Wellbore Stability in Olmos Formation

307 OPERATING (GROUP B)

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Introduction

Wellbore Instability - occurs when wellbore does not maintain the same diameter and shape of the drill bit, and when it does not maintain its structural integrity

Objectives

1. Obtain a stable wellbore to ensure high production levels
2. Reduce or eliminate potential costs due to wellbore instability
3. Provide a safe working environment and abide by governing laws & regulations

Reference: Rueda, Alexander. "Geomechanical Wellbore Stability Modeling." *SciELO Colombia- Scientific Electronic Library Online*. 1 Jan. 2007. Web. 3 Nov. 2014. *Online*

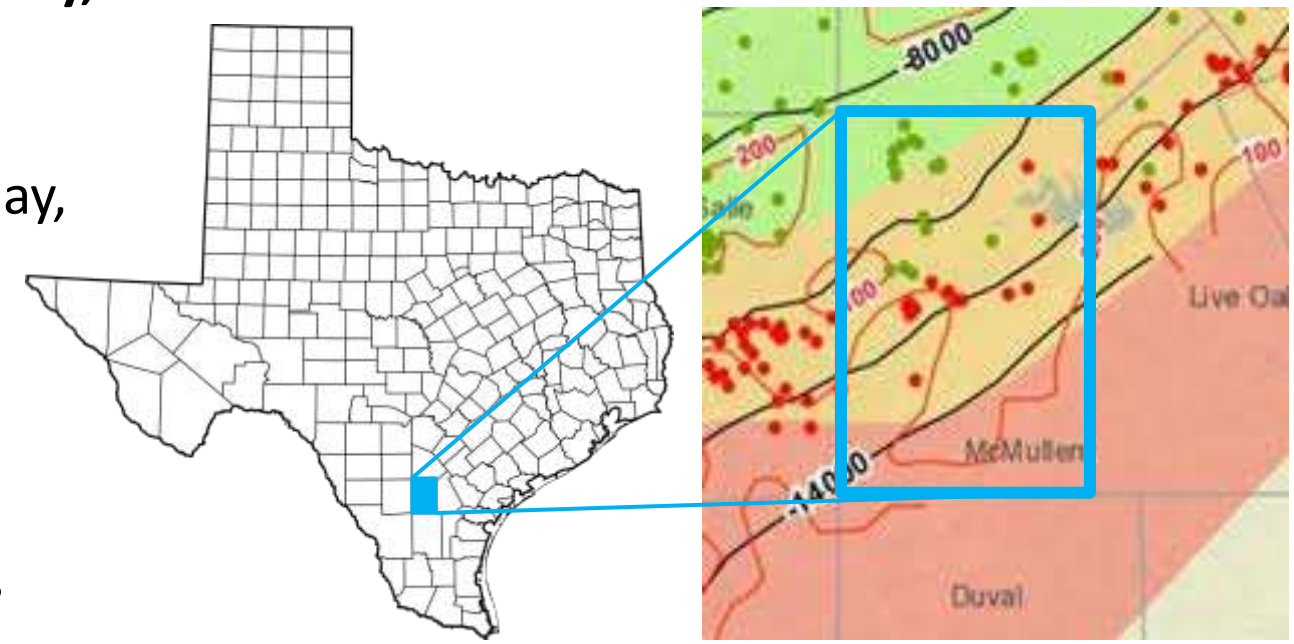
Background

307 Operating is located in McMullen County, Texas

- Approx. 75 miles south of San Antonio
- Formations include Eagle Ford Shale Play, **Olmos**, and Wilcox Formation

Field Geology

- Fine grained to very fine grained sandstone
- High porosity ratios to bed thickness is updip
- Low permeability and porosity in the downdip due to increased clay content



Reference: Dennis, Greg. "Depositional Environments of A. W. P. Olmos Field, McMullen County, Texas." *AAPG Datapages/Archives*. Gulf Coast Association of Geological Societies, 1 Jan. 1999. Web. 6 Nov. 2014.

