2022 Magnolia Drilling Extern Project

University of Houston and Tulsa
Extern Program(s)
Magnolia Drilling Risk Matrix Project

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Final Extern Presentation August 12th 2 PM

Content

- Objectives
- Tools Used
- Generalities
- List of 22 Wells
- Friction Factors
- DP Parameters
- Torque Sensitivity Analysis
- Hook Load Sensitivity Analysis
- Relationship Between Models
- Developing a risk matrix
- Conclusion (suggestions)

Objectives

- During the externship, the major objective of the project for Magnolia Oil and Gas was the creation of a risk matrix. This risk matrix will allow us to determine the increase in Lateral Length and what the maximum step out would be.

- The risk matrix is based on 22 wells supplied by magnolia oil & gas that all met their objectives, and the data from the drilling periods is accessible to optimize future drilling plans.

Tools Used

- The tools used to build the risk matrix are:
  - ✓ Torque and drag model provided by University of Tulsa
  - ✓ Torque and drag model developed by University of Houston
  - ✓ Hook load model provided by University of Tulsa
  - ✓ Hook load model developed by University of Houston

Generalities

- The 22 wells are in the Texas Western Golf basin in the United States, they all have similar trajectories (wells Type L), with 3 sections for the mechanical state (13 1/2”, 9 7/8”, 6 3/4” in multiple cases) but they can also be differentiated into vertical section, curved section, and horizontal section for a better understanding.

List of 22 Wells

Well Name	Friction Factor	Tortuosity Index	Max Torque Real Data [Kf-lbf]	Hookload Real Data [klbs]
Bighorn pass H06 BH	0.25	3.26	22.4	337
Bighorn peak H04 BH	0.3	2.71	20.9	348
Bighorn plains H02 BH	**0.26**	**2.94**	**23.6**	**326**
Borgstedt unit 2H	0.3	2.94	26.8	266
Bucky badger H02 BB	0.4	2.74	24.7	308
Dietz ol unit 3H	0.4	3.11	21.3	314
Fat tire A 1H	0.4	2.78	23.8	269
Fat tire B 1H	0.4	3.64	22.6	335
Grand canyon A 1H	0.4	3.13	21.1	305
Klondike mill H08 KL	0.22	3.15	20.5	334
Klondike rush H06 KL	0.4	3.1	17.5	288

List of 22 Wells

Well Name	Friction Factor	Tortuosity Index	Max Torque Real Data [Kf-lbf]	Hookload Real Data [klbs]
Levi Goodrich unit 2 2H	0.1	2.63	22.4	299
Ozark unit 1H	**0.3**	**2.24**	**19.9**	**351**
Rainier 1H	0.4	4.19	25.9	333
Redwood A 1H	0.4	3.01	16.9	302
Redwood B 1H	**0.4**	**2.94**	**19.1**	**328**
Rommel unit 3H	**0.4**	**3.1**	**20.4**	**354**
Sabine B 2H	0.4	3.27	23.4	368
Sabine D 4H	**0.4**	**3.04**	**23.7**	**377**
Sierra H08 PR	0.35	2.51	22.3	323
Tahoe Mountain H03 PR	0.4	3.25	23.6	378
Yukon A 1H	0.4	2.48	21.6	338

