-0000
05-123-36260-0000	05-123-37077-0000	05-123-37217-0000	05-123-38263-0000	05-123-38691-0000	05-123-39296-0000
05-123-36285-0000	05-123-37078-0000	05-123-37218-0000	05-123-38264-0000	05-123-38692-0000	05-123-39297-0000
05-123-36287-0000	05-123-37079-0000	05-123-37219-0000	05-123-38265-0000	05-123-38705-0000	05-123-39298-0000
05-123-36288-0000	05-123-37080-0000	05-123-37220-0000	05-123-38267-0000	05-123-38706-0000	05-123-39299-0000
05-123-36290-0000	05-123-37081-0000	05-123-37221-0000	05-123-38307-0000	05-123-38733-0000	05-123-39300-0000
05-123-36299-0000	05-123-37082-0000	05-123-37222-0000	05-123-38308-0000	05-123-38734-0000	05-123-39416-0000
05-123-36304-0000	05-123-37083-0000	05-123-37223-0000	05-123-38309-0000	05-123-38735-0000	05-123-39517-0000
05-123-36318-0000	05-123-37084-0000	05-123-37224-0000	05-123-38310-0000	05-123-38736-0000	05-123-39518-0000
05-123-36320-0000	05-123-37085-0000	05-123-37227-0000	05-123-38311-0000	05-123-38887-0000	05-123-39519-0000
05-123-36322-0000	05-123-37086-0000	05-123-37234-0000	05-123-38428-0000	05-123-38888-0000	05-123-39520-0000
05-123-36377-0000	05-123-37087-0000	05-123-37235-0000	05-123-38429-0000	05-123-38889-0000	05-123-39886-0000
05-123-36378-0000	05-123-37090-0000	05-123-37263-0000	05-123-38430-0000	05-123-38890-0000	05-123-39887-0000
05-123-36379-0000	05-123-37092-0000	05-123-37264-0000	05-123-38490-0000	05-123-38892-0000	05-123-39888-0000
05-123-36405-0000	05-123-37093-0000	05-123-37265-0000	05-123-38491-0000	05-123-38893-0100	05-123-39889-0000
05-123-36406-0000	05-123-37098-0000	05-123-37266-0000	05-123-38587-0000	05-123-38909-0000	05-123-39890-0000
05-123-36407-0000	05-123-37136-0000	05-123-37267-0000	05-123-38588-0000	05-123-38910-0000	05-123-39902-0000
05-123-36496-0000	05-123-37137-0100	05-123-37268-0000	05-123-38589-0000	05-123-38925-0000	05-123-39903-0000
05-123-36502-0000	05-123-37138-0000	05-123-37269-0000	05-123-38590-0000	05-123-38926-0000	05-123-39904-0000
05-123-36512-0000	05-123-37139-0000	05-123-37286-0000	05-123-38642-0000	05-123-38927-0000	05-123-39905-0000
05-123-36532-0000	05-123-37140-0000	05-123-37288-0000	05-123-38644-0000	05-123-38928-0000	05-123-39906-0000

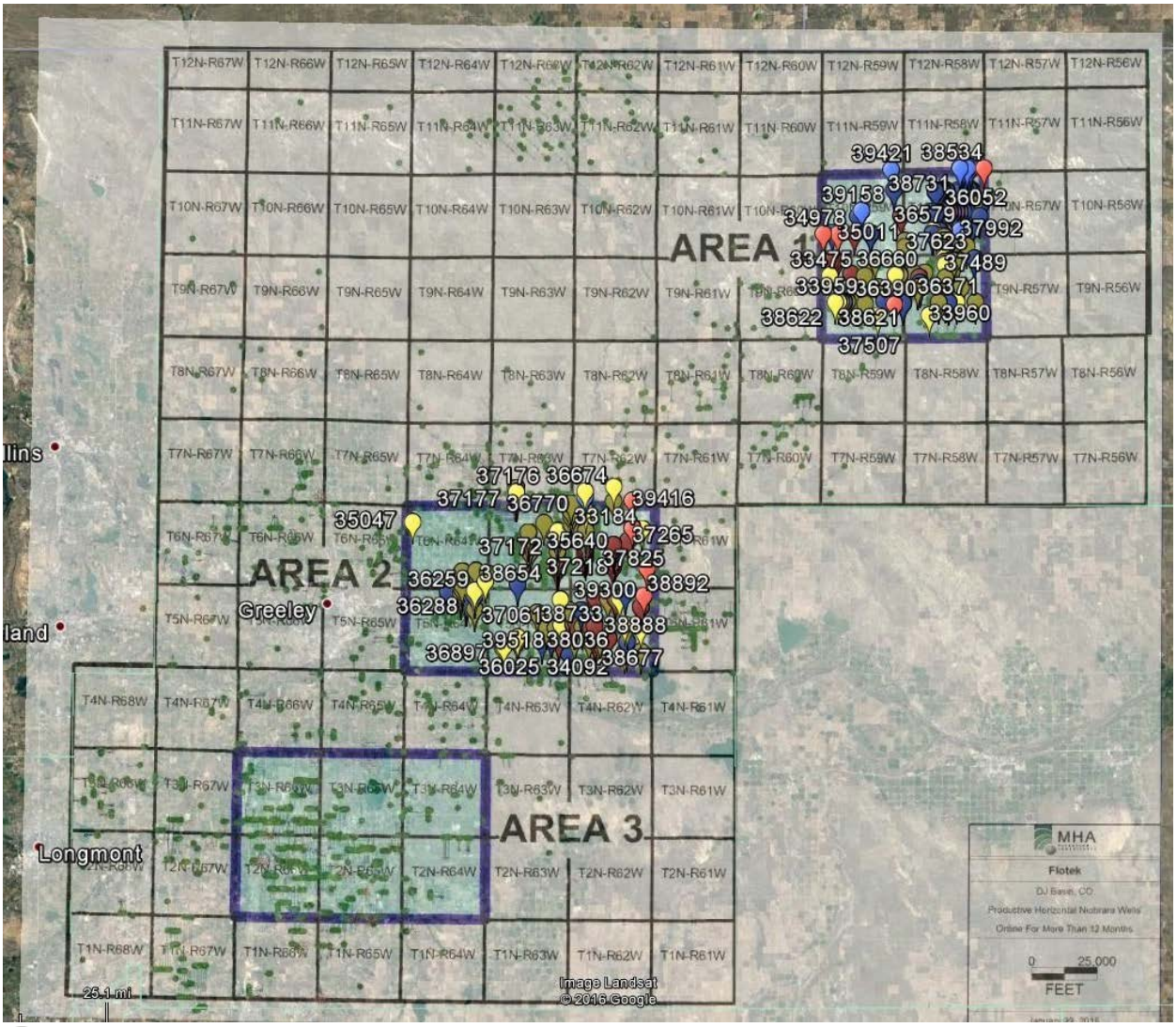
Appendix F - Continued

Area 2 - 337 Well API's - Continued					
05-123-36533-0000	05-123-36827-0000	05-123-37173-0000	05-123-37565-0000	05-123-38655-0000	05-123-39025-0000
05-123-36534-0000	05-123-37141-0000	05-123-37174-0000	05-123-37566-0000	05-123-38656-0000	05-123-39026-0000
05-123-36580-0000	05-123-37142-0000	05-123-37289-0000	05-123-37567-0000	05-123-38657-0000	05-123-39027-0000
05-123-36598-0000	05-123-37143-0000	05-123-37291-0000	05-123-38645-0000	05-123-38658-0000	05-123-39032-0000
05-123-36674-0000	05-123-37164-0000	05-123-37338-0000	05-123-38646-0000	05-123-39003-0000	05-123-39033-0000
05-123-36768-0000	05-123-37165-0000	05-123-37403-0000	05-123-38647-0000	05-123-39004-0000	05-123-39907-0000
05-123-36769-0000	05-123-37168-0000	05-123-37404-0000	05-123-38649-0000	05-123-39006-0000	05-123-39918-0000
05-123-36770-0000	05-123-37169-0000	05-123-37561-0000	05-123-38650-0000	05-123-39007-0000	05-123-39919-0000
05-123-36771-0000	05-123-37170-0000	05-123-37562-0000	05-123-38652-0000	05-123-39008-0000	05-123-40127-0100
05-123-36772-0000	05-123-37171-0000	05-123-37563-0000	05-123-38653-0000	05-123-39009-0000	05-123-40128-0000
05-123-36826-0000	05-123-37172-0000	05-123-37564-0000	05-123-38654-0000	05-123-39010-0000	05-123-40129-0000
					05-123-40131-0000

Appendix F – FourWorld Area 1 and Area 2 Data Set: Well Locations vs MHA Focus Area Overlay

Figure 1 (below) shows the 604 valid wells as designated by FourWorld. Coordinates for each well are listed on COGCC and FracFocus. We have included an overlay of a map used in MHA's January 27 study. FA1 consists of townships T9N-R59W, T10N-R59W, T9N-R58W, and T10N-R58W, shown in Figure 2. FA 2 is made up of townships T5N-R64W, T6N-R64W, T5N-R63W, T6N-R63W, T5N-R62W, T6N-R62W, as illustrated in Figure 3.

Figure 1



= CnF Wells with Trade Name Correctly Identified by MHA

= Non-CnF Wells

= CnF Wells where Trade Name would have been Misidentified by MHA

Appendix F – FourWorld Area 1 and Area 2 Data Set: Well Locations

Figure 2

Figure 2 (above) shows all 267 FA1 wells with complete chemical, production, and well data in the Niobrara formation located within townships T9N-R59W, T10N-R59W, T9N-R58W, and T10N-R58W.