Problem Statement

Design a stable wellbore

- Focus on a zone where hydrocarbons will be extracted (10,062' to 10,562‘)
  - Actual hydrocarbon zone is 10,376' to 10,412'
- Optimize Mud Weight
  - Choose correct mud mixture and counterbalance pressure
  - If mud density < formation pressure a kick may occur
  - If mud density is too high, can create fracture
- Design Drilling Parameters

Data Collection and Analysis

Overburden Stress (Density Log)

- Stress from the weight of the overlying rock in a formation

Pore Pressure (DFIT)

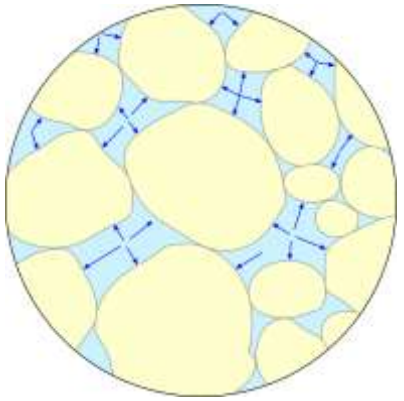
- Pressure of the fluids in the formation on the wellbore

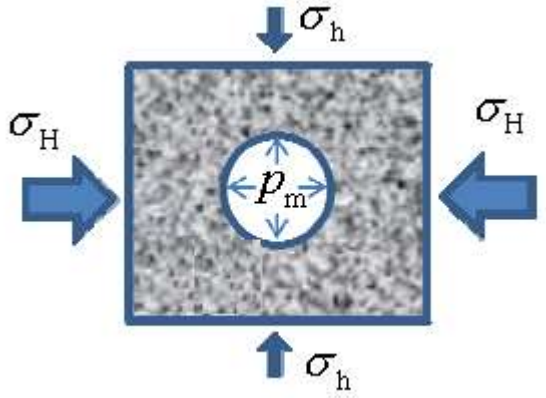
Fracture Pressure (DFIT)

- Pressure required to fracture a formation

Mud Weight Pressure

- Mud weight was calculated to give us our radial stress (σ_r) within the wellbore





Data Collection and Analysis

Minimum Horizontal Stress (σ_h)

- *Method* – International Standard for Rock Mechanics (ISRM)

Maximum Horizontal (σ_H)

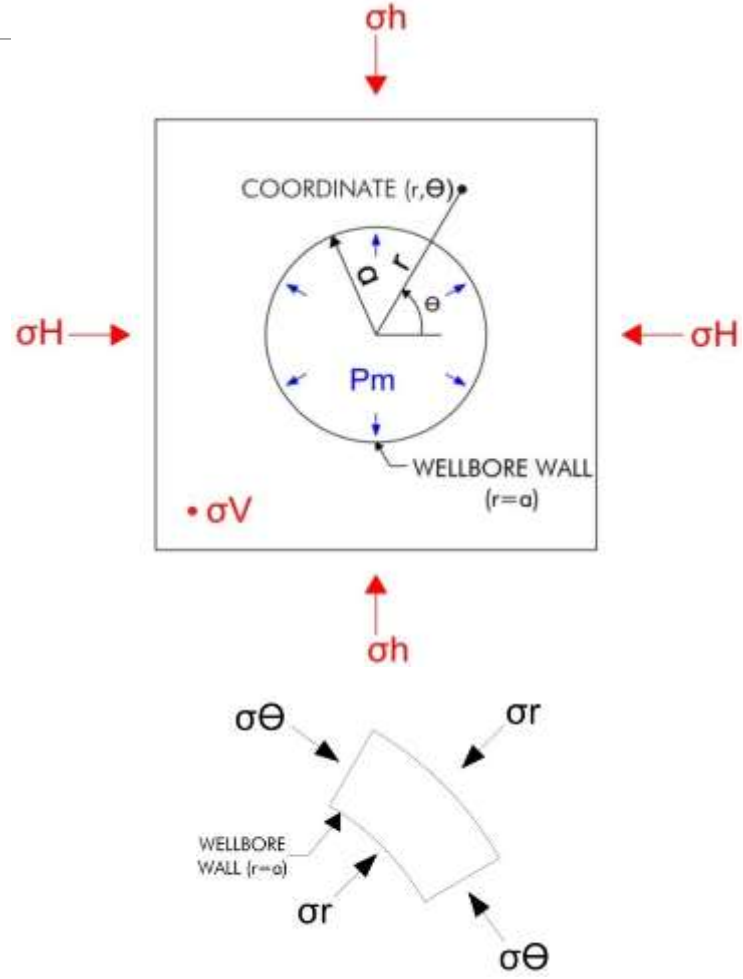
- Function of minimum horizontal stress (σ_h) and fracture re-open pressure (P_r)