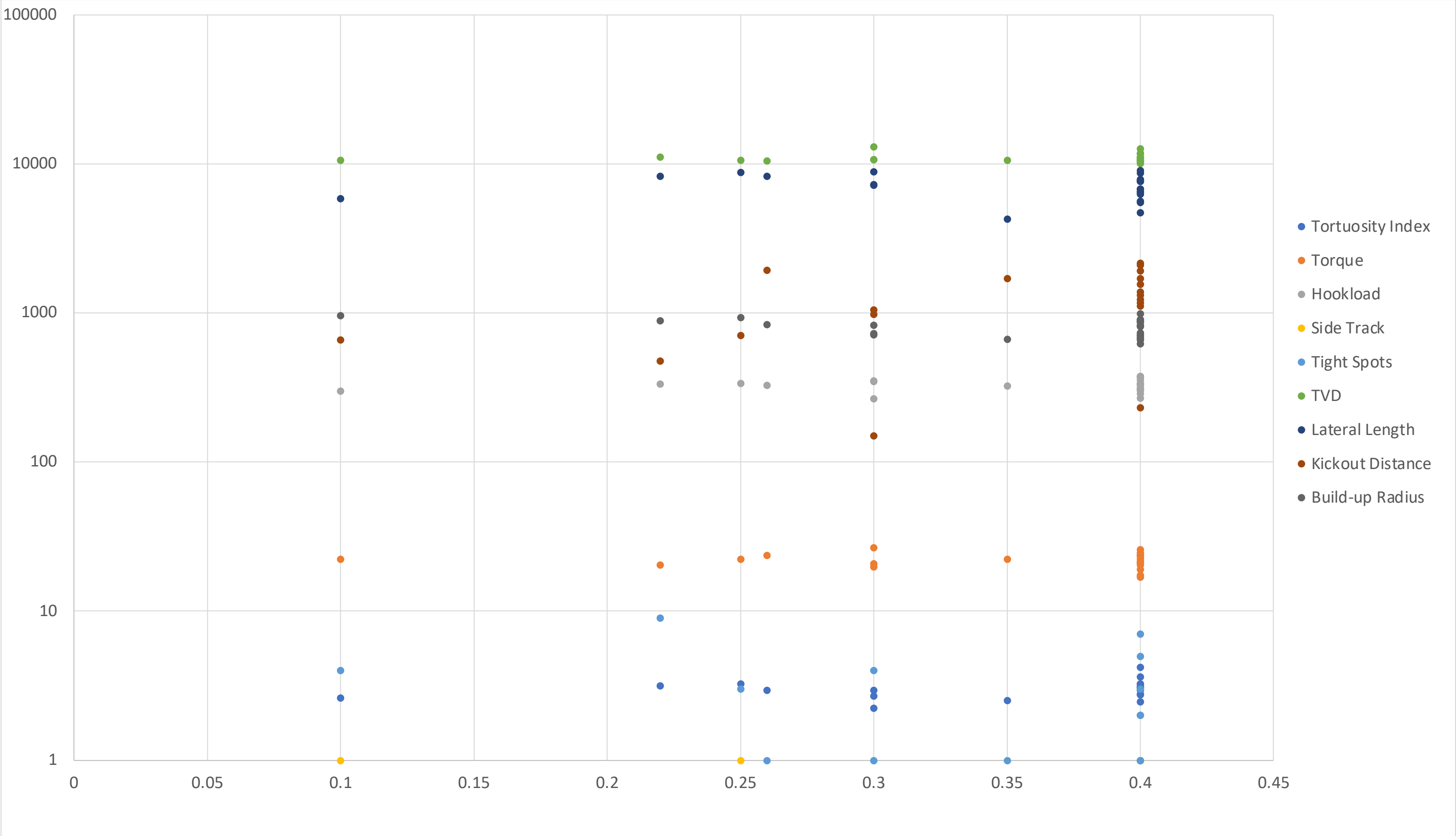
List of 22 Wells

Well Name	Side Tracks	Tight Spots	# BHA	TVD	Lateral section	Kickout Distance	Build Up Radious
Bighorn pass H06 BH	1	3	3	10,640	8,779	708	935
Bighorn peak H04 BH		1	4	10,678	8,906	1,051	828
Bighorn plains H02 BH		**1**	**4**	**10,548**	**8,249**	**1,934**	**835**
Borgstedt unit 2H			4	10,686	7,312	983	714
Bucky badger H02 BB		5	4	10,104	7,641	1,383	895
Dietz ol unit 3H		1	5	10,513	6,779	1,700	991
Fat tire A 1H			3	10,471	6,255	901	716
Fat tire B 1H	1	2	5	10,478	5,653	2,095	736
Grand canyon A 1H		1	5	10,584	6,826	1,320	834
Klondike mill H08 KL		9	4	11,113	8,299	476	891
Klondike rush H06 KL			-	11,164	9,042	232	909

List of 22 Wells

Well Name	Side Tracks	Tight Spots	# BHA	TVD	Lateral section	Kickout Distance	Build Up Radious
Levi goodrich unit 2 2H	1	4	6	10,591	5,876	661	965
Ozark unit 1H		**4**	**6**	**13,098**	**7,183**	**150**	**729**
Rainier 1H	1	7	8	12,701	7,716	1,918	818
Redwood A 1H			3	11,144	6,480	1,119	816
Redwood B 1H		**2**	**4**	**11,682**	**7,661**	**871**	**877**
Rommel unit 3H	**1**		**7**	**11,869**	**8,699**	**1,231**	**689**
Sabine B 2H		3	5	10,616	6,545	2,156	660
Sabine D 4H	**1**		**6**	**10,890**	**5,521**	**1,567**	**709**
Sierra H08 PR		1	4	10,630	4,275	1,701	666
Tahoe Mountain H03 PR			4	10,346	7,912	1,169	622
Yukon A 1H			3	10,942	4,733	672	872