Figure 3

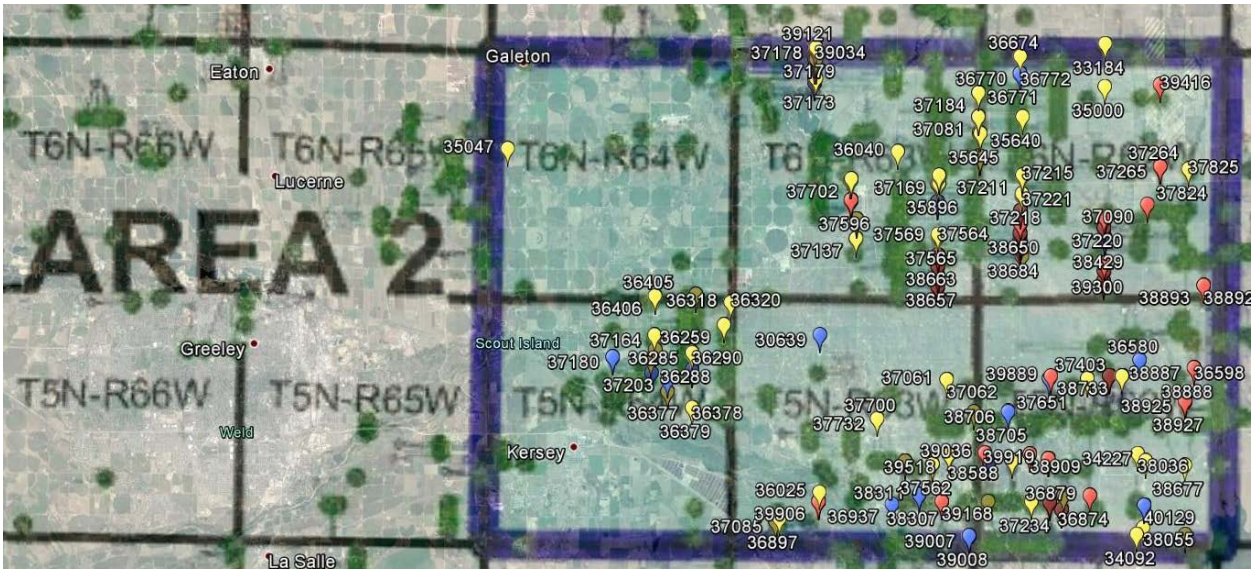


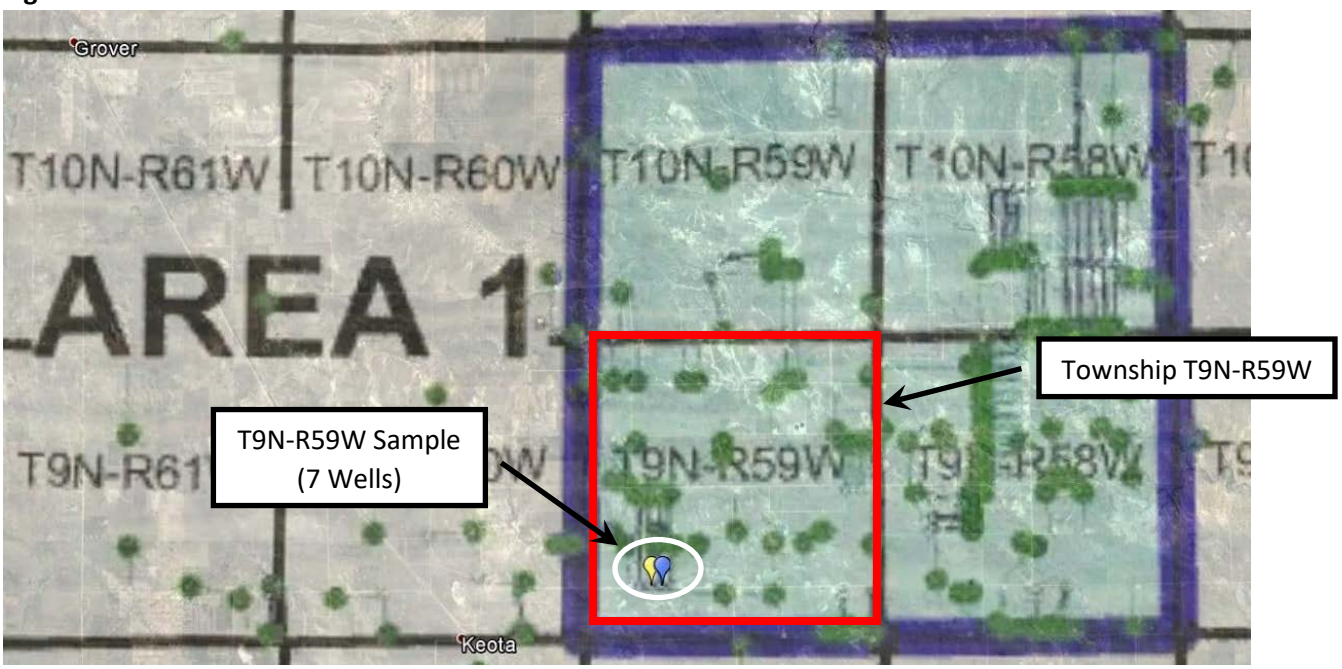
Figure 3 (above) shows all 337 FA2 wells with complete chemical, production, and well data in the Niobrara formation located within townships T5N-R64W, T6N-R64W, T5N-R63W, T6N-R63W, T5N-R62W, and T6N-R62W.

Appendix F – Area 1 Data Set: Sample Wells

The following pages depict sample groupings of wells for FA1 & FA2, respectively, with charts included to demonstrate data compiled by FourWorld to conduct our analysis. Sample sets were taken from township T9N-R59W in FA1, and township T5N-R64W in FA2 Using COGCC's mapping tool, we include a directional drill overlay for each set of wells. Yellow lines are used to show CnF directionals in Figure 5 and Figure 7;blue lines are used for non-CnF directionals. Well heads are noted by red circles, with purple circles showing the well bottom.

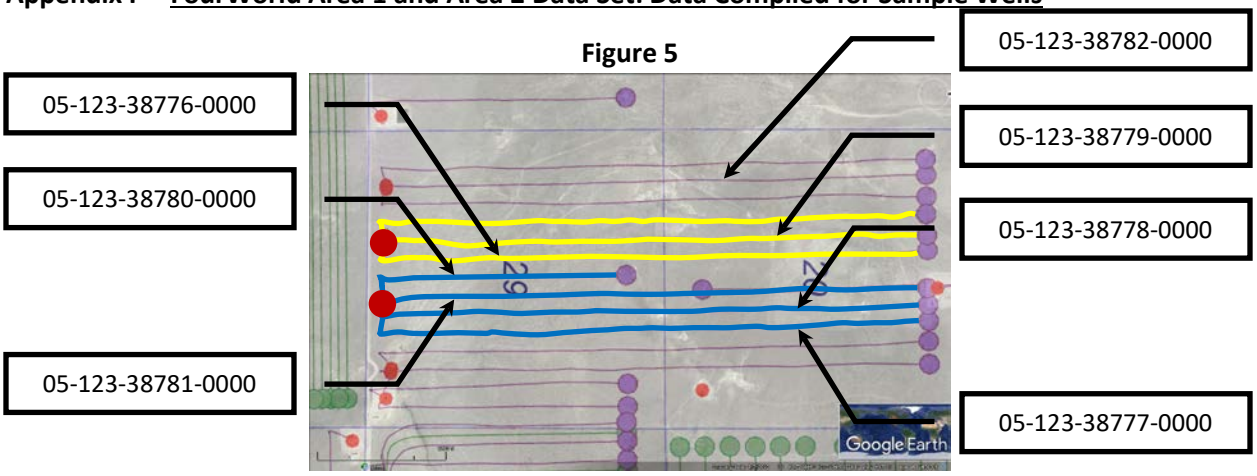
Seven (7) Wells in T9N-R59W of FA1 have been prepared to demonstrate data analyzed by FourWorld. Figure 4 (below) illustrates the location of these wells within FA1. Figure 5 (see next page) shows each well directional, or horizontal drilling path, and includes sample data used in our analysis.

Figure 4



Appendix F – FourWorld Area 1 and Area 2 Data Set: Data Compiled for Sample Wells

Figure 5



Sample of FourWorld Data Compilation

API Number	05-123-38782-0000	05-123-38779-0000	05-123-38776-0000	05-123-38780-0000	05-123-38781-0000	05-123-38778-0000	05-123-38777-0000
Operator	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.
Start Date	7/14/2014	7/14/2014	7/13/2014	7/15/2014	7/15/2014	7/15/2014	7/15/2014
Trade Name	OilPerm FMM-2	OilPerm FMM-2	OilPerm FMM-2	none	none	none	none
CnF Used - FourWorld	Y	Y	Y	N	N	N	N
CnF Used - MHA	Y	Y	Y	N	N	N	N
Linear Feet	8,839	8,922	9,001	3,514	8,781	8,831	8,901
Total Base Water (gal)	5,453,337	5,403,666	5,338,920	2,115,372	4,968,306	5,047,140	5,130,258
Water (gal) / LIN FT GPI	617	606	593	602	566	572	576
Production - Gross BBL of Oil							
Month 1	189	238	184	52	42	35	218
Month 2	6,726	7,008	7,289	6,578	8,317	6,883	8,821
Month 3	13,390	13,445	11,770	13,082	15,086	12,187	10,703
Month 4	12,674	11,640	11,249	11,412	13,967	13,018	14,265
Month 5	11,003	9,891	9,863	8,175	11,674	12,804	14,781
Month 6	9,239	7,956	8,357	6,434	9,407	10,079	11,545
Month 7	6,343	5,895	6,169	4,622	6,146	7,466	8,155
Month 8	6,011	5,561	5,513	4,223	5,670	7,051	7,623
Month 9	5,079	4,779	4,715	3,612	5,414	5,988	6,188
Month 10	4,479	4,282	4,456	3,164	4,505	5,323	5,308
Month 11	3,729	3,684	3,925	2,758	3,848	4,590	4,641
Month 12	3,556	3,487	3,679	2,406	3,632	4,418	4,299
Total 12 Month Production - As Reported	**82,418**	**77,866**	**77,169**	**66,518**	**87,708**	**89,842**	**96,547**
Production - Adjusted Gross BBL of Oil*							
Month 1	1,150	1,810	1,119	527	639	1,065	2,210
Month 2	6,819	7,105	7,390	6,669	8,433	6,979	8,944
Month 3	13,138	13,192	11,549	12,836	14,802	11,958	10,502
Month 4	12,850	11,802	11,405	11,571	14,161	13,199	14,463
Month 5	10,796	9,705	9,677	8,021	11,454	12,563	14,503
Month 6	9,065	7,806	8,200	6,313	9,230	9,889	11,328
Month 7	6,890	6,404	6,701	5,021	6,676	8,110	8,859
Month 8	5,898	5,456	5,409	4,144	5,563	6,918	7,480
Month 9	5,150	4,845	4,780	3,662	5,489	6,071	6,274
Month 10	4,395	4,201	4,372	3,104	4,420	5,223	5,208
Month 11	3,781	3,735	3,980	2,796	3,901	4,654	4,705
Month 12	3,489	3,421	3,610	2,361	3,564	4,335	4,218
Total 12 Month Gross Production - Adjusted	**83,421**	**79,483**	**78,193**	**67,025**	**88,333**	**90,963**	**98,693**
Adjusted Gross BBL of Oil per foot GPI							
Month 1	0.13	0.20	0.12	0.15	0.07	0.12	0.25
Month 2	0.77	0.80	0.82	1.90	0.96	0.79	1.00
Month 3	1.49	1.48	1.28	3.65	1.69	1.35	1.18
Month 4	1.45	1.32	1.27	3.29	1.61	1.49	1.62
Month 5	1.22	1.09	1.08	2.28	1.30	1.42	1.63
Month 6	1.03	0.87	0.91	1.80	1.05	1.12	1.27
Month 7	0.78	0.72	0.74	1.43	0.76	0.92	1.00
Month 8	0.67	0.61	0.60	1.18	0.63	0.78	0.84
Month 9	0.58	0.54	0.53	1.04	0.63	0.69	0.70
Month 10	0.50	0.47	0.49	0.88	0.50	0.59	0.59
Month 11	0.43	0.42	0.44	0.80	0.44	0.53	0.53
Month 12	0.39	0.38	0.40	0.67	0.41	0.49	0.47
Total 12 Month Production Per foot GPI†	**9.44**	**8.91**	**8.69**	**19.07**	**10.06**	**10.30**	**11.09**

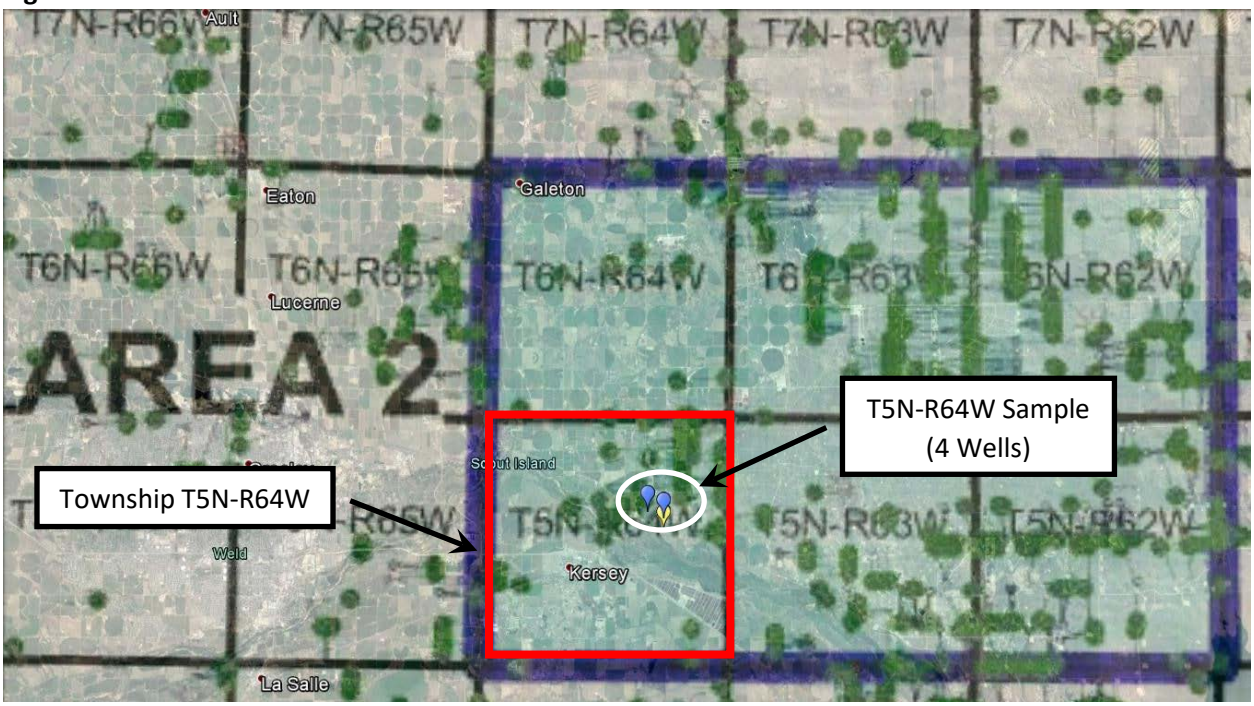
Gross monthly production as stated on COGIS is normalized to 30.4 days using formula ([Gross monthly production/days producing in month][365/12])