Tensile Strength (σ_t)

- Based on min (σ_h) and max (σ_H) values

Wellbore Boundary Stresses (σ_r, σ_θ, and σ_z)

- Based on Kirsch's Equations at the wellbore boundary (r = a)
- Used to find our stresses σ_1, σ_2, σ_3 for Mohr's circle wellbore stability analysis



Reference: Song, Lisa. "Measurement of Horizontal Stress from Logging and Drilling Data in Unconventional Oil and Gas." MS thesis. University of Calgary, 2012. Online.

WELLBORE STABILITY ANALYZER | USER: GROUP B | FORMATION: OLMOS | DATE: 4/26/2015

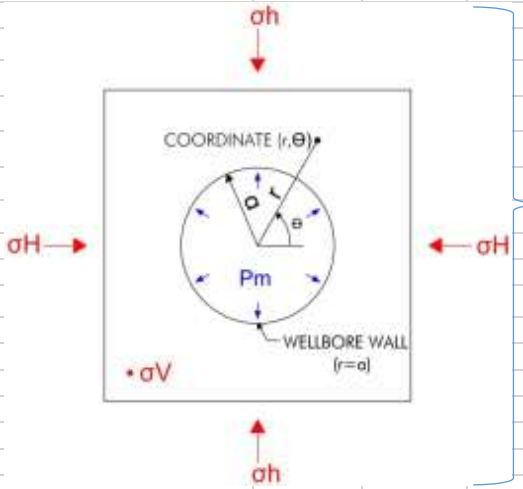
INPUT PARAMETERS		
FLUID DENSITY	ρf (g/cm³)	1
MATRIX DENSITY	ρma	2.65
POISSONS RATIO	ν	0.29
BIOT'S CONSTANT	α	0.75
PORE PRESSURE GRADIENT	PP (psi/ft)	0.677
FRACTURE RE-OPEN PRESSURE	Pr (psi)	8800

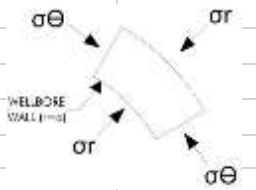
DEPTH	POROSITY	BULK DENSITY
z (ft)	ϕ	ρb (g/cm3)
1600	0.325	2.11375
2600	0.39	2.0065
3600	0.28	2.188
4600	0.225	2.27875
5600	0.225	2.27875
6600	0.1	2.485
7600	0.15	2.4025
8600	0.09	2.5015
9600	0.075	2.52625
10340	0.06	2.551
10470	0.06	2.551