Cross Plots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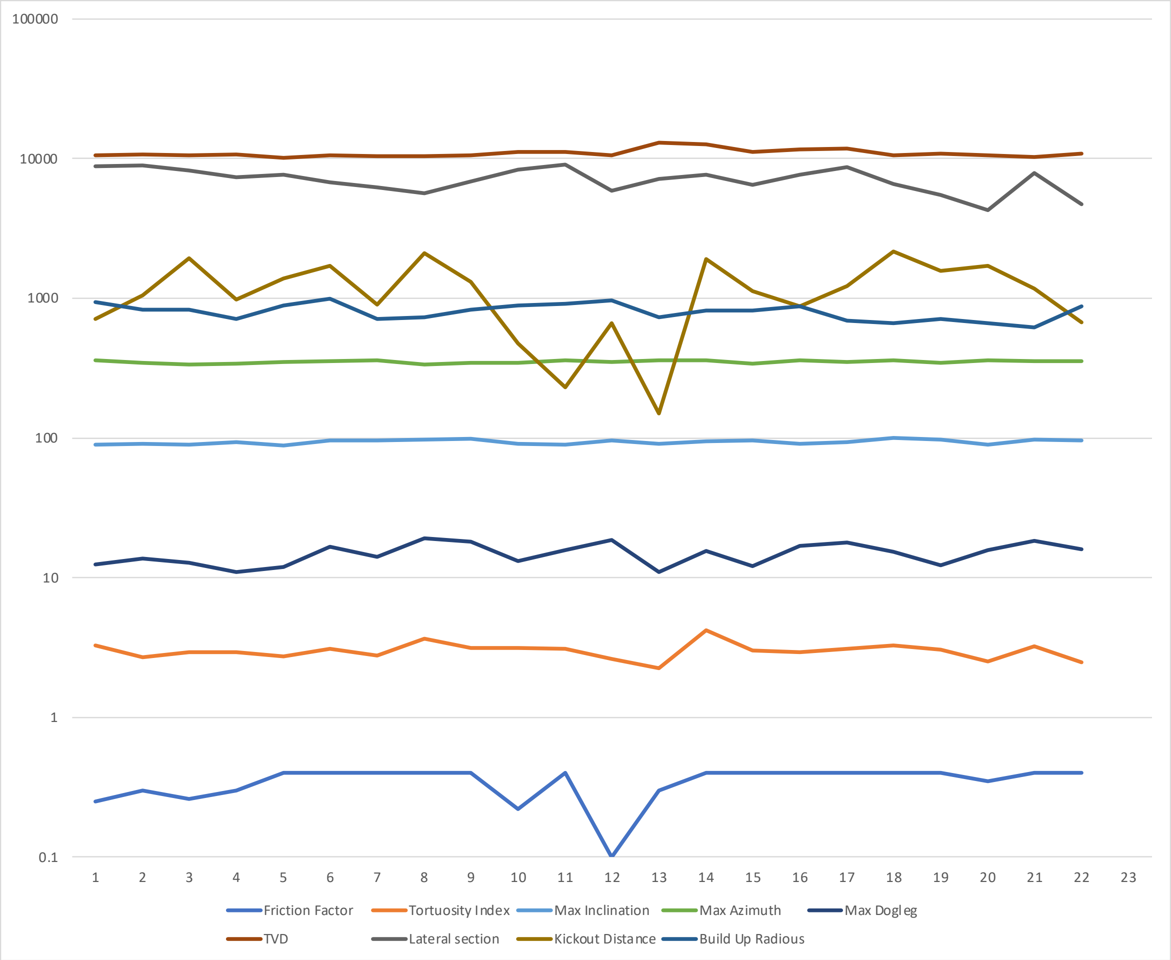
Tortuosity Index
Torque
Hookload
Side Track
Tight Spots
TVD
Lateral Length
Kickout Distance
Build-up Radius