†In the event of shut-in month, production was normalized to 12 months using formula (12/months of non-zero production data)*(Days Adjusted BBL/GPI)

Appendix F - Area 2 Data Set: Sample Wells

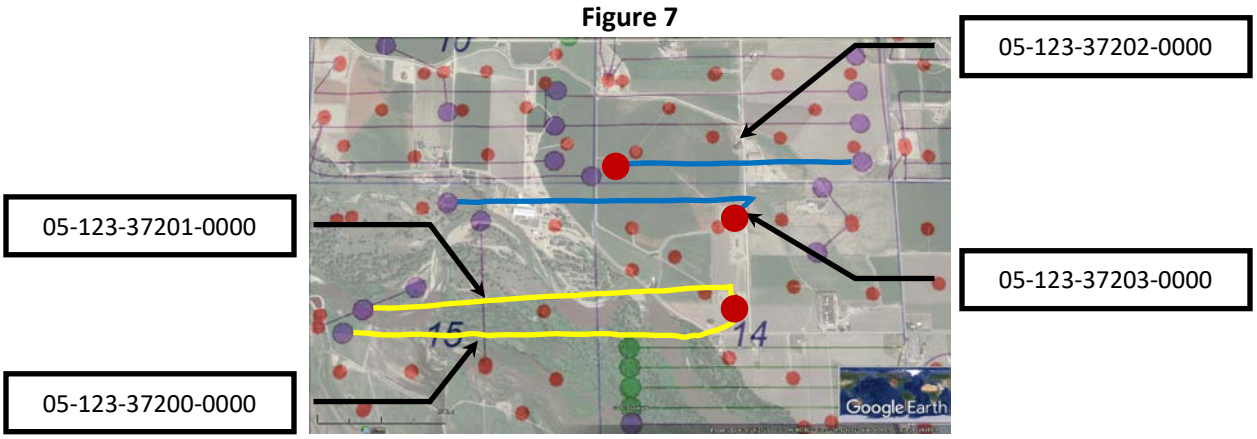
Four (4) Wells in T5N-R64W of FA2 have been prepared to demonstrate data analyzed by FourWorld. Figure 6 (below) illustrates the location of these wells within FA2. Figure 7 (see next page) shows each well directional, or horizontal drilling path, and includes sample data used in our analysis.

Figure 6



Appendix F - Area 2 Data Set: Data Compiled for Sample Wells

Figure 7



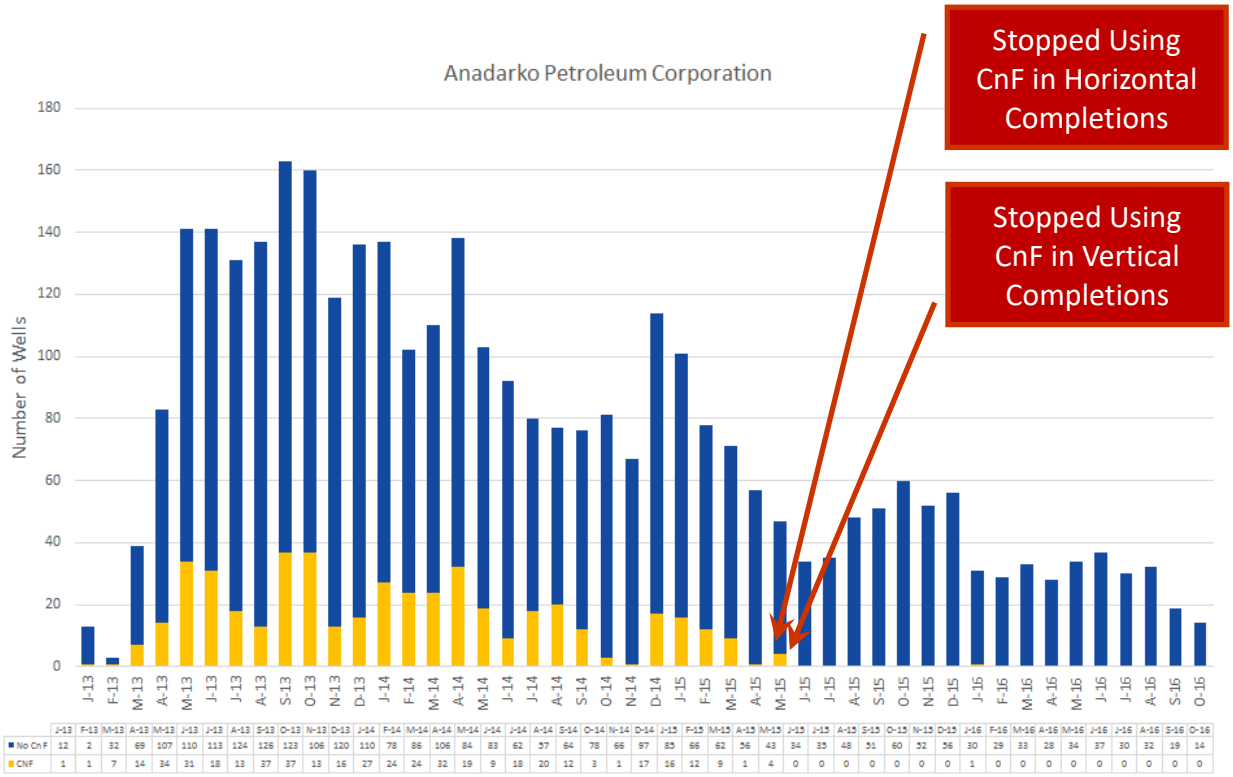
Sample of FourWorld Data Compilation

API Number	05-123-37200-0000	05-123-37201-0000	05-123-37202-0000	05-123-37203-0000
Operator	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.	Noble Energy, Inc.
Start Date	12/16/2013	12/9/2013	1/16/2014	1/13/2014
Trade Name	OilPerm B	OilPerm B	none	none
CnF Used - FourWorld	Y	Y	N	N
CnF Used - MHA	Y	Y	N	N
Linear Feet	5,830	5,458	3,614	4,524
Total Base Water (gal)	4,298,358	3,872,786	3,093,258	3,205,524
Water (gal) / LIN FT GPI	737	710	856	709
Production - Gross BBL of Oil				
Month 1	12,898	11,429	2,711	3,627
Month 2	8,622	6,628	4,157	4,814
Month 3	3,682	2,716	5,276	7,098
Month 4	7,211	5,146	4,520	7,681
Month 5	6,060	4,730	3,378	5,556
Month 6	4,235	3,500	2,664	4,206
Month 7	3,704	3,022	2,099	2,541
Month 8	4,842	3,632	1,872	2,275
Month 9	4,503	3,216	1,907	2,041
Month 10	4,062	3,303	1,529	1,999
Month 11	3,368	2,223	1,106	2,374
Month 12	3,152	2,229	1,104	1,049
Total 12 Month Production - As Reported	**66,339**	**51,774**	**32,323**	**45,261**
Production - Adjusted Gross BBL of Oil*				
Month 1	12,655	11,214	9,162	10,029
Month 2	9,366	7,200	9,032	10,459
Month 3	8,000	5,901	7,642	10,281
Month 4	10,445	7,454	4,435	7,536
Month 5	5,946	4,641	3,425	5,633
Month 6	4,294	3,549	2,701	4,264
Month 7	3,755	3,064	2,060	2,493
Month 8	4,751	3,564	1,898	2,307
Month 9	4,566	3,261	1,871	2,003
Month 10	3,986	3,241	1,550	2,027
Month 11	3,415	2,254	1,085	2,329
Month 12	3,093	2,187	1,083	1,029
Total 12 Month Gross Production - Adjusted	**74,270**	**57,528**	**45,944**	**60,391**
Adjusted Gross BBL of Oil per foot GPI				
Month 1	2.17	2.05	2.54	2.22
Month 2	1.61	1.32	2.50	2.31
Month 3	1.37	1.08	2.11	2.27
Month 4	1.79	1.37	1.23	1.67
Month 5	1.02	0.85	0.95	1.25
Month 6	0.74	0.65	0.75	0.94
Month 7	0.64	0.56	0.57	0.55
Month 8	0.81	0.65	0.53	0.51
Month 9	0.78	0.60	0.52	0.44
Month 10	0.68	0.59	0.43	0.45
Month 11	0.59	0.41	0.30	0.51
Month 12	0.53	0.40	0.30	0.23
Total 12 Month Production Per foot GPI†	**12.74**	**10.54**	**12.71**	**13.35**

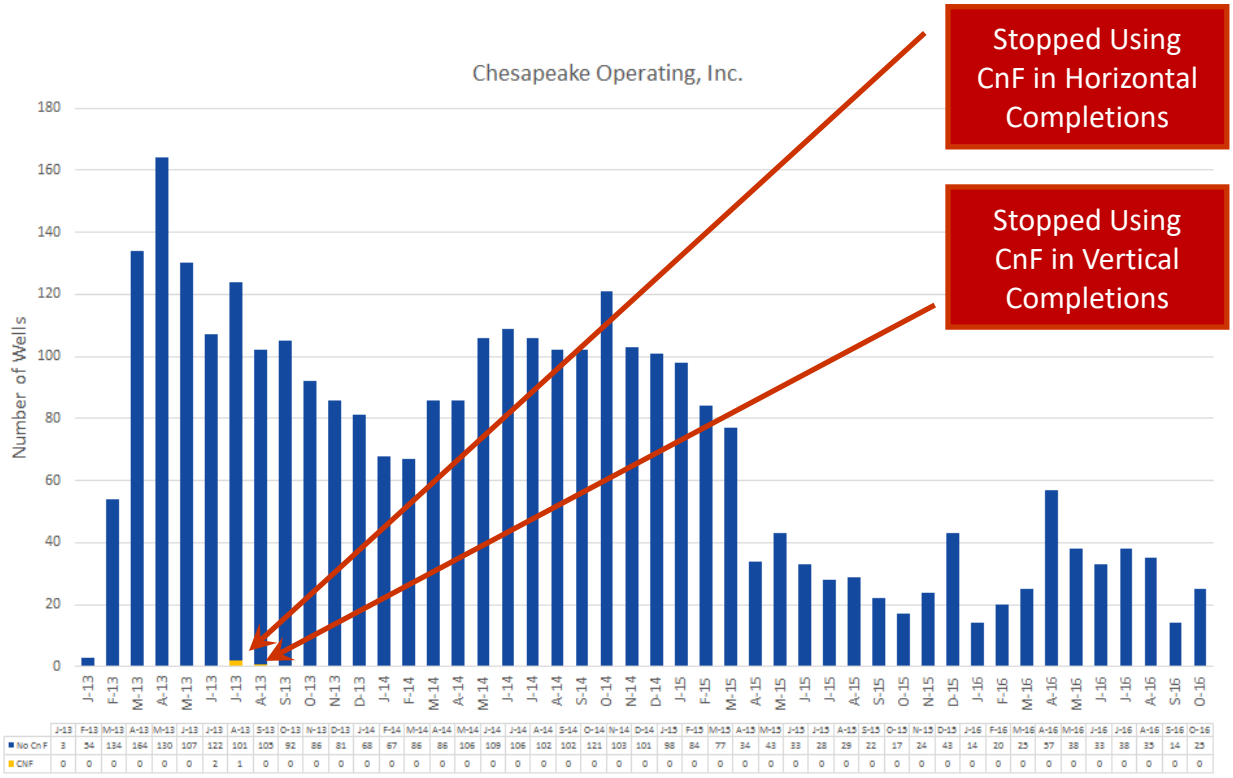
Gross monthly production as stated on COGIS is normalized to 30.4 days using formula ([Gross monthly production/days producing in month][365/12])

