

# The Crawford Equation: Calculation of Effective Propped Fracture Area

Presentation for Society of Petroleum Evaluation Engineers

April 18, 2017 - Casper, Wyoming - Michael T. Borah, PE

Based on SPE paper #12064

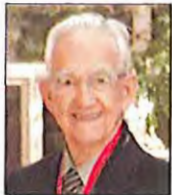
“Proppant Scheduling and Calculation of Fluid Lost During Fracturing”

By H.R. “Randy” Crawford

Presented at the 58<sup>th</sup> Annual Technical Conference and Exhibition

Held in San Francisco, CA October 5 – 8, 1983

## In Memoriam



**HORACE RANDOLPH (RANDY) CRAWFORD**, SPE, died 16 December 2015 at age 87. He was a pioneer in fracture treatment designs and products and was honored as a *JPT* Legend of Production and Operations in 2009.

After graduating with a PhD in chemical engineering from the University of Texas at Austin, Crawford joined Western Company as a research associate and developed acidizing, cementing, and fracturing products and treatment designs. One of his early papers, with other coauthors, “Carbon Dioxide—A Multipurpose Additive for Effective Well Stimulation,” was published in *JPT* in 1963. After Western, Crawford worked for several other companies, including Westco Research (a Western Company subsidiary), Lone Star Gas Company’s Nipak Fertilizer, and Sanitech and Enserch Exploration.

Crawford joined Conoco in 1979, and was tasked with increasing the production rate of the company’s Gulf of Mexico oil wells. He prepared a well completion plan and developed in-house tools to teach the plan to others. The results were successful and Conoco increased the production rates and revenues from the first two platforms by approximately USD 104 million annually.

He authored several technical papers, including methods to calculate the dimensions of a fracture using the properties of the reservoir and fracture fluid. He authored six patents for technologies, including explosive charge assemblies, secondary recovery of petroleum, seismic methods, and transmission of mechanical power.

The coal seam fracture treatments he helped design for Consol Coal, Conoco’s sister company, is considered one of his greatest contributions to the industry. Still being used today, this technology allows engineers to fracture and produce the methane from coal seams before sending miners into the mine. This has made coal mining safer by reducing the methane content in the mine and released into the atmosphere, and has reduced the operational cost. For this contribution, Crawford received a Special Achievement Award from Conoco.

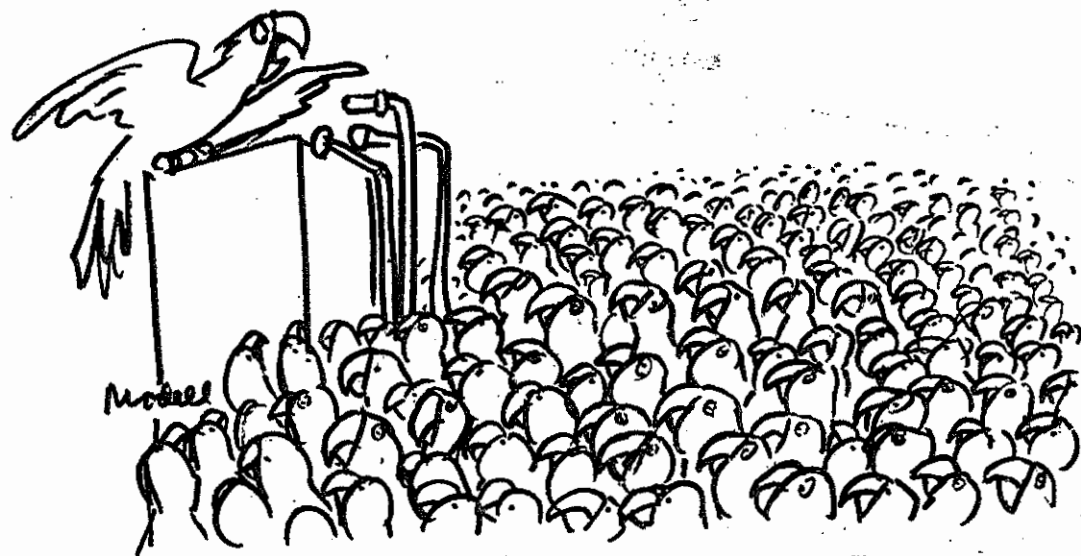
Crawford was passionate about education. With his wife, Louise Crawford, he established two scholarship funds—the Dr. H.R. and Louise Crawford Scholarship Endowment at Texas Tech University and the H.R. Crawford Endowed Graduate Fellowship in Engineering for graduating engineering students at the University of Texas at Austin. These have so far helped more than 100 students attend college.

## The Crawford Equation - Calculation of Effective Propped Fracture Area

| <u>Exhibit</u> | <u>Description</u>                     | <u>Exhibit</u> | <u>Description</u>                     |
|----------------|----------------------------------------|----------------|----------------------------------------|
| #1             | Randy Crawford & Paper Title           | #27            | Micro-Seismic Blackjack Well           |
| #2             | Table: Setback Summary                 | #28            | Decline Curve Roger 3875-20-29 1FH     |
| #3             | Diagram 40-acre Tract                  | #29            | Decline Curve Allemand 12-2/1H         |
| #4             | Joshi #1 Diagram - Dakota              | #30            | Decline Curve Hornbuckle E-28-21H      |
| #5             | Table Fetter Field Area                | #31            | Decline Curve Hornbuckle 14-31/30H     |
| #6             | Decline Curve Niobrara Verticals       | #32            | Sussex PRB Horizontal Wells            |
| #7             | Federal Unit DSU with Joshi #1         | #33            | Decline Curve Clausen 19-34-70 C 10H   |
| #8             | Pinedale Unit DSU with Joshi #1        | #34            | Decline Curve Hardy 34-7 38-73BH       |
| #9             | Plot Perm vs Porosity by Rock Type     | #35            | Niobrara PRB Horizontal Wells          |
| #10            | Crawford Equation & Derivation         | #36            | Decline Curve Spillman 16-1            |
| #11            | Crawford Summary Points                | #37            | Plot Q vs Cum Oil Spillman 16-1H       |
| #12            | Frac Width Equations                   | #38            | Decline Curve Wagonhound 14-1H         |
| #13            | Frac Height Considerations             | #39            | Decline Curve Barton 32-34-67 A 1H     |
| #14            | Log PPMU Communication Frontier        | #40            | Decline Curve Ballista 202-1003H       |
| #15            | Plot PPMU Pressure vs Time             | #41            | Decline Curve Clausen 35-34-70 A 3H    |
| #16            | Frac Model Cole Creek F12-26G Frontier | #42            | Summary of Equations                   |
| #17            | Data Source Halliburton Chesapeake     | #43            | Summary of Equations (page 2)          |
| #18            | Data Source CalFrac Anadarko           | #44            | Formation Properties                   |
| #19            | Frac Summary Niobrara                  | #45            | Formation Properties (page 2)          |
| #20            | Crawford Calculation                   | #46            | Formation Properties (page 3)          |
| #21            | Joshi #2 Drainage Niobrara             | #47            | Formation Properties & $\Delta T$ vs E |
| #22            | Seedy Draw Turner                      | #48            | STAY CALM & FRAC ON !!!                |
| #23            | Colorado Wattenberg Niobrara           |                |                                        |
| #24            | Frac Conductivity vs Closure Stress    |                |                                        |
| #25            | Frontier PRB Horizontal Wells          |                |                                        |
| #26            | Decline Curve Black Jack Well          |                |                                        |

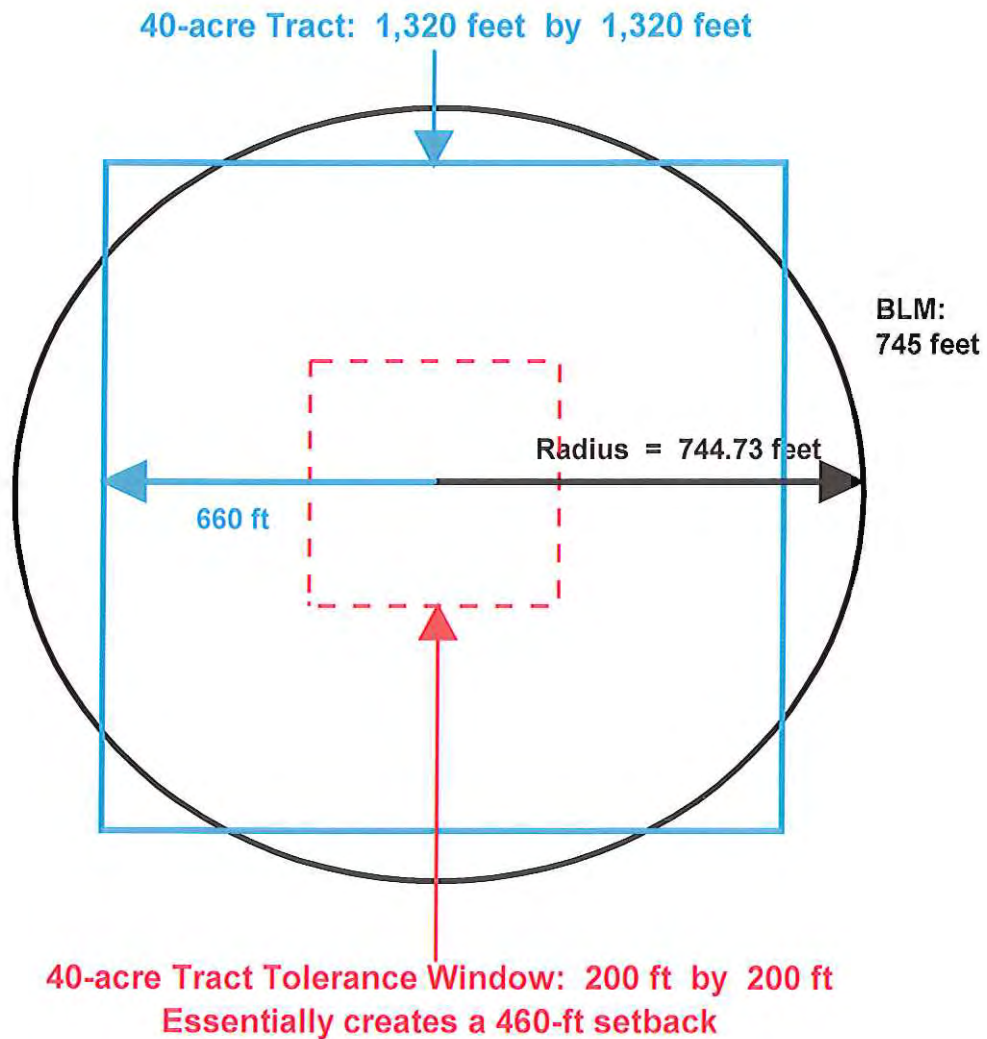
## Setback Summary in Wyoming PRB

|                  | Range             | Range          | Transverse     | Unstimulated   | Effective     |
|------------------|-------------------|----------------|----------------|----------------|---------------|
| <u>Formation</u> | <u>Toe / Heal</u> | <u>Lateral</u> | <u>Drain R</u> | <u>Drain R</u> | <u>Max Xf</u> |
| Sussex           | 200' / 460'       | 330' / 800'    | 331'           | 118'           | 213'          |
| Shannon          | 200' / 460'       | 330' / 800'    | 493'           | 263'           | 230'          |
| Frontier         | 330' / 460'       | 330' / 800'    | 459'           | 232'           | 227'          |
| Niobrara         | 330' / 460'       | 330' / 800'    | 319'           | 132'           | 187'          |
| Mowry            | 330' / 460'       | 330' / 800'    | 305'           | 132'           | 173'          |



*"Not only do I want a cracker—we all want a cracker!"*

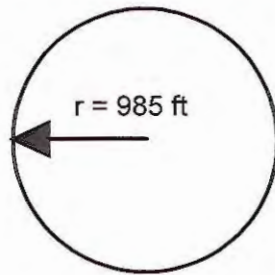
## Comparison of Radial to Square Tract





## Overhead Views: Vertical Dakota Well vs Horizontal Dakota Well

### Drainage Area Calculation (Joshi Method #1):



#### Vertical Well Drainage

$$A = \pi \times r^2 = 70 \text{ acres Moore Ranch 12-13 (12-40N-75W)}$$

$$A = \pi \times (985 \text{ ft})^2 / 43,560 \text{ sq ft / acre}$$

$$\text{Drainage Area } A = 70 \text{ acres}$$

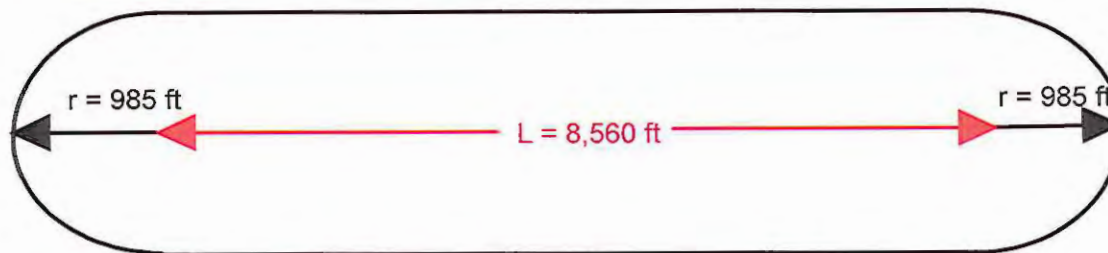
#### Horizontal Well Drainage for 1,280-acre D&S (note: orientation not shown)

$$A = \pi \times r^2 + 2 \times r \times L$$

$$L = 8,560 \text{ ft (1,000-ft setbacks toe \& heal)}$$

$$A = \pi \times (985 \text{ ft})^2 / 43,560 \text{ sq ft / acre} + 2 \times (985 \text{ ft}) \times (8,560 \text{ ft}) / 43,560 \text{ sq ft / acre}$$

$$\text{Horizontal Dakota Well Drainage Area } A = 457 \text{ acres}$$



## Select Vertical & Horizontal Wells In & Around Fetter Field Area

| Count | Well Name          | API No.<br>49-009- | Location                                                       | Frac Size                                  | Zone                                        | Producing<br>Period                           | Cum BO                  | Cum Mcf                      | Cum BW                | EUR BO          | Drainage<br>Area (acres)                       |
|-------|--------------------|--------------------|----------------------------------------------------------------|--------------------------------------------|---------------------------------------------|-----------------------------------------------|-------------------------|------------------------------|-----------------------|-----------------|------------------------------------------------|
| 1     | Hageman 11-22      | 28204              | ne sw 22-33N-71W                                               | 71,000# 40/70<br>201,590# 40/70            | Niobrara<br>Frontier                        | 11-09 to 3-13<br>9-08 to 10-09                | 11,206<br>4,158         | 54,948<br>82,342             | 1,342<br>1,492        | 11,206<br>4,158 | 21.9<br>2.4                                    |
| 2     | Wallis 6-23        | 28170              | se nw 23-33N-71W<br>7,500# 100-mesh & 200,380# 20/40 InterProp | 130,000# 30/50                             | Niobrara<br>Frontier                        | 11-09 to 9-14<br>4-08 to 10-09                | 22,788<br>2,689         | 127,610<br>55,825            | 4,829<br>9,406        | 22,788          | 27.8                                           |
| 3     | Sims 7-25          | 28210              | sw ne 25-33N-71W                                               | 300,400# 20/40 InterProp<br>159,000# 30/50 | Frontier<br>Niobrara<br>Nio - Fr            | 1-09 to 12-09<br>1-10 to 2-10<br>3-10 to 5-15 | 5,736<br>2,457<br>7,831 | 162,401<br>14,179<br>211,355 | 3,788<br>598<br>4,572 | 14,468<br>5,525 | 4.0<br>8.0<br>EUR's Pro-rated 74% FR & 26% Nio |
| 4     | Sims 16-26         | 28085              | se se 26-33N-71W                                               | Open-Hole Completion                       | Nio - Fr<br>Niobrara<br>Frontier<br>Parkman | 9-05 to 4-08<br><br>5-08 to 6-11              | 6,930<br><br>2,875      | 33,438<br><br>0              | 0<br><br>2,040        | 1,802<br>5,128  | 2.5<br>1.5                                     |
| 5     | Sims 15-26H        | 28148              | sw se 26-33N-71W                                               |                                            | Frontier                                    | 8-07 to 8-12                                  | 20,981                  | 770,316                      | 6,997                 |                 |                                                |
| 6     | Sims 33-71 26-1H   | 28323              | se sw 26-33N-71W                                               | 3.56 MM# - 14 Stage                        | Niobrara                                    | 9-11 to 1-17                                  | 211,299                 | 1,476,603                    | 34,944                | 385,000         | 52<br>Joshi #2                                 |
| 7     | Sims 26-33-71 B 2H | 28839              | sw se 26-33N-71W                                               | 3.49 MM# - 13 Stage                        | Niobrara                                    | 12-12 to 1-17                                 | 69,248                  | 698,835                      | 33,208                | 275,000         | 56<br>Joshi #2                                 |
| 8     | Sims 43-28         | 21347              | ne se 28-33N-71W<br>Combined Nio / Fr Frac November 2008:      | 125,000# 30/50<br>300,000# 40/70           | Niobrara<br>Frontier                        | 1-10 to 10-13<br>11-90 to 12-09               | 9,602<br>17,337         | 67,111<br>134,125            | 1,398<br>4,199        | 9,602<br>17,337 | 6.5                                            |
| 9     | Githen 1           | 21662              | ne nw 34-33N-71W                                               | No Frac                                    | Niobrara                                    | 12-80 to 10-83                                | 1,698                   | 0                            | 160                   | 1,698           | 2.0                                            |
| 10    | Red Mtn 1H         | 22804              | ne nw 35-33N-71W                                               |                                            | Frontier                                    | 4-84 to 11-15                                 | 39,475                  | 692,118                      | 7,536                 |                 |                                                |
| 11    | Purple Sage 1      | 21894              | sw se 15-35N-73W                                               | No Frac                                    | Niobrara                                    | 12-81 to 9-82                                 | 442                     | 0                            | 0                     | 442             | 0.5                                            |

Average Drainage Area of Four ( 4 ) Vertical Niobrara Fracture-Stimulated Wells: 16.1 acres  
 Drainage Radius of Vertical Niobrara Fracture-Stimulated Wells: r = 473 feet  
 Average Drainage Area of Two ( 2 ) Vertical Niobrara Non-Stimulated Wells: 1.25 acres  
 Drainage Radius of Vertical Niobrara Non-Stimulated Wells: R = 132 feet

④

Wold Energy Partners

Docket 411 - 2017

Exhibit E - 8

## Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Niobrara Comparison Wells.mdb

Date: 4/5/2017

Time: 11:24 AM

Lease Name: Fetter Area ()

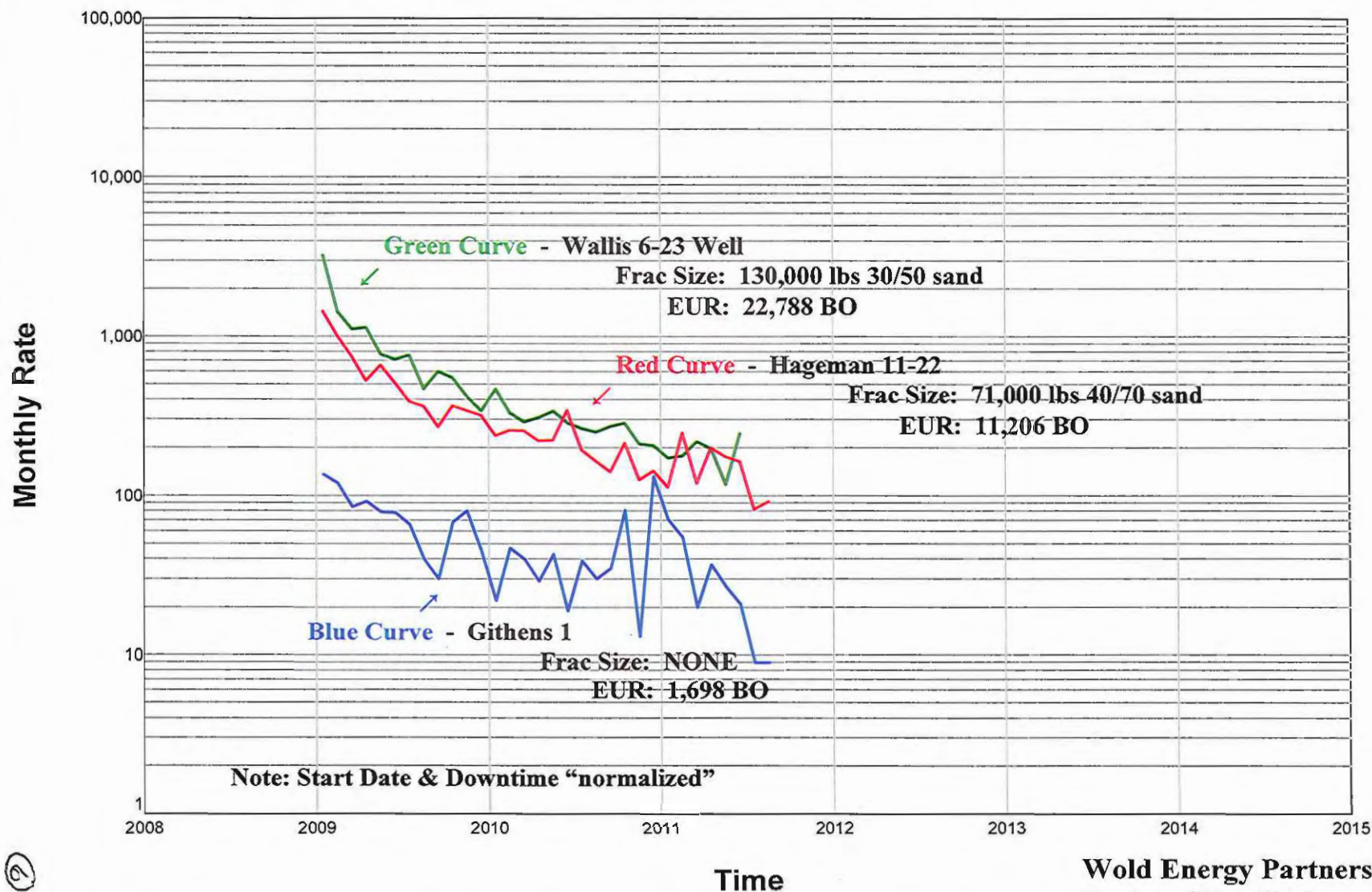
County, ST: Converse, WY

Location: 33N-71W-23

Operator: Chesapeake

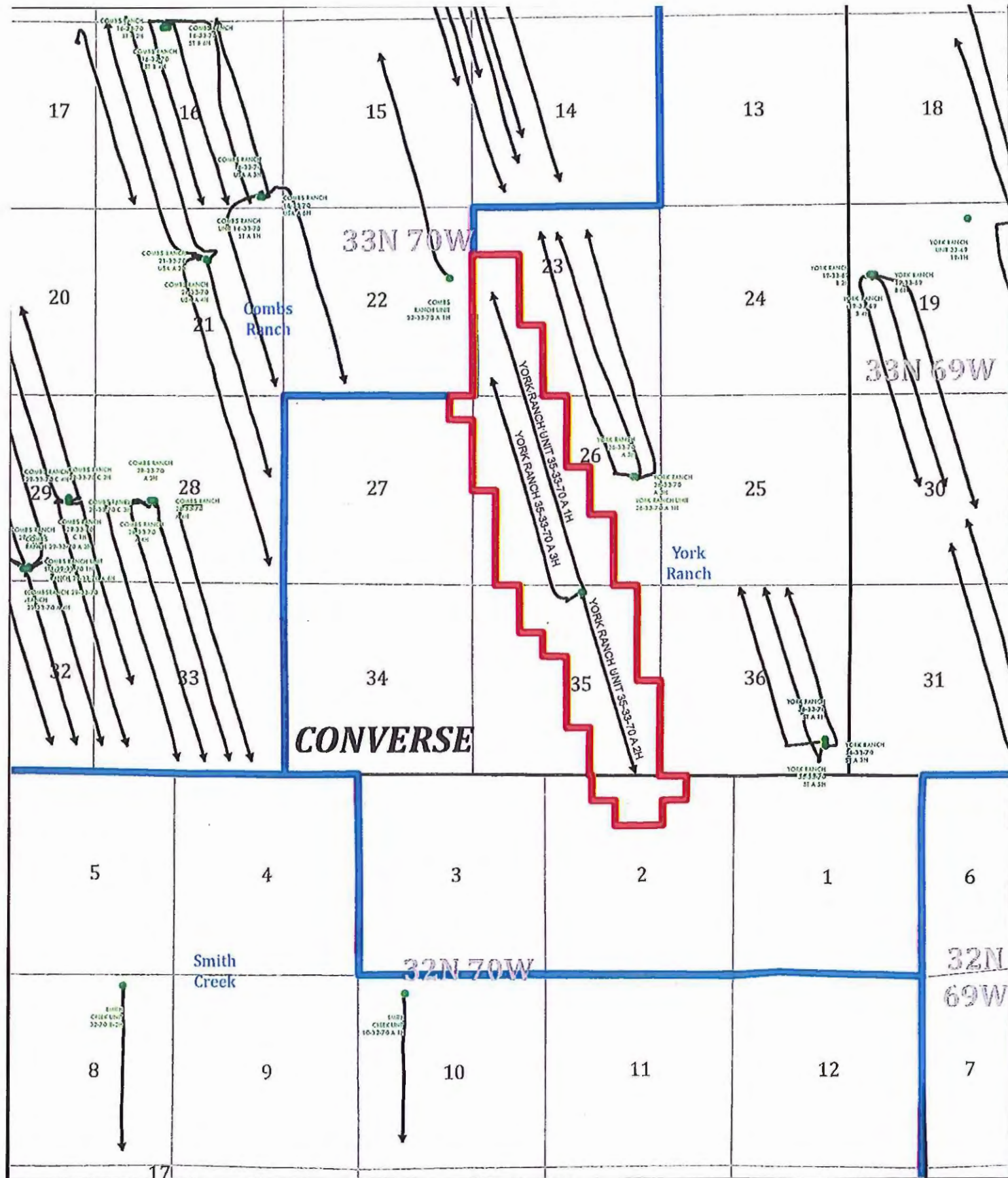
Field Name: Fetter

### Fetter Field Niobrara: Comparison of Fracture-Stimulated Wells to a Non-Stimulated Well



Wold Energy Partners  
Docket 623 - 2016  
Exhibit E - 6





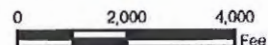
**Legend**

- Producer
- Laterals
- ◉ Abandoned
- ▭ Spacing Area
- ▭ Federal Unit

**Docket No. 848-2016**  
**Exhibit No. L-1**

**33N-70W-23, 26, 27, & 35 & 32N-70W-2**  
**Converse County, WY**

1 inch = 3,500 feet



# JOSHI METHOD

$$D = \frac{2r \times L + \pi \times r^2}{43,560}$$

D = Horizontal Drainage Area (acres)

r = average drainage radius of nearby vertical wells

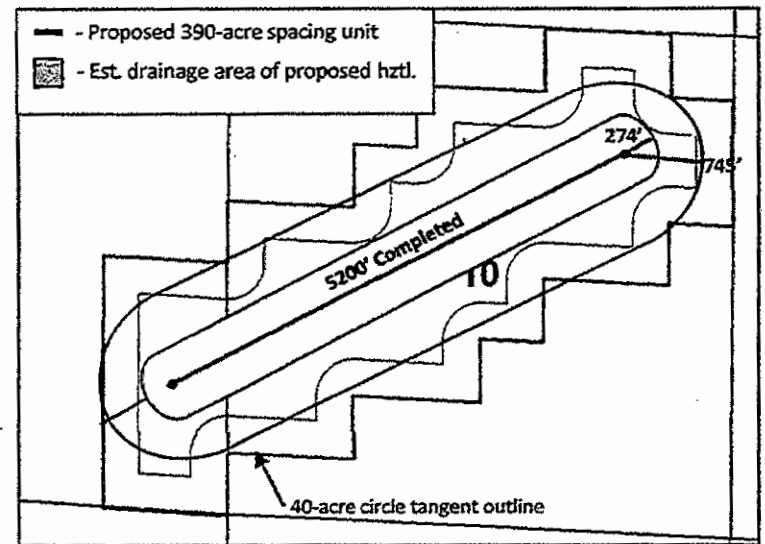
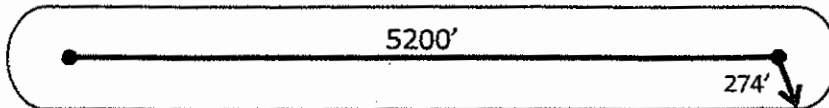
L = completed lateral length of proposed horizontal

AVERAGE DRAIN A = 5.45 ACRES/WELL

**r = 274 feet      D = 71 acres**

**Total Drainage Area in Proposed Unit\*: 142 acres**

11  
VERTICAL  
WELLS  
PINEDALE



**QEP**  
RESOURCES

\*Determined by summing drainage area of 2 horizontals and vertical wells within spacing unit

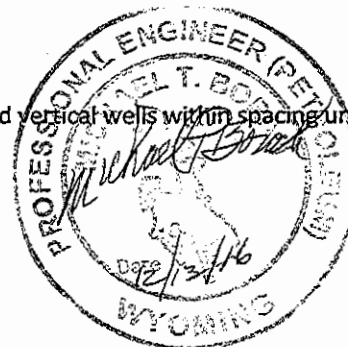
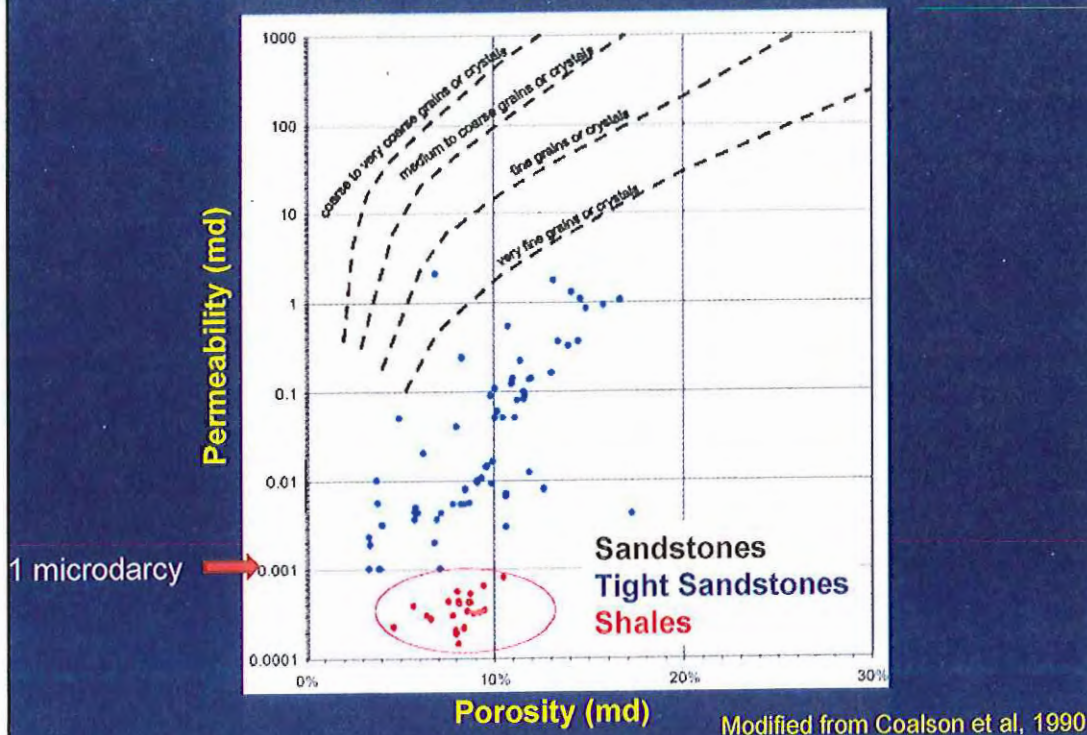


Exhibit E-3  
Cause No. 1  
Order No. 1  
Docket No. 1165-2016  
December 13, 2016

## Permeability Comparison by Rock Type





1957: Howard & Fast presented the basis for fracture design

*"Optimum Fluid Characteristics for Fracture Extension"*

*Drilling & Production Practices, API 1957, page 261*

1967 thru 1970: Howard & Fast prepared the SPE Monograph

*"Hydraulic Fracturing"*

$$A = \frac{0.447 W Q}{C^2} \left[ e^{x^2} \operatorname{erfc}(x) + \frac{2x}{\sqrt{\pi}} - 1 \right], \text{ SQ. FT.}$$

WHERE

$$x = (3.545 C/W) \sqrt{T}, \text{ dimensionless}$$

AND

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-t^2} dt, \text{ dimensionless}$$

1973: Harrington, Whitsett & Hannah presented simpler equations

for the calculation of fracture area & fluid loss

*"Prediction of the Location & Movement of Fluid Interfaces in a Fracture"*

*Southwestern Petroleum Short Course, Texas Tech University*

1983: McLeod presented a high viscosity fracture design program

*"A Simplified Approach to Design of Fracturing Treatments Using High Viscosity Cross-Linked Fluids"*

*SPE Paper 11614: SPE / DOE Joint Symposium on Low Permeability Gas Reservoirs*

*Denver, Colorado, March 1983, Proceedings pp. 121-136*

1983: Crawford presented a practical application of the simpler equations

for the calculation of fracture area & fluid loss

*"Proppant Scheduling & Calculation of Fluid Lost During Fracturing"*

*SPE Paper 12064: 58<sup>th</sup> Annual Technical Conference & Exhibition*

*San Francisco, California, October 1983*

$$A = V / (W + 3 x C x \sqrt{T}) \text{ SQ. FT.}$$

## **Crawford Equation Summary**

- 1. Estimates the Created Fracture Area ( i.e. propped > monolayer )**
- 2. Allows for estimate of effective propped one-wing frac length (  $X_f$  )**
- 3. Provides for high fracture conductivity**
- 4. Calculates the amount of fluid lost**
- 5. Assists with proppant scheduling**
- 6. Avoids potential screenout**
- 7. Helps with on-the-spot decision to continue or abort**

# Fracture Width Equations

## VERTICAL FRACTURES

### PERKINS AND KERN:

$$W_o = 0.38 \left[ \frac{Q\mu L}{E} \right]^{0.25} = 0.38 \left[ \frac{Q\mu L}{E} \frac{(H)}{(H)} \right]^{0.25} \dots (1)$$

$$W(x) = W_o \left[ 1 - (Lx)/L \right]^{0.25} \dots (2)$$

$$W_{avg} = 0.667 W_o \dots (3)$$

### GEERTSMA AND deKLERK:

$$W_o = 0.23 \left[ \frac{Q\mu L^2}{GH} \right]^{0.25} = 0.29 \left[ \frac{Q\mu L}{E} \frac{(L)}{(H)} \right]^{0.25} \dots (4)$$

$$W(x) = W_o \left[ 1 - (Lx)^2/L^2 \right]^{0.5} \dots (5)$$

$$W_{avg} = 0.785 W_o \dots (6)$$

## HORIZONTAL FRACTURES (P&K)

$$W_o = 0.22 \left[ \frac{Q\mu R}{E} \right]^{0.25} \dots (7)$$

$$W(r) = W_o \left[ 1 - r/R \right]^{0.5} \dots (8)$$

$$W_{avg} = 0.667 W_o \dots (9)$$

## WHERE:

$W_o$  = FRACTURE WIDTH AT WELLBORE, INCHES

$Q$  = INJECTION RATE, BARRELS PER MINUTE

$\mu$  = VISCOSITY OF FLUID IN FRACTURE, CENTIPOISE

$\mu_{avg} = 47880 K_f (40.4 Q / W_o^2 H)^{n-1}$ , CENTIPOISE

$L$  = LENGTH OF ONE FRACTURE WING, FEET

$H$  = HEIGHT OF FRACTURE, FEET

$E$  = YOUNG'S MODULUS, PSI

$G$  = SHEAR MODULUS =  $\frac{E}{2 + 2\nu}$ , PSI

$\nu$  = POISSON'S RATIO, (ASSUMED TO BE 0.25 FOR 2ND HALF OF EQN 4.)