AVERAGE DENSITY	mean Pb (g/cm³)	2.353

σv (psi) @ 10,400'	10612.56234

DEPTH OF INTEREST	POROSITY	BULK DENSITY	OVERBURDEN STRESS	PORE PRESSURE	MIN. HORIZ. STRESS	MAX. HORIZ. STRESS
z (ft)	ϕ	ρb (g/cm³)	σv (psi)	PP (psi)	σh (psi)	σH (psi)
10350	0.075	2.52625	10561.54041	7006.95	7422.58587	13467.75761
10360	0.075	2.52625	10571.74479	7013.72	7429.757451	13489.27235
10370	0.085	2.50975	10581.94918	7020.49	7436.929032	13510.78709
10380	0.115	2.46025	10592.15357	7027.26	7444.100612	13532.30184
10390	0.18	2.353	10602.35795	7034.03	7451.272193	13553.81658
10400	**0.12**	**2.452**	**10612.56234**	**7040.8**	**7458.443773**	**13575.33132**
10410	0.15	2.4025	10622.76673	7047.57	7465.615354	13596.84606
10420	0.1	2.485	10632.97112	7054.34	7472.786934	13618.3608
10430	0.135	2.42725	10643.1755	7061.11	7479.958515	13639.87554
10440	0.105	2.47675	10653.37989	7067.88	7487.130095	13661.39029
10450	0.09	2.5015	10663.58428	7074.65	7494.301676	13682.90503
10460	0.075	2.52625	10673.78866	7081.42	7501.473257	13704.41977



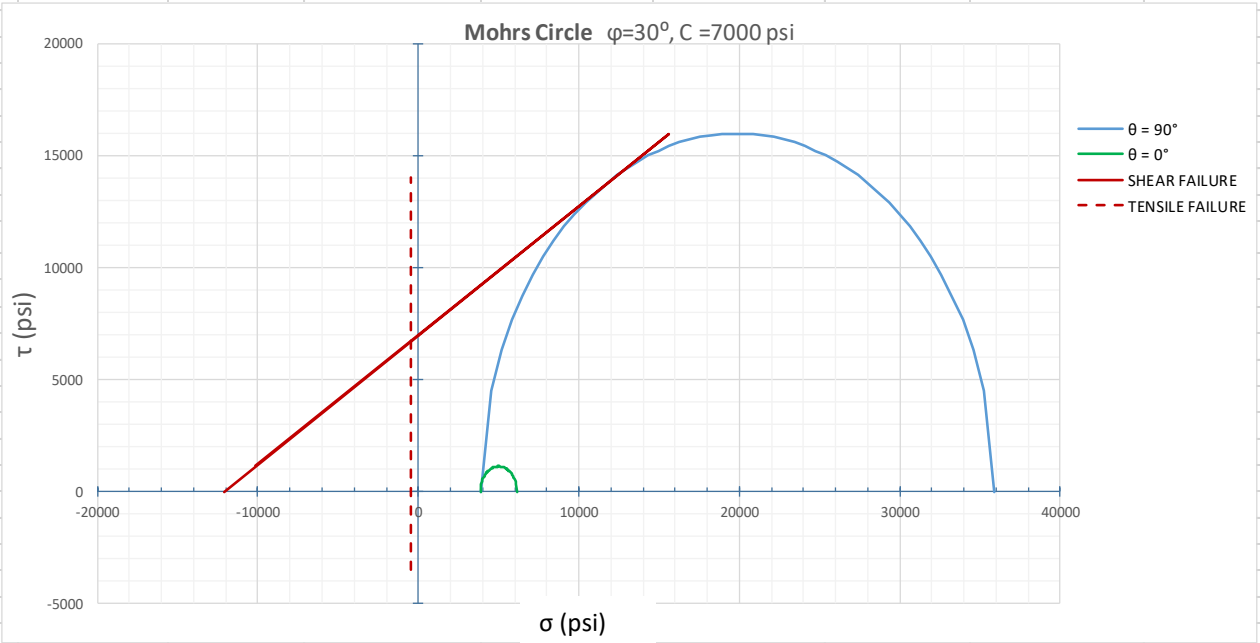


τ_{rz}	0
$\tau_{z\theta}$	0
$\tau_{r\theta}$	0

INPUT PARAMETERS (@r=a)		
DEPTH	z (ft)	10400
FRACTURE RE-OPEN PRESSURE	Pr (psi)	8800
SHUT-IN PRESSURE	Ps (psi)	8267
FORMATION BREAKDOWN PRESSURE	Pf (psi)	9300
COHESION	C (psi)	7000
FRICTION ANGLE	Φ	30