†In the event of shut-in month, production was normalized to 12 months using formula (12/months of non-zero production data)*(Days Adjusted BBL/GPI)

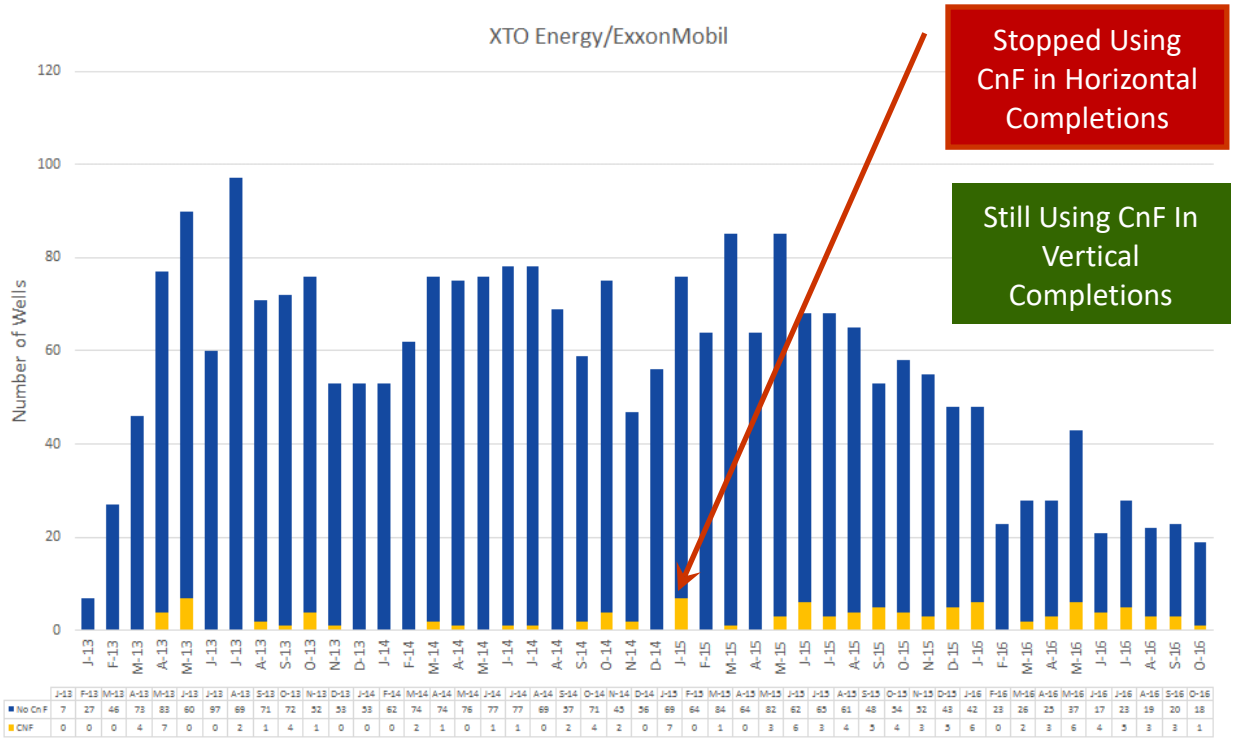
Appendix G – Top 20 Operators by Well Count Since 11/01/2012 (Includes Horizontal and Vertical Wells)



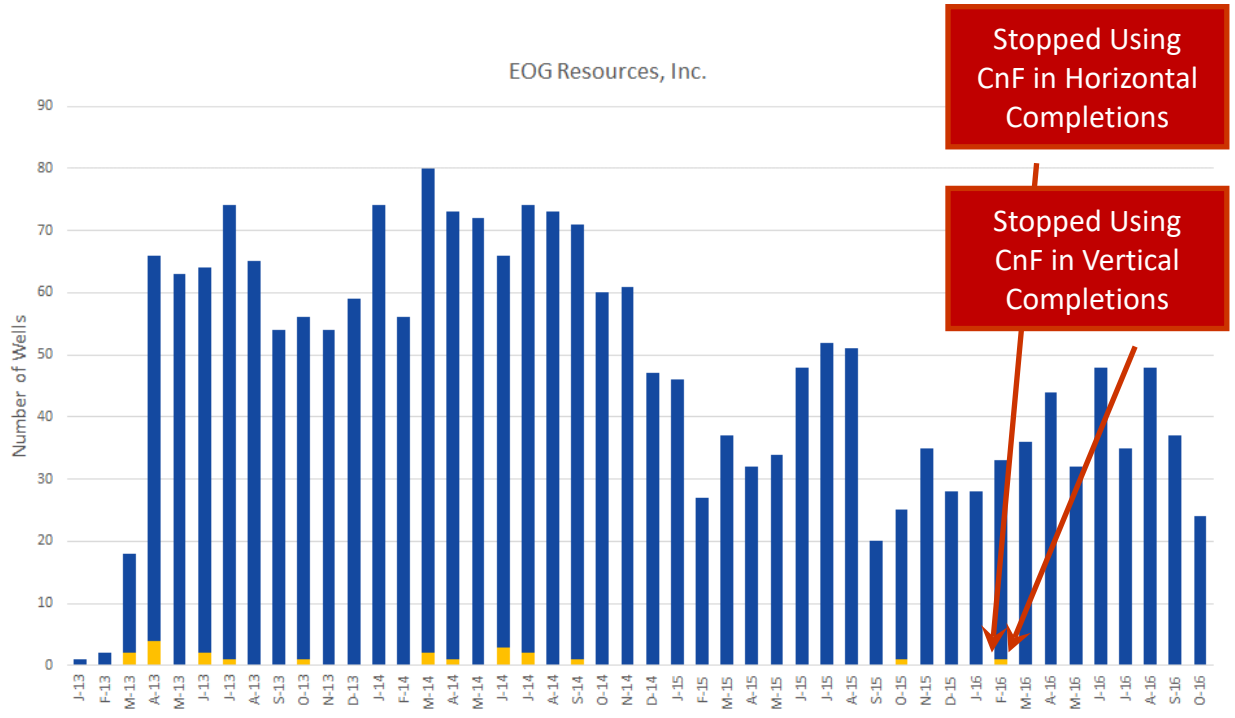
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	12	2	32	69	107	110	113	124	126	123	106	120	110	78	86	106	84	83	62	57	64	78	66	97	85	66	62	56	43	34	35	48	51	60	52	56	30	29	33	28	34	37	30	32	19	14
CNF	1	1	7	14	34	31	18	13	37	37	13	16	27	24	24	32	19	9	18	20	12	3	1	17	16	12	9	1	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0



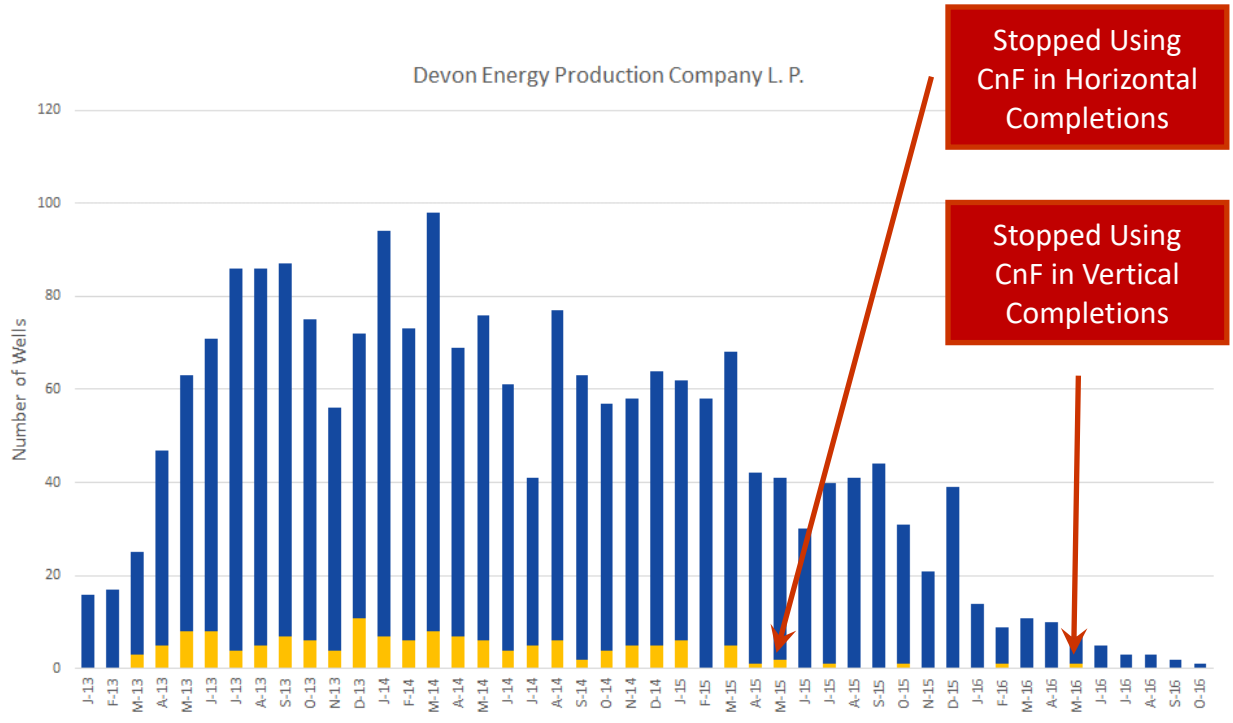
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	3	54	134	164	130	107	122	101	105	92	86	81	68	67	86	86	106	109	106	102	102	121	103	101	98	84	77	34	43	33	28	29	22	17	24	43	14	20	25	57	38	33	38	35	14	25
CNF	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



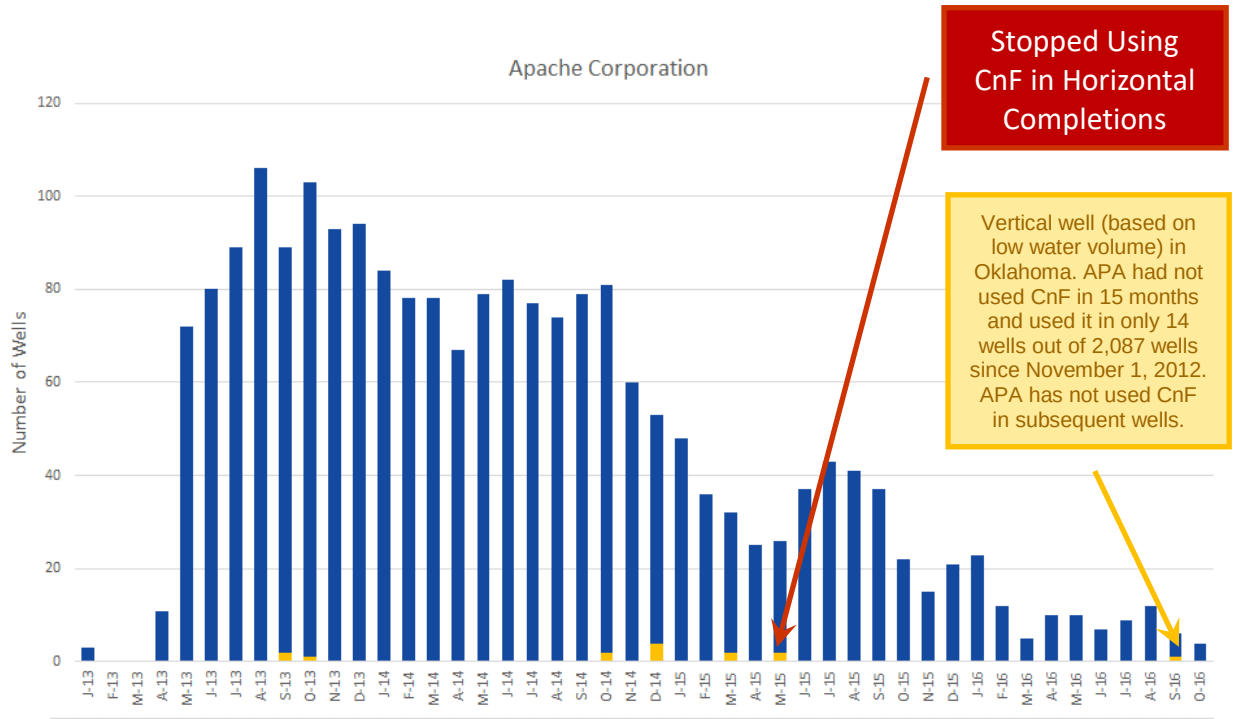
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No CnF	7	27	46	73	83	60	97	69	71	72	52	53	53	62	74	74	76	77	77	69	57	71	45	56	69	64	84	64	82	62	65	61	48	54	52	43	42	23	26	25	37	17	23	19	20	18
CNF	0	0	0	4	7	0	0	2	1	4	1	0	0	0	2	1	0	1	1	0	2	4	2	0	7	0	1	0	3	6	3	4	5	4	3	5	6	0	2	3	6	4	5	3	3	1