$Lx$  = DISTANCE FROM WELLBORE ALONG A FRACTURE OF HALF LENGTH,  $L$ , FEET

$W(x)$  = WIDTH OF FRACTURE AT DISTANCE  $Lx$  FROM WELLBORE, INCHES

$R$  = RADIUS OF FRACTURE, FEET

$r$  = RADIAL DISTANCE TO A POINT IN A FRACTURE OF RADIUS  $R$ , FEET

Crawford: 0.5 inches @ wellbore when concentration > 4.0 ppg

## IN THE BLEACHERS

Steve Moore



"Well, you're a lucky man. It's not a career-ending injury. Of course, you'll have to be careful walking through doorways."

## Fracture Height & Stress Barriers

Higher Poisson's Ratio in adjacent rock will help to provide a barrier to height propagation

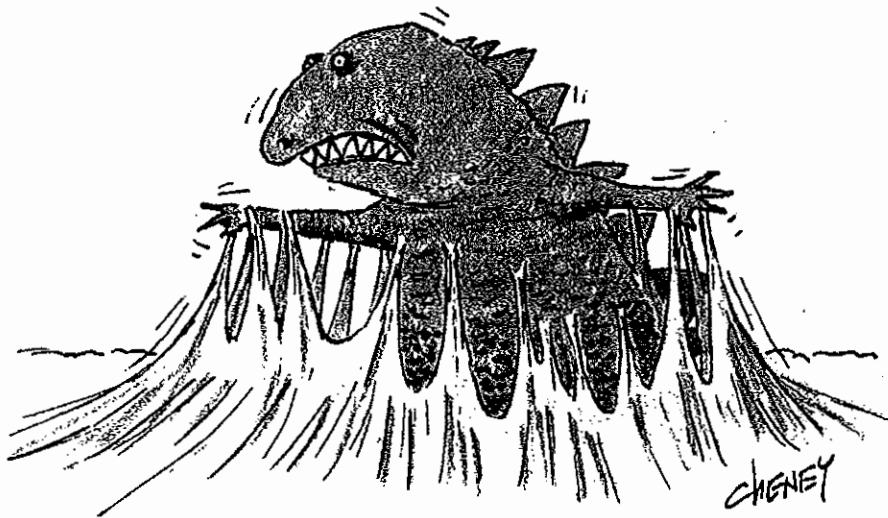
Difference in in-situ stresses is the primary factor in height growth

Sand to shale transitions must be thick enough to act as a barrier

Frac will extend into impermeable shales & siltstones, but narrow width & low leakoff

Most of the horizontal targets in the PRB are in poor quality rocks with minimal stress contrasts above & below: Effective Propped Length is radial in shape

Frontier formation is trickier with sand quality that quickly changes horizontally



**GODZILLA MEETS MOZZARELLA**



12300

## TYPE LOG

ANR Production Co.  
South Powell #2-1  
SE NW SW Sec. 1, T38N, R74W  
Converse County, Wyoming

ANR

ANR Production Company  
A subsidiary of The Conoco Company

Section 1, T38N, R74W  
Converse County, Wyoming

Docket # 282-88

Wyoming Oil & Gas Conservation Commission  
September, 1988

Exhibit \_\_\_\_\_

FIRST FRONTIER

FIRST BENCH

PPMU ZONE

SECOND BENCH

12400

12,412

12,432

12500

Wold Energy Partners

Docket 300 - 2014

Exhibit E - 12

Copy of Exhibit "C"

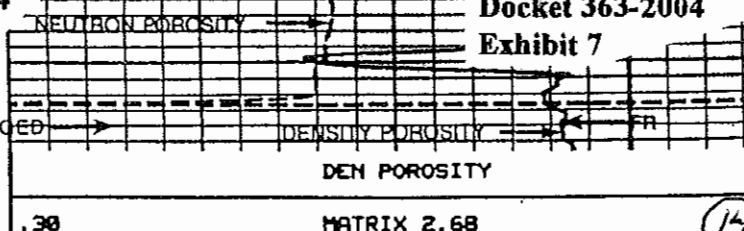
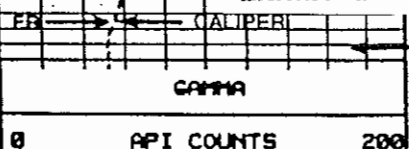
ANR Production Company

Docket 282-88 (Sept. 13, 1988)

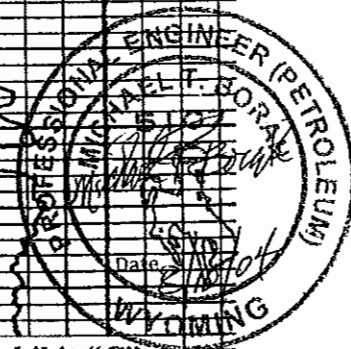
Jetta Operating Company

Docket 363-2004

Exhibit 7

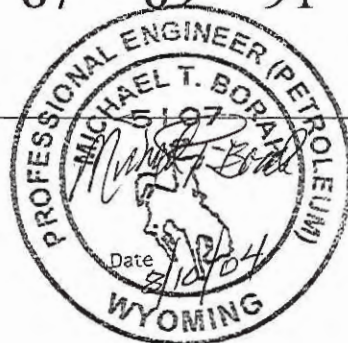


Apud  
11/5/86  
TD 12,561'  
FRAC  
12/11/86  
180,000 gals  
X-Link  
25,000 #  
100-mesh  
260,000 #  
Interpump

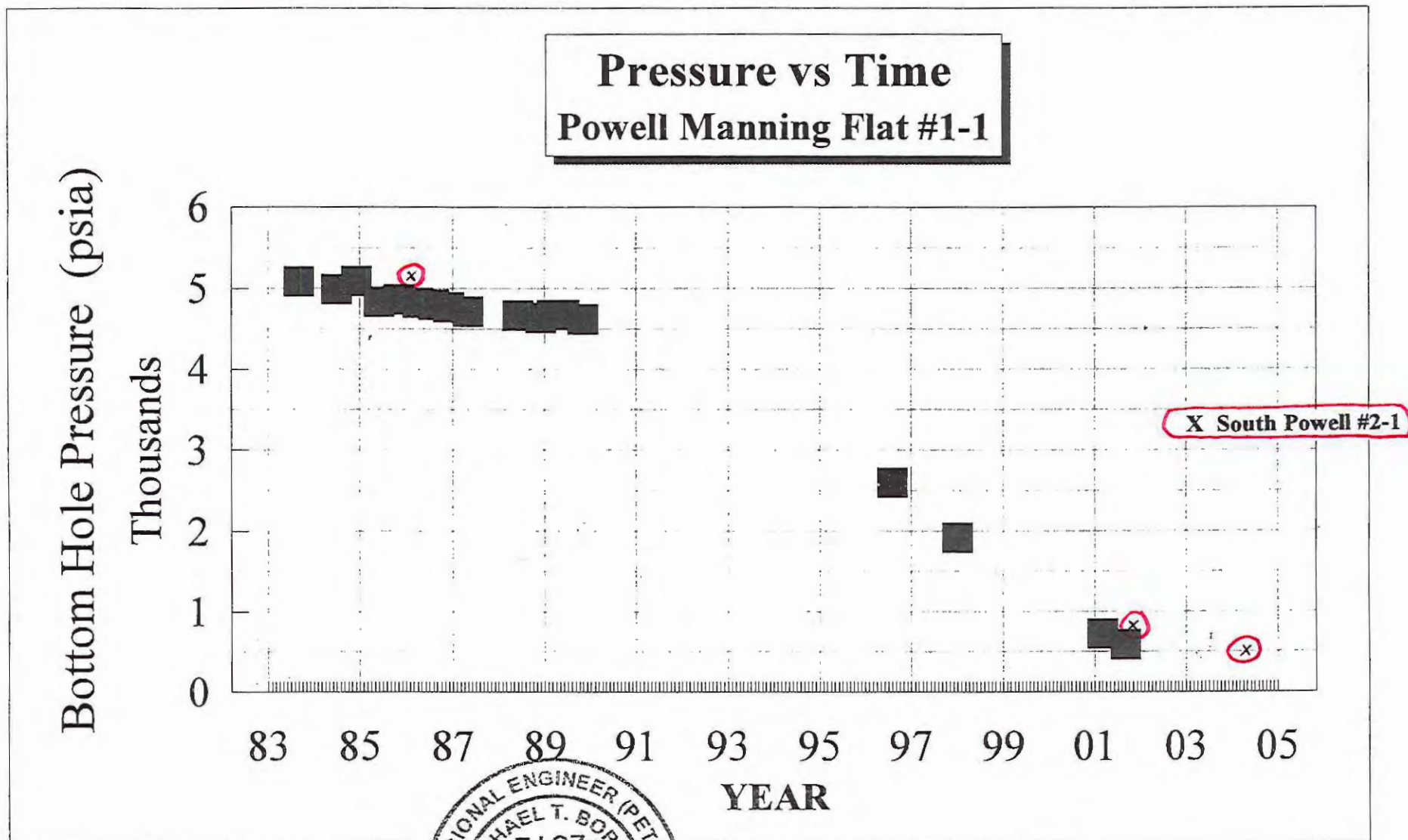


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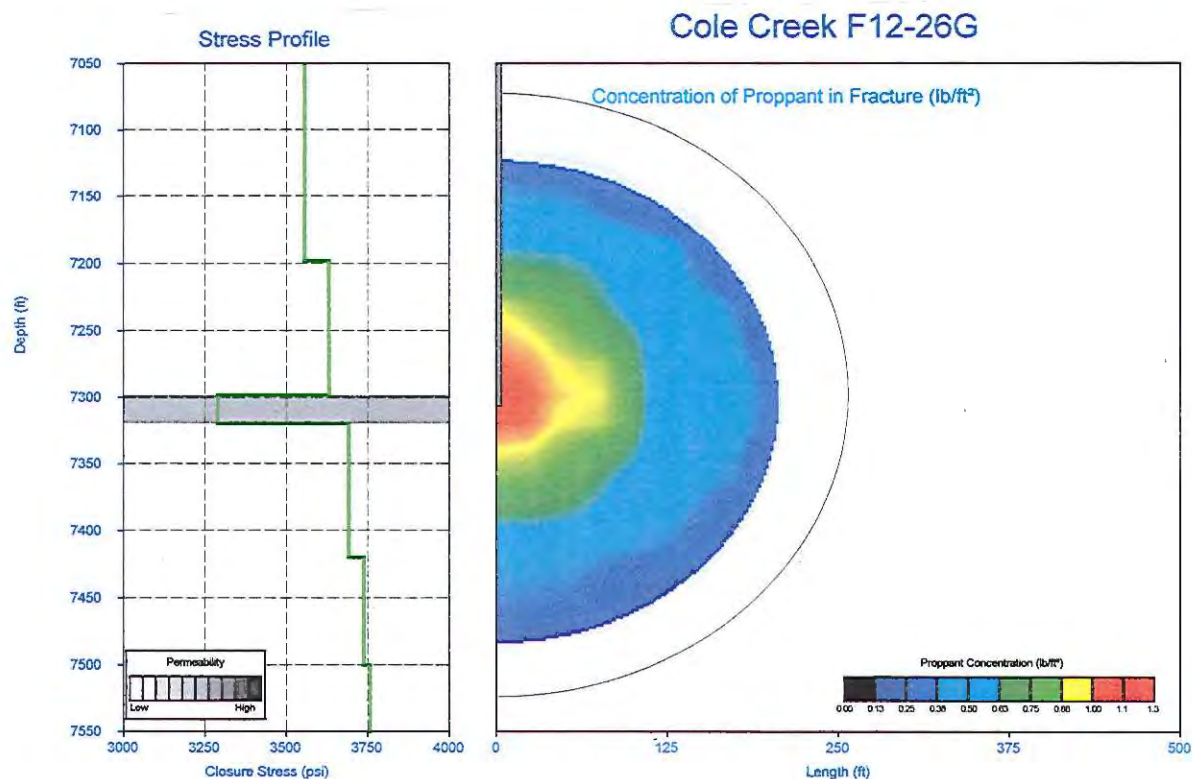
C:\WORK\MFIP.WK4



Jetta Operating Company  
Docket 363-2004  
Exhibit 12



## Cole Creek F-12-26G – Fracture Stimulation of a Vertical Frontier Well



### Cole Creek F12-26G (sw nw 26-35N-77W) API 49-009-06449

Fracture-stimulated on Nov. 9, 2001 - 2nd Frontier perms from 7,300 ft to 7,314 ft with 4 spf 50,920# 20/40 sand & 20,160# 20/40 "PR6000" in a Halliburton "DeltaFrac 2000" X-link system

Average Q = 15.9 bpm with a pump time of 46.3 minutes

|                       | <u>Created Frac Area (propped)</u> | <u>Xf (ft)</u> |
|-----------------------|------------------------------------|----------------|
| Crawford equation     | 58,000 sq ft                       | 136            |
| Halliburton "FracPro" | 80,000 sq ft                       | 160            |

## 4.0 PERFORMANCE HIGHLIGHTS

STAGE 12

### 4.1 Treatment Summary

|                                              |                    |        |
|----------------------------------------------|--------------------|--------|
| Start Time                                   | 03-Oct-12 15:38:30 |        |
| End Time                                     | 03-Oct-12 23:47:23 |        |
| Pump Time                                    | 158.12             | min    |
| Start Averaging Time                         | 03-Oct-12 15:38:40 |        |
| End Averaging Time                           | 03-Oct-12 23:47:23 |        |
| Max Treating Pressure                        | 9902               | psi    |
| Max Slurry Rate                              | 49.8               | bpm    |
| Max Prop Conc                                | 4.54               | lb/gal |
| Avg Treating Pressure                        | 8689               | psi    |
| Avg Slurry Rate                              | 46.7               | bpm    |
| Avg Prop Conc                                | 0.61               | lb/gal |
| Clean Volume                                 | OK 6326.5          | Bbl    |
| Slurry Volume                                | OK 6713            | Bbl    |
| Acid Volume                                  | 2000               | gal    |
| Load to Recover                              | 6326.5             | Bbl    |
| FR-66 Water                                  | 267                | Bbl    |
| 15% FE Acid                                  | 47.6 bbl/s 2000    | gal    |
| Hybor G 35# Fluid                            | 6059.5             | Bbl    |
| SAND - PREMIUM - 40/70, BULK, SK (100064018) | 174,175# 1741.75   | 100*lb |
| SAND - PREMIUM - 30/50, BULK, SK (100009377) | 197,140# 1971.40   | 100*lb |

} 371,315#

Disclaimer: The average and maximum values (except volumes and bottom hole values) are based on the start and end averaging times.

$$SAND V = 371,315\# \times \frac{0.0453}{42} = 400.5 \text{ bbl/s}$$

$$TRUE CLEAN V = 267 + 6059.5 = 6,326.5 \text{ bbl/s}$$

$$TRUE SLURRY V = 6,326.5 + 400.5 = 6,727 \text{ bbl/s}$$

$$T = \frac{6,727}{46.7} = 144.0 \text{ min.}$$



## Treatment Details

### General Info

Loc'n: Trinity Fee 3367-7-31N-H (Sigs 1-12), SESE S7, T33N, R67W  
 Customer: Brett Sisco  
 Anadarko Petroleum Corp.  
 1099 18th Street, Suite 1800  
 Denver, CO 80202

Calfrac Service Line:  
 Job Date: 04/24/13  
 Job Type: Hybrid DynaFlow-ZWR  
 Program Number: FADD0002SD  
 Service Order #: 72270

585

Frac

AVERAGE RATE FROM

OPERATION SUMMARY

### Detailed Stage Summary

| #  | Elapsed Time (h:m:s) | Treating Pressure (psi) |      | Rate (bpm) |       |     |    | Clean Fluid Pumped (bbl) |         | Start Conc. (ppg) | End Conc. (ppg) | Proppant (lb) |         | Stage Details                                     |
|----|----------------------|-------------------------|------|------------|-------|-----|----|--------------------------|---------|-------------------|-----------------|---------------|---------|---------------------------------------------------|
|    |                      | Max                     | Min  | Slurry     | Clean | CO2 | N2 | Stage                    | Total   |                   |                 | Stage         | Total   |                                                   |
| 1  | 0:07:34              | 5991                    | 5528 | 10.3       | 10.3  |     |    | 78.0                     | 78.0    |                   |                 |               |         | Pump In - [Linear Gel] - Stage 1                  |
| 2  | 0:10:01              | 5991                    | 5528 | 38.9       | 10.3  |     |    | 95.2                     | 173.2   |                   |                 |               |         | Acid - [15% HCl] - Stage 1                        |
| 3  | 0:22:49              | 9211                    | 6355 | 38.9       | 58.2  |     |    | 497.8                    | 671.0   |                   |                 |               |         | Pad - [DynaFlow-ZWR] - Stage 1                    |
| 4  | 0:33:05              | 8938                    | 8332 | 50.7       | 49.7  |     |    | 510.1                    | 1181.1  | 0.47              | 0.47            | 10000         | 10000   | 0.5 ppg Sand - [DynaFlow-ZWR / Sand, 100 Mesh]    |
| 5  | 0:40:03              | 8532                    | 8032 | 53.2       | 52.1  |     |    | 362.8                    | 1543.7  | 0.48              | 0.48            | 7283          | 17283   | 0.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 6  | 0:49:14              | 8128                    | 7866 | 53.8       | 51.9  |     |    | 476.2                    | 2019.9  | 0.85              | 0.85            | 17000         | 34283   | 1 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 7  | 0:58:04              | 8178                    | 7874 | 57.4       | 53.9  |     |    | 476.3                    | 2496.2  | 1.40              | 1.40            | 28006         | 62289   | 1.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 8  | 1:06:05              | 7835                    | 7521 | 58.1       | 53.4  |     |    | 428.9                    | 2925.1  | 1.90              | 1.90            | 34226         | 96516   | 2 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 9  | 1:13:49              | 7635                    | 7424 | 58.2       | 52.4  |     |    | 404.9                    | 3330.0  | 2.40              | 2.40            | 40814         | 137330  | 2.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 10 | 1:21:18              | 7562                    | 7202 | 57.9       | 51.0  |     |    | 381.2                    | 3711.2  | 2.96              | 2.98            | 47711         | 185041  | 3 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 11 | 1:29:06              | 7328                    | 6964 | 56.8       | 49.5  |     |    | 386.9                    | 4098.1  | 3.23              | 3.23            | 52500         | 237541  | 3.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 12 | 1:37:24              | 7548                    | 7331 | 56.9       | 49.7  |     |    | 412.7                    | 4510.8  | 2.92              | 2.92            | 50680         | 288221  | 3.5 ppg Sand - [DynaFlow-ZWR / Prime Plus, 40/70] |
| 13 | 1:39:12              | 7007                    | 7545 | 56.8       | 56.8  |     |    | 102.0                    | 4612.8  |                   |                 |               |         | Sweep - [DynaFlow-ZWR]                            |
| 14 | 1:44:47              | 8253                    | 7168 | 56.8       | 56.8  |     |    | 317.5                    | 4930.3  |                   |                 |               |         | Sweep - [Linear Gel]                              |
| 15 | 2:31:53              | 6056                    | 5396 | 14.3       | 14.3  |     |    | 671.8                    | 5601.9  |                   |                 |               |         | Pump In - [Linear Gel] - Ball Seal Stage 2        |
| 16 | 2:36:23              | 5847                    | 5776 | 21.2       | 21.2  |     |    | 95.2                     | 5697.1  |                   |                 |               |         | Acid - [15% HCl]                                  |
| 17 | 2:46:36              | 7346                    | 7093 | 53.2       | 53.2  |     |    | 543.9                    | 6241.0  |                   |                 |               |         | Pad - [DynaFlow-ZWR] - Stage 2                    |
| 18 | 2:53:03              | 6962                    | 6822 | 53.4       | 52.8  |     |    | 340.8                    | 6581.8  | 0.25              | 0.25            | 3576          | 291799  | 0.25 ppg Sand - [DynaFlow-ZWR / Sand, 100 Mesh]   |
| 19 | 2:59:54              | 6894                    | 6734 | 53.4       | 52.4  |     |    | 357.3                    | 6939.1  | 0.50              | 0.50            | 7503          | 299302  | 0.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 20 | 3:06:43              | 7033                    | 6653 | 56.5       | 54.0  |     |    | 476.1                    | 7415.2  | 1.00              | 1.00            | 19996         | 319296  | 1 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 21 | 3:17:30              | 7033                    | 6686 | 57.9       | 54.2  |     |    | 476.1                    | 7891.3  | 1.50              | 1.50            | 29994         | 349293  | 1.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 22 | 3:25:40              | 6962                    | 6590 | 57.2       | 52.5  |     |    | 428.4                    | 8319.7  | 2.00              | 2.00            | 35986         | 385278  | 2 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 23 | 3:33:13              | 7203                    | 7039 | 59.6       | 53.5  |     |    | 403.7                    | 8723.4  | 2.50              | 2.50            | 42389         | 427667  | 2.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 24 | 3:40:28              | 7166                    | 7056 | 59.6       | 52.4  |     |    | 380.2                    | 9103.6  | 3.00              | 3.00            | 47905         | 475572  | 3 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 25 | 3:47:16              | 7191                    | 6852 | 59.6       | 51.4  |     |    | 349.5                    | 9453.1  | 3.50              | 3.50            | 51377         | 526049  | 3.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 26 | 3:55:12              | 6927                    | 6817 | 59.6       | 52.4  |     |    | 415.8                    | 9868.9  | 2.76              | 2.76            | 48260         | 575209  | 3.5 ppg Sand - [DynaFlow-ZWR / Prime Plus, 40/70] |
| 27 | 3:57:05              | 7453                    | 6896 | 59.7       | 59.7  |     |    | 112.4                    | 9961.3  |                   |                 |               |         | Sweep - [DynaFlow-ZWR]                            |
| 28 | 4:02:17              | 7507                    | 7193 | 59.6       | 59.5  |     |    | 309.0                    | 10290.3 |                   |                 |               |         | Sweep - [Linear Gel]                              |
| 29 | 4:03:49              | 5835                    | 3388 | 161.0      | 161.0 |     |    | 232.6                    | 10522.9 |                   |                 |               |         | Pump In - [Linear Gel] - Ball Seal Stage 3        |
| 30 | 4:13:44              | 5384                    | 5140 | 9.6        | 9.6   |     |    | 95.2                     | 10616.1 |                   |                 |               |         | Acid - [15% HCl]                                  |
| 31 | 4:29:34              | 6121                    | 5729 | 43.5       | 43.5  |     |    | 688.8                    | 11306.9 |                   |                 |               |         | Pad - [DynaFlow-ZWR] - Stage 3                    |
| 32 | 4:37:30              | 7544                    | 7377 | 59.0       | 57.6  |     |    | 457.2                    | 11764.0 | 0.52              | 0.52            | 10000         | 575209  | 0.5 ppg Sand - [DynaFlow-ZWR / Sand, 100 Mesh]    |
| 33 | 4:43:42              | 7612                    | 7477 | 58.9       | 57.9  |     |    | 357.1                    | 12121.2 | 0.50              | 0.50            | 7500          | 592709  | 0.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 34 | 4:50:21              | 7607                    | 7411 | 58.9       | 56.0  |     |    | 371.4                    | 12492.6 | 1.15              | 1.15            | 18000         | 610709  | 1 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 35 | 4:57:10              | 7612                    | 7334 | 58.9       | 54.4  |     |    | 371.5                    | 12864.1 | 1.79              | 1.79            | 26000         | 638709  | 1.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 36 | 5:05:55              | 7428                    | 7264 | 58.9       | 54.4  |     |    | 474.7                    | 13338.8 | 1.90              | 1.90            | 37881         | 676590  | 2 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 37 | 5:13:59              | 7394                    | 7202 | 58.9       | 53.1  |     |    | 427.9                    | 13766.7 | 2.40              | 2.40            | 43132         | 719722  | 2.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 38 | 5:21:58              | 7472                    | 7248 | 58.9       | 52.0  |     |    | 413.8                    | 14180.5 | 2.90              | 2.90            | 50401         | 770123  | 3 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 39 | 5:29:05              | 7721                    | 7335 | 58.8       | 51.1  |     |    | 365.5                    | 14546.0 | 3.30              | 3.30            | 50658         | 820781  | 3.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 40 | 5:34:15              | 9259                    | 7604 | 58.4       | 49.8  |     |    | 257.3                    | 14803.3 | 3.50              | 3.50            | 37825         | 856606  | 3.5 ppg Sand - [DynaFlow-ZWR / Prime Plus, 40/70] |
| 41 | 5:36:06              | 9291                    | 8624 | 54.0       | 54.0  |     |    | 100.2                    | 14903.5 |                   |                 |               |         | Sweep - [DynaFlow-ZWR]                            |
| 42 | 5:42:39              | 8853                    | 6740 | 52.5       | 52.5  |     |    | 343.8                    | 15247.3 |                   |                 |               |         | Sweep - [Linear Gel]                              |
| 43 | 5:58:36              | 5804                    | 5022 | 14.6       | 14.6  |     |    | 232.8                    | 15480.1 |                   |                 |               |         | Pump In - [Linear Gel] - Ball Seal Stage 4        |
| 44 | 6:08:07              | 5287                    | 4987 | 10.0       | 10.0  |     |    | 95.2                     | 15575.3 |                   |                 |               |         | Acid - [15% HCl]                                  |
| 45 | 6:16:49              | 7727                    | 7359 | 57.7       | 57.7  |     |    | 501.9                    | 16077.2 |                   |                 |               |         | Pad - [DynaFlow-ZWR] - Stage 4                    |
| 46 | 6:23:55              | 7446                    | 7185 | 59.8       | 58.3  |     |    | 414.1                    | 16491.3 | 0.57              | 0.57            | 10000         | 686606  | 0.5 ppg Sand - [DynaFlow-ZWR / Sand, 100 Mesh]    |
| 47 | 6:30:09              | 7398                    | 7285 | 60.0       | 58.7  |     |    | 385.4                    | 16856.7 | 0.50              | 0.50            | 7873          | 878279  | 0.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 48 | 6:38:27              | 7311                    | 7189 | 60.0       | 57.4  |     |    | 476.2                    | 17332.9 | 1.00              | 1.00            | 20000         | 896280  | 1 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 49 | 6:46:54              | 7266                    | 7142 | 60.1       | 56.5  |     |    | 477.4                    | 17810.3 | 1.38              | 1.38            | 27706         | 923986  | 1.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 50 | 6:54:42              | 7171                    | 7054 | 60.1       | 54.9  |     |    | 428.6                    | 18238.9 | 2.10              | 2.10            | 37803         | 961788  | 2 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 51 | 7:02:14              | 7158                    | 7012 | 60.2       | 53.8  |     |    | 405.1                    | 18644.0 | 2.60              | 2.60            | 44237         | 1006025 | 2.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 52 | 7:09:35              | 7230                    | 7002 | 60.2       | 52.7  |     |    | 388.0                    | 19032.0 | 3.10              | 3.10            | 50518         | 1056543 | 3 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 53 | 7:14:20              | 7377                    | 7186 | 60.1       | 51.6  |     |    | 252.4                    | 19284.4 | 3.60              | 3.60            | 38163         | 1094706 | 3.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 54 | 7:22:44              | 7707                    | 7358 | 59.9       | 53.0  |     |    | 437.8                    | 19722.2 | 2.64              | 2.64            | 48600         | 1143306 | 3.5 ppg Sand - [DynaFlow-ZWR / Prime Plus, 40/70] |
| 55 | 7:24:26              | 8115                    | 7753 | 59.9       | 59.9  |     |    | 100.6                    | 19822.8 |                   |                 |               |         | Sweep - [DynaFlow-ZWR]                            |
| 56 | 7:29:34              | 8115                    | 8115 | 59.4       | 59.4  |     |    | 305.4                    | 20128.2 |                   |                 |               |         | Sweep - [Linear Gel]                              |
| 57 | 7:44:36              | 5488                    | 4764 | 14.7       | 14.7  |     |    | 221.1                    | 20349.3 |                   |                 |               |         | Pump In - [Linear Gel] - Ball Seal - Stage 5      |
| 58 | 7:50:59              | 5659                    | 5361 | 14.9       | 14.9  |     |    | 95.0                     | 20444.3 |                   |                 |               |         | Acid - [15% HCl]                                  |
| 59 | 8:01:21              | 8985                    | 5554 | 46.2       | 46.2  |     |    | 478.9                    | 20923.2 |                   |                 |               |         | Pad - [DynaFlow-ZWR] - Stage 5                    |
| 60 | 8:10:17              | 7076                    | 6855 | 54.0       | 52.8  |     |    | 472.1                    | 21395.3 | 0.50              | 0.50            | 10000         | 1153306 | 0.5 ppg Sand - [DynaFlow-ZWR / Sand, 100 Mesh]    |
| 61 | 8:15:39              | 7388                    | 6968 | 53.9       | 52.7  |     |    | 282.7                    | 21678.0 | 0.50              | 0.50            | 5937          | 1159243 | 0.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 62 | 8:20:10              | 7419                    | 6048 | 59.9       | 59.9  |     |    | 270.2                    | 21948.2 |                   |                 |               |         | Flush - [Linear Gel] - Shutdown                   |
| 63 | 8:29:15              | 7285                    | 3909 | 30.8       | 30.8  |     |    | 280.0                    | 22228.2 |                   |                 |               |         | Pad - [DynaFlow-ZWR]                              |
| 64 | 8:40:12              | 7007                    | 6681 | 49.0       | 46.9  |     |    | 613.2                    | 22741.4 | 1.00              | 1.00            | 21554         | 1180797 | 1 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 65 | 8:50:21              | 6901                    | 6720 | 50.1       | 46.9  |     |    | 476.3                    | 23217.7 | 1.50              | 1.50            | 30007         | 1210804 | 1.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 66 | 8:55:44              | 6836                    | 6630 | 50.2       | 46.0  |     |    | 247.8                    | 23465.5 | 2.00              | 2.00            | 20815         | 1231619 | 2 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 67 | 9:04:28              | 7817                    | 4276 | 54.4       | 54.4  |     |    | 473.2                    | 23938.7 |                   |                 |               |         | Sweep - [Linear Gel]                              |
| 68 | 9:06:50              | 6914                    | 6883 | 49.2       | 45.1  |     |    | 108.3                    | 24047.0 | 2.00              | 2.00            | 9097          | 1240716 | 2.0 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 69 | 9:16:02              | 6858                    | 6725 | 49.2       | 44.2  |     |    | 406.0                    | 24453.0 | 2.50              | 2.50            | 42630         | 1283348 | 2.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 70 | 9:24:50              | 6810                    | 6544 | 49.2       | 43.3  |     |    | 381.0                    | 24833.9 | 3.00              | 3.00            | 48000         | 1331346 | 3 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |
| 71 | 9:35:36              | 6660                    | 6508 | 49.3       | 42.5  |     |    | 457.6                    | 25291.5 | 3.50              | 3.50            | 67267         | 1398813 | 3.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 72 | 9:45:04              | 6666                    | 6508 | 49.2       | 43.0  |     |    | 407.6                    | 25699.1 | 2.92              | 2.92            | 50000         | 1446613 | 3.5 ppg Sand - [DynaFlow-ZWR / Prime Plus, 40/70] |
| 73 | 9:47:06              | 6986                    | 6488 | 49.3       | 49.3  |     |    | 100.3                    | 25799.4 |                   |                 |               |         | Sweep - [DynaFlow-ZWR]                            |
| 74 | 9:53:08              | 7630                    | 6902 | 49.1       | 49.1  |     |    | 295.8                    | 26095.2 |                   |                 |               |         | Sweep - [Linear Gel]                              |
| 75 | 10:09:50             | 5326                    | 4391 | 15.0       | 15.0  |     |    | 250.2                    | 26345.4 |                   |                 |               |         | Pump In - [Linear Gel] - Ball Seal - Stage 6      |
| 76 | 10:14:36             | 5374                    | 5129 | 20.0       | 20.0  |     |    | 95.2                     | 26440.7 |                   |                 |               |         | Acid - [15% HCl]                                  |
| 77 | 10:23:30             | 8338                    | 5787 | 53.5       | 53.5  |     |    | 475.5                    | 26916.2 |                   |                 |               |         | Pad - [DynaFlow-ZWR] - Stage 6                    |
| 78 | 10:32:10             | 6793                    | 6640 | 56.6       | 55.3  |     |    | 479.6                    | 27395.8 | 0.50              | 0.50            | 10072         | 1458685 | 0.5 ppg Sand - [DynaFlow-ZWR / Sand, 100 Mesh]    |
| 79 | 10:38:58             | 6771                    | 6668 | 56.6       | 55.3  |     |    | 375.7                    | 27771.5 | 0.50              | 0.50            | 7890          | 1466575 | 0.5 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70] |
| 80 | 10:47:46             | 6749                    | 6619 | 56.6       | 54.1  |     |    | 476.2                    | 28247.7 | 1.00              | 1.00            | 20000         | 1486575 | 1 ppg Sand - [DynaFlow-ZWR / White Sand, 40/70]   |