Cross Plots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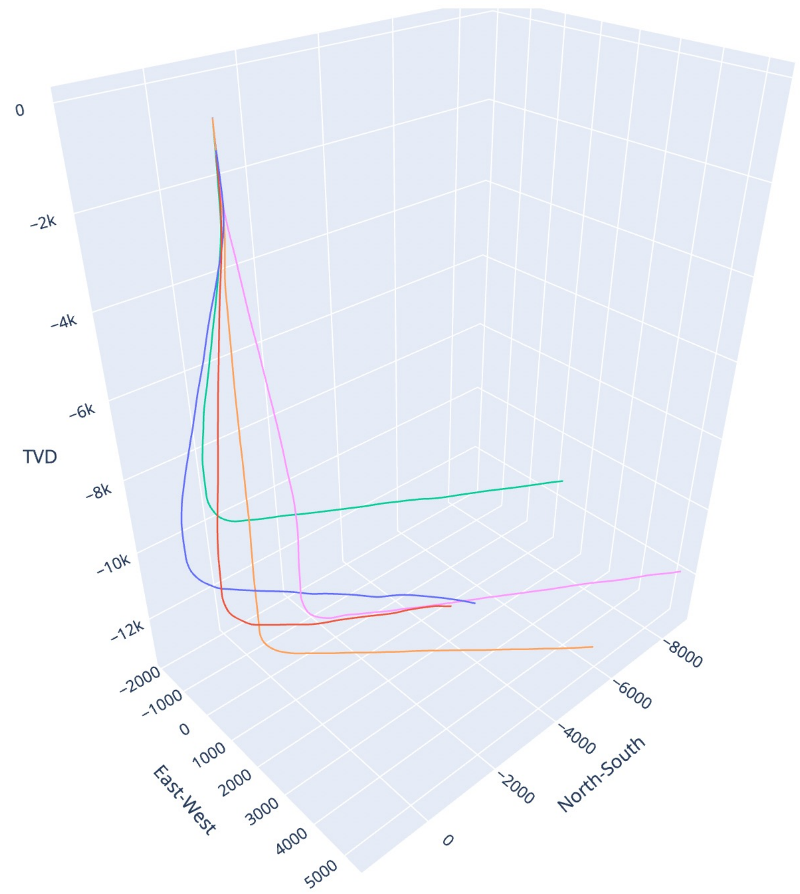
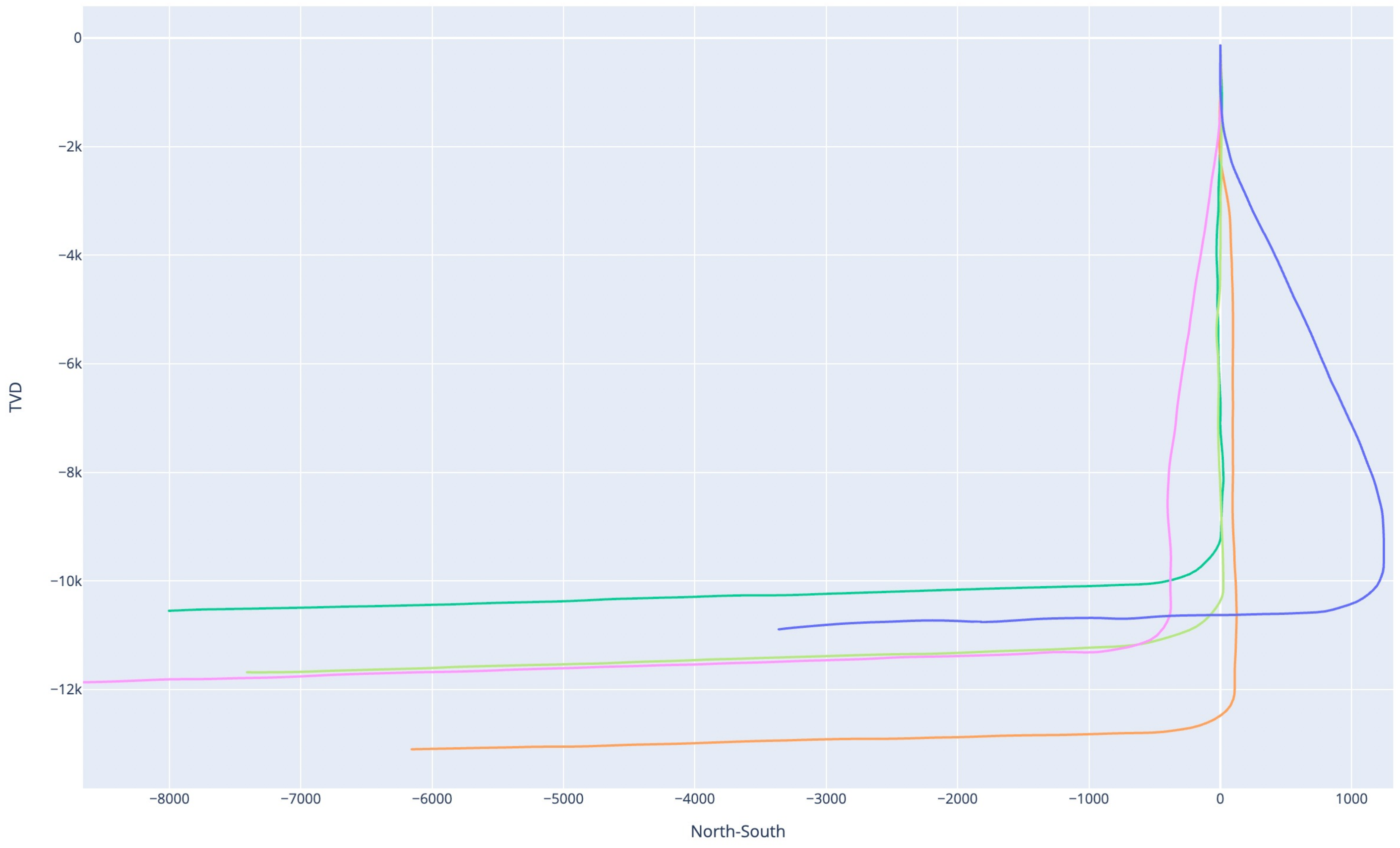
Friction Factor
Tortuosity Index
Max Inclination
Max Azimuth
Max Dogleg
TVD
Lateral section
Kickout Distance
Build Up Radious

Well Trajectory Examples



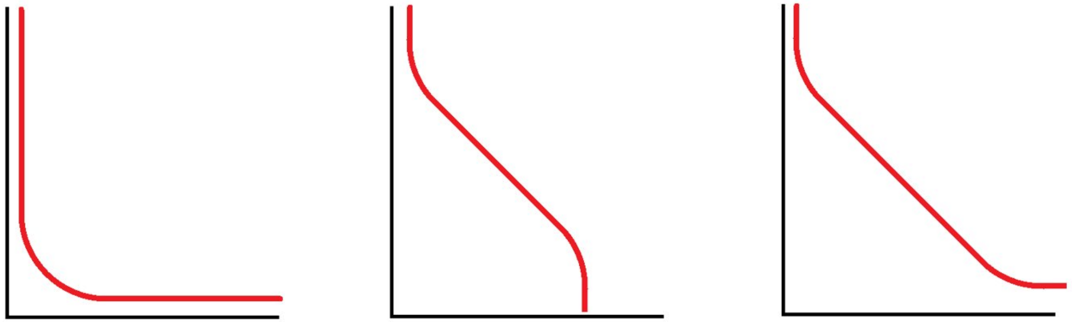


3D Tortuosity Index as Function of TVC and TLC

- Add up Total Vertical Curvature and Divide by 90°
- Add up Total Lateral Curvature and Divide by 90°
- $TI = \sqrt{\left(\frac{TVC}{90}\right)^2 + \left(\frac{TLC}{90}\right)^2}$