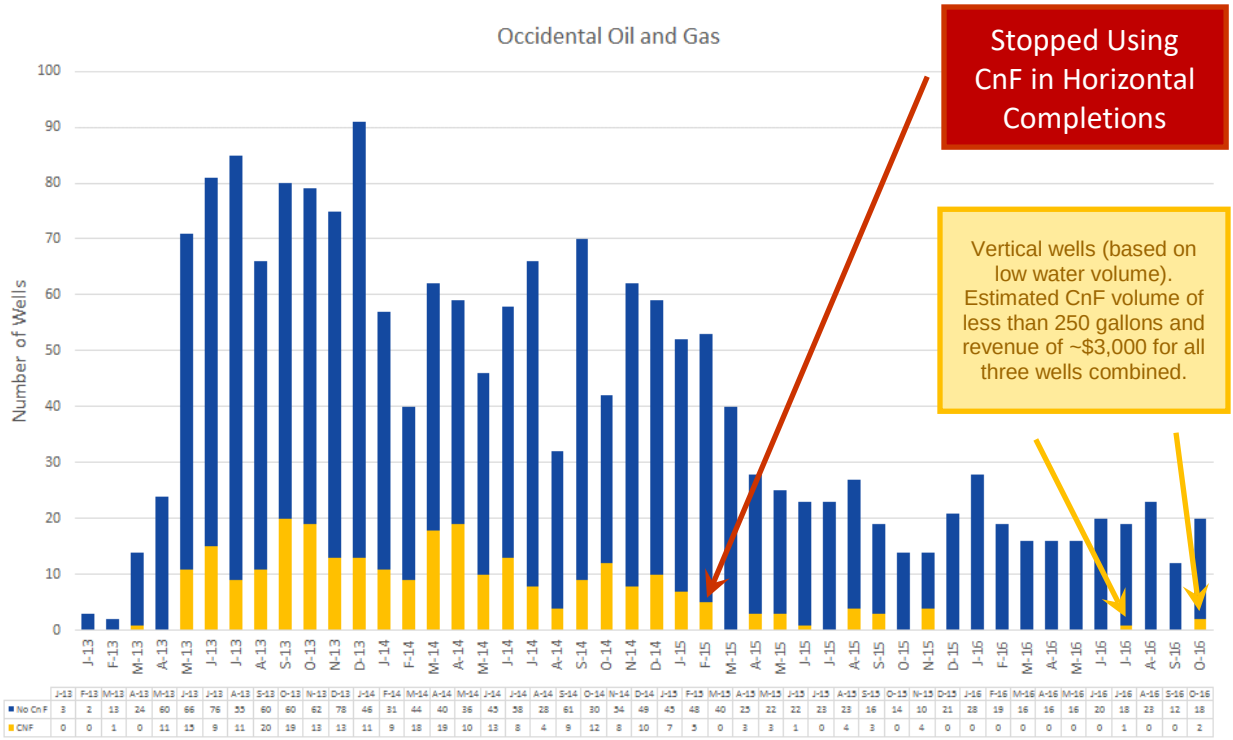
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No CnF	1	2	16	62	63	62	73	65	54	55	54	59	74	56	78	72	72	63	72	73	70	60	61	47	46	27	37	32	34	48	52	51	20	24	35	28	28	32	36	44	32	48	35	48	37	24
CNF	0	0	2	4	0	2	1	0	0	1	0	0	0	0	2	1	0	3	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0



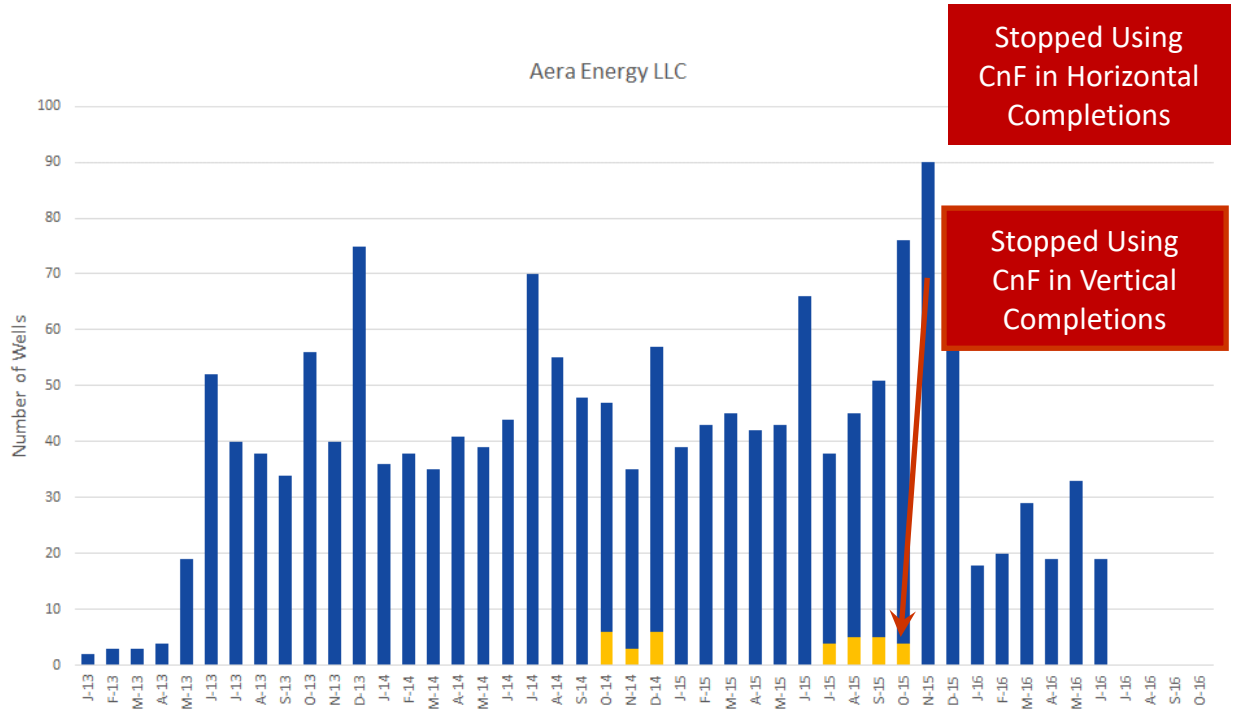
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	16	17	22	42	55	63	82	81	80	69	52	61	87	67	90	62	70	57	36	71	61	53	53	59	56	58	63	41	39	30	39	41	44	30	21	39	14	8	11	10	6	3	3	3	2	1
CNF	0	0	3	5	8	8	4	5	7	6	4	11	7	6	8	7	6	4	5	6	2	4	5	5	6	0	5	1	2	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0



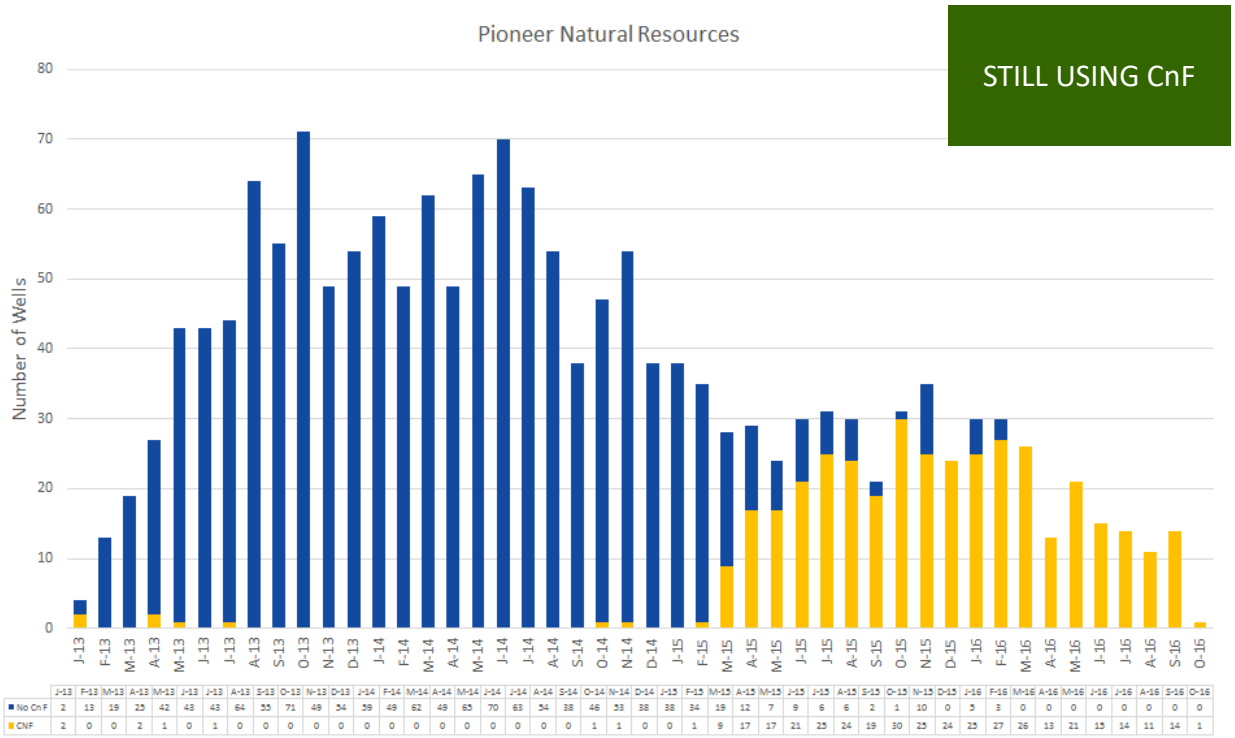
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	3	0	0	11	72	80	89	106	87	102	93	94	84	78	78	67	79	82	77	74	79	79	60	49	48	36	30	25	24	37	43	41	37	22	15	21	23	12	5	10	10	7	9	12	5	4
CNF	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