# **Chesapeake Robinson Ranch 4-34-70 1H Niobrara Well (sw se 4-34N-70W)**

## **Summary of Fracture Stimulation**

| <u>Parameter</u>             | <u>Stage 1</u> | <u>Stage 2</u> | <u>Stage 3</u> | <u>Stage 4</u> | <u>Stage 5</u> | <u>Stage 6</u> | <u>Stage 7</u> | <u>Stage 8</u> | <u>Stage 9</u> | <u>Stage 10</u> | <u>Stage 11</u> | <u>Stage 12</u> | <u>Average</u> |
|------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|----------------|
| <b>Perf Interval</b>         | 14,655-66 ft   | 14,355-56 ft   | 14,055-56 ft   | 13,753-54 ft   | 13,451-52 ft   | 13,149-50 ft   | 12,847-48 ft   | 12,545-46 ft   | 12,243-44 ft   | 11,941-42 ft    | 11,639-40 ft    | 11,337-38 ft    |                |
| <b>24 Perfs per Stage</b>    | 14,580-81 ft   | 14,280-81 ft   | 13,980-81 ft   | 13,678-79 ft   | 13,376-77 ft   | 13,374-75 ft   | 12,772-73 ft   | 12,470-71 ft   | 12,168-69 ft   | 11,866-67 ft    | 11,564-65 ft    | 11,262-63 ft    |                |
| <b>4 Intervals per Stage</b> | 14,505-06 ft   | 14,205-06 ft   | 13,905-06 ft   | 13,603-04 ft   | 13,301-02 ft   | 12,999-00 ft   | 12,697-98 ft   | 12,395-96 ft   | 12,093-94 ft   | 11,791-92 ft    | 11,489-90 ft    | 11,187-88 ft    |                |
| <b>6 Perfs per Interval</b>  | 14,430-31 ft   | 14,130-31 ft   | 13,830-31 ft   | 13,528-29 ft   | 13,226-27 ft   | 12,924-25 ft   | 12,622-23 ft   | 12,320-21 ft   | 12,018-19 ft   | 11,716-17 ft    | 11,414-15 ft    | First Perf      |                |
| <b>Interval Avg 289 ft</b>   |                |                |                |                |                |                |                |                |                |                 |                 |                 |                |
| <b>Pump Time (minutes)</b>   | 137.8          | 152.2          | 153.2          | 143.6          | 140.9          | 144.9          | 147.3          | 143.1          | 137.9          | 146.8           | 138.0           | 144.0           | <b>144.1</b>   |
| <b>Max Pressure (psi)</b>    | 10,613         | 9,203          | 8,258          | 10,916         | 11,382         | 11,011         | 8,651          | 6,563          | 10,409         | 10,495          | 10,835          | 9,902           |                |
| <b>Avg Pressure (psi)</b>    | 8,753          | 8,131          | 7,426          | 7,424          | 7,505          | 7,913          | 5,761          | 5,990          | 7,106          | 7,558           | 8,350           | 8,689           |                |
| <b>Avg Q (bbls/min)</b>      | 49.1           | 46.6           | 46.6           | 49.3           | 50.2           | 49.4           | 47.6           | 48.9           | 50.2           | 47.4            | 49.7            | 46.7            | <b>48.5</b>    |
| <b>Max PPG</b>               | 4.09           | 5.08           | 5.16           | 5.05           | 5.05           | 5.08           | 5.17           | 5.15           | 5.10           | 5.13            | 4.75            | 4.54            |                |
| <b>Avg PPG</b>               | 1.31           | 1.36           | 1.59           | 1.74           | 1.87           | 2.42           | 1.68           | 1.05           | 1.05           | 1.65            | 1.93            | 0.61            |                |
| <b>Sand 40/70 Mesh (lbs)</b> | 159,800        | 165,900        | 159,920        | 150,145        | 162,170        | 164,510        | 160,189        | 160,676        | 157,935        | 160,150         | 166,820         | 174,175         |                |
| <b>Sand 30/50 Mesh (lbs)</b> | 228,140        | 287,130        | 289,120        | 288,236        | 286,747        | 278,821        | 287,738        | 287,629        | 287,770        | 286,616         | 249,990         | 197,140         |                |
| <b>Total Proppant (lbs)</b>  | 387,940        | 453,030        | 449,040        | 438,381        | 448,917        | 443,331        | 447,927        | 448,305        | 445,705        | 446,766         | 416,810         | 371,315         | <b>433,122</b> |
| <b>5,197,467 lbs Total</b>   |                |                |                |                |                |                |                |                |                |                 |                 |                 |                |
| <b>Acid (gals)</b>           | 2,000          | 2,000          | 2,000          | 2,000          | 2,000          | 2,000          | 2,000          | 2,000          | 2,000          | 2,000           | 2,000           | 2,000           |                |
| <b>Slickwater (bbls)</b>     | 307            | 430            | 395            | 376            | 362            | 374            | 333            | 325            | 298            | 293             | 307             | 267             |                |
| <b>Hybor G X-Link (bbls)</b> | 6,041          | 6,181          | 6,258          | 6,227          | 6,220          | 6,299          | 6,195          | 6,181          | 6,147          | 6,182           | 6,108           | 6,060           |                |
| <b>Slurry Volume (bbls)</b>  | 6,766          | 7,100          | 7,137          | 7,076          | 7,066          | 7,151          | 7,011          | 6,990          | 6,926          | 6,957           | 6,865           | 6,727           | <b>6,981</b>   |

**Chesapeake Exploration**  
**Docket 1564 - 2015**  
**Exhibit E - 3**

## Calculation of a Created (Propped) Fracture Area: Robinson Ranch 4-34-70 1H Niobrara

The Crawford equation for the calculation of the Created Frac (Propped) Area:

$$A = V / ( W + 3 \times C \times T^{0.5} ) \text{ in sq ft}$$

$$V = \text{Slurry Volume} = ( 6,981 \text{ barrels} ) \times ( 5.615 \text{ cubic feet per barrel} ) = 39,198 \text{ cubic feet}$$

Note: typical horizontal-well frac-treatment stages are 5,000 barrels total slurry with about 250,000# proppant.

The Robinson Ranch 4-34-70 1H well: average slurry volume of 6,981 barrels with 433,122# proppant.

$$W = \text{Fracture Width} = 0.04167 \text{ feet}$$

$$C = \text{Fluid Loss Coefficient} = 0.0015 \text{ feet per square root of Time}$$

$$T = \text{Pump Time} = 144.1 \text{ minutes average per stage}$$

$$\text{Created Frac Area} = 39,198 / [ 0.04167 + ( 3 \times 0.0015 \times 144.1^{0.5} ) ]$$

$$\text{Created Frac Area (for 1 stage)} = 409,641 \text{ square feet}$$

The Robinson Ranch 4-34-70 1H well: 4 “mini-fracs” per stage in a cemented liner:

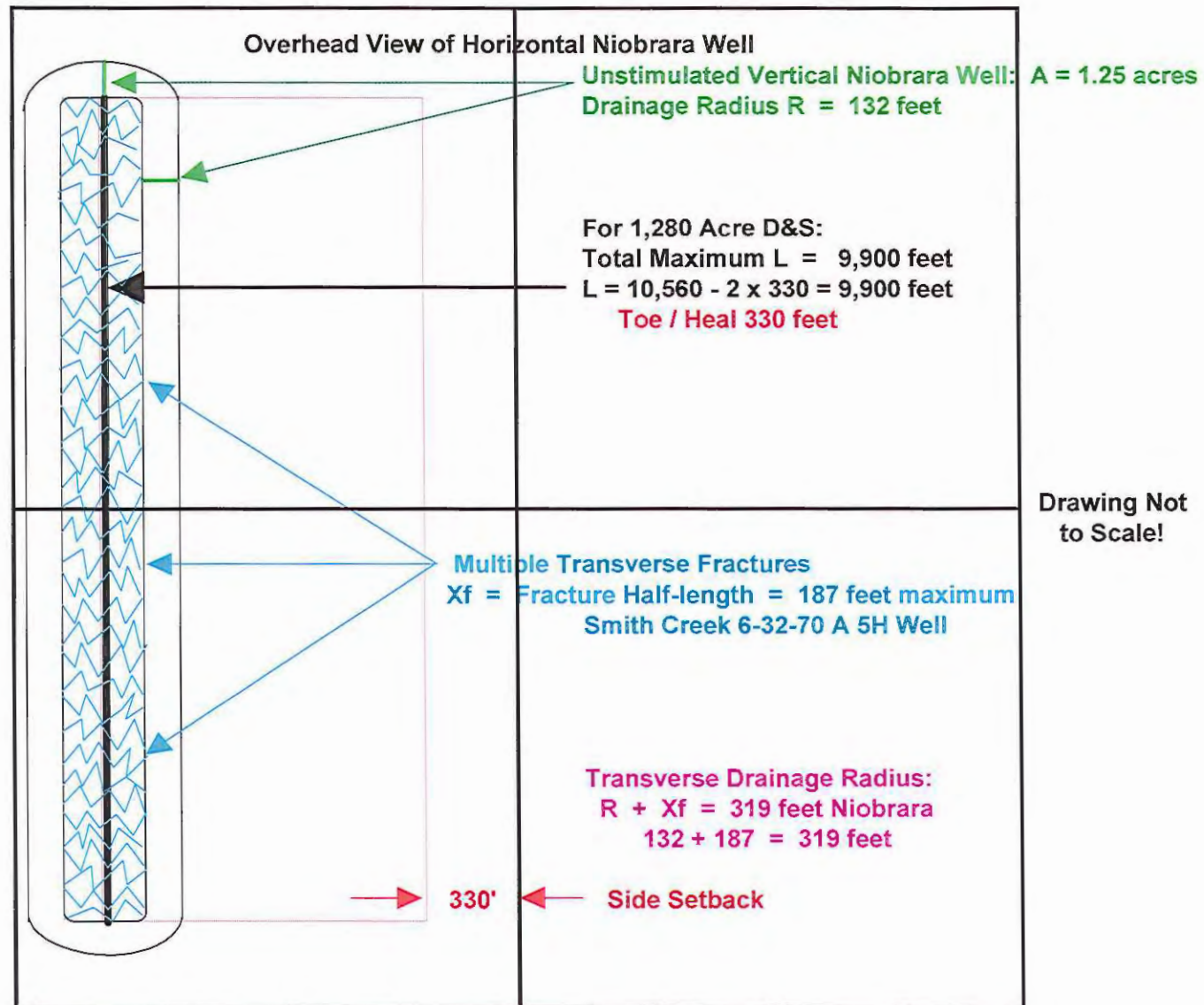
- a) Average spread of 289 feet of horizontal length, and
- b) placed by limited-entry perforation design.

$$\text{Each “mini-frac” will have a created frac area} = ( 409,641 \text{ square feet} ) / 4 = 102,410 \text{ square feet}$$

$$\text{Propped Frac Length (One-Wing)} = X_f = 181 \text{ feet}$$

The Crawford equation & methodology are taken from SPE Paper 12064:

*“Proppant Scheduling and Calculation of Fluid Lost During Fracturing”* by H.R. “Randy” Crawford, Conoco, Inc.



Total Area @ 1,280 D&S (Joshi Method #2) =  $\pi \times R^2 + 2 \times R \times L + 4 \times R \times X_f + 2 \times X_f \times L = 149$  acres

OOIP for Spherical Ovoid =  $7,758 \times 149 \times 40 \times 0.065 \times (1 - 0.21) / 1.44 = +1.6$  MMBO

(21)



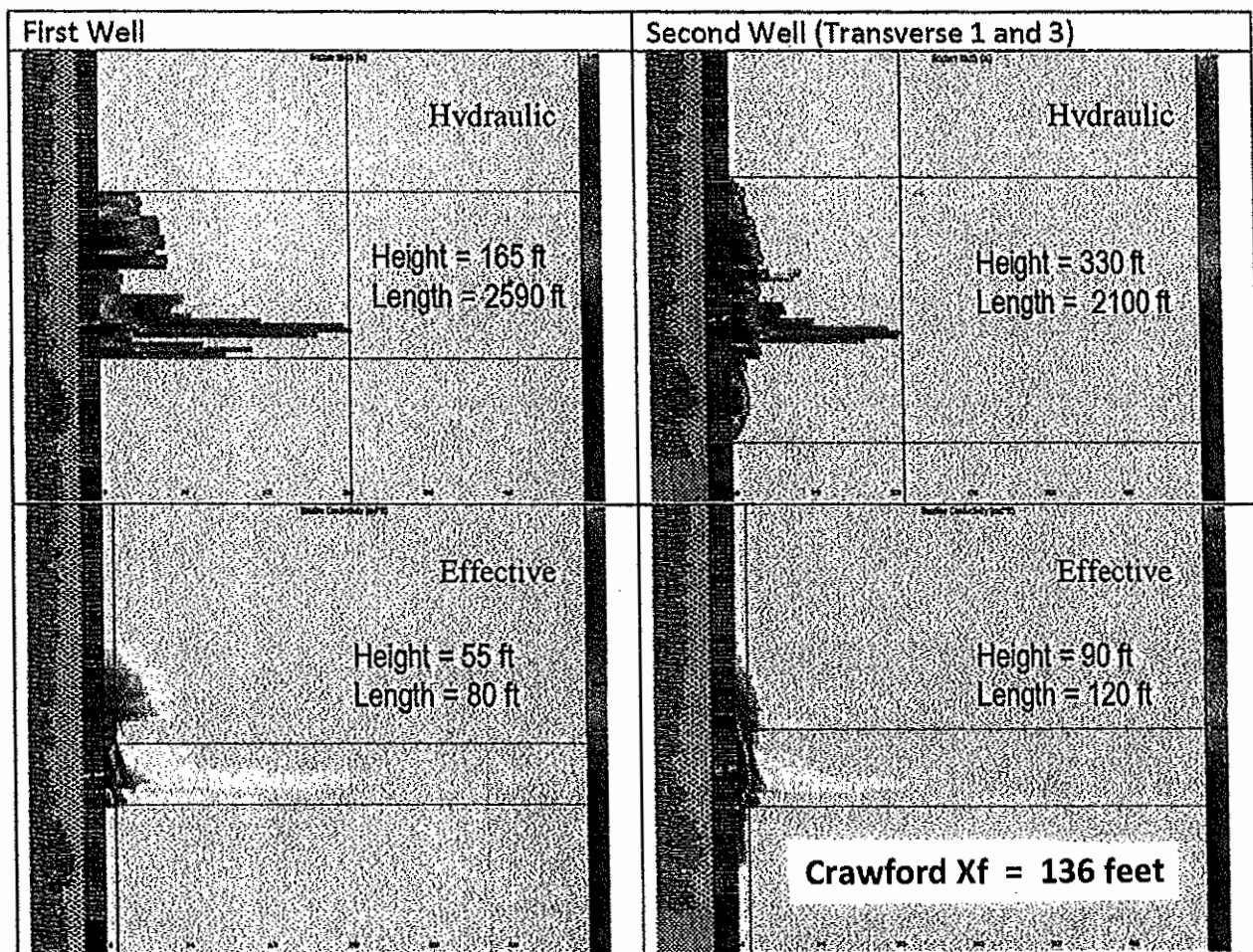


Figure 12—Hydraulic and effective fracture geometries

### Seedy Draw Field ( T40N -R63W )

SPE-182502-MS

## Evaluating the Application of Unconventional Resource Extraction Technology to a Conventional Play

Olubiyi Olaoye, Sanjel; Charles Durkoop, Reed Johnson, and Daniel Anderson, Vermillion Energy; Bilu V Cherian, Kristina Kublik, Santhosh Narasimhan, Mariah Atkinson, Hamza Shaikh, James Gray, and Rafif Rifai, Sanjel

Turner Reservoir approx. 4,900 ft TVD

Avg  $\phi$  = 14%

Avg K = 0.002 to 0.1 md

1<sup>st</sup> Well 14 stage frac: 42,000 lbs 20/40 sand / stage in uncemented liner

2nd Well 14 stage Frac: 114,000 lbs 20/40 / stage in cemented liner



**Summary of Whiting Petroleum - Colorado Docket 1303-AW-17**

**Cause No. 535**

**Docket No. 1303-AW-17**

*Request for 8 Niobrara wells per spacing unit with 100-ft setbacks*

**Order No. 535-296**

**Date: March 25, 2013**

**Engineering testimony of horizontal Niobrara wells in Wattenberg Field:**

**Analysis of data from downhole pressure gauges**

**Analysis of rate transient data**

**Economic analyses**

**Conclusions:**

**Justified 16 wells per 640-acre and 960-acre spacing units**

**Calculated an effective propped frac wing (  $X_f$  ) = 105 feet**

**Commission Orders:**

**Treated interval of the well no closer than 200 feet from another well**

**Treated interval of the well no closer than 100 feet from unit boundary**

**Eight horizontal wells in Niobrara per spacing unit (total 21)**

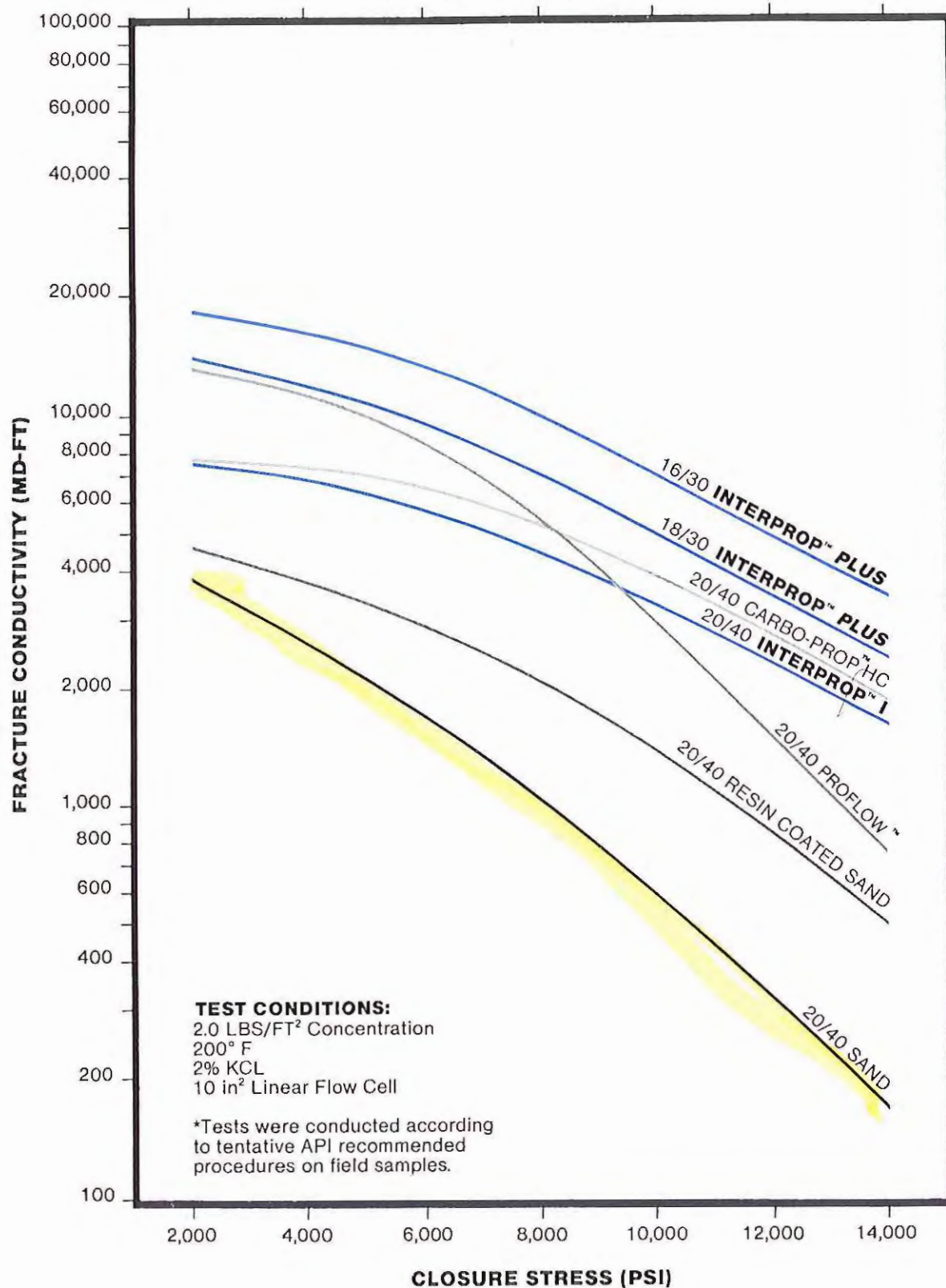
**Chesapeake Exploration**

**Docket 910 – 2013**

**Exhibit E -17**

# NORTON-ALCOA PROPPANTS

## FRACTURE CONDUCTIVITY VS CLOSURE STRESS





## Summary of Selected Frontier Horizontal Wells in the PRB

| Count | Well                                         | Surface Location | API 49-  | Frontier Frac Size                                                                                                                                                                        | Production Completion | Producing Period | Cum BO  | Cum Mcf   | Cum BW  | Kf EUR | Kf EUR | Kf EUR  | Joshi #2 |
|-------|----------------------------------------------|------------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|------------------|---------|-----------|---------|--------|--------|---------|----------|
|       |                                              |                  |          |                                                                                                                                                                                           |                       |                  |         |           |         | MBQ    | MMcf   | BOE     | Drain A  |
| 1     | Ches. Wagonhound 33-71 30-1H                 | se sw 30-33N-71W | 09-28261 | 11 Stages: 3 MM#<br>L = 3,558 ft & Xf = 142 ft                                                                                                                                            | Cemented              | 10-10 thru 2-16  | 84,300  | 422,255   | 254,081 | 171    | 891    | 319,500 | 68       |
|       | BHL:                                         | ne nw 30-33N-71W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 2     | Ches. Wagonhound 33-72 13-1H                 | ne nw 13-33N-72W | 09-28255 | 14 Stages: 2.8 MM#<br>L = 3,142 ft & Xf = 343 ft                                                                                                                                          | Uncemented            | 8-10 thru 11-16  | 111,703 | 375,260   | 117,607 | 247    | 860    | 390,333 | 94       |
|       | BHL:                                         | se sw 13-33N-72W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 3     | Slawson Thunderbolt 1-2H                     | se se 2-37N-74W  | 09-28215 | 7 Stages: 57,340# 100-mesh & 593,660# 30/30 ISP<br>L = 3,953 ft                                                                                                                           | Uncemented            | 9-08 thru 7-16   | 83,321  | 20,355    | 17,488  | 138    | 41     | 144,833 |          |
|       | BHL:                                         | sw ne 2-37N-74W  |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 4     | Helis Henry Land 15-7/6H                     | sw se 7-37N-74W  | 09-28535 | L = 8,724'                                                                                                                                                                                |                       | 2-14 thru 11-16  | 130,335 | 194,177   | 127,237 | 377    | 506    | 461,333 |          |
|       | BHL:                                         | nw ne 6-37N-74W  |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 5     | Helis Federal 16-10/3FH                      | se se 10-37N-74W | 09-28417 | 28 Stages: 3.1 MM# ( 4 stages missing )<br>L = 8,691' & Xf = 156 ft                                                                                                                       | Cemented              | 11-11 thru 11-16 | 442,883 | 483,034   | 79,047  | 726    | 889    | 874,167 | 162      |
|       | BHL:                                         | ne ne 2-37N-74W  |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 6     | Helis Federal 15W-10/3H                      | sw se 10-37N-74W | 09-29135 |                                                                                                                                                                                           |                       | 5-14 thru 11-16  | 357,925 | 519,853   | 64,542  | 621    | 948    | 779,000 |          |
|       | BHL:                                         | nw nw 3-37N-74W  |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 7     | Helis Henry 14-11 2H                         | se sw 11-37N-74W | 09-28669 | 27 Stages: 2.9 MM#<br>L = 8,046 ft & Xf = 235 ft                                                                                                                                          | Uncemented            | 8-13 thru 12-16  | 230,511 | 361,355   | 85,935  | 458    | 803    | 591,833 | 182      |
|       | BHL:                                         | nw nw 2-37N-74W  |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 8     | Helis Henry Federal 41-15H                   | ne ne 15-37N-74W | 09-28240 | 12 Stages: 1.52 MM#<br>L = 4,750 ft & Xf = 127 ft                                                                                                                                         | Cemented              | 5-10 thru 11-16  | 197,904 | 385,281   | 75,236  | 304    | 648    | 412,000 |          |
|       | BHL:                                         | sw sw 15-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 9     | SM Dandy State 3774-16-21-1FH                | ne nw 16-37N-74W | 09-28682 | Stages not reported: 3.58 MM#<br>L = 9,347 ft & Xf unknown                                                                                                                                | Uncemented            | 11-12 thru 11-16 | 285,337 | 620,676   | 52,080  | 590    | 1,099  | 773,167 |          |
|       | BHL:                                         | se sw 21-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 10    | Helis Henry REV 3W-17/20H                    | ne nw 17-37N-74W | 09-28560 | TSI 6 months in early 2016                                                                                                                                                                |                       | 9-15 thru 11-16  | 50,948  | 78,920    | 49,791  | 167    | 302    | 217,333 |          |
|       | BHL:                                         | sw sw 20-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 11    | Wold Henry 3774-44-17H                       | se se 17-37N-74W | 09-28545 | 19 Stages: 2.05 MM# ISP<br>L = 3,630 ft & Xf = 231 ft                                                                                                                                     | Uncemented            | 2-13 thru 11-16  | 119,216 | 945,324   | 31,938  | 198    | 1,573  | 460,167 |          |
|       | BHL:                                         | ne ne 17-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 12    | Wold Federal 41-20-3774FH                    | ne ne 20-37N-74W | 09-28528 | 19 Stages: Proposed 1.84 MM#<br>L = 3,694 ft                                                                                                                                              | Uncemented            | 1-13 thru 11-16  | 147,568 | 1,707,692 | 21,964  | 213    | 3,120  | 733,000 |          |
|       | BHL:                                         | se se 20-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 13    | SM Black Jack 3774-22-27-1FH                 | ne nw 22-37N-74W | 09-28794 | 29 Stages: 4.3 MM# Sand<br>L = 10,148 ft & Xf = 1,000 ft (SM) & Xf = 283 ft (Crawford)<br>MICRO-SEISMIC: N 70 E ORIENTATION                                                               | Uncemented            | 3-14 thru 11-16  | 205,494 | 259,391   | 94,391  | 658    | 835    | 797,167 | 250      |
|       | BHL:                                         | sw sw 27-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 14    | Helis Hornbuckle 14-31/30H                   | se sw 31-37N-74W | 09-28421 | Actual 28 Stages: 3.5 MM# ISP + 83,751 bbls<br>L = 8,140 ft & Xf = 152 ft (Crawford)<br>Proposed 28 Stages: 3.4 MM# ISP + 90,871 bbls<br>Xf = 164 ft ( Helis ) & Xf = 165 ft ( Crawford ) | Cemented              | 11-12 thru 11-16 | 180,753 | 216,766   | 133,147 | 430    | 547    | 521,167 | 151      |
|       | BHL:                                         | ne nw 30-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 15    | Helis Hornbuckle 16-32/29H                   | se se 32-37N-74W | 09-28422 | 28 Stages: 3.92 MM#<br>L = 8,704 ft & Xf = 151 ft                                                                                                                                         | Uncemented            | 11-13 thru 11-16 | 190,508 | 772,793   | 160,638 | 321    | 1,084  | 501,667 |          |
|       | BHL:                                         | ne ne 29-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 16    | Helis Hornbuckle 15-33/28H                   | sw se 33-37N-74W | 09-28537 | Proposed 28 Stages: 3.8 MM# ISP<br>L = 7,922 ft & Xf = 178 ft                                                                                                                             | Uncemented            | 2-13 thru 11-16  | 351,665 | 372,178   | 145,938 | 654    | 751    | 779,167 |          |
|       | BHL:                                         | nw ne 28-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 17    | Helis Hornbuckle 14W-33/28H                  | se sw 33-37N-74W | 09-29295 | 30 Stages: 3.4 MM# ISP<br>L = 8,820 ft & Xf = 147 ft ( Crawford )<br>Stage 1 Single Port - Remaining Stages 3 Clusters/Stage<br>SIGMA 3 Model: Xf = 193 ft ( taken to < 0.10 lb / sq ft ) | Uncemented            | 2-14 thru 11-16  | 267,897 | 328,832   | 99,383  | 590    | 761    | 716,833 | 161      |
|       | BHL:                                         | nw nw 28-37N-74W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |
| 18    | Helis MBU 7/12 1H<br>East - West Orientation | sw nw 8-37N-75W  | 09-28788 | 22 Stages: 2.63 MM# ISP<br>L = 9,015 ft & Xf = ???                                                                                                                                        | Cemented              | 2-14 thru 11-16  | 14,994  | 12,693    | 54,896  | 21     | 18     | 24,000  |          |
|       | BHL:                                         | sw nw 12-37N-76W |          |                                                                                                                                                                                           |                       |                  |         |           |         |        |        |         |          |

Wold Energy Partners

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Exhibit E - 12



## Summary of Selected Frontier Horizontal Wells in the PRB

| Count | Well                                                | Surface Location                     | API 49-  | Frontier Frac Size                                                                                             | Production Completion   | Producing Period                    | Cum BO         | Cum Mcf          | Cum BW           | Kf EUR MBO | Kf EUR MMcf | Kf EUR BOE | Joshi #2 Drain A |
|-------|-----------------------------------------------------|--------------------------------------|----------|----------------------------------------------------------------------------------------------------------------|-------------------------|-------------------------------------|----------------|------------------|------------------|------------|-------------|------------|------------------|
| 19    | Helis Henry 3W-13/24H                               | ne nw 13-37N-75W<br>sw sw 24-37N-75W | 09-29417 |                                                                                                                |                         | 2-15 thru 11-16                     | 197,026        | 521,074          | 40,149           |            |             |            |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 20    | Helis MBU Hornbuckle E-28/21H                       | sw se 28-37N-75W<br>nw ne 21-37N-75W | 09-29742 | 18 Stages: 3.09 MM#<br>L = 8,878 ft & Xf = 152 ft                                                              | Uncemented              | 3-15 thru 1-17                      | 115,332        | 236,928          | 122,650          | 391        | 762         | 518,000    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 21    | Anadarko Pine Gulch 29-44H                          | se se 29-37N-75W<br>sw ne 29-37N-75W | 09-28165 | 7 Stages: 1.29 MM# VersaProp<br>L = 3,035 ft & Xf = 249 ft                                                     | Uncemented              | 9-08 thru 8-16                      | 38,298         | 154,878          | 35,909           | 60         | 272         | 105,333    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 22    | SM Allemand 12-2/1H<br>East - West Orientation      | nw sw 2-38N-75W<br>se se 1-38N-75W   | 09-28824 | 30 Stages: 4.37 MM#<br>L = 9,074 ft                                                                            | Uncemented              | 2-15 thru 11-16                     | 10,484         | 90,927           | 28,346           | 18         | 133         | 40,167     |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 23    | SM Roger Leo 3875-20-29-1FH                         | ne ne 20-38N-75W<br>se se 29-38N-75W | 09-29320 | 29 Stages: 4.4 MM# Sand<br>L = 8,490 ft & Xf = 279 ft (Crawford)<br>Sanjel Model: 300 ft high by 800 ft long   | Uncemented              | 3-15 thru 11-16                     | 135,946        | 319,190          | 176,108          | 251        | 703         | 368,167    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 24    | Helis Patterson 14W-36/1/12H                        | se sw 36-38N-75W<br>se sw 12-37N-75W | 09-29594 | 30 Stages: 3.4MM# ISP<br>L = 9,107 ft & Xf = 209 ft ( Helis )                                                  | Uncemented              | 9-14 thru 11-16                     | 210,814        | 343,882          | 71,257           | 594        | 957         | 753,500    | 201              |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 25    | SM Dynamite 3975-16-21-1FH                          | nw nw 16-39N-75W<br>sw sw 21-39N-75W | 09-29319 | 36 Stages: 4.54 MM# ISP<br>L = 9,896 ft & Xf = 274 ft (Crawford)<br>Schlumberger: 300 ft high by 1,000 ft long | Uncemented              | 7-14 thru 11-16                     | 88,141         | 452,809          | 146,237          | 216        | 1,438       | 455,667    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 26    | SM Cactus 3976-35-36-1FH<br>East - West Orientation | sw sw 35-39N-76W<br>se se 36-39N-76W | 09-29691 | 30 Stages: 6.0 MM#<br>L = 9,219 ft & Xf = 286 ft ( ??? )                                                       | Uncemented              | 7-15 thru 11-16                     | 99,134         | 251,419          | 129,917          | 177        | 500         | 260,333    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 27    | SM Loco Fed. 4076-9-4-1FH                           | se se 9-40N-76W<br>ne ne 4-40N-076W  | 09-28878 | 32 Stages: 4.2 MM# ISP<br>L = 8,852 ft & Xf = 273 ft (Crawford)                                                | Uncemented              | 6-13 thru 11-16                     | 182,747        | 547,005          | 149,633          | 313        | 1,353       | 538,500    | 212              |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 28    | SM Flash State 4076-13-24-1FH                       | nw nw 13-40N-76W<br>sw sw 24-40N-76W | 09-28853 | 30 Stages: 6.78 MM# ISP<br>L = 9,122 ft & Xf = 700 ft (SM) & Xf = 322 ft (Crawford)                            | Uncemented              | 9-14 thru 11-16                     | 125,726        | 286,914          | 138,223          | 297        | 730         | 418,667    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 29    | SM Razor State 4076-12-1-1FH                        | nw nw 13-40N-76W<br>nw nw 1-40N-76W  | 09-29095 | 30 Stages: 4.46 MM# ISP<br>L = 9,369 ft & Xf = 280 ft                                                          | Uncemented              | 10-14 thru 11-16                    | 117,185        | 263,951          | 99,977           | 437        | 900         | 587,000    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 30    | Anschutz Buster 4176-12-24TH                        | sw sw 1-41N-76W<br>se sw 12-41N-76W  | 05-62567 | 17 Stages: 3.2 MM#<br>L = 4,777 ft & Xf = 319 ft                                                               | Uncemented<br>Lance ??? | 1-16 thru 11-16<br>10-15 thru 12-15 | 8,292<br>8,487 | 16,872<br>12,052 | 22,141<br>26,698 | 40         | 80          | 53,333     |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 31    | Devon Iberlin Ranch 044176-1XFH                     | se sw 4-41N-76W<br>nw nw 33-42N-76W  | 05-61926 | 25 Stages: 11.94 MM#<br>L = 8,723 ft & Xf = 227 ft (Crawford)<br>Halliburton Model: 60 ft high by 518 ft long  | Cemented                | 1-14 thru 11-16                     | 215,289        | 421,208          | 96,776           | 512        | 820         | 648,667    | 193              |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
|       |                                                     | WOGGCC: 41N for BHL<br>Has to be 42N |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 32    | Devon Pine Tree IRF 044176-4FH                      | ne ne 9-41N-76W<br>ne ne 4-41N-76W   | 05-62228 | Frac only 2 of 27 stages & L = 259 ft<br>Devon: TSI "depressed economic environment"                           |                         | 4-15 TSI                            | 0              | 0                | 0                |            |             |            |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 33    | Anschutz Shadow 4176-9-24TH                         | nw nw 9-41N-76W<br>se sw 9-41N-76W   | 05-62568 |                                                                                                                |                         | 9-15 thru 11-16                     | 127,460        | 202,993          | 48,369           | 255        | 638         | 361,333    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 34    | SM Trigger Fed. 4176-16-21-1FH                      | ne nw 16-41N-76W<br>sw sw 21-41N-76W | 05-62135 |                                                                                                                |                         | 9-15 thru 11-16                     | 127,423        | 336,583          | 66,702           | 399        | 1,185       | 596,500    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 35    | SM Target Fed. 4176-17-20-1FH                       | ne nw 17-41N-76W<br>sw sw 20-41N-76W | 19-30015 | 30 Stages: 4.41 MM# ISP<br>L = 9,784 ft & Xf = 279 ft                                                          | Uncemented              | 10-14 thru 11-16                    | 161,326        | 286,874          | 199,962          | 229        | 419         | 298,833    |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |
| 36    | Devon Iberlin Ranch Fed 074276-2FH                  | ne nw 7-42N-76W<br>se sw 7-42N-76W   | 19-29955 |                                                                                                                |                         | 3-14 thru 11-16                     | 11,367         | 20,320           | 34,063           |            |             |            |                  |
|       | BHL:                                                |                                      |          |                                                                                                                |                         |                                     |                |                  |                  |            |             |            |                  |