- These common profiles would all have

a perfect TI of 1

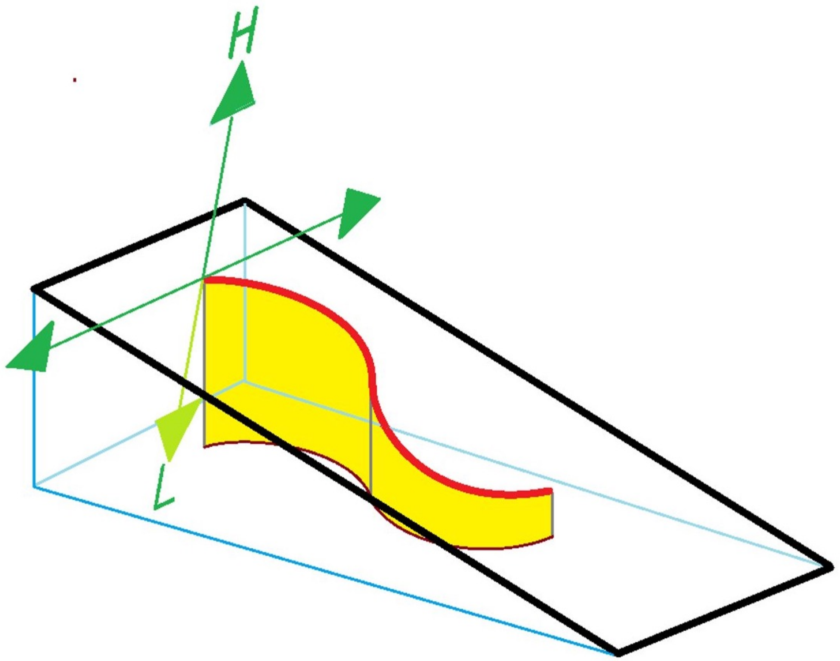


TLC Concept ad Function of Effective Turn

- Effective Turn is the dogleg in the lateral plane across the wellbore. This is **NOT** the azimuth change at inclinations other than horizontal.