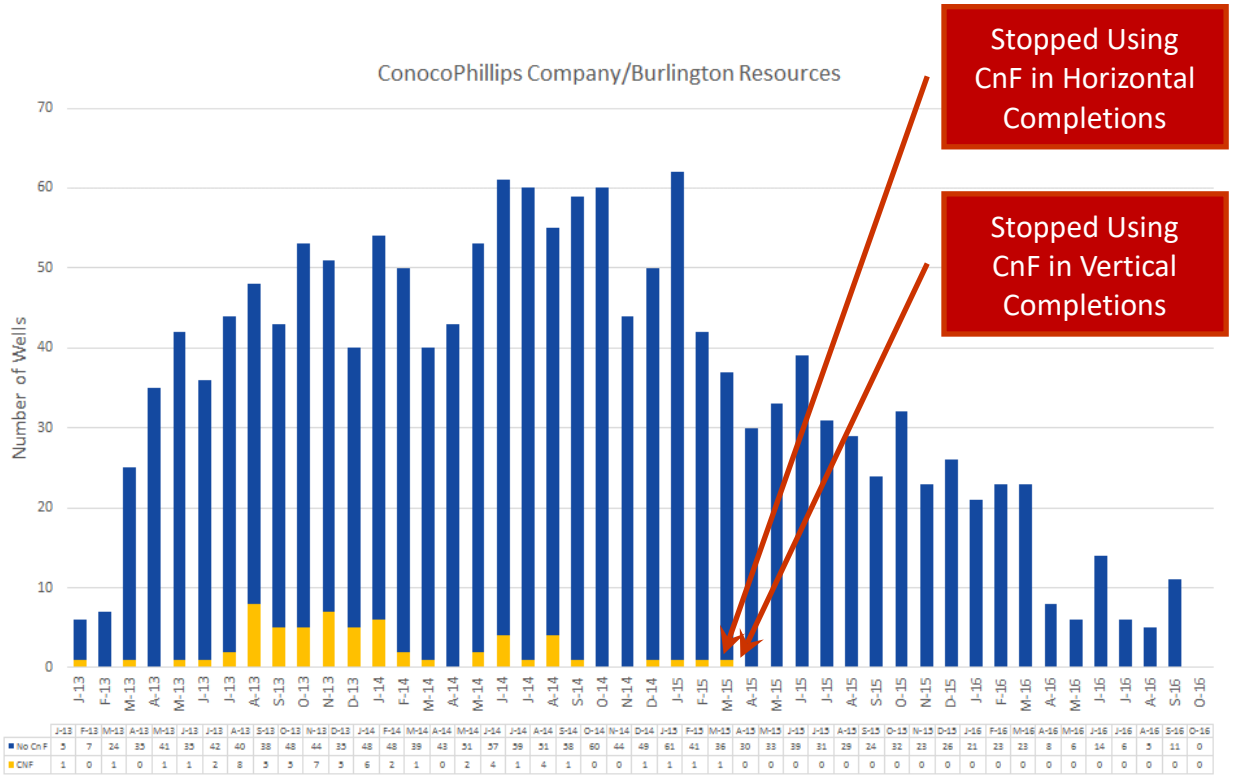


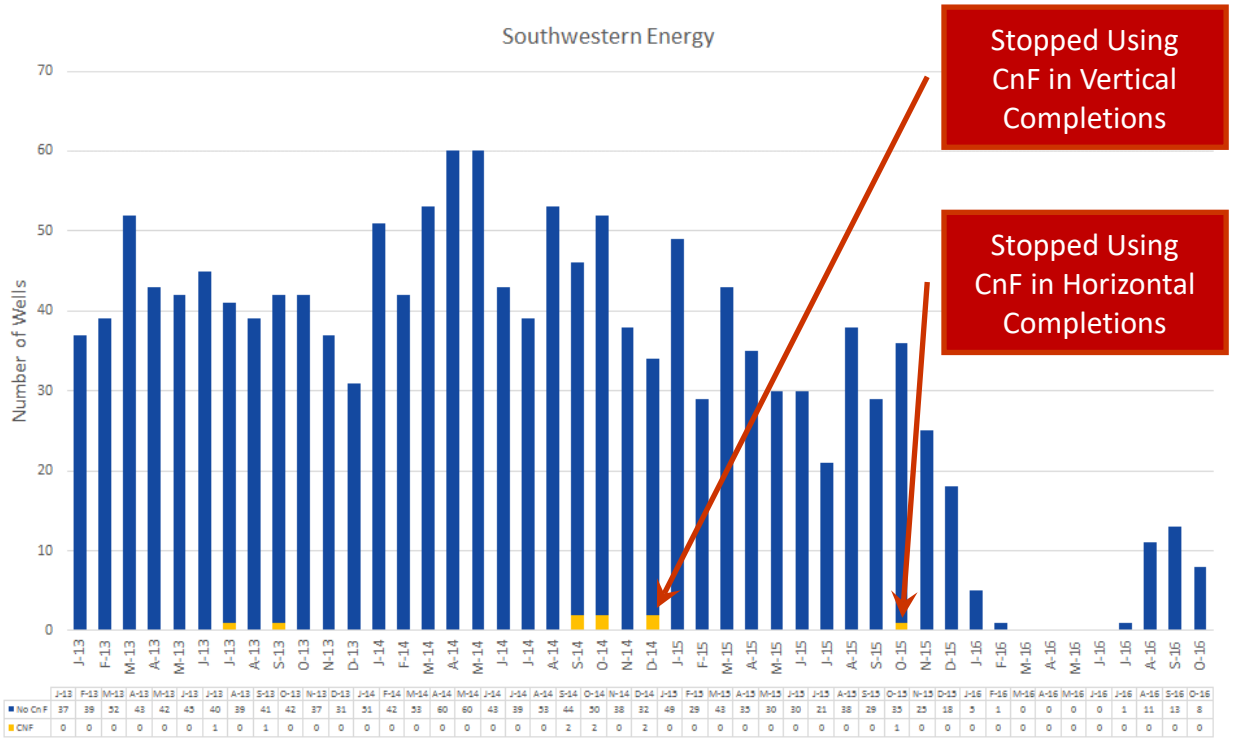
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	3	2	13	24	60	66	76	55	60	60	62	78	46	31	44	40	36	45	58	28	61	30	54	49	45	48	40	25	22	22	23	23	16	14	10	21	28	19	16	16	16	20	18	23	12	18
CNF	0	0	1	0	11	15	9	11	20	19	13	13	11	9	18	19	10	13	8	4	9	12	8	10	7	5	0	3	3	1	0	4	3	0	4	0	0	0	0	0	0	0	1	0	0	2



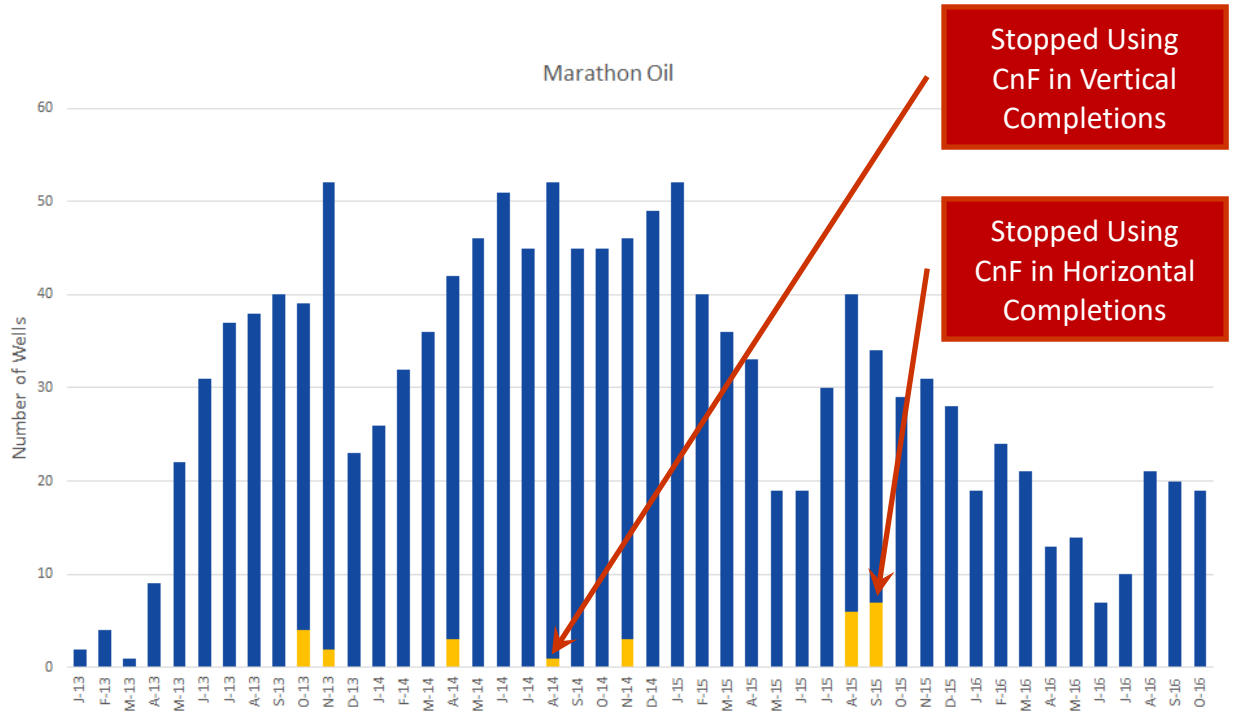
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	2	3	3	4	19	52	40	38	34	56	40	75	36	38	35	41	39	44	70	55	48	41	32	51	39	43	45	42	43	66	34	40	46	72	90	80	18	20	29	19	33	19	0	0	0	0
CNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	6	0	0	0	0	0	0	4	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0


Pioneer Natural Resources
STILL USING CnF
Number of Wells
0
10
20
30
40
50
60
70
80
J-13 F-13 M-13 A-13 M-13 J-13 J-13 A-13 S-13 O-13 N-13 D-13 J-14 F-14 M-14 A-14 M-14 J-14 J-14 A-14 S-14 O-14 N-14 D-14 J-15 F-15 M-15 A-15 M-15 J-15 J-15 A-15 S-15 O-15 N-15 D-15 J-16 F-16 M-16 A-16 M-16 J-16 J-16 A-16 S-16 O-16
No Cn F: 2 13 19 25 42 43 43 64 55 71 49 54 59 49 62 49 65 70 63 54 38 46 53 38 38 34 19 12 7 9 6 6 2 1 10 0 5 3 0 0 0 0 0 0 0
CNF: 2 0 0 2 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 9 17 17 21 25 24 19 30 25 24 25 27 26 13 21 15 14 11 14 1

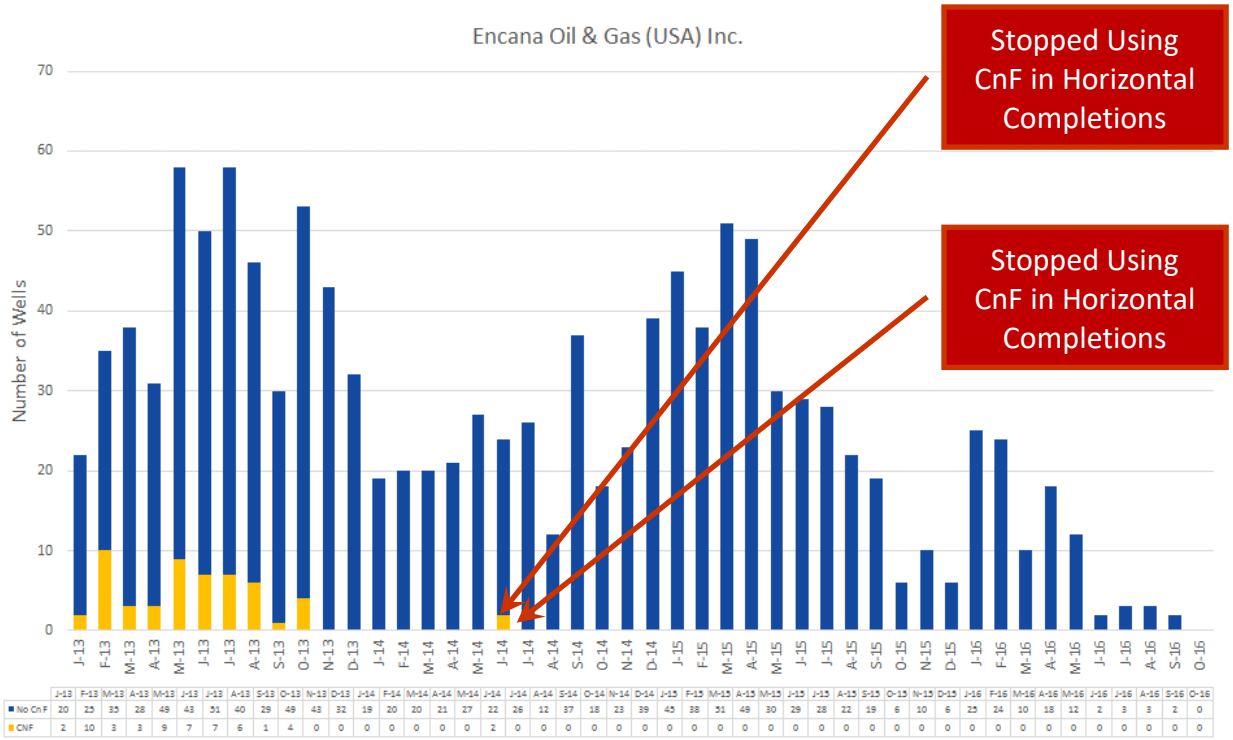

ConocoPhillips Company/Burlington Resources
Stopped Using CnF in Horizontal Completions
Stopped Using CnF in Vertical Completions
Number of Wells
0
10
20
30
40
50
60
70
J-13 F-13 M-13 A-13 M-13 J-13 J-13 A-13 S-13 O-13 N-13 D-13 J-14 F-14 M-14 A-14 M-14 J-14 J-14 A-14 S-14 O-14 N-14 D-14 J-15 F-15 M-15 A-15 M-15 J-15 J-15 A-15 S-15 O-15 N-15 D-15 J-16 F-16 M-16 A-16 M-16 J-16 J-16 A-16 S-16 O-16
No Cn F: 5 7 24 35 41 35 42 40 38 48 44 35 48 48 39 43 51 57 59 51 58 60 44 49 61 41 36 30 33 39 31 29 24 32 23 26 21 23 23 8 6 14 6 5 11 0
CNF: 1 0 1 0 1 1 2 8 5 5 7 5 6 2 1 0 2 4 1 4 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0