Wold Energy Partners

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Exhibit E - 12



## Summary of Selected Frontier Horizontal Wells in the PRB

| Count | Well                                                                                                                                                                                                                                                                                                     | Surface Location                     | API 49-  | Frontier Frac Size                                                                                                               | Production Completion | Producing Period                                                                                | Cum BO  | Cum Mcf | Cum BW | Kf EUR MBO | Kf EUR MMcf                            | Kf EUR BOE | Joshi #2 Drain A |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------------------------------------|---------|---------|--------|------------|----------------------------------------|------------|------------------|
| 37    | Devon Iberlin Ranch Fed 194276-2FH<br>BHL:                                                                                                                                                                                                                                                               | se sw 18-42N-76W<br>sw se 19-42N-76W | 19-29953 |                                                                                                                                  |                       | 7-14 thru 11-16                                                                                 | 56,779  | 85,892  | 27,681 |            |                                        |            |                  |
| 38    | Devon Iberlin Ranch Fed 184276-2FH<br>BHL:                                                                                                                                                                                                                                                               | se sw 18-42N-76W<br>ne nw 18-42N-76W | 19-29956 | 11 Stages: 5.14 MM#<br>L = 3,935 ft & Xf = 226 ft (Crawford)<br>Halliburton Model: 60 ft high by 518 ft long                     | Cemented              | 6-14 thru 11-16                                                                                 | 37,423  | 46,876  | 37,856 | 103        | 137                                    | 125,833    | 92               |
| 39    | Wold Mojave Fed. 4277-25-31FH<br>BHL:                                                                                                                                                                                                                                                                    | se se 25-42N-77W<br>nw ne 25-42N-77W | 19-29723 | 13 Stages: 2.91 MM#<br>L = 3,796 ft & Xf = 295 ft                                                                                | Uncemented            | 2-13 thru 1-17                                                                                  | 142,663 | 287,748 | 59,768 | 194        | 400                                    | 260,667    | 102              |
| 40    | Wold Mojave Fed. 4277-23-31FH<br>BHL:                                                                                                                                                                                                                                                                    | ne ne 26-42N-77W<br>nw ne 23-42N-77W | 19-29924 | 14 Stages: 3.2 MM#<br>L = 4,029 ft & Xf = 138 ft (Crawford)                                                                      | Cemented              | 5-14 thru 1-17                                                                                  | 25,539  | 32,216  | 45,843 | 115        | 203                                    | 148,833    | 76               |
| 41    | Wold Mojave Fed. 4277-23-34FH<br>BHL:                                                                                                                                                                                                                                                                    | ne ne 26-42N-77W<br>sw se 26-42N-77W | 19-29925 |                                                                                                                                  |                       | 5-14 thru 11-16                                                                                 | 88,417  | 117,088 | 69,521 |            |                                        |            |                  |
| 42    | Wold Mojave Fed. 4277-22-41FH<br>BHL:                                                                                                                                                                                                                                                                    | nw ne 27-42N-77W<br>ne ne 22-42N-77W | 19-29887 | 13 Stages: 2.94 MM#<br>L = 3,529 ft & Xf = 134 ft                                                                                | Cemented              | 2-14 thru 11-16                                                                                 | 42,766  | 44,127  | 69,722 | 120        | 170                                    | 148,333    |                  |
| 43    | Wold Mojave Fed. 4277-27-44FH<br>BHL:                                                                                                                                                                                                                                                                    | nw ne 27-42N-77W<br>se se 27-42N-77W | 19-29847 |                                                                                                                                  |                       | 2-14 thru 11-16                                                                                 | 84,390  | 138,578 | 81,045 |            |                                        |            |                  |
| 44    | SM Rush State 4277-36-1FH<br>BHL:                                                                                                                                                                                                                                                                        | nw ne 36-42N-77W<br>se se 36-42N-77W | 19-29986 |                                                                                                                                  |                       | 4-14 thru 11-16                                                                                 | 119,359 | 203,059 | 93,612 |            |                                        |            |                  |
| 45    | Anadarko Mojave 4377-16-11FH<br>BHL:                                                                                                                                                                                                                                                                     | se sw 16-43N-77W<br>nw nw 16-43N-77W | 19-29944 | 13 Stages: 2.66 MM#<br>L = 3,545 ft & Xf = 286 ft                                                                                | Uncemented            | 10-13 thru 11-16                                                                                | 15,579  | 6,598   | 43,034 | 40         | 21                                     | 43,500     | 95               |
|       | Key Missing Well: Chesapeake Wagonhound 23-1H Well in Section 23 of T33N - R72W: "Conventional" SS Frontier ???                                                                                                                                                                                          |                                      |          |                                                                                                                                  |                       |                                                                                                 |         |         |        |            |                                        |            |                  |
|       | Key Parameters for EUR Determination in IHS PowerTools: \$80 / bbl + \$2 / Mcf + \$2,000 / month LOE ( Approx. 1 BOPD )<br>Decline Curve Default From Hyperbolic to Exponential 6% / year: Change From Transient Flow to Boundary-Dominated Flow<br>Oil & Gas Curves "Best Fit" to Rate versus Cum Plots |                                      |          |                                                                                                                                  |                       |                                                                                                 |         |         |        |            |                                        |            |                  |
|       | 8 North-South Wells - Cemented Liner / Casing:                                                                                                                                                                                                                                                           |                                      |          | Total L = 45,355 feet ( avg 5,669 ft / well )<br>Highest Xf = 227 feet ( avg 163 feet )<br>Total 142 Stages: Avg 319 ft / stage  |                       | Total EUR = 2,481 MBO ( avg 310 MBO / well )<br>Total EUR = 4,305 MMcf ( avg 538 MMcf / well )  |         |         |        |            | Avg 54.7 BO / ft<br>Avg 94.9 Mcf / ft  |            |                  |
|       | 22 North-South Wells - Uncemented Liner:                                                                                                                                                                                                                                                                 |                                      |          | Total L = 156,047 feet ( avg 7,093 ft / well )<br>Highest Xf = 343 feet ( avg 252 feet )<br>Total 486 Stages: Avg 321 ft / stage |                       | Total EUR = 7,129 MBO ( avg 324 MBO / well )<br>Total EUR = 18,962 MMcf ( avg 862 MMcf / well ) |         |         |        |            | Avg 45.7 BO / ft<br>Avg 121.5 Mcf / ft |            |                  |
|       | 3 East-West Wells:                                                                                                                                                                                                                                                                                       |                                      |          | Total L = 27,308 feet ( avg 9,103 ft / well )<br>Highest Xf = n/a<br>Total 82 Stages: Avg 333 ft / stage                         |                       | Total EUR = 216 MBO ( avg 72 MBO / well )<br>Total EUR = 651 MMcf ( avg 217 MMcf / well )       |         |         |        |            | Avg 7.9 BO / ft<br>Avg 23.8 Mcf / ft   |            |                  |

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Wold Energy Partners

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Exhibit E - 12

# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Black Jack 3774-22-27-1FH Frontier.mdb

Date: 4/6/2017

Time: 1:20 PM

Lease Name: BLACK JACK FEDERAL 3774-22 (27-1FH)

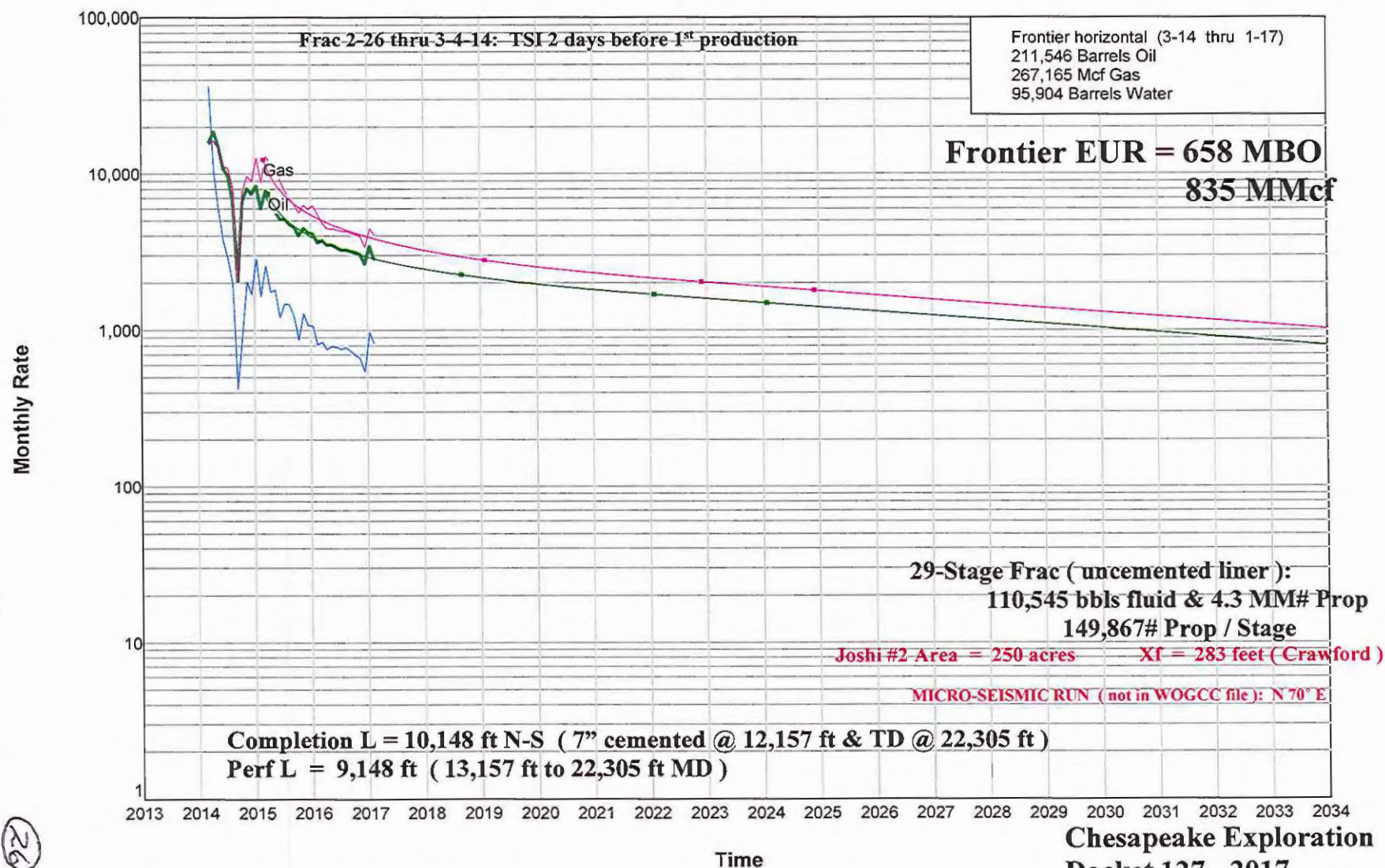
County, ST: CONVERSE, WY

Location: N37 W74 22 NW

Operator: SM ENERGY COMPANY

Field Name: PHILLIPS CREEK

## Phillips Creek Field: SM BlackJack 3774-22-27-1FH Frontier (ne nw 22-37N-74W) API 49-009-28794

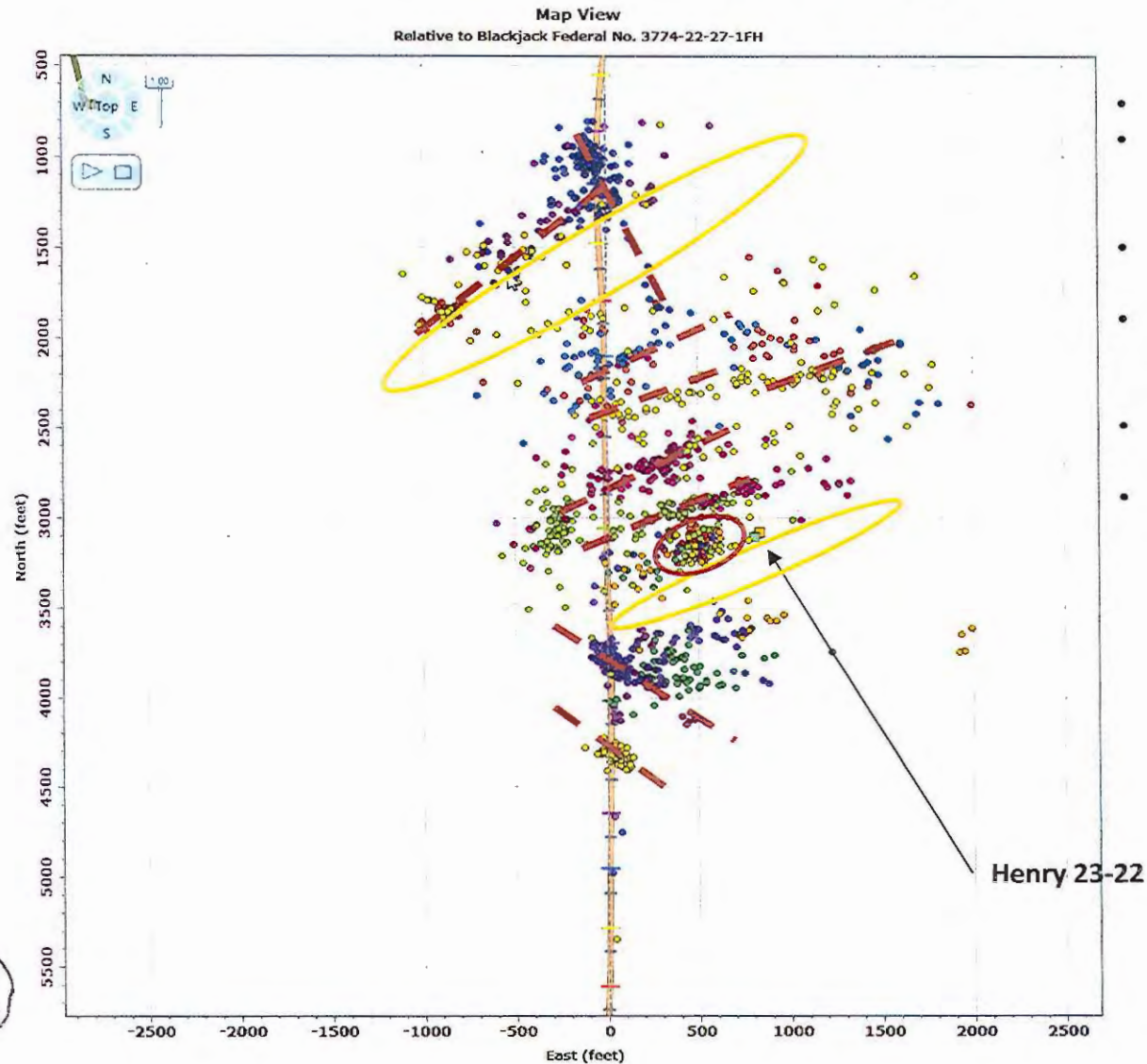


22

Chesapeake Exploration  
Docket 127 - 2017  
Exhibit E - 7



# All Stages



- Dominant N70E fracture orientation
- NW trending fracture conjugate set
  - Mostly simple, linear fracs
  - Some moderate complex fracs
- NE trending zones of low microseismicity
  - Depletion?, Unstimulated?
- Stages 14-18 (?) had several microseismic events in 300'x250' zone west of monitor well
- Higher pump rates generated longer half-lengths
- Linear progression along half-length noticed on several stages

# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Roger Leo 20-29-1FH Frontier 20-38N-75W.mdb Date: 4/10/2017

Time: 8:45 AM

Lease Name: ROGER LEO FEDERAL (3875-20-2)

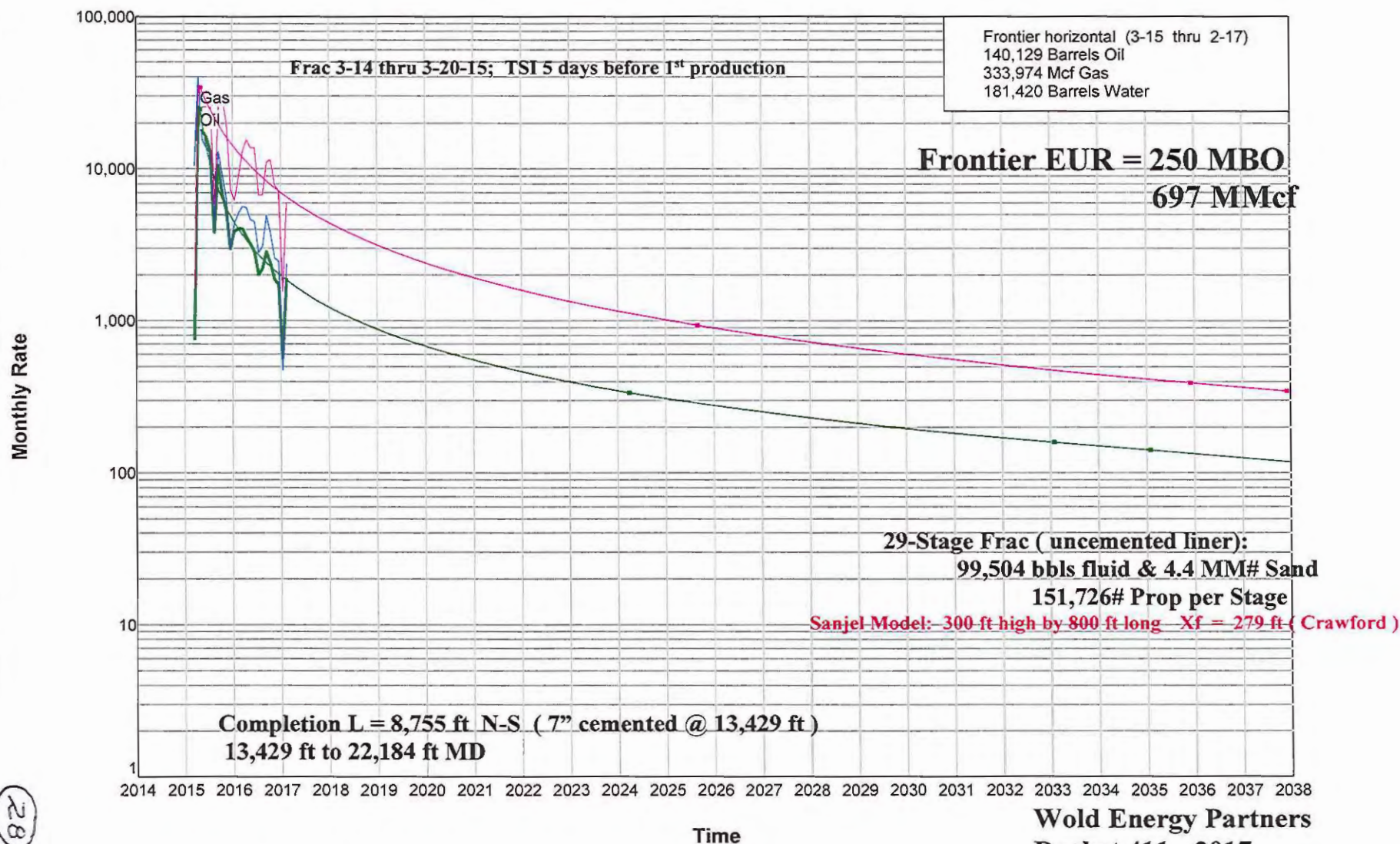
County, ST: CONVERSE, WY

Location: N38 W75 20 NE

Operator: SM ENERGY COMPANY

Field Name: SNAKE CHARMER DRAW

## Snake Charmer Draw Field: Roger Leo 3875-20-29-1FH Frontier (ne ne 20-38N-75W) API 49-009-29320



Wold Energy Partners  
Docket 411 - 2017  
Exhibit E - 7



# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Allemand 12-2-1H Frontier 2-38N-75W.mdb

Date: 4/10/2017

Time: 8:53 AM

Lease Name: ALLEMAND (12-2-1H)

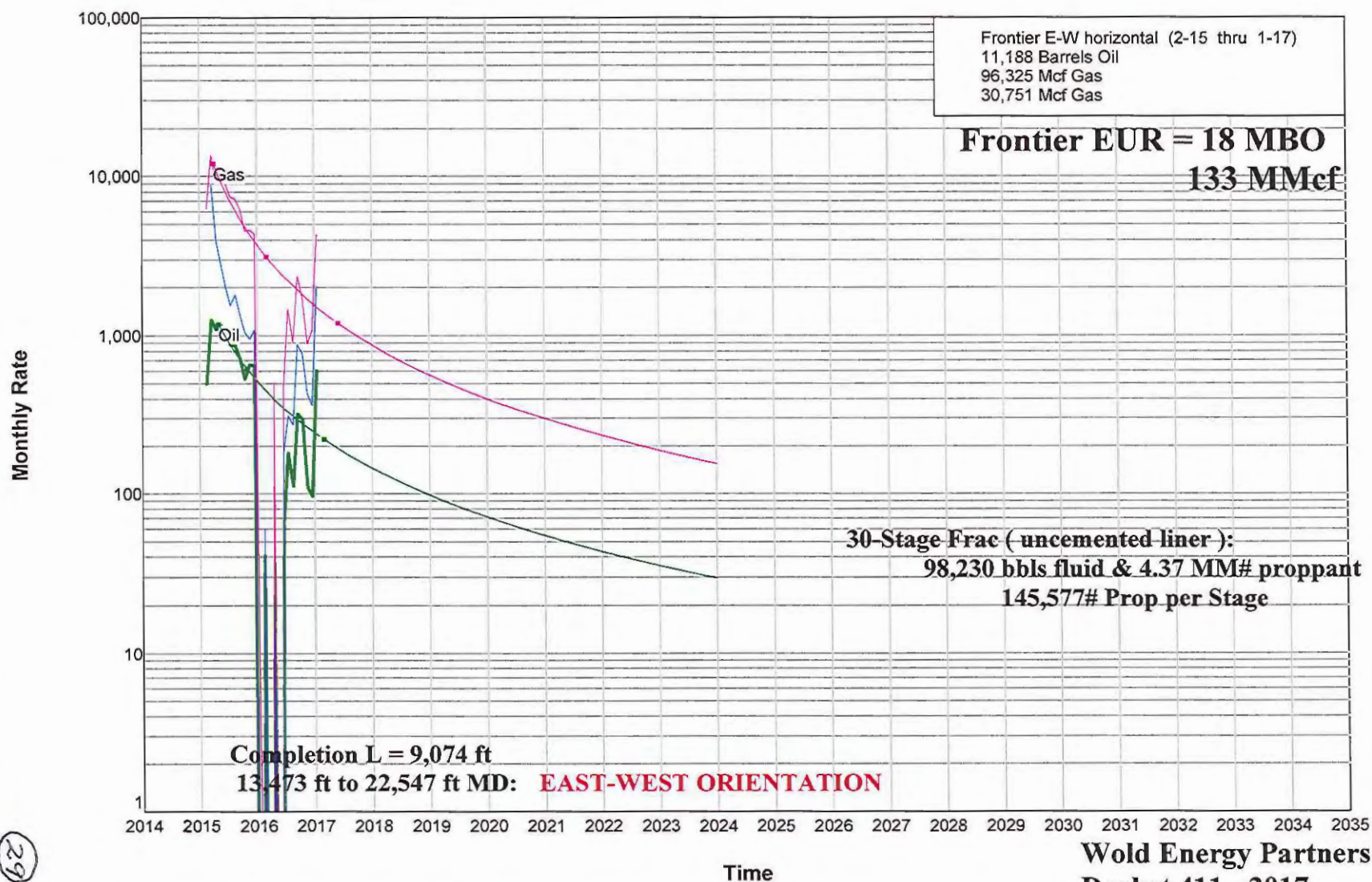
County, ST: CONVERSE, WY

Location: N38 W75 2 SW

Operator: SM ENERGY COMPANY

Field Name: UNNAMED

## Finley Draw Field: Allemand 12-2/1H Frontier (nw sw 2-38N-75W) API 49-009-28824



Wold Energy Partners  
Docket 411 - 2017  
Exhibit E - 7



# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Hornbuckle 28-21H Frontier 28-37N-75W.mdb

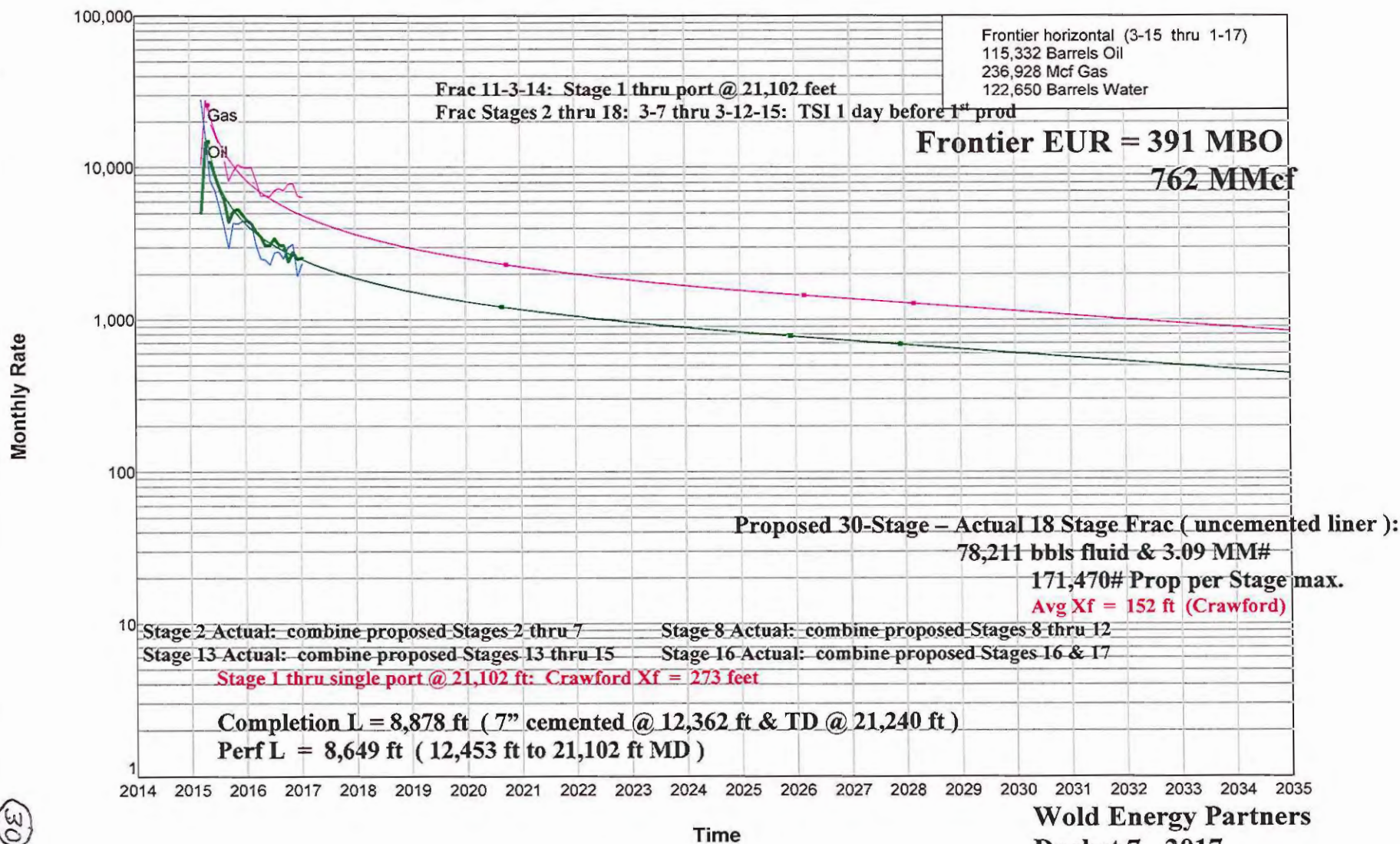
Date: 3/21/2017

Time: 12:46 PM

Lease Name: MAPLES BUTTE UNIT HORNBUCKLE (E-28-21H)  
County, ST: CONVERSE, WY  
Location: N37 W75 28 SE

Operator: HELIS OIL & GAS COMPANY LLC  
Field Name: SPEARHEAD RANCH

## Helis Hornbuckle E-28/21H Frontier (sw se 28-37N-75W) API 49-009-29742



Wold Energy Partners  
Docket 7 - 2017  
Exhibit E - 7

# Rate/Time Graph

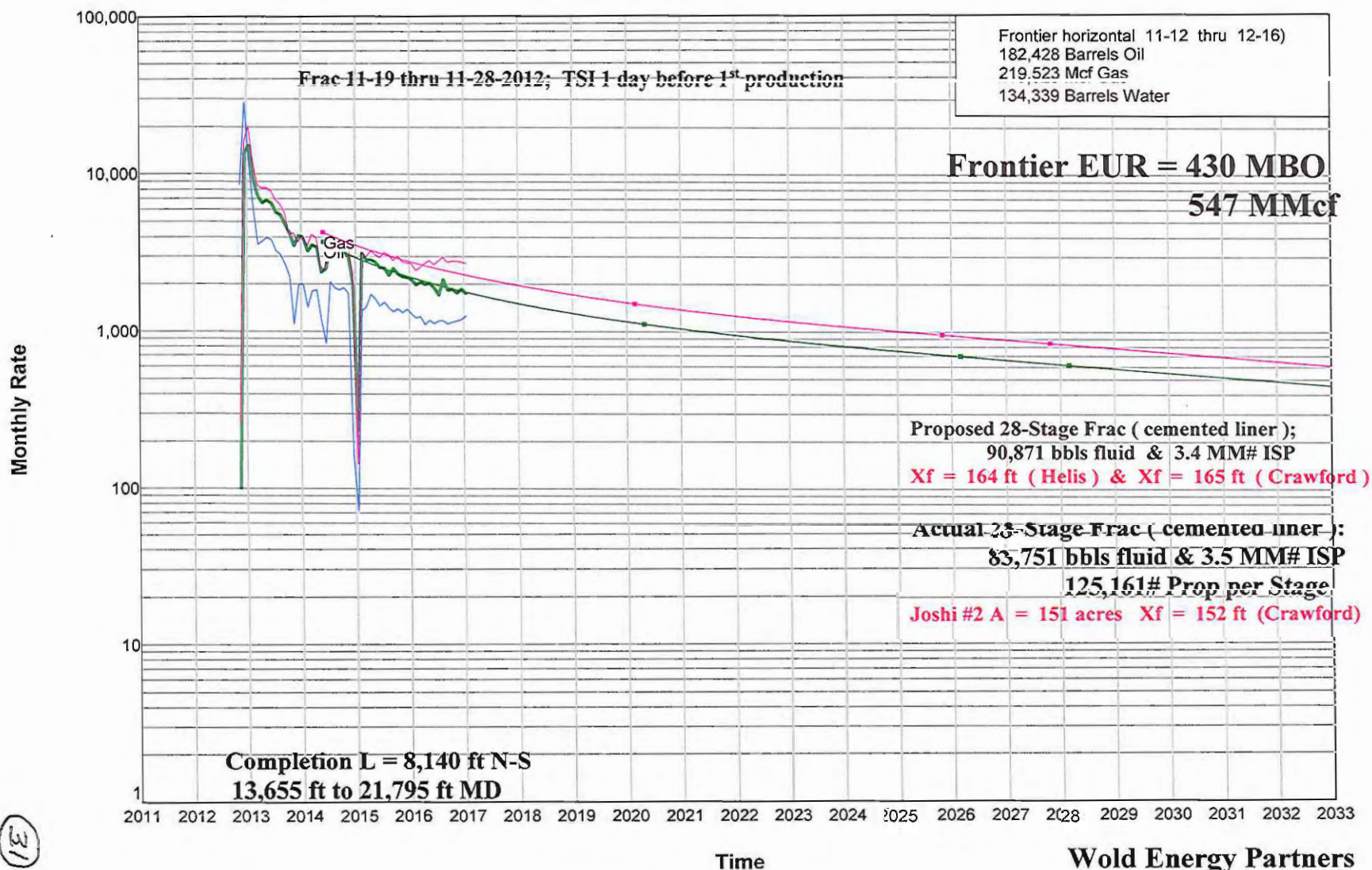
Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Hornbuckle 14-31-30H Frontier 31-37N-74W.mdb Date: 4/3/2017

Time: 12:26 PM

Lease Name: HORNBUCKLE (14-31 30H)  
County, ST: CONVERSE, WY  
Location: N37 W74 31 SE SW