DEGREESE TO RADIANS		
MAX. HORIZ. ANGL.	DEGREES	RADIANS
θ	0	0
θ	90	1.5708

	MUD WEIGHT	MAX. HORIZ. STRESS	MIN. HORIZ. STRESS	TENSILE STRENGTH	RADIAL STRESS	TANGENTAIL STRESS	VERTICAL STRESS	MAX IN-SITU STRESS	MIN. IN-SITU STRESS
	Pm (lb/gal)	σH (psi)	σh (psi)	σt (psi)	σr (psi)	σθ (psi)	σz (psi)	σ1 (psi)	σ3 (psi)
θ=0	7.157366965	16001	8267	-500	3870.704055	4929.295945	6126.842	6126.842341	3871
θ=90	7.157366965	16001	8267	-500	3870.70	35865.30	15098.28	35865.29595	3870.704055



STRESS REGIME ---> STRIKE-SLIP
BLOWOUT RISK ---> LOW

TENSILE FAILURE STATUS		SHEAR FAILURE STATUS	
AT 0°	SAFE	AT 0°	SAFE
AT 90°	SAFE	AT 90°	SAFE

THERE ARE NO STRESS FAILURES, THE CHOSEN MUD WEIGHT IS ACCEPTABLE

FIND MAX MUD WEIGHT

FIND MIN. MUD WEIGHT

Data Collection and Analysis

Data from Wapiti Operating in Houston, TX

- DFIT (mini-frac test)
- Open-hole Well Logs
- Drilling Reports

Hydrocarbon Zone (10,376'-10,412')

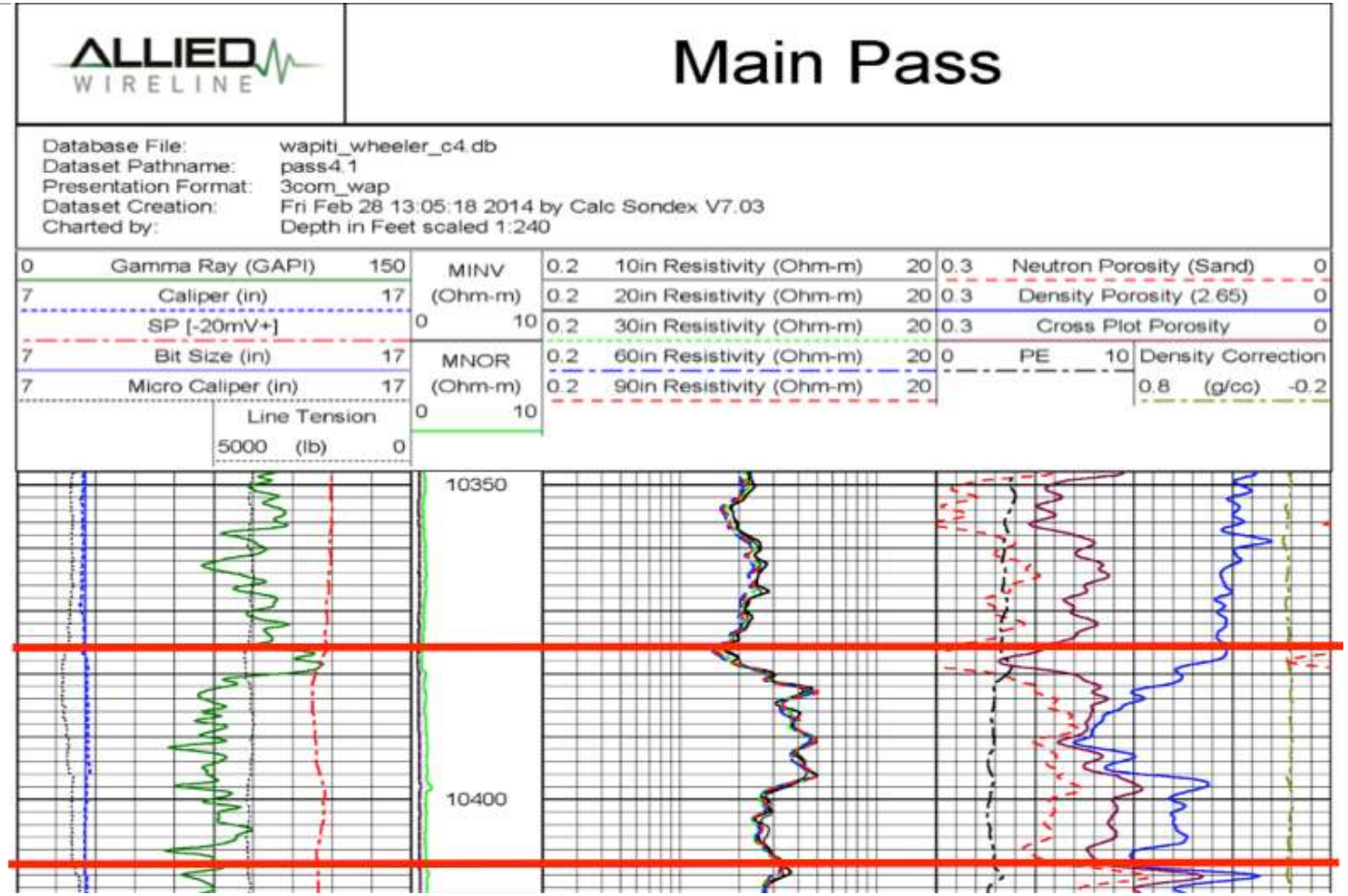
- Based on gamma, resistivity, and porosity logs