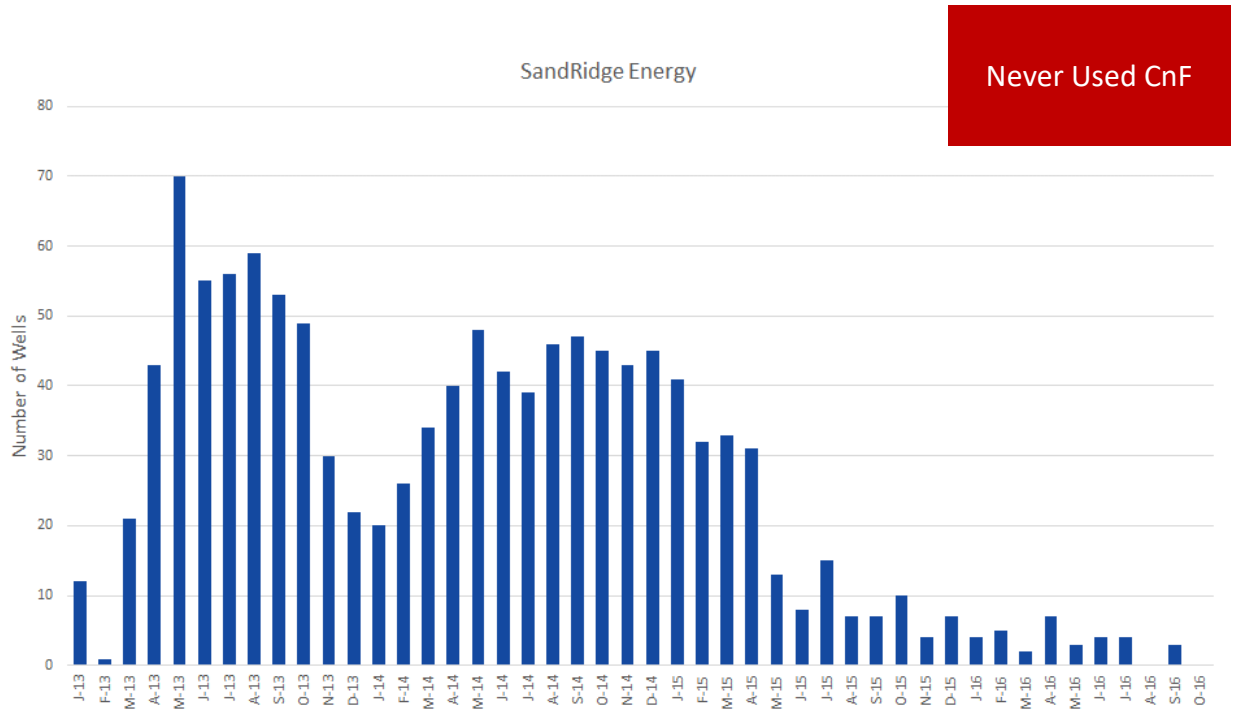
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	37	39	52	43	42	45	40	39	41	42	37	31	51	42	53	60	60	43	39	53	44	50	38	32	49	29	43	35	30	30	21	38	29	35	25	18	5	1	0	0	0	0	1	11	13	8
CnF	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0



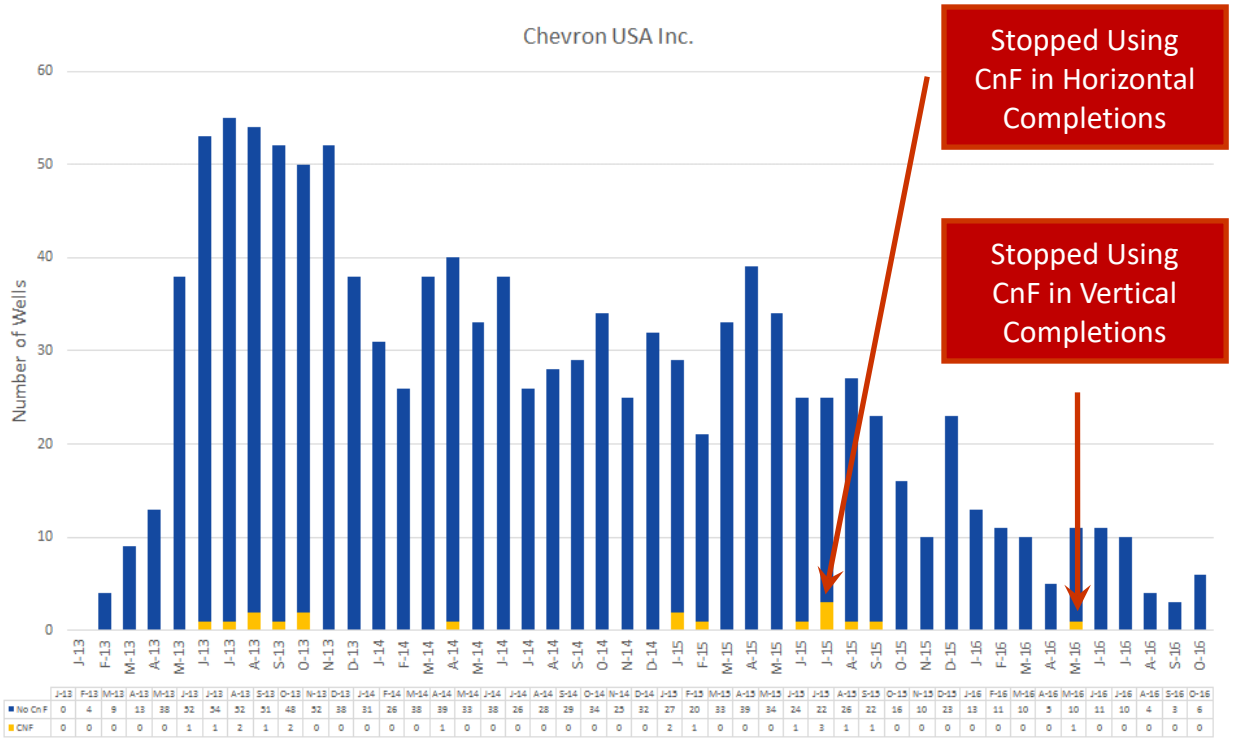
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	2	4	1	9	22	31	37	38	40	35	50	23	26	32	36	39	46	51	45	51	45	45	43	49	52	40	36	33	19	19	30	34	27	29	31	28	19	24	21	13	14	7	10	21	20	19
CnF	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	3	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0



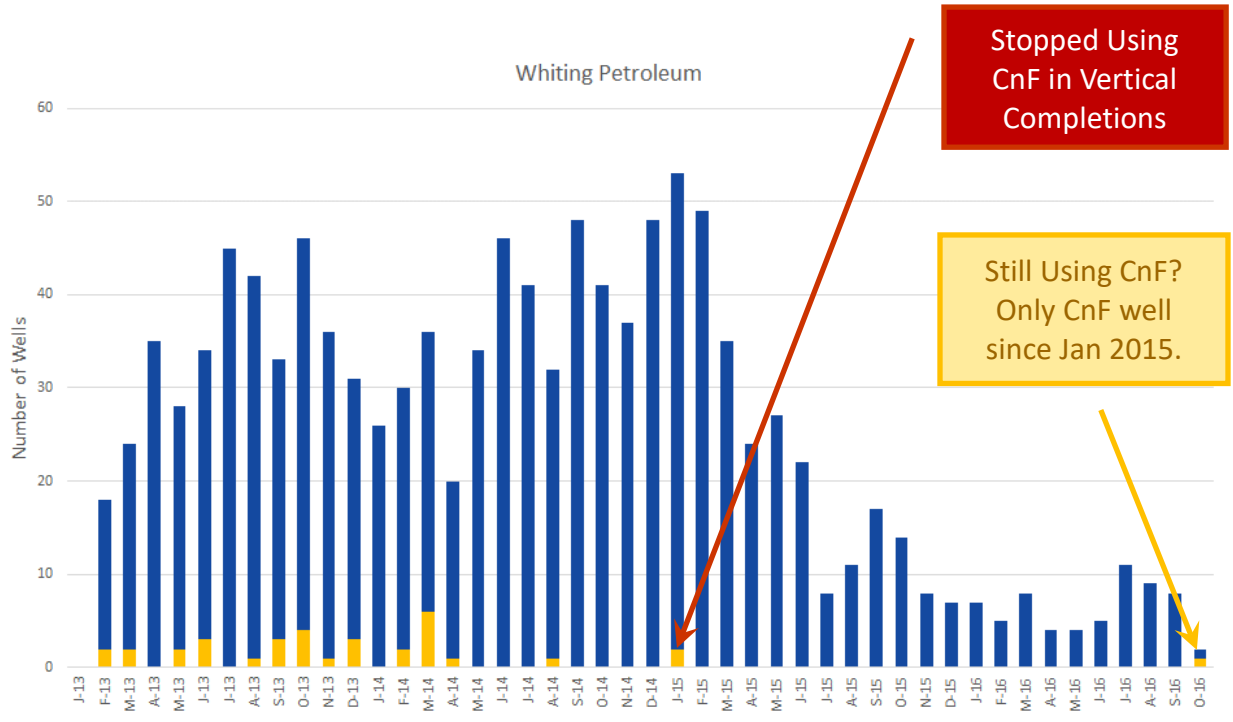
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	20	25	35	28	49	43	51	40	29	49	43	32	19	20	20	21	27	22	26	12	37	18	23	39	45	38	51	49	30	29	28	22	19	6	10	6	25	24	10	18	12	2	3	3	2	0
CnF	2	10	3	3	9	7	7	6	1	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



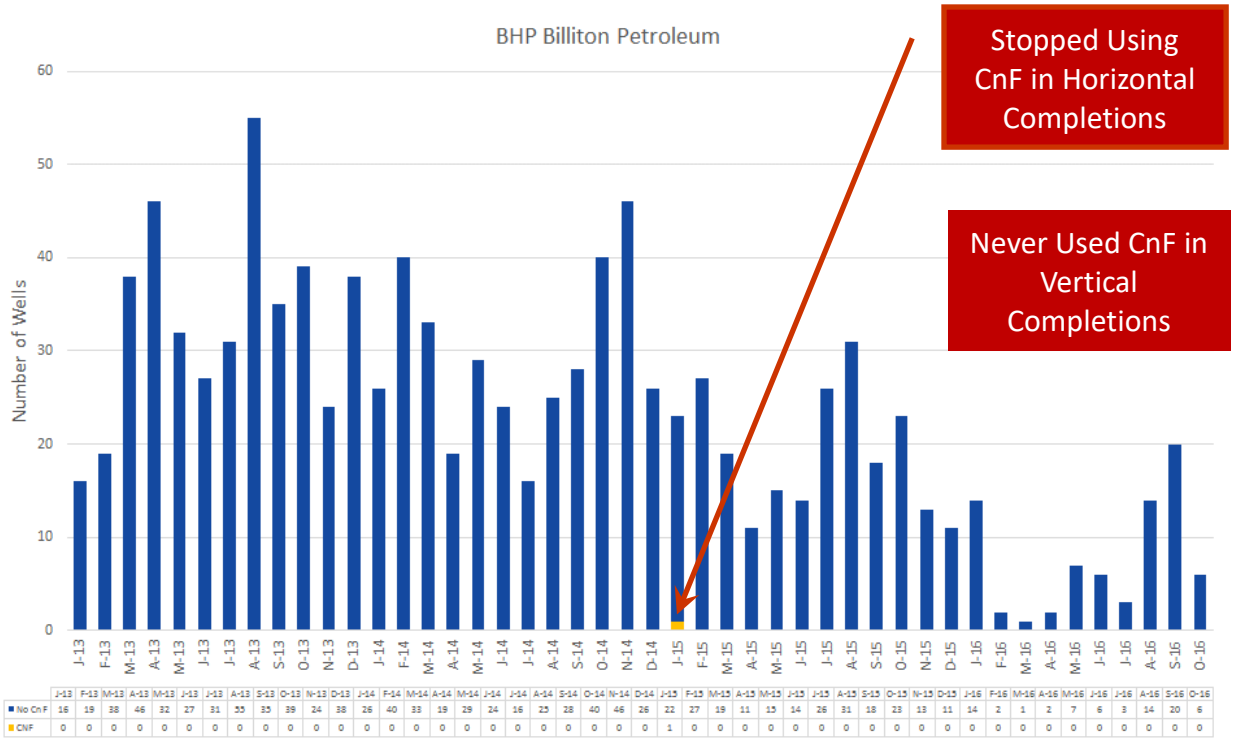
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	12	1	21	43	70	55	56	59	53	49	30	22	20	26	34	40	48	42	39	46	47	45	43	45	41	32	33	31	13	8	15	7	7	10	4	7	4	5	2	7	3	4	4	0	3	0
CnF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