Operator: HELIS OIL & GAS COMPANY LLC  
Field Name: UNNAMED

## Helis Hornbuckle 14-31/30H Frontier (se sw 31-37N-74W) API 49-009-28421



Wold Energy Partners  
Docket 411 - 2017  
Exhibit E - 13



## Summary of Selected Sussex Horizontal Wells in the PRB

| Count | Well                         | Surface Location                          | API No.<br>49-009- | Sussex<br>Frac Size                                    | Days TSI<br>1st Prod | Frac<br>Method   | Producing<br>Period | Cum BO  | Cum Mcf   | Cum BW  | Sx EUR<br>MBQ | Sx EUR<br>MMcf | Sx EUR<br>BOE | Joshi #2<br>Drain A |
|-------|------------------------------|-------------------------------------------|--------------------|--------------------------------------------------------|----------------------|------------------|---------------------|---------|-----------|---------|---------------|----------------|---------------|---------------------|
| 1     | Combs 17-33-70 ST C SX 18H   | ne ne 17-33N-70W<br>BHL: se sw 16-33N-70W | 29995              | 15-Stage Frac: 3.6 MM#<br>L = 5,100 ft & Xf = 143 ft   | 65                   | Cemented Liner   | 11-15 thru 8-16     | 54,349  | 412,486   | 33,216  | 232           | 2,339          | 621,833       | 64                  |
| 2     | Combs 29-33-70 C SX 7H       | ne se 29-33N-70W<br>BHL: nw se 20-33N-70W | 29269              | 16-Stage Frac: 6.1 MM#<br>L = 4,796 ft & Xf = 165 ft   | 12                   | Cemented Liner   | 1-14 thru 8-16      | 351,967 | 1,653,124 | 108,196 | 853           | 3,841          | 1,493,167     | 66                  |
| 3     | Combs 29-33-70 B SX 11H      | sw sw 29-33N-70W<br>BHL: ne se 19-33N-70W | 29443              | 15-Stage Frac: 8.05 MM#<br>L = 5,506 ft & Xf = 213 ft  | 86                   | Cemented Liner   | 5-15 thru 8-16      | 44,997  | 199,033   | 27,318  | 191           | 967            | 352,167       | 87                  |
| 4     | Combs 29-33-70 D SX 11H      | ne sw 29-33N-70W<br>BHL: sw nw 20-33N-70W | 29839              | 23-Stage Frac: 8.9 MM#<br>L = 6,498 ft & Xf = 172 ft   | 42                   | Cemented Liner   | 6-15 thru 8-16      | 138,048 | 834,921   | 46,356  | 360           | 3,247          | 901,167       | 90                  |
| 5     | Combs 29-33-70 D SX 12H      | ne sw 29-33N-70W<br>BHL: se se 32-33N-70W | 29841              | 23-Stage Frac: 9.0 MM#<br>L = 6,761 ft & Xf = 172 ft   | 50                   | Cemented Liner   | 7-15 thru 8-16      | 154,721 | 995,656   | 42,297  | 396           | 3,404          | 963,333       | 93                  |
| 6     | Combs 29-33-70 USA B SX 13H  | sw sw 29-33N-70W<br>BHL: nw ne 19-33N-70W | 29521              | 30-Stage Frac: 16.0 MM#<br>L = 8,702 ft & Xf = 208 ft  | 38                   | Cemented Liner   | 3-15 thru 8-16      | 104,106 | 406,742   | 71,362  | 220           | 860            | 363,333       | 134                 |
| 7     | Combs 29-33-70 D SX 14H      | ne sw 29-33N-70W<br>BHL: sw sw 33-33N-70W | 29842              | 22-Stage Frac: 8.0 MM#<br>L = 6,549 ft & Xf = 169 ft   | 38                   | Cemented Liner   | 7-15 thru 8-16      | 196,768 | 984,646   | 47,570  | 535           | 3,883          | 1,182,167     | 90                  |
| 8     | Combs 29-33-70 ST D SX 16H   | ne sw 29-33N-70W<br>BHL: sw se 32-33N-70W | 29840              |                                                        |                      | Cemented Liner   | 7-15 thru 8-16      | 123,230 | 799,454   | 44,557  |               |                |               |                     |
| 9     | Clausen 19-34-70 USA A SX 7H | nw nw 19-34N-70W<br>BHL: se nw 12-34N-71W | 28983              | 30-Stage Frac: 11.74 MM#<br>L = 8,957 ft & Xf = 172 ft | 51                   | Cemented Liner   | 4-15 thru 8-16      | 124,512 | 371,877   | 95,040  | 396           | 1,277          | 608,833       | 123                 |
| 10    | Clausen 19-34-70 A SX 8H     | nw nw 19-34N-70W<br>BHL: ne nw 30-34N-70W | 29028              |                                                        |                      | Cemented Liner   | 4-15 thru 8-16      | 58,432  | 415,013   | 55,500  |               |                |               |                     |
| 11    | Clausen 19-34-70 USA A SX 9H | nw nw 19-34N-70W<br>BHL: sw ne 12-34N-71W | 28980              | 21-Stage Frac: 8.2 MM#<br>L = 8,741 ft & Xf = 173 ft   | 39                   | Cemented Liner   | 4-15 thru 8-16      | 147,534 | 581,081   | 117,284 | 334           | 1,133          | 522,833       | 120                 |
| 12    | Clausen 19-34-70 C SX 10H    | nw nw 19-34N-70W<br>BHL: se sw 19-34N-70W | 28857              | 15-Stage Frac: 6.2 MM#<br>L = 4,528 ft & Xf = 170 ft   | 7                    | Cemented Liner   | 1-14 thru 8-16      | 195,081 | 899,270   | 110,791 | 293           | 1,667          | 570,833       | 63                  |
| 13    | Graham 26-35-71 A SX 10H     | nw ne 26-35N-71W<br>BHL: sw se 26-35N-71W | 29480              | 20-Stage Frac: 7.8 MM#<br>L = 4,027 ft & Xf = 171 ft   | 19                   | Cemented Liner   | 7-14 thru 8-16      | 141,989 | 126,309   | 84,127  | 442           | 354            | 501,000       | 57                  |
| 14    | RKI Box Creek 35-71 29-1SXH  | nw nw 29-35N-71W<br>BHL: se sw 29-35N-71W | 28978              | 15-Stage Frac: 2.8 MM#<br>L = 3,615 ft & Xf = 212 ft   | 10                   | Uncemented Liner | 6-13 thru 7-16      | 26,207  | 23,462    | 64,068  | 52            | 59             | 61,833        |                     |
| 15    | Samson Ravenna 21-19H 37-73H | ne nw 19-37N-73W<br>BHL: se sw 19-37N-73W | 28662              | 12-Stage Frac: 4.3 MM#<br>L = 4,574 ft & Xf = 267 ft   | 4                    | Uncemented Liner | 6-12 thru 8-16      | 175,757 | 102,750   | 39,342  | 300           | 239            | 339,833       | 85                  |
| 16    | Samson Hardy 13-1807-38-73BH | ne nw 7-38N-73W<br>BHL: nw sw 18-38N-73W  | 28828              |                                                        |                      |                  | 8-14 thru 8-16      | 108,849 | 69,321    | 28,256  |               |                |               |                     |
| 17    | Samson Hardy 34-7 38-73BH    | ne nw 7-38N-73W<br>BHL: sw se 7-38N-73W   | 29224              | 12-Stage Frac: 1.2 MM#<br>L = 4,472 ft & Xf = 204 ft   |                      | Uncemented Liner | 8-14 thru 8-16      | 57,672  | 43,885    | 13,484  | 158           | 177            | 187,500       | 70                  |
| 18    | Samson Hardy 24-15 38-73H    | se sw 15-38N-73W<br>BHL: ne nw 15-38N-73W | 28465              | 15-Stage Frac: 2.47 MM#<br>L = 4,279 ft & Xf = 196 ft  |                      | Uncemented Liner | 4-12 thru 8-16      | 39,770  | 65,470    | 17,935  | 110           | 190            | 141,667       | 65                  |
| 19    | Samson Russell 21-19H        | ne nw 19-38N-73W<br>BHL: se sw 19-38N-73W | 28321              | 10-Stage Frac: 2.36 MM#<br>L = 4,177 ft & Xf = 233 ft  |                      | Uncemented Liner | 6-11 thru 8-16      | 124,370 | 86,887    | 19,787  | 152           | 136            | 174,667       | 71                  |
| 20    | Samson Russell 31-18 38-73BH | ne nw 19-38N-73W<br>BHL: nw ne 18-38N-73W | 28563              | 11-stage Frac: 3.94 MM#<br>L = 4,235 ft & Xf = 270 ft  | 8                    | Uncemented Liner | 2-12 thru 8-16      | 159,993 | 140,343   | 32,092  | 226           | 243            | 266,500       | 80                  |

Wold Energy Partners

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Exhibit E - 4



## Summary of Selected Sussex Horizontal Wells in the PRB

| Count                       | Well                              | Surface Location                          | API No. | Sussex Frac Size                                                                                                                                                              | Days TSI | Frac Method      | Producing Period                             | Cum BO  | Cum Mcf | Cum BW | Sx EUR MBO | Sx EUR MMcf | Sx EUR BOE       | Joshi #2 Drain A |
|-----------------------------|-----------------------------------|-------------------------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------------------|----------------------------------------------|---------|---------|--------|------------|-------------|------------------|------------------|
| 21                          | Samson Russell 14-19 38-73BH      | ne nw 19-38N-73W<br>BHL: sw sw 19-38N-73W | 28761   |                                                                                                                                                                               |          |                  | 8-12 thru 7-16                               | 71,924  | 73,599  | 24,211 |            |             |                  |                  |
| 22                          | Samson GH Federal 21-26H          | se sw 23-38N-73W<br>BHL: se sw 26-38N-73W | 28270   |                                                                                                                                                                               |          |                  | 11-10 thru 7-16                              | 52,690  | 68,134  | 23,463 |            |             |                  |                  |
| 23                          | Samson Hardy Federal 24-23 38-73H | se sw 23-38N-73W<br>BHL: ne nw 23-38N-73W | 28326   |                                                                                                                                                                               |          |                  | 8-11 thru 7-16                               | 85,756  | 79,231  | 29,086 |            |             |                  |                  |
| 24                          | Samson Buffum 24-30 38-73H        | se sw 30-38N-73W<br>BHL: ne nw 30-38N-73W | 28435   |                                                                                                                                                                               |          |                  | 5-12 thru 7-16                               | 113,404 | 77,694  | 19,465 |            |             |                  |                  |
| 25                          | Samson Henry 24-31 38-73BH        | se sw 30-38N-73W<br>BHL: se sw 31-38N-73W | 28548   |                                                                                                                                                                               |          |                  | 5-12 thru 7-16                               | 81,833  | 76,968  | 18,429 |            |             |                  |                  |
| 26                          | Wold / BBC Fed. 44-1-3874SXH      | se se 1-38N-74W<br>BHL: nw ne 1-38N-74W   | 28625   | 17-Stage Frac: 2.5 MM#<br>L = 4,351 ft & Xf = 223 ft                                                                                                                          | n/a      | Uncemented Liner | 9-12 thru 8-16                               | 85,962  | 47,766  | 26,910 | 208        | 124         | 228,667          | 72               |
| 27                          | Samson Patterson 34-16H           | sw se 16-38N-74W<br>BHL: nw ne 16-38N-74W | 28427   |                                                                                                                                                                               |          |                  | 9-12 thru 7-15                               | 0       | 0       | 1,453  |            |             |                  |                  |
| 28                          | Samson Henry 31-36 38-74H         | nw ne 36-38N-74W<br>BHL: sw se 36-38N-74W | 28707   |                                                                                                                                                                               |          |                  | 6-12 thru 10-14                              | 21,052  | 27,059  | 19,247 |            |             |                  |                  |
| 29                          | Samson Hardy 11-19 39-73H         | nw nw 19-39N-73W<br>BHL: sw sw 19-39N-73W | 28829   | 10-Stage Frac: 2.3 MM#<br>L = 4,970 ft & Xf = 223 ft                                                                                                                          | 4        | Uncemented Liner | 10-12 thru 9-16                              | 77,370  | 99,447  | 12,993 | 168        | 272         | 213,333          | 82               |
| 30                          | SM Hardy 16-14-39-74SXH           | se se 14-39N-74W<br>BHL: nw sw 14-39N-74W | 28743   | 15-Stage Frac Failed<br>Re-Frac 13-Stage: 2.2 MM#<br>L = 4,828 ft & Xf = 227 ft                                                                                               | 2        | Uncemented Liner | 8-12 thru 9-16                               | 82,629  | 41,227  | 29,922 | 198        | 140         | 221,333          | 80               |
| 31                          | Samson Dilts Ranch 34-16 39-74H   | sw se 16-39N-74W<br>BHL: nw ne 16-39N-74W | 28661   |                                                                                                                                                                               |          |                  | 6-12 thru 2-16                               | 48,028  | 141,180 | 10,359 |            |             |                  |                  |
| 32                          | SM Hardy 4-23-39-74SXH            | nw nw 23-39N-74W<br>BHL: se ne 23-39N-74W | 28744   | 15-Stage Frac: 2.17 MM#<br>L = 5,159 ft & Xf = 221 ft                                                                                                                         |          | Uncemented Liner | 6-12 thru 1-17                               | 130,170 | 144,175 | 11,565 | 190        | 232         | 228,667          | 84               |
| 33                          | Samson GH Federal 44-25H          | se se 25-39N-74W<br>BHL: nw ne 25-39N-74W | 28325   | IHS Missing 8-11 thru 12-11                                                                                                                                                   |          |                  | 8-11 thru 12-16                              | 177,082 | 227,045 | 17,838 | 290        | 430         | 361,667          |                  |
| 34                          | SM Hardy 12-26H                   | nw sw 26-39N-74W<br>BHL: se se 26-39N-74W | 28615   | 15-stage Frac 2.6 MM#<br>L = 4,192 ft & Xf = 216 ft                                                                                                                           |          | Uncemented Liner | 9-12 thru 12-16                              | 100,155 | 56,415  | 17,479 | 188        | 122         | 208,333          | 68               |
| 35                          | SM Hardy 12-27-3974SXH            | ne se 28-39N-74W<br>BHL: se se 27-39N-74W | 28742   | Frac 3 MM#: Details n/a<br>L = 5,494 ft                                                                                                                                       |          | Uncemented Liner | 10-12 thru 1-16                              | 73,204  | 30,775  | 21,149 | 200        | 115         | 219,167          |                  |
| 36                          | Samson Allemand 14-29 39-74H      | sw sw 29-39N-74W<br>BHL: nw nw 29-39N-74W | 28583   | 11-stage Frac 2.57 MM#<br>L = 4,009 ft & Xf = 226 ft                                                                                                                          | 11       | Uncemented Liner | 4-12 thru 11-16                              | 44,460  | 47,244  | 33,906 | 109        | 172         | 137,667          | 67               |
| 11 Wells Cemented Liner:    |                                   |                                           |         | Total L = 70,165 feet ( avg 6,379 feet / well )<br>Highest Xf = 213 feet ( Lowest Xf = 143 feet & Avg 175 feet )<br>Total Stages 230: Avg 21 Stages / Well & 305 feet / stage |          |                  | Total EUR = 4,252 MBO ( avg 387 MBO / well ) |         |         |        |            |             | Avg 60.6 BO / ft |                  |
| 13 Wells Un-Cemented Liner: |                                   |                                           |         | Total L = 58,355 feet ( avg 4,489 feet / well )<br>Highest Xf = 270 feet ( Lowest Xf = 196 feet & Avg 227 feet )<br>Total Stages 156: Avg 13 Stages / Well & 339 feet / stage |          |                  | Total EUR = 2,259 MBO ( avg 174 MBO / well ) |         |         |        |            |             | Avg 38.7 BO / ft |                  |

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Exhibit E - 4



# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Clausen 19-34-70 C SX 10H Sussex.mdb

Date: 4/8/2017

Time: 11:43 AM

Lease Name: CLAUSEN 19-34 (70 C SX 1)

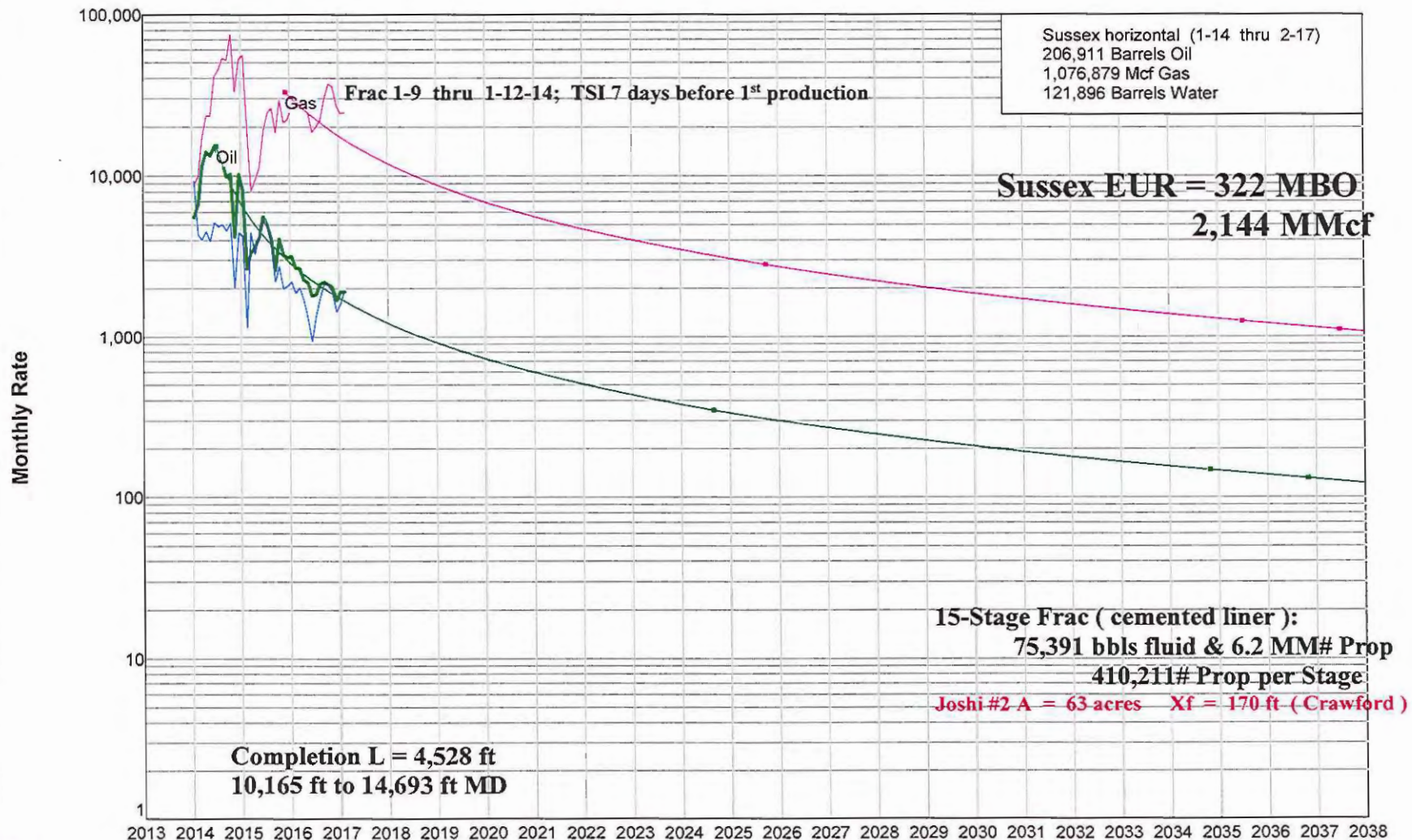
County, ST: CONVERSE, WY

Location: N34 W70 19 NW

Operator: CHESAPEAKE OPERATING LLC

Field Name: UNNAMED

## Clausen Ranch Unit 19-34-70 C SX 10H Sussex (nw nw 19-34N-70W) API 49-009-28857



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Chesapeake Exploration  
Docket 1179 - 2015  
Exhibit E - 7

# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Hornbuckle Hardy 34-7 38-73BH Sussex.mdb

Date: 4/8/2017

Time: 11:47 AM

Lease Name: HARDY FEDERAL 34-7 (38-73BH)

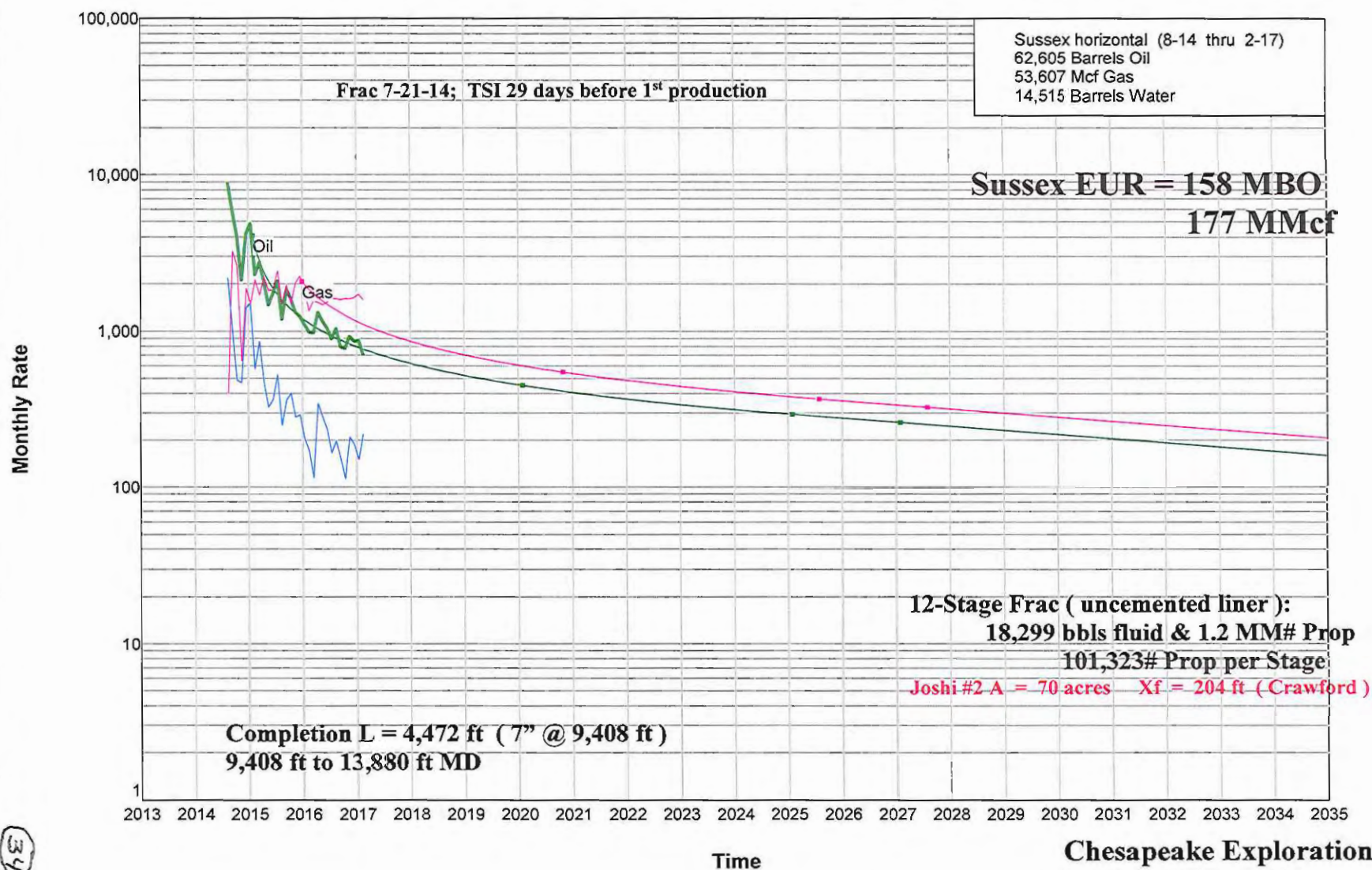
County, ST: CONVERSE, WY

Location: N38 W73 7 NW

Operator: SAMSON RESOURCES COMPANY

Field Name: HORNBUCKLE

## Hardy 34-7 38-73BH Sussex (ne nw 7-38N-73W) API 49-009-29224



Chesapeake Exploration  
Docket 1029 - 2015  
Exhibit E - 7



**Summary of Selected Niobrara Horizontal Wells in the PRB**

| Count | Well Name                 | Locations        | API No.<br>49 - | Stimulation                              | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>Xf (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|---------------------------|------------------|-----------------|------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 1     | Smith Creek 6-32-70 A 1H  | se sw 6-32N-70W  | 09-29066        | 19-Stage: 5.7 MM#                        | 301,719             | 3,978           | 209             | 24-Jul-14         | 63                  | 161                 | 158        | 1,371       | 386.5       |
|       | BHL:                      | nw nw 6-32N-70W  |                 | Stage 19 Screenout                       |                     |                 |                 |                   |                     |                     |            |             |             |
| 2     | Smith Creek 6-32-70 A 3H  | se sw 6-32N-70W  | 09-29065        | 13-Stage: 6.2 MM#                        | 478,127             | 4,237           | 326             | 23-Jul-14         | 55                  | 185                 | 72         | 761         | 198.8       |
|       | BHL:                      | ne nw 6-32N-70W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 3     | Smith Creek 6-32-70 A 5H  | se sw 6-32N-70W  | 09-29064        | 13-Stage: 5.9 MM#                        | 450,742             | 4,270           | 328             | 02-Jul-14         | 24                  | 187                 | 57         | 634         | 162.7       |
|       | BHL:                      | ne nw 6-32N-70W  |                 | Stage 1 Ineffective                      |                     |                 |                 |                   |                     |                     |            |             |             |
| 4     | Smith Creek 6-32-70 B 1H  | ne ne 6-32N-70W  | 09-29029        | 10-Stage: 4.4 MM#                        | 439,155             | 4,372           | 437             | 21-Oct-13         | 113                 | 171                 | 56         | 480         | 136.0       |
|       | BHL:                      | sw se 6-32N-70W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 5     | Smith Creek 6-32-70 B 2H  | ne ne 6-32N-70W  | 09-29052        | Planned 13-Stage: 2.0 MM# Actual         | 279,263             | 2,408           | 344             | 02-Nov-13         | 122                 | 157                 | 11         | 120         | 31.0        |
|       | BHL:                      | sw se 6-32N-70W  |                 | Casing Problems: Stages 5 thru 10 Failed |                     |                 |                 |                   |                     |                     |            |             |             |
| 6     | Smith Creek 6-32-70 B 3H  | ne ne 6-32N-70W  | 09-29053        | 11-Stage: 4.4 MM#                        | 397,912             | 4,790           | 435             | 22-Oct-13         | 106                 | 166                 | 74         | 977         | 236.8       |
|       | BHL:                      | se se 6-32N-70W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 7     | Smith Creek 6-32-70 B 4H  | ne ne 6-32N-70W  | 09-29051        | 11-Stage: 4.9 MM#                        | 446,742             | 4,907           | 446             | 31-Oct-13         | 113                 | 171                 | 136        | 885         | 283.5       |
|       | BHL:                      | se se 6-32N-70W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 8     | Smith Creek 32-70 8 2H    | nw ne 8-32N-70W  | 09-28490        | 12-Stage: 4.1 MM#                        | 338,525             | 4,042           | 337             | 12-Aug-12         | 1                   | 164                 | 113        | 922         | 266.7       |
|       | BHL:                      | sw se 8-32N-70W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 9     | Smith Creek 10-32-70 A 1H | nw nw 10-32N-70W | 09-28565        | 12-Stage: 3.6 MM#                        | 298,589             | 3,861           | 322             | 16-Aug-12         | 1                   | 166                 | 143        | 802         | 276.7       |
|       | BHL:                      | sw sw 10-32N-70W |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 10    | Trinity Fee 3367-7-31NH   | se se 7-33N-67W  | 09-28998        | 12-Stage: 3.6 MM#                        | 296,078             | 3,568           | 297             | 27-Apr-13         | 1                   | 147                 | 336        | 728         | 457.3       |
|       | BHL:                      | nw ne 7-33N-67W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 11    | State 16-33-68 A 2H       | sw sw 16-33N-68W | 09-29244        | 13-Stage: 6.1 MM#                        | 468,834             | 4,201           | 323             | 06-Jun-14         | 19                  | 180                 | 443        | 1,417       | 679.2       |
|       | BHL:                      | nw nw 16-33N-68W |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 12    | York Ranch 4-33-69 A 4H   | ne sw 4-33N-69W  | 09-28960        | 12-Stage: 3.7 MM#                        | 329,908             | 3,997           | 333             | 05-May-13         | 11                  | 161                 | 175        | 996         | 341.0       |
|       | BHL:                      | sw ne 9-33N-69W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 13    | York Ranch 4-33-69 A 6H   | ne sw 4-33N-69W  | 09-28959        | 17-Stage: 3.5 MM#                        | 213,906             | 5,557           | 327             | 13-May-13         | 11                  | 152                 | 161        | 855         | 303.5       |
|       | BHL:                      | se se 9-33N-69W  |                 | Stage 14 Ineffective                     |                     |                 |                 |                   |                     |                     |            |             |             |
| 14    | York Ranch 33-69 5-1H     | sw ne 5-33N-69W  | 09-28429        | 10-Stage: 1.6 MM#                        | 161,000             | 2,351           | 235             | 17-Feb-12         | 3                   | 131                 | 762        | 6,465       | 1,839.5     |
|       | BHL:                      | se sw 32-34N-69W |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 15    | York Ranch 17-33-69 A 1H  | se nw 17-33N-69W | 09-29164        | 18-Stage: 6.0 MM#                        | 333,352             | 5,380           | 299             | 17-Oct-14         | 38                  | 182                 | 227        | 1,345       | 451.2       |
|       | BHL:                      | sw nw 8-33N-69W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 16    | York Ranch 17-33-69 A 3H  | se nw 17-33N-69W | 09-29166        | 17-Stage: 7.1 MM#                        | 419,076             | 5,421           | 319             | 22-Sep-14         | 89                  | 182                 | 100        | 936         | 256.0       |
|       | BHL:                      | sw nw 8-33N-69W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 17    | York Ranch 17-33-69 A 5H  | se nw 17-33N-69W | 09-29163        | 17-Stage: 5.7 MM#                        | 336,696             | 4,948           | 291             | 17-Oct-14         | 49                  | 163                 | 170        | 1,571       | 431.8       |
|       | BHL:                      | se nw 8-33N-69W  |                 |                                          |                     |                 |                 |                   |                     |                     |            |             |             |

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### Summary of Selected Niobrara Horizontal Wells in the PRB

| Count | Well Name                  | Locations                                 | API No.<br>49 - | Stimulation                                                            | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>Xf (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|----------------------------|-------------------------------------------|-----------------|------------------------------------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 18    | York Ranch 33-69 19-1H     | ne ne 19-33N-69W<br>BHL: nw nw 29-33N-69W | 09-28438        | 16-Stage: 5.2 MM#                                                      | 326,155             | 5,118           | 320             | 25-May-12         | 12                  | 169                 | 317        | 2,095       | 666.2       |
| 19    | York Ranch 33-69 19-2H     | ne ne 19-33N-69W<br>BHL: nw ne 18-33N-69W | 09-28559        | 16-Stage: 5.0 MM#                                                      | 311,290             | 4,788           | 299             | 05-Jun-12         | 1                   | 162                 | 259        | 2,428       | 663.7       |
| 20    | York Ranch 19-33-69 B 2H   | sw nw 19-33N-69W<br>BHL: sw nw 30-33N-69W | 09-29306        | 18-Stage: 8.2 MM#                                                      | 456,060             | 4,695           | 261             | 06-Sep-14         | 54                  | 186                 | 372        | 2,905       | 856.2       |
| 21    | York Ranch 19-33-69 B 4H   | sw nw 19-33N-69W<br>BHL: se nw 30-33N-69W | 09-29307        | 18-Stage: 7.3 MM#<br>Stages 9 & 15 ineffective                         | 448,782             | 5,740           | 319             | 04-Sep-14         | 41                  | 184                 | 120        | 1,090       | 301.7       |
| 22    | York Ranch 19-33-69 B 6H   | sw nw 19-33N-69W<br>BHL: nw se 30-33N-69W | 09-29308        | 20-Stage: 8.4 MM#<br>Stage 1 Ineffective                               | 436,854             | 6,368           | 318             | 03-Sep-14         | 47                  | 185                 | 192        | 1,625       | 462.8       |
| 23    | York Ranch 31-33-69 A 1H   | se se 31-33N-69W<br>BHL: ne se 30-33N-69W | 09-28624        | 20-Stage: 6.0 MM#                                                      | 299,025             | 6,079           | 304             | 20-Feb-13         | 23                  | 171                 | 330        | 1,575       | 592.5       |
| 24    | York Ranch 31-33-69 A 3H   | se se 31-33N-69W<br>BHL: sw se 30-33N-69W | 09-28909        | 18-Stage: 5.3 MM#                                                      | 291,670             | 5,311           | 295             | 25-Feb-13         | 10                  | 153                 | 206        | 1,274       | 418.3       |
| 25    | Combs Ranch 7-33-70 A 3H   | se nw 7-33N-70W<br>BHL: ne ne 1-33N-70W   | 09-28840        | 21-Stage: 5.7 MM#                                                      | 272,959             | 6,176           | 294             | 30-Oct-12         | 17                  | 162                 | 167        | 1,352       | 392.3       |
| 26    | Combs Ranch 33-70 8-1H     | sw se 8-33N-70W<br>BHL: ne nw 8-33N-70W   | 09-28504        | 13-Stage: 4.0 MM#<br>MULTIPLE CORES                                    | 308,232             | 3,928           | 302             | 23-Oct-12         | 3                   | 167                 | 237        | 1,722       | 524.0       |
| 27    | Combs Ranch 10-33-70 A 1H  | nw ne 10-33N-70W<br>BHL: sw nw 14-33N-70W | 09-28706        | 20-Stage: 6.0 MM#                                                      | 300,083             | 5,911           | 300             | 17-Jan-13         | 33                  | 169                 | 63         | 534         | 152.0       |
| 28    | Combs Ranch 10-33-70 A 2H  | nw ne 10-33N-70W<br>BHL: se ne 15-33N-70W | 09-28842        | 21-Stage: 6.0 MM#                                                      | 284,426             | 6,226           | 296             | 09-Jan-13         | 32                  | 169                 | 135        | 1,027       | 306.2       |
| 29    | Combs Ranch 10-33-70 A 3H  | nw ne 10-33N-70W<br>BHL: ne nw 3-33N-70W  | 09-28929        | 20-Stage: 7.3 MM#<br>Stage 1 Ineffective                               | 362,523             | 5,283           | 264             | 06-Nov-14         | 97                  | 179                 | 56         | 512         | 141.3       |
| 30    | Combs Ranch 10-33-70 A 4H  | nw ne 10-33N-70W<br>BHL: ne nw 3-33N-70W  | 09-28992        | 21-Stage: 8.0 MM#                                                      | 378,538             | 5,731           | 273             | 06-Nov-14         | 106                 | 176                 | 179        | 1,926       | 500.0       |
| 31    | Combs Ranch 10-33-70 A 5H  | nw ne 10-33N-70W<br>BHL: nw ne 3-33N-70W  | 09-28993        | 21-Stage: 7.7 MM#                                                      | 368,825             | 5,500           | 262             | 27-Sep-14         | 86                  | 175                 | 128        | 1,228       | 332.7       |
| 32    | Combs Ranch 10-33-70 A 6H  | nw ne 10-33N-70W<br>BHL: ne sw 14-33N-70W | 09-28856        | 27-Stage: 8.7 MM#                                                      | 320,801             | 7,851           | 291             | 26-Jan-13         | 30                  | 171                 | 87         | 744         | 211.0       |
| 33    | Combs Ranch 10-33-70 A 8H  | nw ne 10-33N-70W<br>BHL: sw sw 14-33N-70W | 09-29595        | 33-Stage: 12.4 MM#<br>Stage 1 Ineffective<br>REMEDIAL CEMENT FOX HILLS | 386,034             | 9,072           | 275             | 18-Dec-14         | 223                 | 178                 | 102        | 1,032       | 274.0       |
| 34    | Combs Ranch 10-33-70 A 10H | nw ne 10-33N-70W<br>BHL: se sw 14-33N-70W | 09-29603        | 38-Stage: 12.2 MM#<br>REMEDIAL CEMENT FOX HILLS                        | 320,694             | 8,432           | 222             | 17-Dec-14         | 224                 | 166                 | 85         | 929         | 239.8       |