- $ET = T \cdot \sin\theta$,

- Where ET is Effective Turn,
- T is Turn and θ is the inclination

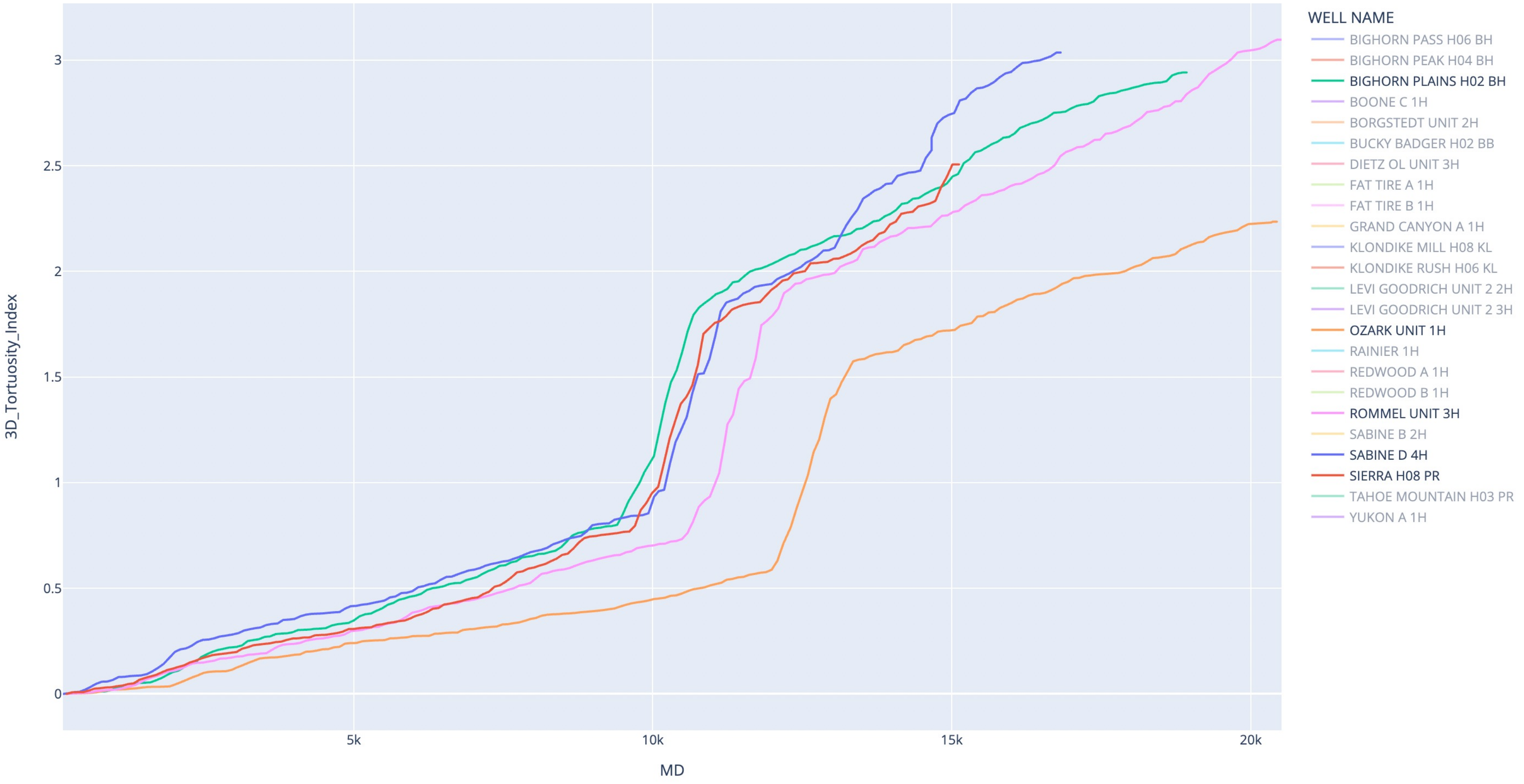


3D Tortuosity Index

- Calculate TLC and TVC for the well
- Calculate Lateral Tortuosity Index
- LTI = TLC / 90
- Calculate Vertical Tortuosity Index
- VTI = TVC / 90
- Calculate 3D Tortuosity Index

$$3DTI = \sqrt{(LTI)^2 + (VTI)^2}$$

Tortuosity Index Examples



Friction Factors

- The Friction Factor can be described by the representation of the friction between the wellbore/casing and the work string. The friction factor is dependent on mud type, geometry and wellbore (between many more parameters).

- The friction factor was calculated using the hook load model, in which the trip out data was filtered, to have greater accuracy, in the following images we will see multiple examples of how we determine the exact value and how the different trend lines show us a F.F. specifically for each well.

Drill Pipe Parameters

Command Tubular Products

Drill Pipe Specs

Size: 4 1/2"
Weight: 16.6 lbs/ft
Grade: S-135
Range: II (31.5')
Connection: CET43

Tube

	New		Premium	
	in	mm	in	mm
OD	4.500	114.3	4.365	110.9
Wall thickness	0.337	8.6	0.270	6.8
ID	3.826	97.2	3.826	97.2
	ft-lbs	N-m	ft-lbs	N-m
Torsional strength	55,453	75,200	43,451	58,900
80% Torsional strength	44,362	60,200	34,761	47,100
	lbs	daN	lbs	daN
Tensile strength	595,004	265,300	468,297	208,800
	psi	kPa	psi	kPa
Internal Pressure capacity	17,693	121,985	16,176	111,530
Collapse capacity	16,769	115,615	10,959	75,561
	in²	mm²	in²	mm²
Cross sectional area body	4.407	2844	3.469	2238
Cross sectional area OD	15.904	10261	14.966	9655
Cross sectional area ID	11.497	7417	11.497	7417
	in³	mm³	in³	mm³
Section modulus	4.271	69995	3.347	54845
Polar section modulus	8.543	139989	6.694	109690