Drill to a total depth of 10,562'

- ~150' of rat hole

Area of Design (10,062'-10,562')

- Most important area

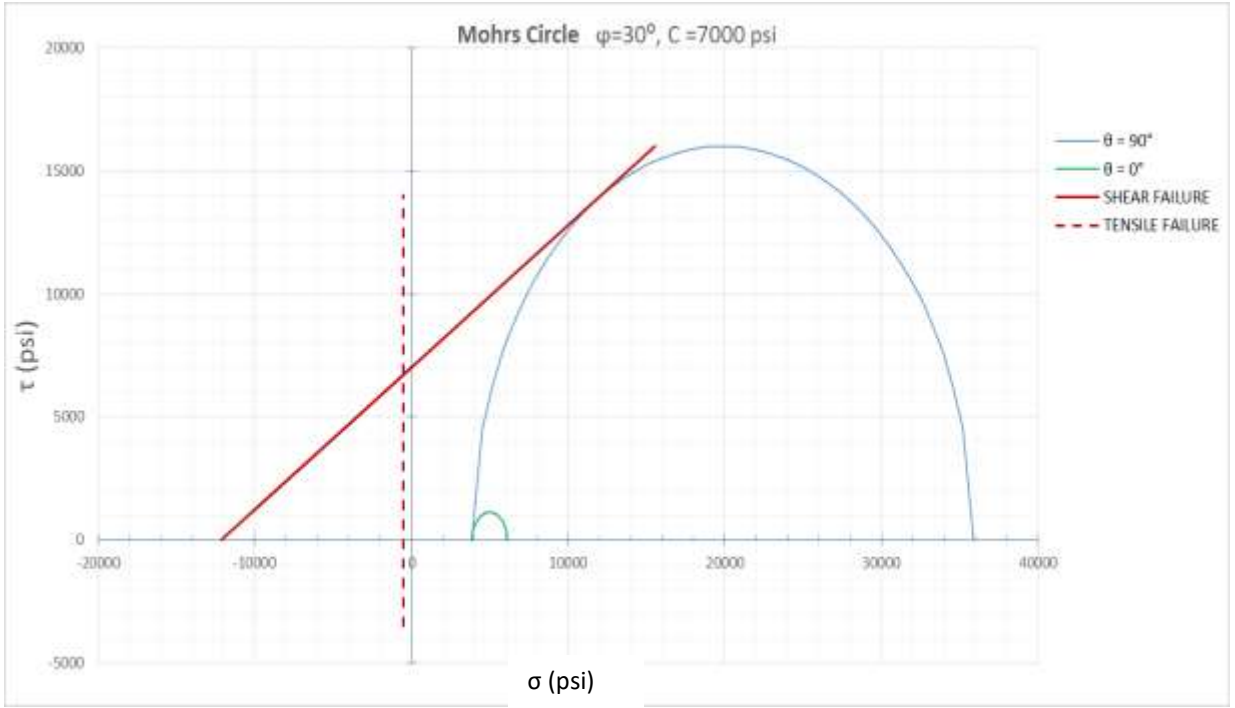


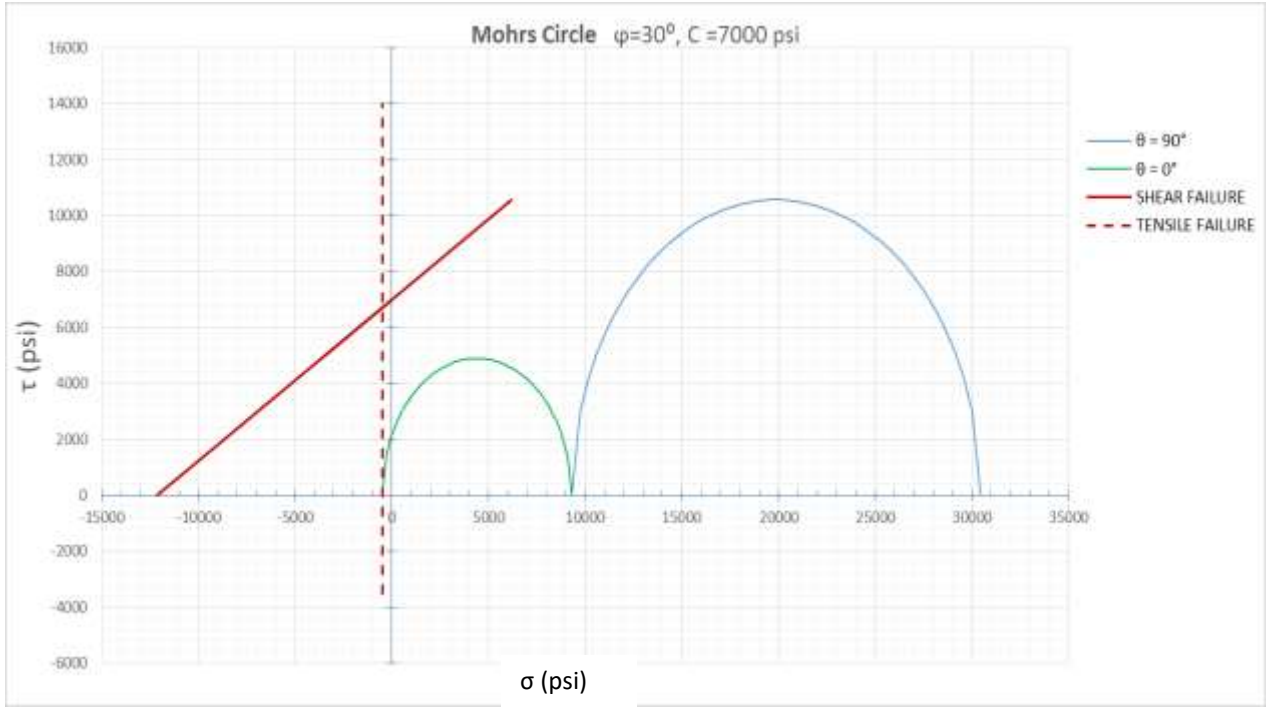
Mud Weight Design

Cohesion (Research)
- 7000 psi

Friction Angle (Research)
- 30°

Mud Weight Range (Excel)
- 7.16 - 17.2 ppg





Well Economics													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13
Oil Production (stb)	23,725	16,425	14,600	12,775	11,315	9,125	6,570	3,650	2,555	1,825	1,278	1,095	730
Gas Production (Mscf)	91,250	63,875	54,750	52,925	53,655	45,990	40,150	36,500	35,770	34,675	33,945	32,120	28,105
Gross Revenue	$ 1,586,746	$ 1,100,293	$ 972,908	$ 863,992	$ 782,399	$ 637,848	$ 477,055	$ 300,943	$ 236,516	$ 192,027	$ 158,890	$ 143,843	$ 112,825
Taxes	$(231,664.95)	$(160,642.71)	$(142,044.50)	$(126,142.76)	$(114,230.31)	$(93,125.87)	$(69,650.03)	$(43,937.61)	$(34,531.39)	$(28,035.87)	$(23,197.94)	$(21,001.06)	$(16,472.47)
Royalty @ 12.5%	$ (198,343)	$ (137,537)	$ (121,613)	$ (107,999)	$ (97,800)	$ (79,731)	$ (59,632)	$ (37,618)	$ (29,565)	$ (24,003)	$ (19,861)	$ (17,980)	$ (14,103)
Net Operating Revenue	$ 1,156,738	$ 802,113	$ 709,250	$ 629,850	$ 570,369	$ 464,992	$ 347,773	$ 219,387	$ 172,420	$ 139,987	$ 115,831	$ 104,861	$ 82,250