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**Summary of Selected Niobrara Horizontal Wells in the PRB**

| Count | Well Name                     | Locations         | API No.<br>49 - | Stimulation                                              | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>X1 (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|-------------------------------|-------------------|-----------------|----------------------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 35    | Combs Ranch 11-33-70 B 2H     | nw sw 11-33N-70W  | 09-29175        | 26-Stage: 8.0 MM#                                        | 306,014             | 6,975           | 268             | 03-Mar-15         | 160                 | 172                 | 116        | 2,144       | 473.3       |
|       | BHL:                          | se sw 14-33N-70W  |                 | Stage 21 Ineffective                                     |                     |                 |                 |                   |                     |                     |            |             |             |
| 36    | Combs Ranch 11-33-70 B 5H     | nw sw 11-33N-70W  | 09-29176        | 21-Stage: 6.9 MM#                                        | 329,733             | 5,722           | 272             | 02-Mar-15         | 161                 | 175                 | 181        | 1,922       | 501.3       |
|       | BHL:                          | nw sw 2-33N-70W   |                 | Stage 1 Ineffective                                      |                     |                 |                 |                   |                     |                     |            |             |             |
| 37    | York Ranch 12-33-70 A 3H      | ne nw 12-33N-70W  | 09-28953        | 14-Stage: 5.0 MM#                                        | 355,733             | 5,417           | 387             | 26-May-13         | 12                  | 158                 | 101        | 994         | 266.7       |
|       | BHL:                          | nw nw 1-33N-70W   |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 38    | York Ranch 12-33-70 A 5H      | ne nw 12-33N-70W  | 09-28952        | 16-Stage: 4.9 MM#                                        | 341,032             | 6,205           | 388             | 04-May-13         | 30                  | 163                 | 177        | 1,761       | 470.5       |
|       | BHL:                          | nw nw 1-33N-70W   |                 | Stages 4 & 13 Ineffective                                |                     |                 |                 |                   |                     |                     |            |             |             |
| 39    | Combs Ranch 16-33-70 ST A 1H  | se se 16-33N-70W  | 09-28705        | 11-Stage: 3.0 MM#                                        | 301,680             | 4,345           | 395             | 09-Oct-12         | 1                   | 174                 | 186        | 679         | 299.2       |
|       | BHL:                          | nw ne 16-33N-70W  |                 | Stage 7 FAILED                                           |                     |                 |                 |                   |                     |                     |            |             |             |
| 40    | Combs Ranch 16-33-70 ST B 2H  | ne nw 16-33N-70W  | 09-29022        | 14-Stage: 4.8 MM#                                        | 345,315             | 4,953           | 354             | 11-Aug-13         | 312                 | 170                 | 32         | 276         | 78.0        |
|       | BHL:                          | sw se 16-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 41    | Combs Ranch 16-33-70 ST B 4H  | ne nw 16-33N-70W  | 09-29021        | 15-Stage: 4.6 MM#                                        | 308,675             | 4,884           | 326             | 11-Aug-13         | 319                 | 153                 | 212        | 1,780       | 508.7       |
|       | BHL:                          | sw se 16-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 42    | Combs Ranch 16-33-70 ST B 6H  | ne nw 16-33N-70W  | 09-29023        | 13-Stage: 4.5 MM#                                        | 342,084             | 4,452           | 342             | 05-Aug-13         | 331                 | 170                 | 79         | 492         | 161.0       |
|       | BHL:                          | se se 16-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 43    | Combs Ranch 16-33-70 USA A 5H | se se 16-33N-70W  | 09-28949        | 25-Stage: 7.6 MM#                                        | 302,945             | 5,040           | 202             | 10-Mar-15         | 73                  | 162                 | 151        | 1,421       | 387.8       |
|       | BHL:                          | se se 21-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 44    | Combs Ranch 16-33-70 USA A 6H | se se 16-33N-70W  | 09-28945        | 21-Stage: 8.2 MM#                                        | 390,322             | 5,391           | 257             | 09-Mar-15         | 24                  | 173                 | 220        | 2,076       | 566.0       |
|       | BHL:                          | se sw 22-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 45    | Combs Ranch 17-33-70 A 2H     | nw sw 17-33N-70W  | 09-28971        | 14-Stage: 4.8 MM#                                        | 344,415             | 5,552           | 397             | 25-Nov-13         | 154                 | 164                 | 183        | 1,650       | 458.0       |
|       | BHL:                          | nw sw 20-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 46    | Combs Ranch 17-33-70 A 4H     | nw sw 17-33N-70W  | 09-28974        | Proposed 14-Stage: 4.9 MM#                               | 350,919             | 5,322           | 380             | 27-Dec-13         | 138                 | 165                 | 66         | 877         | 212.2       |
|       | BHL:                          | ne sw 20-33N-70W  |                 | Frac Details in WOGCC File:<br>Combs Ranch 29-33-70 C 4H |                     |                 |                 |                   |                     |                     |            |             |             |
| 47    | Combs Ranch 17-33-70 A 6H     | nw sw 17-33N-70W  | 09-28970        | 14-Stage: 3.9 MM#                                        | 278,915             | 4,689           | 335             | 27-Nov-13         | 184                 | 161                 | 112        | 1,620       | 382.0       |
|       | BHL:                          | se nw 20-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 48    | Combs Ranch 22-33-70 A 1H     | se ne 22-33N-70W  | 09-28621        | 20-Stage: 9.1 MM#                                        | 453,189             | 6,070           | 304             | 17-Dec-12         | 2                   | 163                 | 235        | 1,943       | 558.8       |
|       | BHL:                          | nw ne 15-22N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
|       | BHL ERROR:                    | Completion Sundry |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 49    | York Ranch 26-33-70 A 1H      | se ne 26-33N-70W  | 09-28562        | 20-Stage: 2.9 MM#                                        | 136,302             | 6,591           | 330             | 01-Aug-12         | 2                   | 143                 | 104        | 728         | 225.3       |
|       | BHL:                          | ne nw 23-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 50    | York Ranch 26-33-70 A 3H      | se ne 26-33N-70W  | 09-28922        | 21-Stage: 9.9 MM#                                        | 472,578             | 6,699           | 319             | 18-Sep-14         | 49                  | 187                 | 211        | 1,941       | 534.5       |
|       | BHL:                          | ne nw 23-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |
| 51    | York Ranch 26-33-70 A 5H      | se ne 26-33N-70W  | 09-28927        | 21-Stage: 9.9 MM#                                        | 470,683             | 6,752           | 322             | 18-Sep-14         | 62                  | 186                 | 294        | 2,722       | 747.7       |
|       | BHL:                          | nw ne 23-33N-70W  |                 |                                                          |                     |                 |                 |                   |                     |                     |            |             |             |

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### Summary of Selected Niobrara Horizontal Wells in the PRB

| Count | Well Name                   | Locations                                 | API No.<br>49 - | Stimulation                                    | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>Xf (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|-----------------------------|-------------------------------------------|-----------------|------------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 52    | Combs Ranch 28-33-70 A 2H   | ne sw 28-33N-70W<br>BHL: se sw 33-33N-70W | 09-29195        | 32-Stage: 9.7 MM#                              | 301,483             | 6,874           | 215             | 17-Aug-14         | 73                  | 183                 | 112        | 1,003       | 279.2       |
| 53    | Combs Ranch 28-33-70 A 4H   | ne sw 28-33N-70W<br>BHL: sw se 33-33N-70W | 09-29196        | 22-Stage: 10.7 MM#                             | 486,569             | 7,087           | 322             | 16-Aug-14         | 49                  | 185                 | 229        | 1,980       | 559.0       |
| 54    | Combs Ranch 28-33-70 A 6H   | ne sw 28-33N-70W<br>BHL: sw se 33-33N-70W | 09-29197        | 22-Stage: 10.2 MM#                             | 464,556             | 6,811           | 310             | 16-Aug-14         | 41                  | 186                 | 221        | 2,282       | 601.3       |
| 55    | Combs Ranch 29-33-70 1H     | sw se 29-33N-70W<br>BHL: ne sw 20-33N-70W | 09-28568        | 20-Stage: 4.7 MM#<br>Stage 8 FAILED            | 246,361             | 5,996           | 300             | 21-Jul-12         | 2                   | 170                 | 127        | 1,365       | 354.5       |
| 56    | Combs Ranch 29-33-70 A 2H   | sw se 29-33N-70W<br>BHL: se se 32-33N-70W | 09-28871        | 15-Stage: 4.8 MM#                              | 316,499             | 5,156           | 344             | 15-Jun-13         | 72                  | 158                 | 118        | 1,071       | 296.5       |
| 57    | Combs Ranch 29-33-70 A 4H   | sw se 29-33N-70W<br>BHL: se se 32-33N-70W | 09-28873        | 14-Stage: 4.5 MM#                              | 322,448             | 4,512           | 322             | 15-Jun-15         | 59                  | 157                 | 90         | 732         | 212.0       |
| 58    | Combs Ranch 29-33-70 A 6H   | sw se 29-33N-70W<br>BHL: sw sw 33-33N-70W | 09-28875        | 15-Stage: 4.6 MM#                              | 305,149             | 4,869           | 325             | 28-Jun-13         | 39                  | 159                 | 54         | 489         | 135.5       |
| 59    | Combs Ranch 29-33-70 C 1H   | ne se 29-33N-70W<br>BHL: ne sw 20-33N-70W | 09-28987        | 16-Stage: 5.1 MM#<br>REMEDIAL CEMENT FOX HILLS | 321,118             | 5,141           | 321             | 15-Dec-13         | 88                  | 167                 | 86         | 977         | 248.8       |
| 60    | Combs Ranch 29-33-70 C 2H   | ne se 29-33N-70W<br>BHL: sw sw 33-33N-70W | 09-28986        | 20-Stage: 6.5 MM#                              | 325,367             | 6,684           | 334             | 27-Dec-13         | 86                  | 164                 | 136        | 1,288       | 350.7       |
| 61    | Combs Ranch 29-33-70 C 3H   | ne se 29-33N-70W<br>BHL: nw se 20-33N-70W | 09-29060        | 14-Stage: 4.9 MM#                              | 349,274             | 5,062           | 362             | 15-Dec-13         | 105                 | 165                 | 134        | 1,167       | 328.5       |
| 62    | Combs Ranch 29-33-70 C 4H   | ne se 29-33N-70W<br>BHL: nw sw 33-33N-70W | 09-28985        | 23-Stage: 8.6 MM#<br>Stage 2 Ineffective       | 389,880             | 4,740           | 206             | 27-Dec-13         | 99                  | 177                 | 58         | 529         | 146.2       |
| 63    | York Ranch 35-33-70 A 1H    | nw ne 35-33N-70W<br>BHL: sw nw 23-33N-70W | 09-28643        | 20-Stage: 7.8 MM#                              | 388,406             | 8,211           | 411             | 14-Apr-13         | 21                  | 176                 | 229        | 1,688       | 510.3       |
| 64    | York Ranch 35-33-70 A 2H    | nw ne 35-33N-70W<br>BHL: se se 35-33N-70W | 09-28592        | 20-Stage: 4.6 MM#                              | 378,892             | 4,660           | 388             | 21-Apr-13         | 22                  | 170                 | 243        | 1,396       | 475.7       |
| 65    | York Ranch 35-33-70 A 3H    | nw ne 35-33N-70W<br>BHL: sw sw 23-33N-70W | 09-28923        | 15-Stage: 5.4 MM#                              | 360,550             | 5,651           | 377             | 26-Apr-13         | 20                  | 170                 | 144        | 1,156       | 336.7       |
| 66    | York Ranch 36-33-70 ST A 1H | se se 36-33N-70W<br>BHL: ne nw 36-33N-70W | 09-28917        | 12-Stage: 4.1 MM#                              | 340,850             | 4,027           | 336             | 09-Jul-13         | 95                  | 169                 | 137        | 696         | 253.0       |
| 67    | York Ranch 36-33-70 ST A 3H | se se 36-33N-70W<br>BHL: nw ne 36-33N-70W | 09-28644        | 13-Stage: 4.3 MM#                              | 334,132             | 4,592           | 353             | 09-Jul-13         | 105                 | 160                 | 143        | 1,096       | 325.7       |
| 68    | York Ranch 36-33-70 ST A 5H | se se 36-33N-70W<br>BHL: nw ne 36-33N-70W | 09-28916        | 12-Stage: 4.1 MM#                              | 340,815             | 4,138           | 345             | 10-Jul-13         | 111                 | 169                 | 214        | 1,335       | 436.5       |
| 69    | NW Fetter 7-1H              | sw ne 7-33N-71W<br>BHL: ne se 18-33N-71W  | 09-28526        | 19-Stage: 5.5 MM#                              | 288,186             | 5,626           | 296             | 11-Jun-12         | 1                   | 158                 | 132        | 541         | 222.2       |

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**Summary of Selected Niobrara Horizontal Wells in the PRB**

| Count | Well Name                      | Locations                                 | API No.<br>49 - | Stimulation                                                       | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>Xf (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|--------------------------------|-------------------------------------------|-----------------|-------------------------------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 70    | NW Fetter Lizard Head 1-8H     | nw nw 8-33N-71W<br>BHL: se sw 6-33N-71W   | 09-22885        | 16-Stage: 2.5 MM#<br>RE-ENTER FROM<br>FRONTIER TO NIOBRARA        | 156,396             | 4,119           | 257             | 04-Dec-11         | 3                   | 122                 | 122        | 382         | 185.7       |
| 71    | Combs Ranch 24-33-71 A 2H      | sw se 24-33N-71W<br>BHL: sw sw 13-33N-71W | 09-29114        | 19-Stage: 6.2 MM#<br>Stages 1 thru 4 ineffective                  | 325,894             | 4,855           | 256             | 28-Dec-14         | 35                  | 176                 | 125        | 1,035       | 297.5       |
| 72    | Combs Ranch 24-33-71 A 3H      | sw se 24-33N-71W<br>BHL: nw nw 24-33N-71W | 09-29070        | 17-Stage: 4.0 MM#<br>Stages 1, 16 & 17 FAILED                     | 286,427             | 3,489           | 205             | 28-Dec-14         | 46                  | 159                 | 131        | 1,061       | 307.8       |
| 73    | Sims 33-71 25-1H               | se sw 25-33N-71W<br>BHL: ne nw 25-33N-71W | 09-28299        | 12-Stage: 2.3 MM#                                                 | 189,455             | 2,752           | 229             | 03-May-11         | 2                   | 164                 | 203        | 1,977       | 532.5       |
| 74    | Sims 33-71 26-1H               | se sw 26-33N-71W<br>BHL: ne nw 26-33N-71W | 09-28323        | 14-Stage: 3.4 MM#                                                 | 254,412             | 3,472           | 248             | 16-Sep-11         | 1                   | 170                 | 274        | 2,254       | 649.7       |
| 75    | Sims 26-33-71 B 2H             | sw se 26-33N-71W<br>BHL: nw ne 26-33N-71W | 09-28839        | 14-Stage: 3.5 MM#<br>Stage 1 ineffective                          | 266,693             | 3,826           | 294             | 05-Dec-12         | 1                   | 166                 | 134        | 1,358       | 360.3       |
| 76    | Idarado 33-71 27-1H            | se se 27-33N-71W<br>BHL: ne ne 27-33N-71W | 09-28312        | 14-Stage: 4.1 MM#<br>SIDETRACK @ 8,050 ft                         | 293,760             | 3,357           | 240             | 18-Jul-11         | 2                   | 170                 | 178        | 895         | 327.2       |
| 77    | Idarado 27-33-71 A 2H          | se se 27-33N-71W<br>BHL: nw ne 27-33N-71W | 09-28851        | 13-Stage: 3.6 MM#                                                 | 275,722             | 4,081           | 314             | 22-Dec-12         | 14                  | 161                 | 143        | 755         | 268.8       |
| 78    | Sims 33-71 28-1H               | ne nw 28-33N-71W<br>BHL: se sw 28-33N-71W | 09-28412        | 15-Stage: 2.3 MM#                                                 | 155,774             | 3,586           | 239             | 28-Oct-11         | 4                   | 137                 | 116        | 382         | 179.7       |
| 79    | NW Fetter 33-72 1-2H           | nw ne 1-33N-72W<br>BHL: se sw 25-34N-72W  | 09-28447        | 20-Stage: 3.1 MM#                                                 | 153,820             | 5,759           | 288             | 27-Jan-12         | 2                   | 141                 | 175        | 318         | 228.0       |
| 80    | Wagonhound 33-72 14-1H         | ne ne 14-33N-72W<br>BHL: se se 14-33N-72W | 09-28272        | 12-Stage: 3.3 MM#<br>Stage 12 FAILED<br>SLIDING SLEEVES / PACKERS | 299,874             | 2,980           | 248             | 08-Jan-11         | 6                   | 315                 | 55         | 77          | 67.8        |
| 81    | Stroock Federal 33-72 23-1H    | nw nw 23-33N-72W<br>BHL: sw sw 23-33N-72W | 09-28527        | 12-Stage: 2.0 MM#                                                 | 169,045             | 3,321           | 277             | 31-Jan-12         | 1                   | 146                 | 35         | 45          | 42.5        |
| 82    | Wagonhound 33-72 24-1H         | nw ne 24-33N-72W<br>BHL: sw se 24-33N-72W | 09-28358        | 15-Stage: 2.4 MM#                                                 | 157,223             | 3,685           | 246             | 05-Oct-11         | 1                   | 138                 | 118        | 224         | 155.3       |
| 83    | Wagonhound 33-72 25-1H         | sw se 25-33N-72W<br>BHL: nw ne 25-33N-72W | 09-28290        | 15-Stage: 2.3 MM#                                                 | 152,511             | 3,726           | 248             | 10-Oct-11         | 1                   | 138                 | 63         | 122         | 83.3        |
| 84    | West Orpha 33-73 14-1H         | ne nw 14-33N-73W<br>BHL: sw sw 14-33N-73W | 09-28281        | 13-Stage: 4.2 MM#                                                 | 325,147             | 3,766           | 290             | 08-Mar-11         | 1                   | 169                 | 4          | 6           | 5.0         |
| 85    | Barton 32-34-67 USA A 1H       | ne nw 32-34N-67W<br>BHL: ne nw 20-34N-67W | 09-28623        | 47-Stage: 19.1 MM#                                                | 406,299             | 9,572           | 204             | 01-Oct-15         | 7                   | 176                 | 799        | 1,828       | 1,103.7     |
| 86    | Anadarko Trinity 3468-17-31N-H | se se 17-34N-68W<br>BHL: nw ne 17-34N-68W | 09-28808        | 13-Stage: 3.9 MM#                                                 | 296,742             | 3,847           | 296             | 04-Feb-13         | 1                   | 181                 | 200        | 622         | 303.7       |

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### Summary of Selected Niobrara Horizontal Wells in the PRB

| Count | Well Name                       | Locations                                 | API No.<br>49 - | Stimulation                                                                             | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod         | One-Wing<br>Xf (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|---------------------------------|-------------------------------------------|-----------------|-----------------------------------------------------------------------------------------|---------------------|-----------------|-----------------|-------------------|-----------------------------|---------------------|------------|-------------|-------------|
| 87    | Linden Federal 17-1H            | ne nw 17-34N-69W<br>BHL: ne nw 20-34N-69W | 09-28420        | 18-Stage: 5.1 MM#                                                                       | 280,767             | 5,326           | 296             | 18-Oct-12         | 2                           | 161                 | 229        | 659         | 338.8       |
| 88    | Linden 20-34-69 B 2H            | sw ne 20-34N-69W<br>BHL: sw se 29-34N-69W | 09-29177        | 17-Stage: 6.5 MM#                                                                       | 383,259             | 7,001           | 412             | 13-Oct-13         | 153                         | 170                 | 130        | 530         | 218.3       |
| 89    | Linden 20-34-69 B 4H            | sw ne 20-34N-69W<br>BHL: sw se 29-34N-69W | 09-28772        | 21-Stage: 6.3 MM#                                                                       | 298,526             | 6,241           | 297             | 12-Feb-13         | 3                           | 160                 | 88         | 472         | 166.7       |
|       |                                 |                                           |                 |                                                                                         |                     |                 |                 |                   | Intermittent                |                     |            |             |             |
| 90    | Linden 20-34-69 B 6H            | sw ne 20-34N-69W<br>BHL: se se 29-34N-69W | 09-29178        | 17-Stage: 6.5 MM#                                                                       | 380,517             | 6,962           | 410             | 13-Oct-13         | 163                         | 169                 | 102        | 411         | 170.5       |
| 91    | Robinson Ranch 4-34-70 1H       | sw se 4-34N-70W<br>BHL: nw ne 4-34N-70W   | 09-28433        | 12-Stage: 5.2 MM#                                                                       | 433,122             | 3,469           | 289             | 27-Sep-12         | 2                           | 181                 | 206        | 553         | 298.2       |
| 92    | Clausen Ranch 34-70 16-1H       | nw ne 16-34N-70W<br>BHL: sw se 16-34N-70W | 09-28291        | 14-Stage: 4.0 MM#                                                                       | 288,730             | 3,237           | 231             | 10-May-11         | 1                           | 170                 | 142        | 512         | 227.3       |
| 93    | Clausen Ranch 19-34-70 A 1H     | nw nw 19-34N-70W<br>BHL: se sw 19-34N-70W | 09-28587        | 13-Stage: 3.9 MM#                                                                       | 299,328             | 3,622           | 279             | 21-Aug-12         | 2                           | 172                 | 341        | 1,067       | 518.8       |
| 94    | Clausen Ranch 35-34-70 A 1H     | se se 26-34N-70W<br>BHL: ne nw 26-34N-70W | 09-28933        | 13-Stage: 4.0 MM#<br>Stage 3 Ineffective                                                | 358,477             | 4,283           | 357             | 25-Jul-13         | 359                         | 164                 | 110        | 405         | 177.5       |
|       |                                 | WELL NAME vs SECTION: ERROR ???           |                 |                                                                                         |                     |                 |                 |                   |                             |                     |            |             |             |
| 95    | Clausen Ranch 34-70 29-1H       | nw nw 29-34N-70W<br>BHL: nw ne 32-34N-70W | 09-28503        | 16-Stage: 2.9 MM#<br>SIDETRACK @ 8,943 ft                                               | 181,232             | 5,213           | 326             | 08-Mar-12         | 1                           | 145                 | 298        | 1,036       | 470.7       |
| 96    | Clausen Ranch 35-34-70 A 3H     | ne ne 35-34N-70W<br>BHL: nw ne 26-34N-70W | 09-28935        | 12-Stage: 4.3 MM#                                                                       | 353,759             | 4,407           | 367             | 18-Jul-13         | 374                         | 146                 | 93         | 490         | 174.7       |
| 97    | Clausen Ranch 35-34-70 A 5H     | ne ne 35-34N-70W<br>BHL: nw ne 26-34N-70W | 09-28934        | 12-Stage: 4.0 MM#                                                                       | 335,450             | 4,272           | 356             | 19-Jul-13         | 376                         | 164                 | 173        | 812         | 308.3       |
| 98    | Clausen Ranch 25-34-71 ST A 1H  | se sw 25-34N-71W<br>BHL: sw se 36-34N-71W | 09-28731        | 15-Stage: 5.2 MM#                                                                       | 343,508             | 5,194           | 346             | 01-Sep-12         | 2                           | 167                 | 72         | 327         | 126.5       |
|       |                                 |                                           |                 |                                                                                         |                     |                 |                 |                   | Intermittent<br>TSI 28 mos. |                     |            |             |             |
| 99    | Clausen Ranch 25-34-71 ST A 2H  | se sw 25-34N-71W<br>BHL: sw se 36-34N-71W | 09-28946        | 39-Stage: 7.5 MM#<br>7" Stuck @ 10,693 ft; Cement as is<br>WHIPSTOCK                    | 192,259             | 5,765           | 148             | 11-Nov-14         | 181                         | 154                 | 194        | 972         | 356.0       |
| 100   | Clausen Ranch 25-34-71 USA A 3H | ne sw 25-34N-71W<br>BHL: se ne 23-34N-71W | 09-28973        | 27-Stage: 7.7 MM#<br>Stage 1 FAILED<br>Stages 8, 14, 16, 26 & 27 Ineffective            | 297,436             | 7,369           | 273             | 21-Nov-14         | 171                         | 181                 | 145        | 656         | 254.3       |
| 101   | Clausen Ranch 25-34-71 USA A 4H | se sw 25-34N-71W<br>BHL: se ne 23-34N-71W | 09-28968        | 34-Stage: 10.6 MM#<br>Stages 8 & 11 Ineffective                                         | 327,508             | 7,324           | 215             | 10-Dec-14         | 140                         | 169                 | 220        | 722         | 340.3       |
| 102   | Clausen Ranch 25-34-71 USA A 5H | se sw 25-34N-71W<br>BHL: sw sw 24-34N-71W | 09-28967        | 16-Stage: 6.1 MM#                                                                       | 381,617             | 4,291           | 268             | 09-Dec-14         | 128                         | 177                 | 163        | 511         | 248.2       |
| 103   | Clausen Ranch 25-34-71 ST A 6H  | se sw 25-34N-71W<br>BHL: se se 36-34N-71W | 09-28944        | 22-Stage: 7.7 MM#<br>Stages 1 & 17 Ineffective<br>Stage Collar @ 7,216' failed: squeeze | 379,873             | 5,690           | 259             | 21-Dec-14         | 67                          | 179                 | 243        | 911         | 394.8       |

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### Summary of Selected Niobrara Horizontal Wells in the PRB

| Count | Well Name                   | Locations                                 | API No.<br>49 - | Stimulation                                                             | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>Xf (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|-----------------------------|-------------------------------------------|-----------------|-------------------------------------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 104   | NW Fetter 34-71 28-1H       | nw nw 28-34N-71W<br>BHL: se sw 28-34N-71W | 09-28305        | 18-Stage: 2.0 MM#                                                       | 113,376             | 3,267           | 182             | 19-Oct-11         | 2                   | 130                 | 145        | 343         | 202.2       |
| 105   | Sundquist Flats 34-72 12-1H | se sw 12-34N-72W<br>BHL: se se 2-34N-72W  | 09-28346        | 18-Stage: 4.2 MM#<br>Stage 1 Re-Frac Twice<br>HORIZONTAL OPEN-HOLE LOGS | 234,077             | 5,438           | 302             | 23-Jun-11         | 1                   | 162                 | 176        | 223         | 213.2       |
| 106   | Sundquist Flats 34-72 16-1H | se se 16-34N-72W<br>BHL: ne nw 16-34N-72W | 09-28347        | 16-Stage: 2.7 MM#                                                       | 169,538             | 4,829           | 302             | 23-Oct-11         | 2                   | 128                 | 152        | 247         | 193.2       |
| 107   | Sundquist Flats 34-72 19-1H | nw se 19-34N-72W<br>BHL: nw sw 18-34N-72W | 09-28474        | 15-Stage: 4.1 MM#                                                       | 276,319             | 4,498           | 300             | 19-Jun-12         | 1                   | 164                 | 106        | 111         | 124.5       |
| 108   | Gilbert Ditch 34-73 4-2H    | nw ne 4-34N-73W<br>BHL: sw nw 10-34N-73W  | 09-28283        | 20-Stage: 6.3 MM#                                                       | 315,715             | 6,043           | 302             | 23-May-11         | 1                   | 154                 | 236        | 187         | 267.2       |
| 109   | Gilbert Ditch 34-73 14-1H   | nw nw 14-34N-73W<br>BHL: sw ne 23-34N-73W | 09-28354        | 20-Stage: 3.7 MM#                                                       | 185,785             | 6,409           | 320             | 06-Nov-11         | 10                  | 155                 | 115        | 67          | 126.2       |
| 110   | S. Hylton Ranch 34-74 24-1H | nw ne 24-34N-74W<br>BHL: nw ne 25-34N-74W | 09-28403        | 16-Stage: 5.0 MM#<br>HORIZONTAL OPEN-HOLE LOGS                          | 313,085             | 4,042           | 253             | 28-Jul-11         | 3                   | 172                 | 47         | 31          | 52.2        |
| 111   | Graham 23-35-71 A 1H        | se sw 23-35N-71W<br>BHL: ne nw 23-35N-71W | 09-28674        | 11-Stage: 1.6 MM#                                                       | 147,475             | 3,828           | 348             | 24-Jul-12         | 1                   | 137                 | 130        | 149         | 154.8       |
| 112   | Box Creek 24-35-71 1H       | se se 24-35N-71W<br>BHL: nw ne 24-35N-71W | 09-28555        | 13-Stage: 3.3 MM#<br>Stage 1 Ineffective                                | 252,144             | 3,775           | 290             | 04-Jul-12         | 2                   | 163                 | 184        | 201         | 217.5       |
| 113   | Graham 26-35-71 A 1H        | nw ne 26-35N-71W<br>BHL: sw se 26-35N-71W | 09-28683        | 11-Stage: 3.8 MM#                                                       | 347,825             | 3,913           | 356             | 13-Jul-12         | 3                   | 158                 | 277        | 268         | 321.7       |
| 114   | Box Creek 29-35-71 1H       | ne nw 29-35N-71W<br>BHL: se sw 32-35N-71W | 09-28464        | 16-Stage: 3.4 MM#                                                       | 210,305             | 3,612           | 226             | 29-Jun-12         | 3                   | 171                 | 166        | 187         | 197.2       |
| 115   | Box Creek 30-35-71 A 1H     | ne nw 30-35N-71W<br>BHL: se sw 30-35N-71W | 09-28471        | 16-Stage: 2.5 MM#                                                       | 157,759             | 3,409           | 213             | 12-Dec-11         | 5                   | 136                 | 206        | 238         | 245.7       |
| 116   | State 36-35-71 ST A 1H      | ne ne 36-35N-71W<br>BHL: se se 36-35N-71W | 09-28570        | 12-Stage: 1.8 MM#                                                       | 148,357             | 3,530           | 294             | 05-Aug-12         | 2                   | 144                 | 139        | 185         | 169.8       |
| 117   | Spillman Draw 35-73 10-1H   | se se 10-35N-73W<br>BHL: ne nw 10-35N-73W | 09-28411        | 19-Stage: 5.5 MM#<br>HORIZONTAL OPEN-HOLE LOGS                          | 287,221             | 4,914           | 259             | 28-Aug-11         | 3                   | 165                 | 199        | 191         | 230.8       |
| 118   | Spillman Draw 35-73 15-1H   | ne sw 15-35N-73W<br>BHL: se se 9-35N-73W  | 09-28248        | 14-Stage: 3.6 MM#<br>Stage 8 Re-Frac                                    | 259,869             | 4,152           | 296             | 31-Mar-11         | 4                   | 170                 | 123        | 106         | 140.7       |
| 119   | Spillman Draw State 16-1H   | se sw 16-35N-73W<br>BHL: nw nw 16-35N-73W | 09-28224        | 15-Stage: 3.5 MM#                                                       | 231,620             | 4,380           | 292             | 29-Jan-10         | 1                   | 149                 | 273        | 231         | 311.5       |
| 120   | Spillman Draw 35-73 17-1H   | sw ne 17-35N-73W<br>BHL: se ne 20-35N-73W | 09-28257        | 16-Stage: 3.8 MM#<br>Density Tool Lost @ TD<br>RED CEMENT @ CASING SHOE | 235,309             | 4,027           | 252             | 04-Oct-11         | 1                   | 162                 | 99         | 84          | 113.0       |