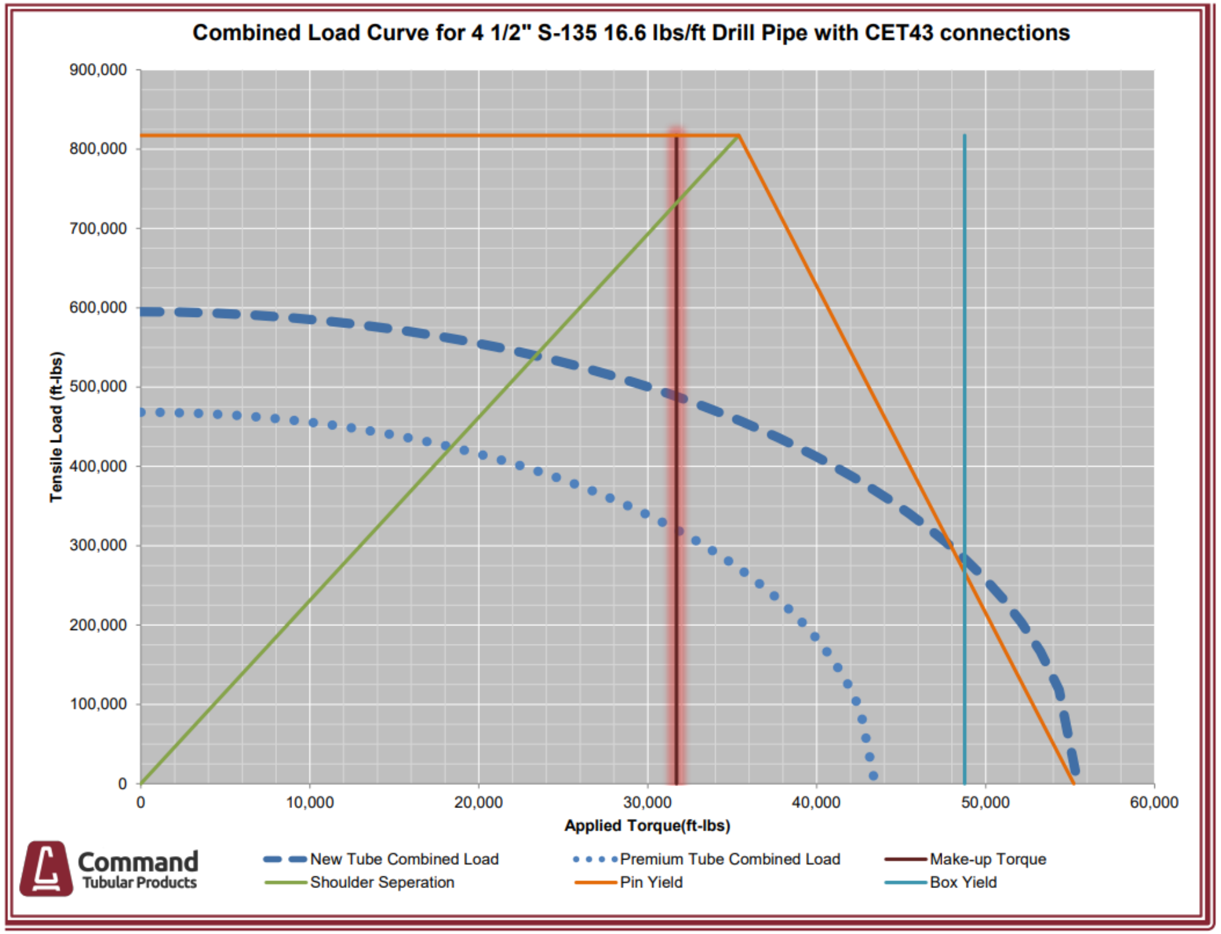
Tool Joint

	New		1.15 Friction Factor	
	psi	kPa	psi	kPa
Yield Strength	130,000	896,318	130,000	896,318
	in	mm	in	mm
OD	5.375	136.5	5.375	136.5
ID	3.000	76.2	3.000	76.2
Pin length	11.0	279.4	11.0	279.4
Box length	14.0	355.6	14.0	355.6
	ft-lbs	N-m	ft-lbs	N-m
Torsional Strength	48,800	66,200	56,200	76,200
Recommended Make-up Torque	31,700	43,000	36,500	49,500
Min Make-up Torque	28,100	38,100	32,400	44,000
	lbs	daN	lbs	daN
Tensile strength	817,300	364,400	817,300	364,400
Tool joint/Drill pipe torsional ratio	0.88		1.29	

Drill Pipe Assembly with Connection

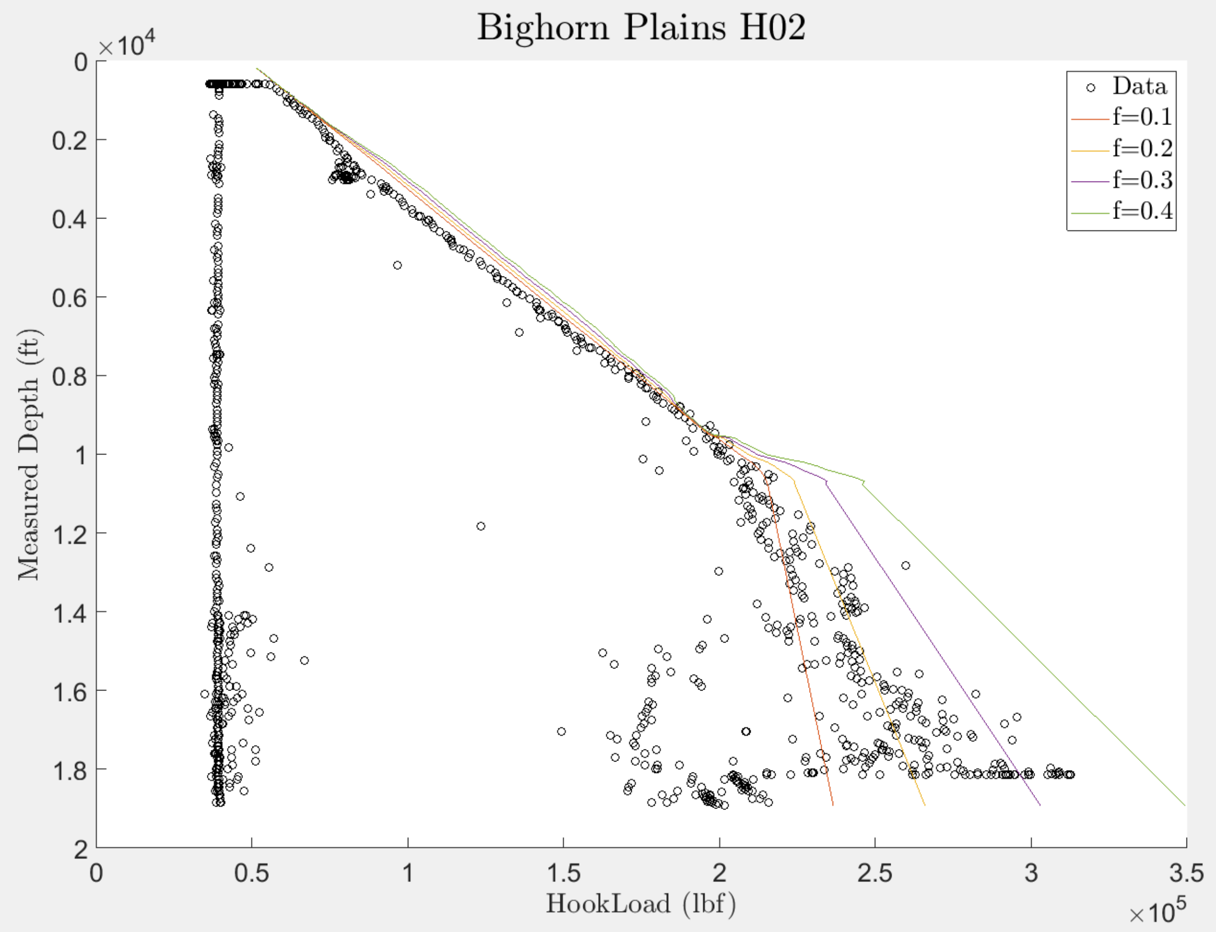
	lbs/ft	kg/m
Adjusted weight	17.84	26.60
	ft	m
Approximate length	31.50	9.60
	gal/ft	m³/m
Fluid displacement	0.273	0.003389
Fluid capacity	0.582	0.007228
	in	mm
Drift size	2.8750	73