Operating Costs	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)	$ (100,000)
IDC's	$ (1,000,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Depreciation	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)	$ (23,333)
Taxable After Depreciation	$ 33,405	$ 678,780	$ 585,916	$ 506,516	$ 447,036	$ 341,658	$ 224,440	$ 96,054	$ 49,087	$ 16,654	$ (7,503)	$ (18,472)	$ (41,084)
Loss Forward	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.00	$ 2.00	$ 3.00	$ 4.00	$ 5.00	$ 6.00
Taxable Income	$ 33,405	$ 678,780	$ 585,916	$ 506,516	$ 447,036	$ 341,658	$ 224,440	$ 96,055	$ 49,089	$ 16,657	$ (7,499)	$ (18,467)	$ (41,078)
Tax @ 30%	$ (10,021)	$ (203,634)	$ (175,775)	$ (151,955)	$ (134,111)	$ (102,497)	$ (67,332)	$ (28,816)	$ (14,727)	$ (4,997)	$ 2,250	$ 5,540	$ 12,323
Net Income	$ 23,383	$ 475,146	$ 410,141	$ 354,562	$ 312,925	$ 239,161	$ 157,108	$ 67,238	$ 34,362	$ 11,660	$ (5,249)	$ (12,927)	$ (28,754)
Add Depreciation	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333	$ 23,333
Add Loss Forward	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Tangible Drilling Costs	$ (700,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