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Summary of Selected Niobrara Horizontal Wells in the PRE

| Count | Well Name                 | Locations                                 | API No.<br>49 - | Stimulation                                                                                      | Stage<br>Prop (lbs) | Total<br>L (ft) | Stage<br>L (ft) | Last Frac<br>Date | Days to<br>1st Prod | One-Wing<br>XT (ft) | EUR<br>MBO | EUR<br>MMcf | EUR<br>MBOE |
|-------|---------------------------|-------------------------------------------|-----------------|--------------------------------------------------------------------------------------------------|---------------------|-----------------|-----------------|-------------------|---------------------|---------------------|------------|-------------|-------------|
| 121   | Spillman Draw 36-73 36-1H | sw nw 36-36N-73W<br>BHL: sw ne 1-35N-73W  | 09-28409        | 20-Stage: 3.8 MM#<br>HORIZONTAL OPEN-HOLE LOGS                                                   | 187,461             | 6,239           | 254             | 15-Nov-11         | 3                   | 130                 | 143        | 154         | 168.7       |
| 122   | Crow Unit 27-37-69 1H     | ne sw 27-37N-69W<br>BHL: nw se 34-37N-69W | 09-28571        | 12-Stage: 6.0 MM#<br>Niobrara Core Plug Analyses                                                 | 501,117             | 4,475           | 373             | 20-Nov-12         | 10                  | 156                 | 267        | 234         | 306.0       |
| 123   | Hornbuckle 1-11H          | ne ne 11-37N-74W<br>BHL: se se 11-37N-74W | 09-28280        | 12-Stage: 1.3 MM#<br>UNCEMENTED LINER - Stage 1 Ineffective<br>Niobrara & Frontier Core Analyses | 116,212             | 4,166           | 347             | 03-May-11         | 11                  | 188                 | 104        | 160         | 130.7       |
| 124   | Discovery 1-35NH          | sw se 35-40N-76W<br>BHL: nw nw 35-40N-76W | 09-28416        | Insufficient Detail in WUGCC File<br>UNCEMENTED LINER<br>Niobrara Core Plug Analyses             |                     |                 |                 |                   |                     |                     | 65         | 161         | 91.8        |
| 125   | Crossbow 3-19H            | se sw 19-41N-71W<br>BHL: nw nw 19-41N-71W | 05-59607        | 16-Stage: 2.3 MM#<br>Stage 14 SCREENOUT                                                          | 141,450             | 3,287           | 205             | 09-Aug-08         | 1<br>Stage 16 Only  | 127                 | 81         | 302         | 131.3       |
| 126   | Ballista 202-1003H        | se se 10-41N-73W<br>BHL: ne ne 3-41N-73W  | 05-61806        | 52-Stage: 16.5 MM#<br>Stage 30 FAILED<br>Produce 2 months after Stages 1 thru 29                 | 322,875             | 8,852           | 170             | 10-Jun-14         |                     | 173                 | 469        | 1,263       | 679.5       |
| 127   | Ponderosa 215-1NH         | nw nw 2-41N-75W<br>BHL: se sw 2-41N-75W   | 05-61354        | 18-Stage: 3.1 MM#<br>Halliburton Model: 210' high x 787' long                                    | 170,970             | 3,823           | 212             |                   |                     | 136                 | 52         | 132         | 74.0        |
| 128   | Iberlin Ranch 3626-1NH    | sw sw 36-42N-76W<br>BHL: nw nw 36-42N-76W | 05-61661        | 17-Stage: 3.4 MM#<br>Halliburton Model: 60' high x 518' long                                     | 200,892             | 3,585           | 211             | 10-Jan-13         | 1                   | 168                 | 83         | 138         | 106.0       |
|       |                           |                                           | Average:        |                                                                                                  | 308,354             | 5,022           | 299             |                   |                     | 165                 | 167        | 946         | 324.5       |

W  
S

Wold Energy Partners

Docket 411 - 2017

Exhibit E - 7

# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Spillman 16-1H Niobrara 16-35N-73W.mdb

Date: 3/24/2017

Time: 10:25 AM

Lease Name: SPILLMAN DRAW DEEP UNIT STATE (16-1H)

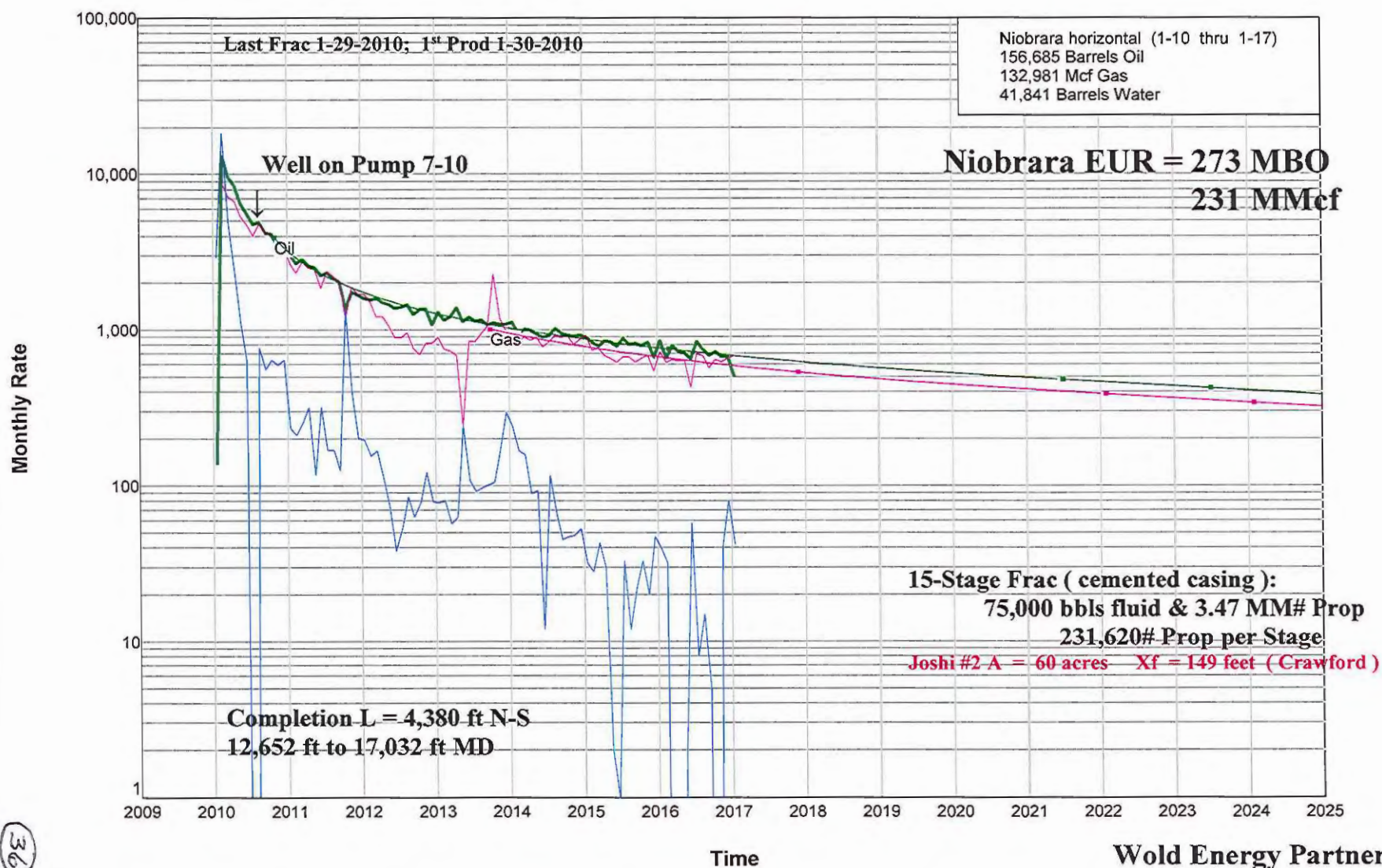
County, ST: CONVERSE, WY

Location: N35 W73 16 SE SW

Operator: RKI EXPLORATION & PRODUCTION LLC

Field Name: UNNAMED

## Spillman Draw Unit State 16-1H Niobrara (se sw 16-35N-73W) API 49-009-28224



**Wold Energy Partners  
Docket 333 - 2017  
Exhibit E - 2**



# Rate/Cum Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Spillman 16-1H Niobrara 16-35N-73W.mdb

Date: 3/24/2017

Time: 10:28 AM

Lease Name: SPILLMAN DRAW DEEP UNIT STATE (16-1H)

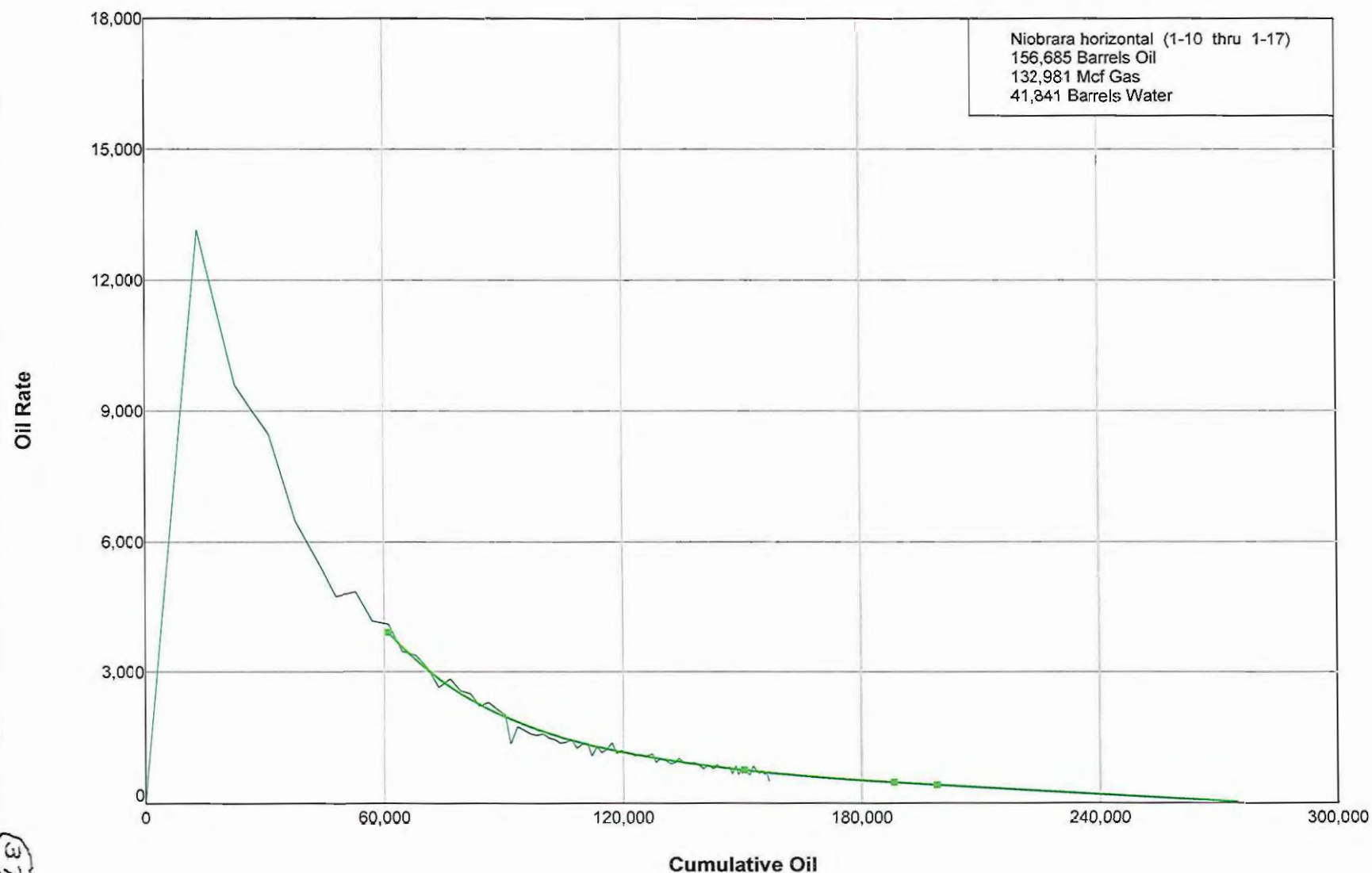
County, ST: CONVERSE, WY

Location: N35 W73 16 SE SW

Operator: RKI EXPLORATION & PRODUCTION LLC

Field Name: UNNAMED

## Spillman Draw Unit State 16-1H Niobrara (se sw 16-35N-73W) API 49-009-28224



# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Wagonhound 14-1H Niobrara 14-33N-72W.mdb Date: 3/21/2017

Time: 9:41 AM

Lease Name: WAGONHOUND (33-72-14-)

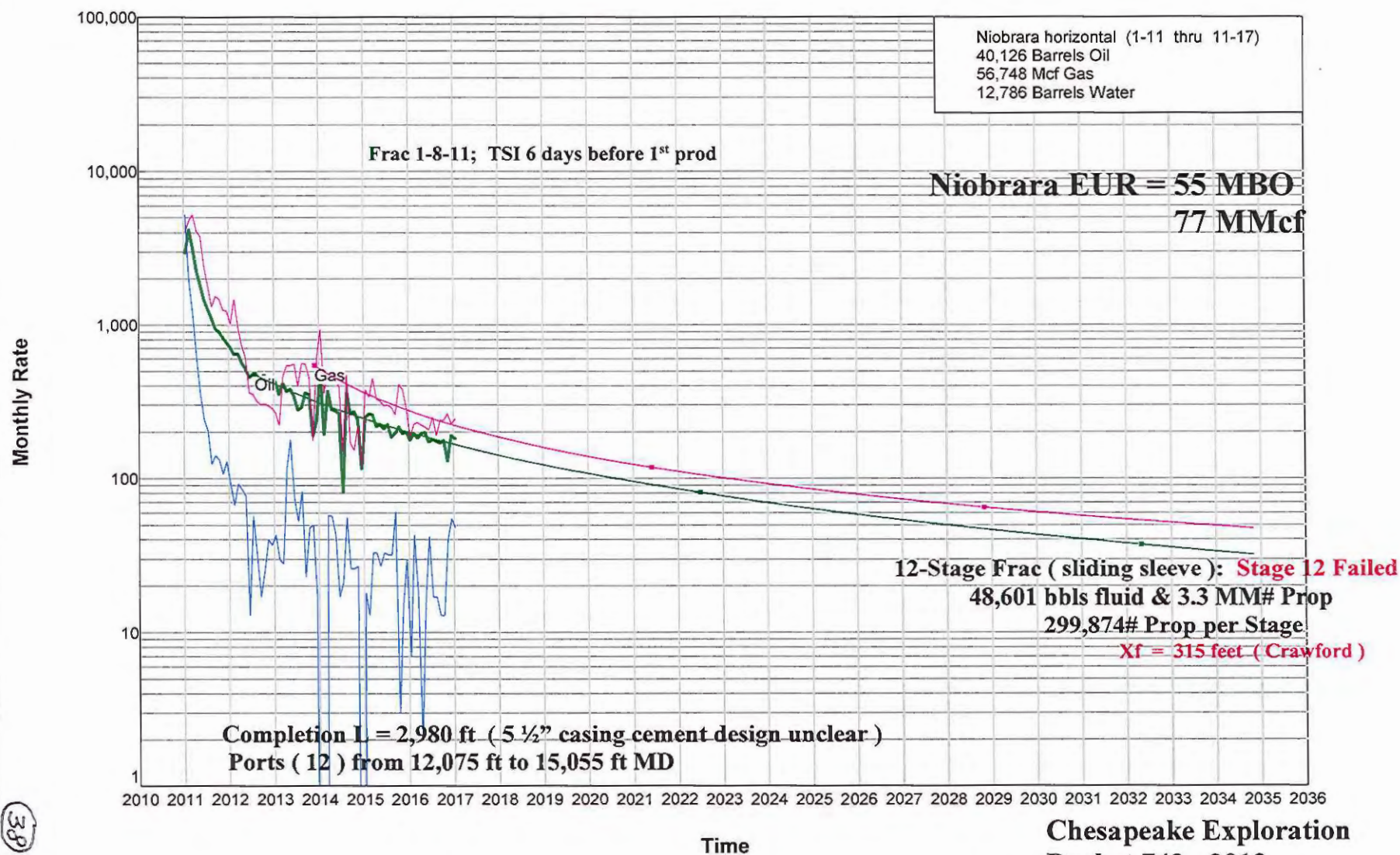
County, ST: CONVERSE, WY

Location: N33 W72 14 NE NE

Operator: CHESAPEAKE OPERATING LLC

Field Name: ORPHA

## Orpha Field: Wagonhound 33-72 14-1H Niobrara (ne ne 14-33N-72W) API 49-009-28272



38

Chesapeake Exploration  
Docket 743 - 2012  
Exhibit E - 7



# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Barton 32-34-67 A 1H Niobrara.mdb

Date: 3/21/2017

Time: 11:55 AM

Lease Name: BARTON UNIT (32-34-67)

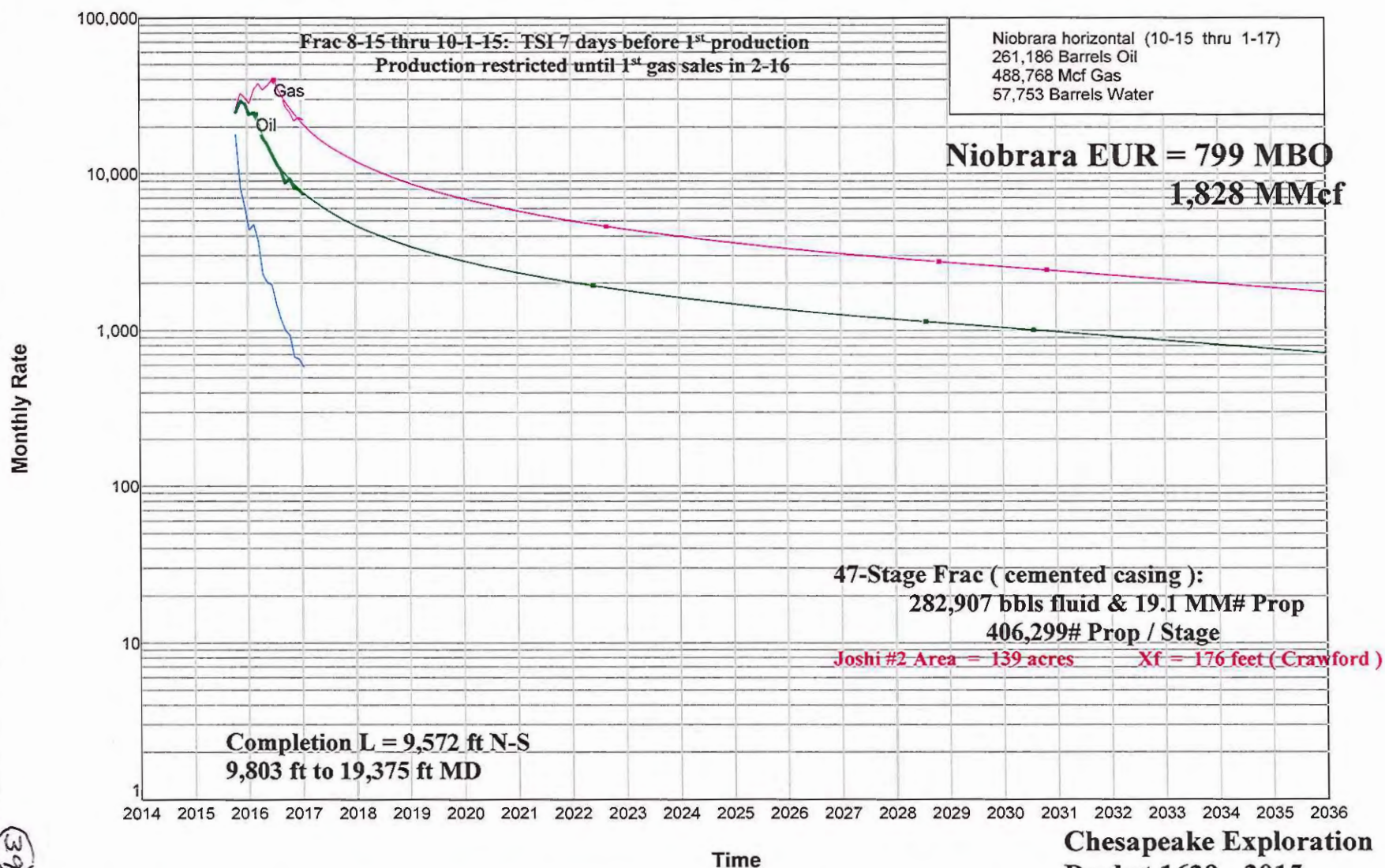
County, ST: CONVERSE, WY

Location: N34 W67 32 NW

Operator: CHESAPEAKE OPERATING LLC

Field Name: UNNAMED

## Barton Unit 32-34-67 USA A 1H Niobrara (ne nw 32-34N-67W) API 49-009-28623



(39)

**Chesapeake Exploration**  
**Docket 1629 - 2015**  
**Exhibit E - 7**

# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Ballista 202-1003H Niobrara 10-41N-73W.mdb

Date: 3/27/2017

Time: 12:59 PM

Lease Name: BALLISTA (202-1003H)

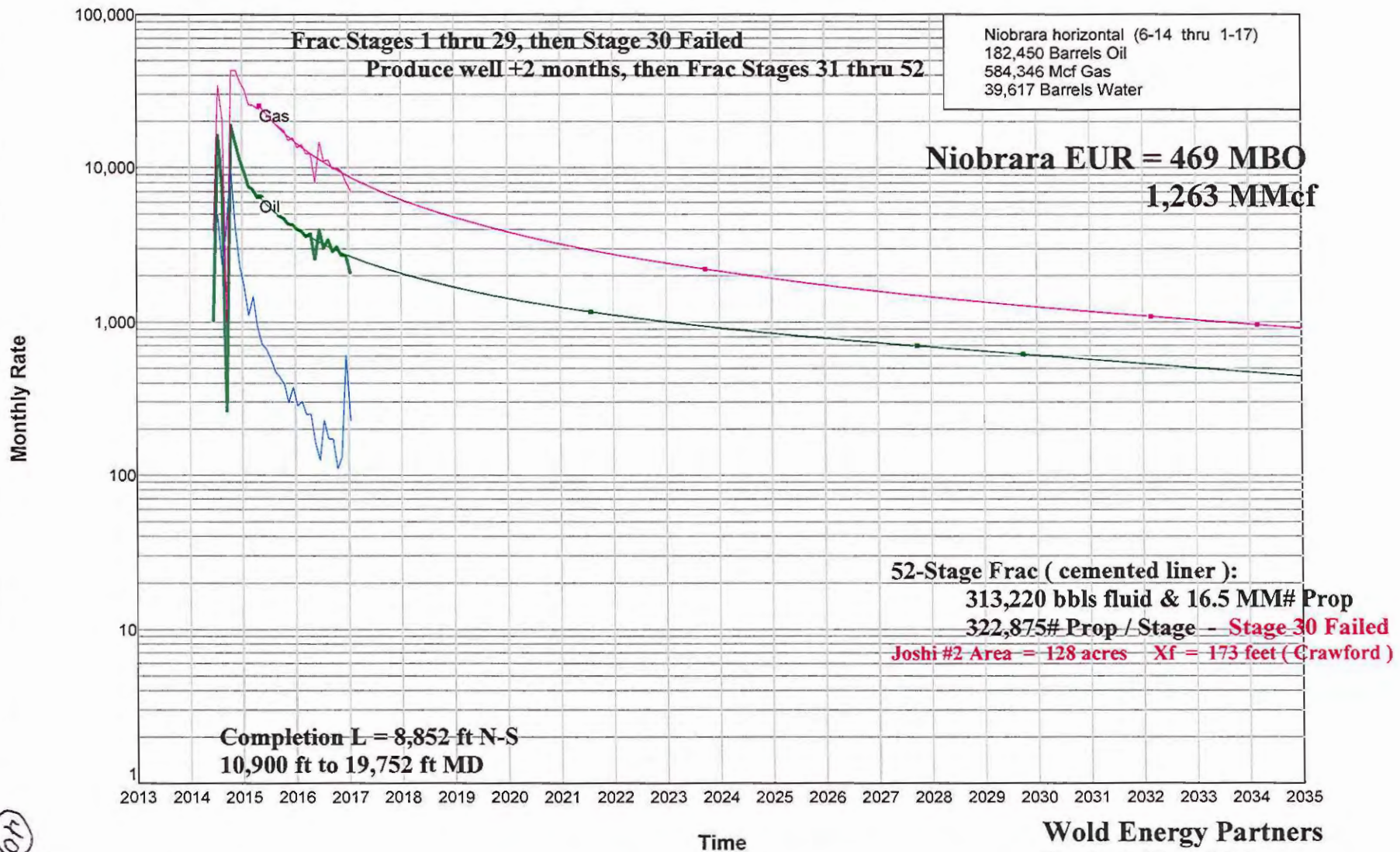
County, ST: CAMPBELL, WY

Location: N41 W73 10 SE

Operator: EOG RESOURCES INCORPORATED

Field Name: CROSSBOW

## Crossbow Field: EOG Ballista 202-1003H Niobrara (se se 10-41N-73W) API 49-005-61806



**Wold Energy Partners**  
**Docket 41 - 2017**  
**Exhibit E - 7**



# Rate/Time Graph

Project: C:\Users\User\Documents\IHS\PowerTools\Projects v9.3\Clausen 35-34-70 A 3H Niobrara.mdb

Date: 4/10/2017

Time: 9:02 AM

Lease Name: CLAUSEN RANCH 35-34 (70A-3H)

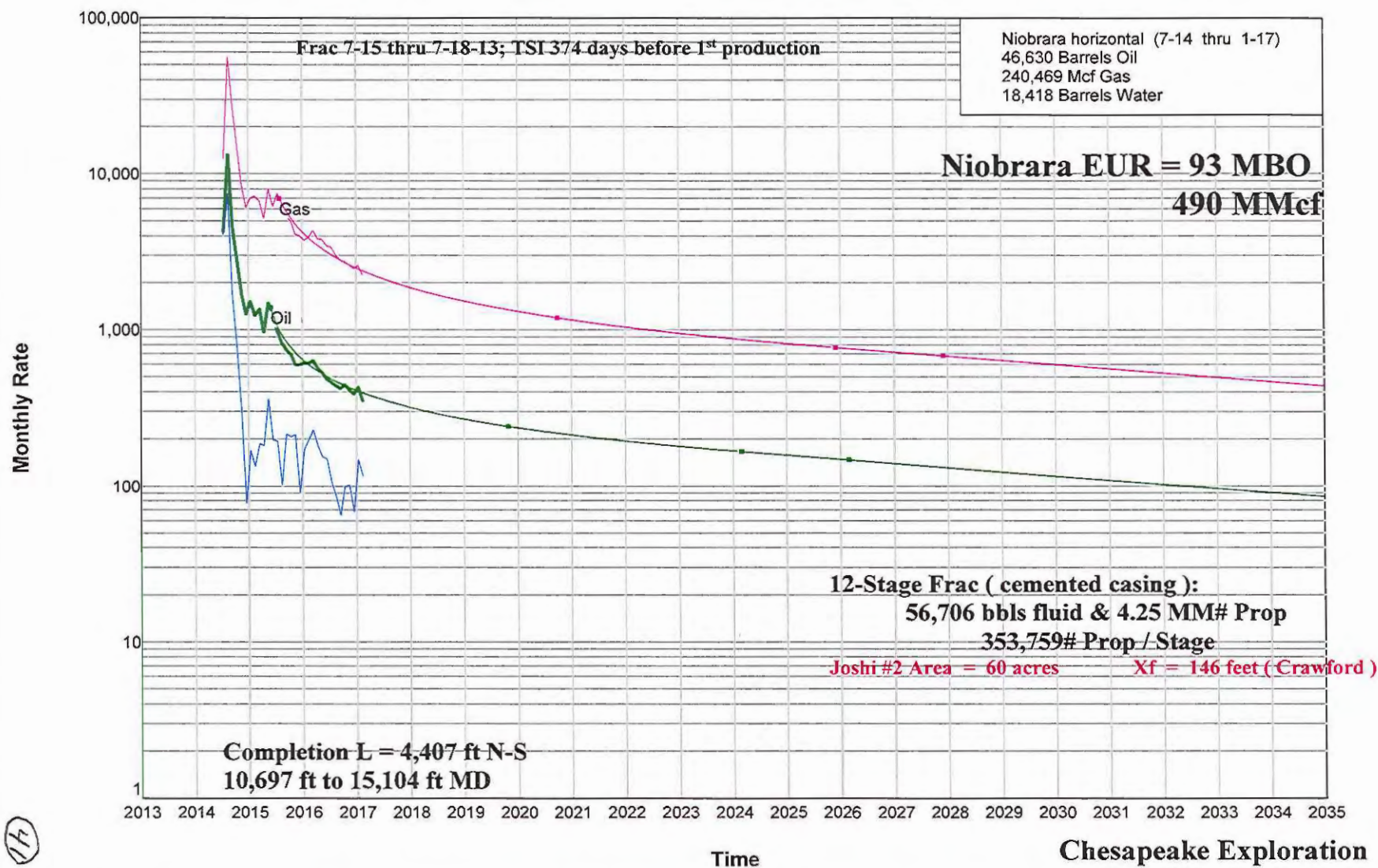
County, ST: CONVERSE, WY

Location: N34 W70 35 NE

Operator: CHESAPEAKE OPERATING LLC

Field Name: UNNAMED

## Clausen Ranch Unit 35-34-70 A 3H Niobrara (ne ne 35-34N-70W) API 49-009-28935



Chesapeake Exploration  
Docket 127 - 2017  
Exhibit E - 7

## CREATED FRACTURE AREA EQUATIONS

CRAWFORD

$$A = V / (W + 3C\sqrt{T}), \text{ SQ.FT.} \quad \dots (1)$$

$$2V^{.5} = 3AC/q^{.5} + [3AC/q^{.5} + 4AW]^{.5}, \text{ FT.}^{1.5} \quad \dots (2)$$

$$E = W / (W_{eff} + 3C\sqrt{T}) \quad \dots (3)$$

HOWARD, FAST, & CARTER

$$A = \frac{qW}{4\pi C^2} \left[ e^{x^2} \operatorname{erfc}(x) + \frac{2x}{\sqrt{\pi}} - 1 \right], \text{ SQ.FT.} \quad \dots (4)$$

WHERE

$$x = (3.545 C / W) \sqrt{T}, \text{ DIMENSIONLESS} \quad \dots (4b)$$

AND

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-t^2} dt, \text{ DIMENSIONLESS} \quad \dots (4c)$$

IF

$$v(t) = C / \sqrt{t}, \text{ FT/MIN} \quad \dots (5)$$

$$C_v = 0.00149 \sqrt{k \frac{\Delta p}{\mu}} \quad \text{FT}/\sqrt{\text{MIN}} \quad \dots (4)$$

$$C_c = 0.00118 \Delta p \sqrt{k \frac{C_v}{\mu}} \quad \text{FT}/\sqrt{\text{MIN}} \quad \dots (7)$$

$$C_w = 0.0164 \text{ m/s (EXPERIMENTALLY DETERMINED), FT}/\sqrt{\text{MIN}} \quad \dots (8)$$

$$m = \text{SLOPE OF STRAIGHT LINE PART OF LEAK OFF VS. } \sqrt{\text{TIME}}, \text{ cc}/\sqrt{\text{MIN}} \quad \dots (8b)$$

$$C = 1/(1/C_w + 1/C_c) \text{ OR } 1/(1/C_v + 1/C_c), \text{ FT}/\sqrt{\text{MIN}} \quad \dots (9)$$

$$W_{eff} = W + W_{sp}, \text{ FT} \quad \dots (10)$$

$$W_{sp} = 2 V_{sp} / 30.48 \text{ in} = V_{sp} / 15.24 \text{ in} = 0.055 V_{sp} / \text{in}, \text{ FT} \quad \dots (10b)$$

$$V_{sp} = \text{SPURT LOSS DURING LEAK OFF TEST, cc} \quad \dots (10c)$$

## TREATMENT HYDRAULICS EQUATIONS

$$P_s = \text{BHPT} - P_h + \Delta P_f + \Delta P_{pf} \quad \text{, PSI} \quad \dots (1)$$

$$\text{BHPT} = \text{ISIP} + P_h \quad \text{, PSI} \quad \dots (2)$$

$$P_h = 0.433 q (\text{DEPTH, FT}) \quad \text{, PSI} \quad \dots (3)$$

$$\Delta P_{pf} = \frac{3.1 q Q^2}{d_{pf}^4 N^2} \quad \text{, PSI} \quad \dots (4)$$

$$\text{HHP} = \frac{P_s Q}{40.8} \quad \text{, HP} \quad \dots (5)$$

TURBULENT NEWTONIAN PIPE FLOW

$$\frac{\Delta P_f}{L} = 0.484 \frac{Q^{1.84}}{d^{4.84}} \frac{\mu^{.16}}{e^{.84}} \quad \text{, PSI/FT} \quad \dots (6)$$

TURBULENT NEWTONIAN CONCENTRIC ANNULUS

$$\frac{\Delta P_f}{L} = \left[ \frac{0.484}{(d_2 - d_1)^3} \right] \left[ \frac{Q}{d_2 + d_1} \right]^{1.84} \frac{\mu^{.16}}{e^{.84}} \quad \text{, PSI/FT} \quad \dots (7)$$

TURBULENT GUAR SOLUTIONS

$$\frac{\Delta P_f}{L} = \left[ \frac{1 + .01 C}{v \cdot 2C^{.33}} \right] \times \left[ \frac{\Delta P_f}{L} \text{ (FROM EQ 6 OR 7)} \right] \quad \text{, PSI/FT} \quad \dots (8)$$

WHERE:

$$v = 17.16 Q / d^2 \text{ INSIDE PIPE, FT/SEC}$$

$$v = 17.16 Q / (d_2^2 - d_1^2) \text{ IN ANNULUS, FT/SEC}$$

TURBULENT COMBINED TUBING & ANNULUS FLOW.

$$\frac{Q_A}{Q_p} = \left[ \frac{d_2 + d_1}{d} \right] \left[ \frac{d_2 - d_1}{d} \right]^{1.83} \quad \dots (9)$$

$$d_e = d \left[ 1 + \frac{Q_A}{Q_p} \right]^{0.38} \quad \dots (10)$$

ROUGHNESS CORRECTION FACTOR

$$R_F = [ (E/D + 0.0001) / 0.0005 ]^{0.24} \quad \dots (11)$$

## TREATMENT HYDRAULICS NOMENCLATURE

$P_s$  = SURFACE TREATING PRESSURE, PSI  
 $\text{BHPT}$  = BOTTOM HOLE TREATING PRESSURE, PSI  
 $\text{ISIP}$  = INSTANTANEOUS SHUT-IN SURFACE PRESSURE, PSI  
 $P_h$  = HYDROSTATIC HEAD, PSI  
 $\Delta P_f$  = FRICTION LOSS IN PIPE, PSI  
 $\Delta P_{pf}$  = PRESSURE DROP ACROSS PERFORATIONS, PSI  
 $\text{HHP}$  = HYDRAULIC HORSEPOWER  
 $Q$  = FLOW RATE, BARRELS/MINUTE  
 $Q_A$  = FLOW RATE IN ANNULUS, BPM  
 $Q_p$  = FLOW RATE IN TUBING, BPM  
 $d_p$  = DIAMETER OF PERFORATIONS, INCHES  
 $d$  = INTERNAL DIAMETER OF PIPE, INCHES  
 $d_2$  = I.D. OF CASING, INCHES  
 $d_1$  = O.D. OF TUBING, INCHES  
 $d_e$  = EQUIVALENT DIAMETER FOR COMBINED TUBING & ANNULUS FLOW, INCHES  
 $L$  = LENGTH OF PIPE, FEET  
 $Q$  = DENSITY OF FLUID (SLURRY) PUMPED, GRAMS/ML.  
 $\mu$  = VISCOSITY OF FLUID, CENTIPOISE  
 $C$  = CONCENTRATION OF GUAR GUM, LB/1000 GAL.  
 $v$  = VELOCITY OF FLOW, FEET/SECOND  
 $R_F$  = ROUGHNESS CORRECTION FACTOR, DIMENSIONLESS  
 $\epsilon$  = ABSOLUTE ROUGHNESS, INCHES