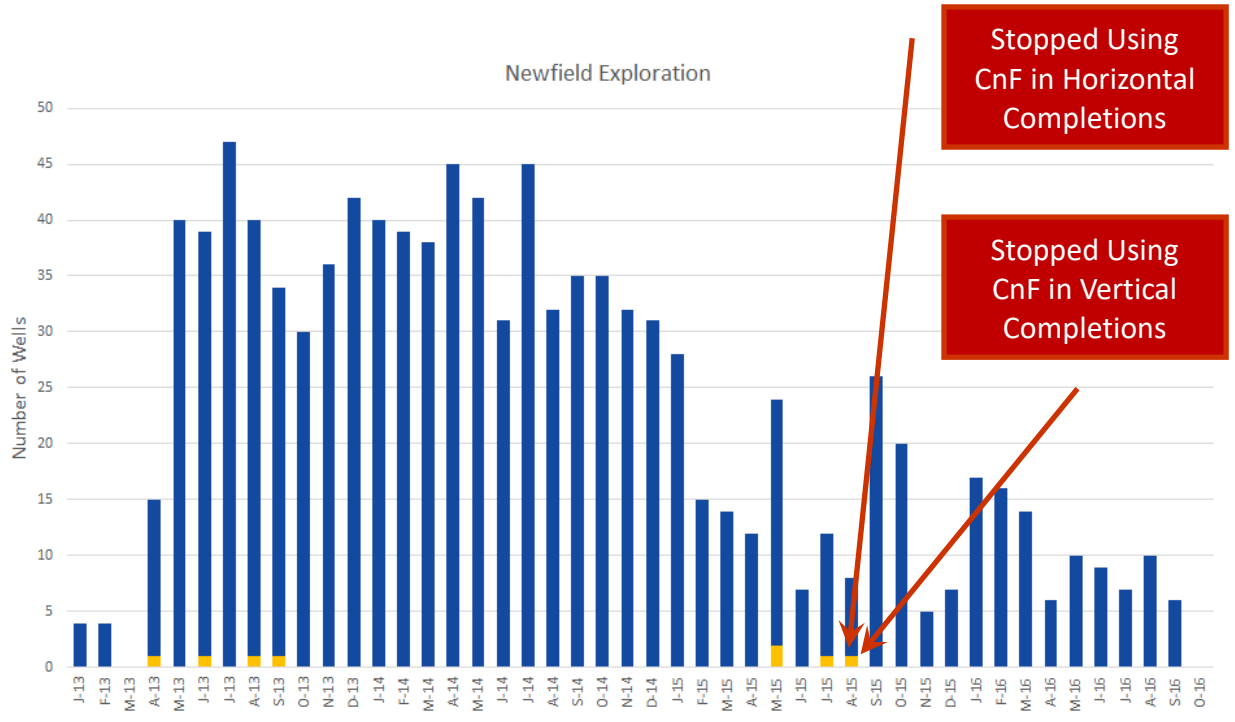
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	0	4	9	13	38	52	54	52	51	48	52	38	31	26	38	39	33	38	26	28	29	34	25	32	27	20	33	39	34	24	22	26	22	16	10	23	13	11	10	5	10	11	10	4	3	6
CnF	0	0	0	0	0	1	1	2	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	1	3	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0



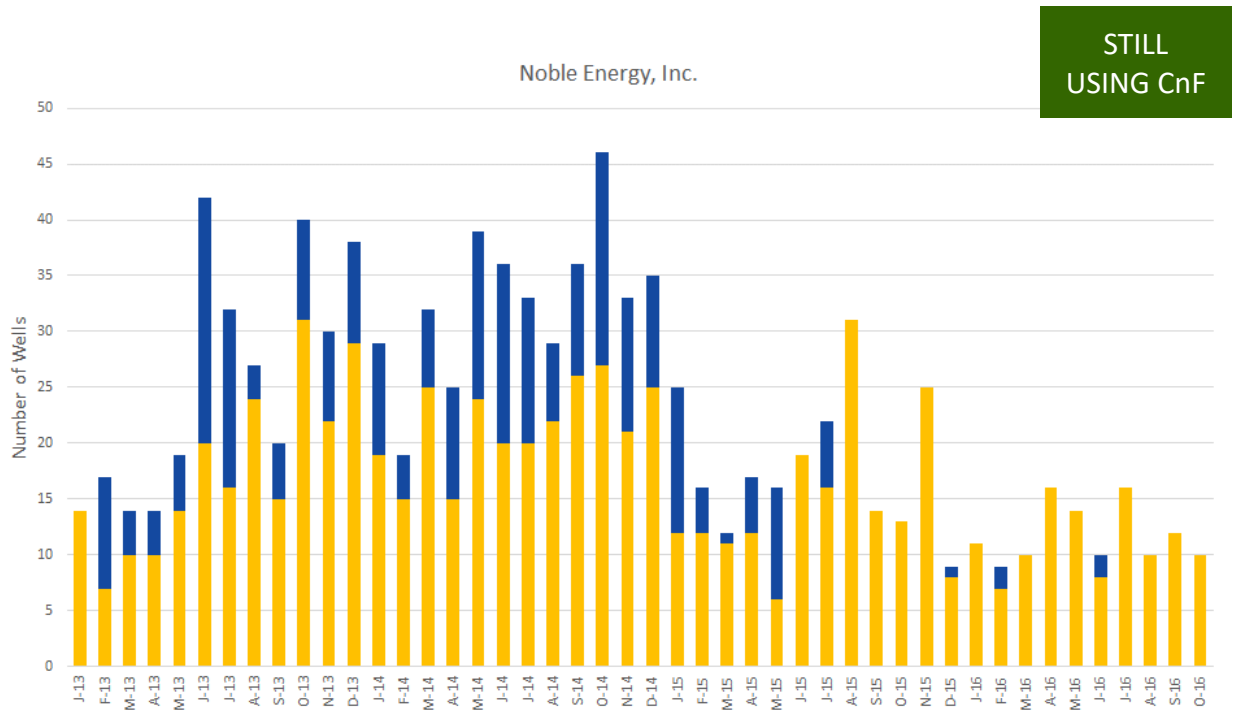
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	0	16	22	35	26	31	45	41	30	42	35	28	26	28	30	19	34	46	41	31	48	41	37	48	51	49	35	24	27	22	8	11	17	14	8	7	7	5	8	4	4	5	11	9	8	1
CnF	0	2	2	0	2	3	0	1	3	4	1	3	0	2	6	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1



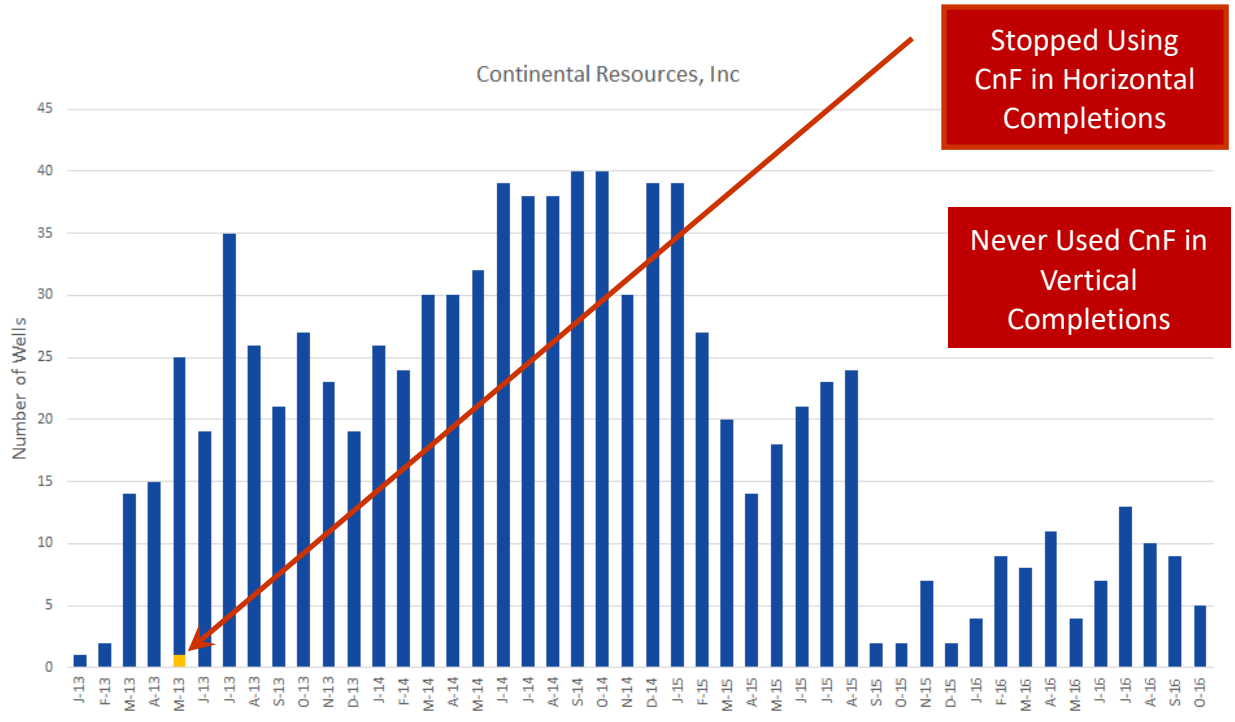
	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	16	19	38	46	32	27	31	55	35	39	24	38	26	40	33	19	29	24	16	25	28	40	46	26	22	27	19	11	15	14	26	31	18	23	13	11	14	2	1	2	7	6	3	14	20	6
CNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	4	4	0	14	40	38	47	39	33	30	36	42	40	39	38	45	42	31	45	32	35	35	32	31	28	15	14	12	22	7	11	7	26	20	5	7	17	16	14	6	10	9	7	10	6	0
CNF	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0



	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	0	10	4	4	5	22	16	3	5	9	8	9	10	4	7	10	15	16	13	7	10	19	12	10	13	4	1	5	10	0	6	0	0	0	0	1	0	2	0	0	0	2	0	0	0	0
CNF	14	7	10	10	14	20	16	24	15	31	22	29	19	15	25	15	24	20	20	22	26	27	21	25	12	12	11	12	6	19	16	31	14	13	25	8	11	7	10	16	14	8	16	10	12	10



	J-13	F-13	M-13	A-13	M-13	J-13	J-13	A-13	S-13	O-13	N-13	D-13	J-14	F-14	M-14	A-14	M-14	J-14	J-14	A-14	S-14	O-14	N-14	D-14	J-15	F-15	M-15	A-15	M-15	J-15	J-15	A-15	S-15	O-15	N-15	D-15	J-16	F-16	M-16	A-16	M-16	J-16	J-16	A-16	S-16	O-16
No Cn F	1	2	14	15	24	19	35	26	21	27	23	19	26	24	30	30	32	39	38	38	40	40	30	39	39	27	20	14	18	21	23	24	2	2	7	2	4	9	8	11	4	7	13	10	9	5
CNF	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0