After-Tax Net Cash Flow	$ (653,283)	$ 498,479	$ 433,475	$ 377,895	$ 336,258	$ 262,494	$ 180,441	$ 90,572	$ 57,696	$ 34,993	$ 18,084	$ 10,407	$ (5,421)
After-Tax Net Cash Flow Discounted @ 10%	$ (622,881)	$ 432,074	$ 341,572	$ 270,705	$ 218,981	$ 155,403	$ 97,114	$ 44,315	$ 25,663	$ 14,150	$ 6,648	$ 3,478	$ (1,647)

Design

Coastal Drilling Company will drill well and Halliburton will fracture well

- Total cost - $1.7MM

Drilling Parameters

- 4.5”, 43.4 lbs/ft drill string
- Weight on bit – 180,677 to 189,655 lbs in zone of interest
- Rate of penetration – 38.6 ft/hr
- Rotary speed – 110 RPM
- Polycrystalline diamond bit
- Trip time – 1 stand/min or greater

Design

Mud Weight Design

- Cohesion – 7,000 psi
- Friction angle – 30°
- Mud weight – 7.16 to 17.2 ppg

Government Regulations

- Follow Texas Railroad Commission regulations
  - Hundreds of regulations

Environmental Considerations

- Every effort made to keep design environmentally friendly

Recommendation

Net Present Value @ 10% discount (NPV10)

- $939,707.84

Internal Rate of Return (IRR)

- 61%

Break-even Point

- 3 years

Economic Limit

- 12 years

Based on these values, 307 Operating recommends that this well be drilled and completed for production using the previously discussed stable wellbore design.

Thank You!

Questions??