## CREATED AREA NOMENCLATURE

$A$  = AREA OF FRACTURE CREATED DURING INJECTION, SQ. FT.  
 $a$  = AREA OF CORE USED IN LEAK-OFF TEST, SQ. CM.  
 $C$  = LEAK OFF OR FLUID LOSS COEFFICIENT, USUALLY THE COMBINED EFFECT OF  $C_v$ ,  $C_c$ , AND/OR  $C_w$ , FT / MIN.<sup>5</sup>  
 $C_v$  = LEAK OFF COEFFICIENT FOR FRAC FLUID VISCOSITY, FT/MIN.<sup>5</sup>  
 $C_c$  = LEAK OFF COEFFICIENT FOR COMPRESSIBILITY AND VISCOSITY OF FORMATION FLUID, FT/MIN.<sup>5</sup>  
 $C_w$  = LEAK OFF COEFFICIENT FOR WALL BUILDING EFFECT OF FLUID LOSS ADDITIVES, FT/MIN.<sup>5</sup>  
 $C_f$  = COMPRESSIBILITY, PSI<sup>-1</sup> : APPROXIMATELY  
 $= 3 \times 10^{-6}$  FOR WATER  
 $= 1 \times 10^{-5}$  FOR CRUDE OIL  
 $= 2/(\text{BHPT} + P_i)$  FOR GAS  
 $E$  = FRAC EFFICIENCY = VOLUME OF FRACTURE /  $V$ , FRACTION  
 $e$  = 2.71828...  
 $\operatorname{erfc}(x)$  = ERROR FUNCTION COMPLEMENT OF  $x$ , DIMENSIONLESS  
 $k$  = PERMEABILITY OF THE RESERVOIR, MD  
 $q$  = INJECTION RATE OF FRAC SLURRY, CU FT/MIN  
 $t$  = LENGTH OF TIME THAT A GIVEN PART OF THE FRACTURE FACE HAS BEEN EXPOSED TO THE FRAC FLUID, MINUTES  
 $T$  = TOTAL TIME OF INJECTION =  $V/q$ , MIN  
 $v(t)$  = VELOCITY OF LEAKOFF, AS A FUNCTION OF TIME,  $t$ , FOR THAT PARTICULAR PART OF THE FRACTURE FACE, FT/MIN.  
 $V$  = TOTAL VOLUME OF FRAC SLURRY PUMPED, CU.FT.  
 $W$  = AVERAGE WIDTH OF FRACTURE, FEET  
 $W_{eff}$  =  $W + W_{sp}$ , FEET  
 $W_{sp}$  = WIDTH OF SPURT LOSS, FEET  
 $x$  =  $x^{.5}$  TIMES RATIO OF ONE-SIDED LEAK OFF DISTANCE TO (FRAC WIDTH), DIMENSIONLESS  
 $\Delta P$  =  $(P_i - P_r)$ , PRESSURE DIFFERENCE FROM FRACTURE TO RESERVOIR, PSI  
 $P_i$  = PRESSURE IN THE FRACTURE, PSI  
 $P_r$  = PRESSURE IN THE RESERVOIR, PSI  
 $\phi$  = POROSITY, FRACTION  
 $\mu_t$  = VISCOSITY OF TREATING (FRAC) FLUID, CP  
 $\mu_r$  = VISCOSITY OF RESERVOIR FLUID, CP

## BOTTOM HOLE TREATING PRESSURE FROM ROCK PROPERTIES (& VICE VERSA)

AN EQUATION RELATING BOTTOM HOLE TREATING PRESSURE AND ROCK PROPERTIES IS:

$$\text{BHPT} = (s_v - P_r) \frac{v}{1-v} + P_r \quad \dots (1)$$

WHERE:

$\text{BHPT}$  = BOTTOM HOLE TREATING PRESSURE, PSI

$s_v$  = TOTAL VERTICAL STRESS (LOAD), WEIGHT OF OVERBURDEN, PSI

$P_r$  = RESERVOIR (PORE) PRESSURE, PSI

$s_v - P_r$  = VERTICAL STRESS (LOAD) SUPPORTED BY ROCK MATRIX, PSI

$v$  = POISSON'S RATIO, DIMENSIONLESS

$\frac{v}{1-v}$  = FACTOR TO CHANGE VERTICAL ROCK STRESS TO HORIZONTAL ROCK STRESS, DIMENSIONLESS

$(s_v - P_r) \frac{v}{1-v}$  = HORIZONTAL ROCK (STATIC CLOSURE) STRESS, PSI

$(s_v - P_r) \frac{v}{1-v} + P_r$  = TOTAL HORIZONTAL STRESS, = BHPT, PSI

IF:

DEPTH: 10000

OVERBURDEN WEIGHT: 10200 LB/IN<sup>2</sup>

1.02 PSI/FT

RESERVOIR PRESSURE,  $P_r$  = 4200 PSI

POISSON'S RATIO  $v$  = .25 & .33

|                                                       | $P_r$ | 4200 PSI | 1200 PSI |
|-------------------------------------------------------|-------|----------|----------|
| FIND:                                                 | $v$   | .25      | .33      |
| TOTAL VERTICAL LOAD, PSI                              |       | 10200    | 10200    |
| VERTICAL ROCK STRESS, PSI                             |       | 6000     | 6000     |
| HORIZONTAL ROCK STRESS, PSI OR STATIC CLOSURE STRESS  |       | 2000     | 3000     |
| TOTAL HORIZONTAL STRESS, PSI OR FRAC PRESSURE OR BHPT |       | 6200     | 7200     |
| FRAC GRADIENT, (PSI/FT)                               |       | .62      | .72      |

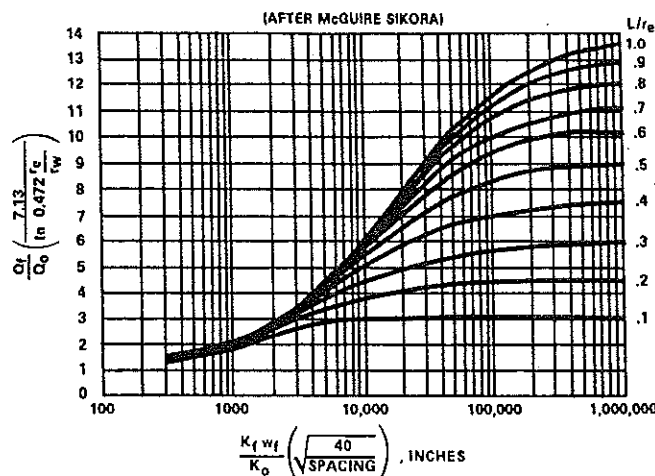
## ROCK PROPERTIES (APPROXIMATE)

| DESCRIPTION | MODULUS, 10 <sup>6</sup> PSI |       | POISSON'S RATIO |
|-------------|------------------------------|-------|-----------------|
|             | YOUNG'S                      | SHEAR |                 |
| LIQUID      | 0                            | 0     | 0.50            |
| VERY SOFT   | 1                            | 0.38  | 0.40            |
| SOFT        | 2                            | 0.76  | 0.34            |
| MEDIUM HARD | 5                            | 2.00  | 0.26            |
| HARD        | 10                           | 4.30  | 0.17            |
| VERY HARD   | 13                           | 5.65  | 0.15            |

SHEAR MODULUS = YOUNG'S MODULUS  $\div (2 + 2v)$



# THE EFFECT OF VERTICAL FRACTURES ON PRODUCTIVITY



## PERMEABILITY AND POROSITY OF GRADED SANDS (1)

| MESH                          | 8-12    | 10-20   | 10-20 | 10-30 | 20-40 | 40-60              |
|-------------------------------|---------|---------|-------|-------|-------|--------------------|
|                               | ANGULAR | ANGULAR | ROUND | ROUND | ROUND | ROUND              |
| PERMEABILITY, DARCYS (APPROX) | 1745    | 981     | 325   | 191   | 121   | 45 (UNDER NO LOAD) |
| POROSITY, PERCENT (APPROX)    | 35      | 36      | 32    | 33    | 35    | 32 (UNDER NO LOAD) |

(1) VAN POOLLEH, TINSLEY, SAUNDERS, SPEC. AIME, TP 890-G, DALLAS, OCT. 1957

## FRACTURE WIDTH EQUATIONS

### VERTICAL FRACTURES

PERKINS AND KERN:

$$W_o = 0.38 \left[ \frac{Q_o L}{E} \right]^{0.25} = 0.38 \left[ \frac{Q_o L}{E} \frac{(H)}{(H)} \right]^{0.25} \dots (1)$$

$$W(x) = W_o \left[ 1 - (Lx/L)^2 \right]^{0.25} \dots (2)$$

$$W_{avg} = 0.667 W_o \dots (3)$$

GEERTSMA AND deKLERK:

$$W_o = 0.23 \left[ \frac{Q_o L^2}{GH} \right]^{0.25} = 0.29 \left[ \frac{Q_o L}{E} \frac{(L)}{(H)} \right]^{0.25} \dots (4)$$

$$W(x) = W_o \left[ 1 - (Lx/L)^2 \right]^{0.5} \dots (5)$$

$$W_{avg} = 0.785 W_o \dots (6)$$

### HORIZONTAL FRACTURES (P&K)

$$W_o = 0.22 \left[ \frac{Q_o L}{E} \right]^{0.25} \dots (7)$$

$$W(x) = W_o \left[ 1 - x/R \right]^{0.5} \dots (8)$$

$$W_{avg} = 0.667 W_o \dots (9)$$

WHERE:

$W_o$  = FRACTURE WIDTH AT WELLBORE, INCHES

$Q$  = INJECTION RATE, BARRELS PER MINUTE

$\mu$  = VISCOSITY OF FLUID IN FRACTURE, CENTIPOISE

$\mu_{avg} = 47880 K_f [40.4 Q / W^2 H]^{0.1}$ , CENTIPOISE

$L$  = LENGTH OF ONE FRACTURE WING, FEET

$H$  = HEIGHT OF FRACTURE, FEET

$E$  = YOUNG'S MODULUS, PSI

$G$  = SHEAR MODULUS =  $\frac{E}{2 + 2\nu}$ , PSI

$\nu$  = POISSON'S RATIO, (ASSUMED TO BE 0.25 FOR 2ND HALF OF EQN 4.)

$Lx$  = DISTANCE FROM WELLBORE ALONG A FRACTURE OF HALF LENGTH, L, FEET

$W(x)$  = WIDTH OF FRACTURE AT DISTANCE  $Lx$  FROM WELLBORE, INCHES

$R$  = RADIUS OF FRACTURE, FEET

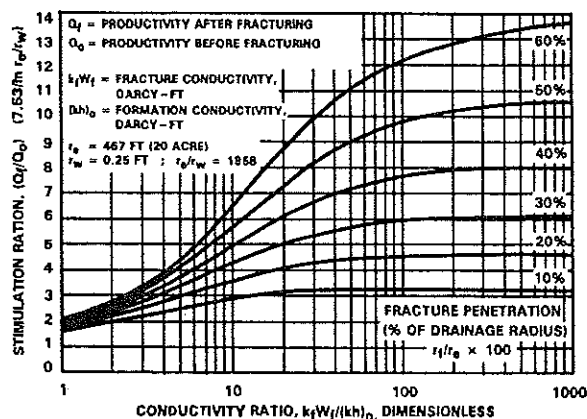
$r$  = RADIAL DISTANCE TO A POINT IN A FRACTURE OF RADIUS  $R$ , FEET

## SIEVE OPENINGS

| U.S. MESH    | SIEVE OPENING |         |
|--------------|---------------|---------|
|              | INCHES        | MICRONS |
| 4            | 0.1875        | 4760    |
| 6            | 0.1323        | 3350    |
| 8            | 0.0937        | 2350    |
| 10           | 0.0787        | 2000    |
| 12           | 0.0661        | 1680    |
| 16           | 0.0469        | 1190    |
| 18           | 0.0394        | 1000    |
| 20           | 0.0331        | 841     |
| 25           | 0.0278        | 707     |
| 30           | 0.0232        | 595     |
| 35           | 0.0197        | 500     |
| 40           | 0.0165        | 420     |
| 50           | 0.0117        | 297     |
| 60           | 0.0098        | 250     |
| 70           | 0.0083        | 210     |
| 100          | 0.0059        | 149     |
| 200          | 0.0029        | 74      |
| 325          | 0.0017        | 44      |
| 400          | 0.0016        | 37      |
| SILICA FLOUR | 0.00008       | 2       |
|              | TO            | TO      |
|              | 0.0017        | 44      |

## PRODUCTIVITY INCREASE FOR HORIZONTAL FRACTURES

(AFTER HOWARD & FAST)



# Formation Properties

| Formation              | Depth<br>(ft) | Location              | Young's<br>Modulus (E)<br>(x 10 <sup>6</sup> ) | Poisson's<br>Ratio | Perm<br>(Air)<br>md | Porosity (φ)<br>% |
|------------------------|---------------|-----------------------|------------------------------------------------|--------------------|---------------------|-------------------|
| Arbuckle Lime          | 3688-92       | Kay Co., Okla.        | 3.99                                           | 0.350              | 0.03                | 4.8               |
| Austin Chalk           | 2319-2582     | Caldwell Co., Tex.    | 2.38                                           | 0.276              | 0.03                | 17.6              |
| Aux Vases              | 2010-19       | Lawrence Co., Ill.    | 6.03                                           | 0.274              | <0.01               | 5.5               |
| Bartlesville           | 1300          | Washington Co., Okla. | —                                              | —                  | 0.08                | 11.1              |
| Bartlesville           | 7900          | Cleveland Co., Okla.  | 6.80                                           | 0.124              | 1304.00             | 16.6              |
| Bartlesville           | 8301          | Canadian Co., Okla.   | 4.80                                           | 0.144              | 7.70                | 11.8              |
| Bartlesville           | —             | Greenwood Co., Kan.   | 2.27                                           | 0.147              | 0.67                | 14.5              |
| Basal Atoka            | 5995-6055     | Wise Co., Tex.        | 13.50                                          | 0.200              | —                   | —                 |
| Basal Quartz           | 4427-4506     | Calgary, Canada       | 2.08                                           | 0.147              | 0.86                | 13.4              |
| Benoist                | 1961-85       | Marion Co., Ill.      | 3.89                                           | 0.176              | 12.90               | 13.1              |
| Benson Sand            | 4373-74       | Lewis Co., W. Va.     | 3.82                                           | 0.240              | —                   | —                 |
| Bethel                 | 2155-2204     | Muhlenberg Co., Ky.   | 5.13                                           | 0.169              | 137.00              | 13.4              |
| Big Injun (Injun)      | 2297-2514     | Roane, W. Va.         | 3.34                                           | 0.107              | <0.01               | 6.3               |
| Bois D'Arc             | 7826-66       | Tulsa Co., Okla.      | 6.08                                           | 0.336              | 0.08                | 2.1               |
| Bromide                | —             | Garvin Co., Okla.     | 6.18                                           | 0.074              | 0.10                | 2.0               |
| Bromide                | 15,000        | Grady Co., Okla.      | 8.10                                           | 0.127              | 10.60               | 6.8               |
| Brown Dolomite         | 2649-2767     | Beckham Co., Okla.    | 7.50                                           | 0.308              | 0.01                | 4.8               |
| Buda Lime              | 5969-6084     | Frio Co., Tex.        | 3.75                                           | 0.245              | <0.01               | 2.1               |
| Buick Sand             | 3598-99.6     | Canada                | 3.46                                           | 0.233              | —                   | —                 |
| Burbank                | 2920-30       | Osage Co., Okla.      | 2.96                                           | 0.107              | 0.06                | 13.1              |
| Caddo Conglomerate     | 4132-70       | Parker Co., Tex.      | 2.98                                           | 0.192              | 0.18                | 11.1              |
| Canyon                 | 6725          | Crockett Co., Tex.    | 4.83                                           | 0.125              | <0.01               | 7.1               |
| Canyon                 | 6461-27       | Irion Co., Tex.       | 5.79                                           | 0.131              | 1.00                | 10.6              |
| Cherokee Sand          | 4942-58       | Woods Co., Okla.      | 6.45                                           | 0.230              | —                   | —                 |
| Clearfork              | 5541-5761     | Ector Co., Tex.       | 5.81                                           | 0.340              | <0.01               | 11.8              |
| Clearfork Dolomite     | 6400          | Lea Co., N. Mex.      | 9.25                                           | 0.238              | <0.01               | 2.8               |
| Clearfork (Upper)      | 6718          | Yoakum Co., Tex.      | 8.85                                           | 0.226              | <0.01               | 3.0               |
| Clearfork (Lower)      | 3074-75.2     | Howard Co., Tex.      | 5.85                                           | 0.240              | <0.01               | 7.1               |
| Cleveland              | 5603-19       | Garfield Co., Okla.   | 2.45                                           | 0.047              | 0.11                | 10.2              |
| Clinton Sand           | 3234-3310     | Ashtabula Co., Ohio   | 4.12                                           | 0.086              | —                   | —                 |
| Clinton Sand           | 5395          | Stark Co., Ohio       | 9.10                                           | 0.067              | —                   | —                 |
| Cochran                | 8533          | Eddy Co., N. Mex.     | 4.28                                           | 0.094              | <0.01               | 3.4               |
| Cotton Valley (Sexton) | 8993          | Claiborne Par., La.   | 2.61                                           | 0.016              | 0.28                | 8.7               |
| Cromwell               | 3096-3135     | Coal Co., Okla.       | 0.76                                           | 0.144              | 0.14                | 12.4              |
| Cypress                | 2472-84       | White Co., Ill.       | 4.12                                           | 0.145              | 14.70               | 14.5              |
| Dakota                 | 6076-6119     | San Juan Co., N. Mex. | 2.66                                           | 0.163              | 0.24                | 7.5               |

(Continued)



# Formation Properties (Continued)

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| Formation         | Depth (ft) | Location                | Young's Modulus (E) (x 10 <sup>6</sup> ) | Poisson's Ratio | Perm (Air) md | Porosity (φ) % |
|-------------------|------------|-------------------------|------------------------------------------|-----------------|---------------|----------------|
| Dakota            | 7893-94    | Rio Arriba Co., N. Mex. | 8.35                                     | 0.095           | <0.01         | 1.3            |
| Dean Sand         | 8717       | Dawson Co., Tex.        | 3.32                                     | 0.077           | 0.46          | 11.1           |
| Desert Creek      | 5885-88    | San Juan Co., Utah      | 7.98                                     | 0.155           | <0.01         | 6.1            |
| Devonian          | 12,100     | Ector Co., Tex.         | 5.18                                     | 0.185           | 0.03          | 3.5            |
| Devonian          | 11,009     | Glasscock Co., Tex.     | 6.20                                     | 0.088           | <0.01         | 5.1            |
| Devonian          | 5200       | Pecos Co., Tex.         | 3.91                                     | 0.133           | —             | —              |
| Ellenburger       | 13,014-20  | Upton Co., Tex.         | 8.97                                     | 0.314           | <0.01         | 0.7            |
| Fredericksburg    | 2304-37    | Caddo Par., La.         | 6.67                                     | 0.393           | —             | —              |
| Fredericksburg    | 3044-55    | De Soto Par., La.       | 2.53                                     | 0.092           | 0.02          | 8.7            |
| Frio              | 9039-42    | Aransas Co., Tex.       | 0.95                                     | 0.150           | 1880.00       | 27.1           |
| Gallup            | 5531-5627  | San Juan Co., N. Mex.   | 2.37                                     | 0.157           | —             | —              |
| Glorietta         | 5647-78    | Yoakum Co., Tex.        | 7.41                                     | 0.238           | 0.41          | 4.9            |
| Grayburg          | 4332       | Andrews Co., Tex.       | 3.13                                     | 0.114           | 1.30          | 12.4           |
| Grayburg          | 3922       | Crane Co., Tex.         | 5.36                                     | 0.226           | 1.10          | 9.6            |
| Grayburg          | 2870-71    | Crockett Co., Tex.      | 4.79                                     | 0.342           | 2.40          | 16.9           |
| Grayburg          | 4262       | Lea Co., N. Mex.        | 5.32                                     | 0.130           | 0.05          | 6.4            |
| Grayburg          | 2170       | Upton Co., Tex.         | 2.82                                     | 0.137           | 0.06          | 10.4           |
| Halfway Sand      | 5398-5400  | Canada                  | 2.30                                     | 0.082           | —             | —              |
| Hardinsburg       | 2040       | Webster Co., Ky.        | 2.54                                     | 0.088           | 42.00         | 14.8           |
| Hosston           | 10,263-291 | Yazoo Co., Miss.        | 4.05                                     | 0.281           | 74.40         | 13.8           |
| Hoxbar            | 6217       | Stephens Co., Okla.     | 4.90                                     | 0.042           | 0.03          | 1.4            |
| Hunton            | 5100       | Noble Co., Okla.        | 4.86                                     | 0.157           | 45.80         | 15.2           |
| Hunton            | 2700       | Pontotoc Co., Okla.     | 4.70                                     | 0.160           | 0.06          | 3.5            |
| Jennings          | 3244-46    | Coleman Co., Tex.       | 4.00                                     | 0.153           | 39.80         | 14.5           |
| Manning           | 6817-87    | Garfield Co., Okla.     | 7.00                                     | 0.277           | 0.02          | 3.5            |
| Maramec           | 7929-32    | Kingfisher Co., Okla.   | 6.10                                     | 0.186           | 0.02          | 1.4            |
| Marble Falls      | 3221       | Erath Co., Tex.         | 3.52                                     | 0.125           | —             | —              |
| McClosky Dolomite | 2971-3008  | White Co., Ill.         | 4.19                                     | 0.330           | <0.01         | 8.3            |
| McClosky Lime     | 3298-3307  | Edwards Co., Ill.       | 7.17                                     | 0.370           | 35.00         | 9.7            |
| Mesa Verde        | 2330-80    | Sublette Co., Wyo.      | 1.43                                     | 0.146           | 3.00          | 18.7           |
| Mississippi Chat  | 5014       | Kiowa Co., Kan.         | 4.40                                     | 0.186           | —             | —              |
| Mississippian     | 8859-61    | Calgary, Canada         | 7.97                                     | 0.288           | <0.01         | 4.3            |
| Mississippian     | 4471-84    | Lincoln Co., Okla.      | 3.40                                     | 0.184           | <0.01         | 2.8            |
| Mississippian     | 4287-97    | Noble Co., Okla.        | 4.98                                     | 0.264           | 0.13          | 6.2            |
| Mississippian     | 8982-83    | San Juan Co., N. Mex.   | 7.85                                     | 0.110           | 0.45          | 5.5            |
| Mississippian     | 8985-9022  | San Juan Co., N. Mex.   | 6.97                                     | 0.145           | 0.02          | 4.1            |

(Continued)

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# Formation Properties (Continued)

| Formation       | Depth<br>(ft) | Location              | Young's<br>Modulus (E)<br>(x 10 <sup>6</sup> ) | Poisson's<br>Ratio | Perm<br>(Air)<br>md | Porosity (φ)<br>% |
|-----------------|---------------|-----------------------|------------------------------------------------|--------------------|---------------------|-------------------|
| Mississippian   | 9245-319      | San Miguel Co., Colo. | 5.65                                           | 0.220              | 0.03                | 8.3               |
| Morringsport    | 4589          | Sabine Par., La.      | 3.45                                           | 0.282              | 0.24                | 11.1              |
| Morrow          | 9105-28       | Blaine Co., Okla.     | 4.99                                           | 0.120              | 0.28                | 12.0              |
| Morrow (Upper)  | 8924-27       | Lipscomb Co., Tex.    | 6.75                                           | 0.126              | <0.01               | 6.3               |
| Morrow Lime     | 15,011-101    | Lea Co., N. Mex.      | 6.50                                           | 0.190              | —                   | —                 |
| Mt. Simon Sand  | 2952-89       | Cass Co., Ind.        | 5.36                                           | 0.190              | 79.80               | 13.8              |
| Muddy           | 6907-31       | Campbell Co., Wyo.    | 1.96                                           | 0.143              | 10.70               | 18.3              |
| Nacatoch        | 1510          | De Soto Par., La.     | 5.96                                           | 0.110              | 0.02                | 15.7              |
| Nacatoch        | 4596-4647     | Jack Co., Tex.        | 1.15                                           | 0.330              | 2.60                | 24.9              |
| Navarro Sand    | 3474          | Milam Co., Tex.       | 1.60                                           | 0.200              | —                   | —                 |
| Navarro Sand    | 3733-3853     | Webb Co., Tex.        | 7.57                                           | 0.230              | <0.01               | 1.4               |
| Newburg         | 5370-5430     | Mercer Co., Penn.     | 2.53                                           | 0.261              | —                   | —                 |
| Oriskany        | 5039          | Potter Co., Penn.     | 7.42                                           | 0.204              | —                   | —                 |
| Oriskany        | 6000          | Potter Co., Penn.     | 4.50                                           | 0.262              | 0.03                | 3.5               |
| Osborne         | 9221-54       | McClain Co., Okla.    | 4.35                                           | 0.084              | 0.32                | 10.4              |
| Oswego Lime     | 4296-4318     | Garfield Co., Okla.   | 4.35                                           | 0.260              | 0.11                | 6.2               |
| Page Sand       | 6145-53       | Harrison Co., Tex.    | 3.03                                           | 0.119              | 19.00               | 15.7              |
| Penrose         | 875           | Chaves Co., N. Mex.   | 2.29                                           | 0.150              | <0.01               | 3.0               |
| Penrose Queen   | 3569          | Lea Co., N. Mex.      | 3.01                                           | 0.089              | 0.02                | 6.8               |
| Phosphoria      | 8744-54       | Wyo.                  | 2.66                                           | 0.185              | 0.39                | 13.4              |
| Queen           | 1633-50       | Howard Co., Tex.      | 1.38                                           | 0.123              | 0.13                | 16.3              |
| Queen           | 3812-13       | Lea Co., N. Mex.      | 2.18                                           | 0.116              | —                   | —                 |
| Red Oak         | 6474-6641     | Latimer Co., Okla.    | 2.04                                           | 0.115              | 0.81                | 13.1              |
| Redfork         | 1915-22       | Tulsa Co., Okla.      | 2.89                                           | 0.106              | 0.41                | 13.1              |
| Rodessa         | 9425-55       | Jones Co., Miss.      | 1.37                                           | 0.137              | 185.10              | 19.7              |
| San Andres      | 3348-60       | Chaves Co., N. Mex.   | 4.44                                           | 0.207              | 0.10                | 6.9               |
| San Andres      | 1933-69       | Crockett Co., Tex.    | 2.30                                           | 0.220              | —                   | —                 |
| San Andres      | 2189-99       | Howard Co., Tex.      | 4.87                                           | 0.228              | 0.87                | 12.8              |
| San Andres      | 3012-16       | Ward Co., Tex.        | 6.40                                           | 0.260              | 0.03                | 6.3               |
| San Andres      | 5228-68       | Yoakum Co., Tex.      | 6.19                                           | 0.375              | —                   | —                 |
| San Andres Lime | 4533-47       | Lea Co., N. Mex.      | 7.86                                           | 0.283              | 0.16                | 8.3               |
| San Cristobal   | 6679          | Folche Fld., Peru     | 6.70                                           | 0.340              | —                   | —                 |
| San Miguel      | 1698-1748     | Maverick Co., Tex.    | 4.67                                           | 0.242              | 0.02                | 4.2               |
| San Miguel      | 2743-44       | Zavala Co., Tex.      | 2.35                                           | 0.156              | —                   | —                 |
| San Miguel      | 2748-49       | Zavala Co., Tex.      | 1.44                                           | 0.262              | 0.03                | 4.2               |
| Second Frontier | 7315-55       | Sublette Co., Wyo.    | 1.52                                           | 0.110              | 0.10                | 12.4              |

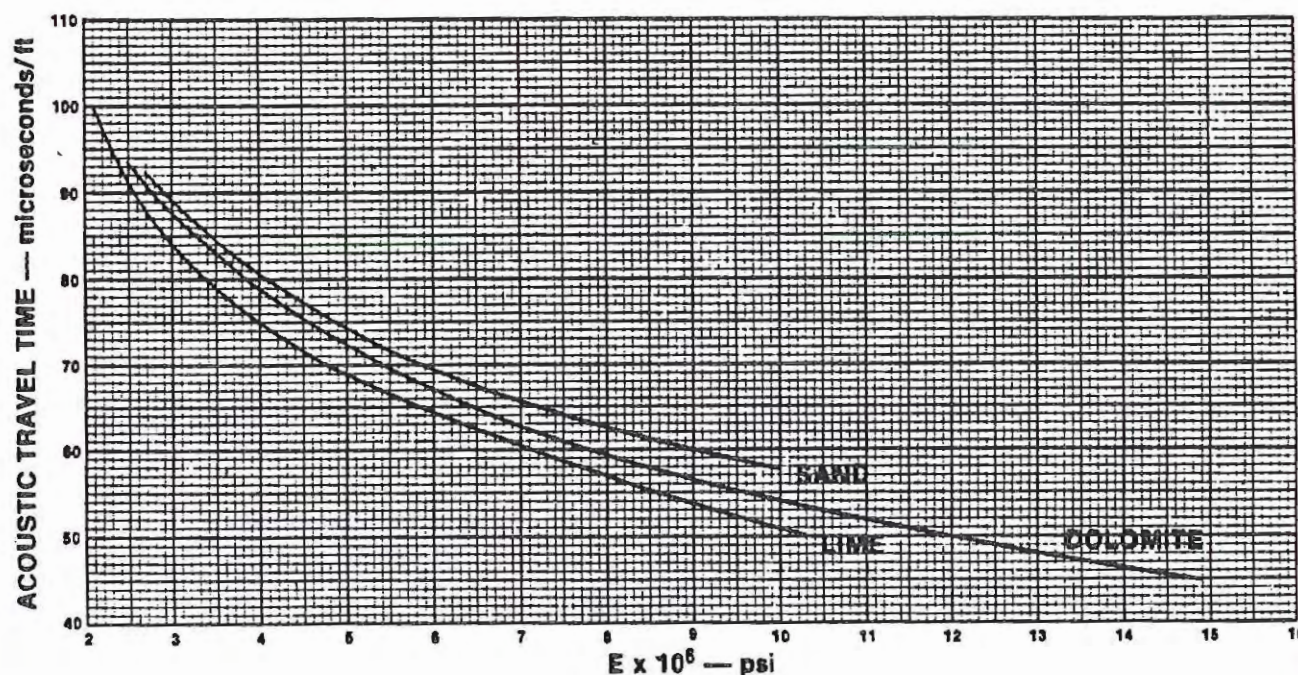
(Continued)



# Formation Properties (Continued)

| Formation         | Depth (ft) | Location                | Young's Modulus (E) ( $\times 10^6$ ) | Poisson's Ratio | Perm (Air) md | Porosity ( $\phi$ ) % |
|-------------------|------------|-------------------------|---------------------------------------|-----------------|---------------|-----------------------|
| Serpentine        | 1458       | Bastrop Co., Tex.       | 0.76                                  | 0.164           | 0.06          | 25.6                  |
| Shaunavan (Upper) | 4573-91    | Swn. Saskatchewan, Can. | 2.83                                  | 0.180           | 1.40          | 14.8                  |
| Sims              | —          | Carter Co., Okla.       | 3.05                                  | 0.250           | 2.20          | 9.7                   |
| Skinner           | 3200       | Pawnee Co., Okla.       | 2.65                                  | 0.141           | 0.69          | 12.4                  |
| Smackover         | 9505-55    | Navarro Co., Tex.       | 5.38                                  | 0.310           | 4.90          | 20.1                  |
| Smackover         | 11,650     | Quitman Co., Miss.      | 1.96                                  | 0.320           | 8.60          | 14.1                  |
| Smackover         | 13,274-94  | Rains Co., Tex.         | 10.77                                 | 0.271           | 0.11          | 6.2                   |
| Spiro             | 11,868-78  | Latimer Co., Okla.      | 6.23                                  | 0.204           | 0.16          | 6.2                   |
| Spraberry         | —          | Midland Co., Tex.       | 1.85                                  | 0.048           | 0.16          | 9.1                   |
| Springer          | 12,320-38  | Caddo Co., Okla.        | 1.80                                  | 0.234           | 106.70        | 24.2                  |
| St. Louis         | 350        | Clark Co., Ill.         | 4.20                                  | 0.170           | —             | —                     |
| Strawn            | 5138-5752  | Nolan Co., Tex.         | 5.56                                  | 0.240           | <0.01         | 0.7                   |
| Strawn            | 2700       | Wichita Co., Tex.       | 4.98                                  | 0.178           | 2.60          | 13.1                  |
| Strawn Sand       | 6476       | Kent Co., Tex.          | 0.73                                  | 0.330           | 8.00          | 13.6                  |
| Tar Springs       | 1786-1813  | Webster Co., Ky.        | 3.96                                  | 0.184           | 0.40          | 9.0                   |
| Tensleep          | 8782-86    | Wyoming                 | 5.88                                  | 0.268           | 2.40          | 9.0                   |
| Tonkawa           | 6655-8731  | Roger Mills Co., Okla.  | —                                     | —               | <0.01         | 2.9                   |
| Travis Peak       | 6401-25    | Panola Co., Tex.        | 4.08                                  | 0.100           | 0.45          | 11.8                  |
| Vogtsburger       | 4584       | Archer Co., Tex.        | 4.47                                  | 0.135           | 0.89          | 11.1                  |
| Waltersburg       | 2310-20    | White Co., Ill.         | 3.46                                  | 0.229           | 11.80         | 18.0                  |
| Wilcox            | 8771-8801  | Bee Co., Tex.           | 4.90                                  | 0.181           | 0.11          | 9.0                   |

## YOUNG'S MODULUS (E) vs ACOUSTIC TRAVEL TIME





*Wyoming Designated Driver*

**STAY CALM & FRAC ON !!!**