While every effort has been made to insure the accuracy of the tables herein, this material is presented as a reference guide only. Command Tubular Products cannot assume responsibility for the results obtained through the use of this material. No expressed or implied warranty is intended. All torques are based on a 1.0 friction factor.



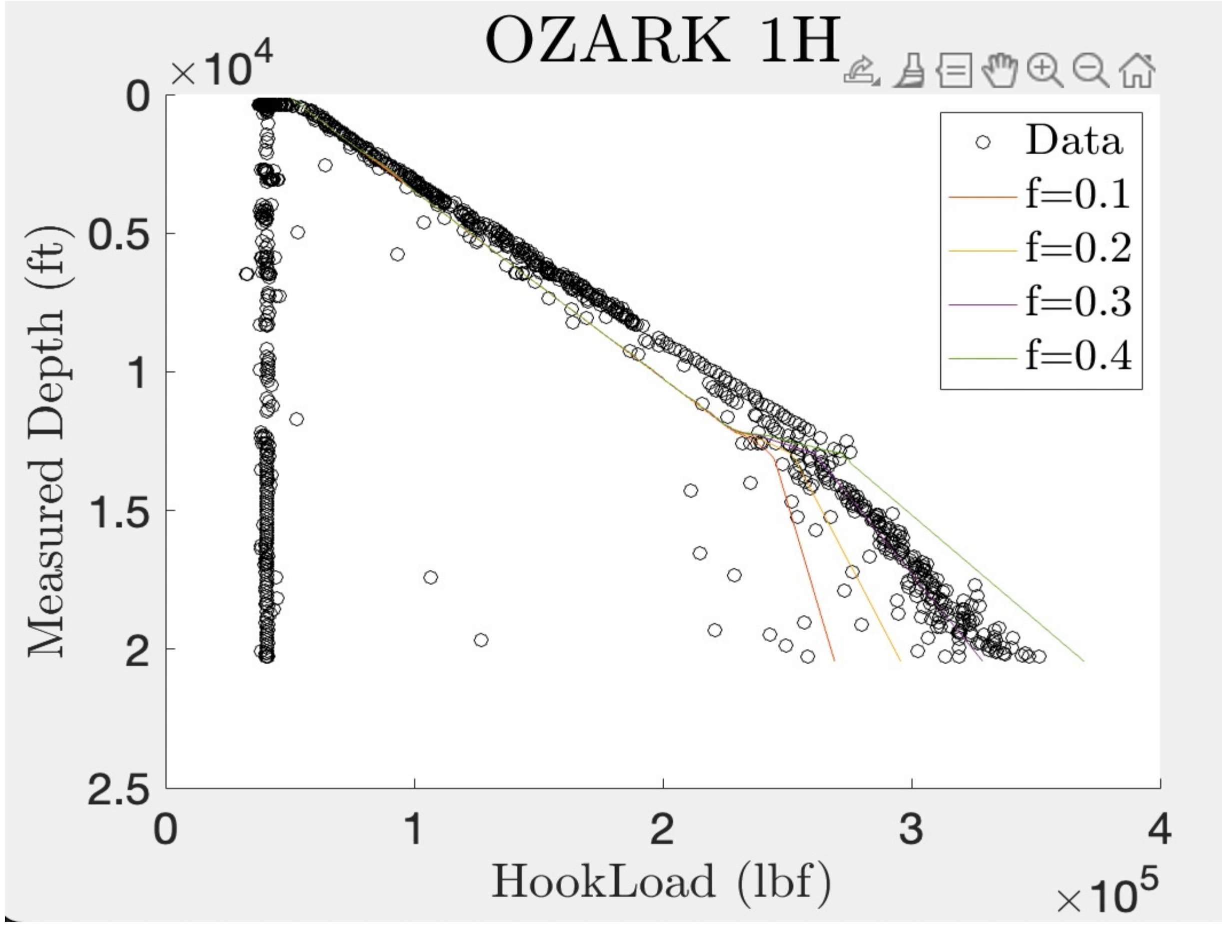
Model Output

- Axial forces tuned with different friction factors while tripping out compared to hook load from Pason for BIGHORN PLAINS H02.
- Friction Factor of 0.26 was chosen for this well.



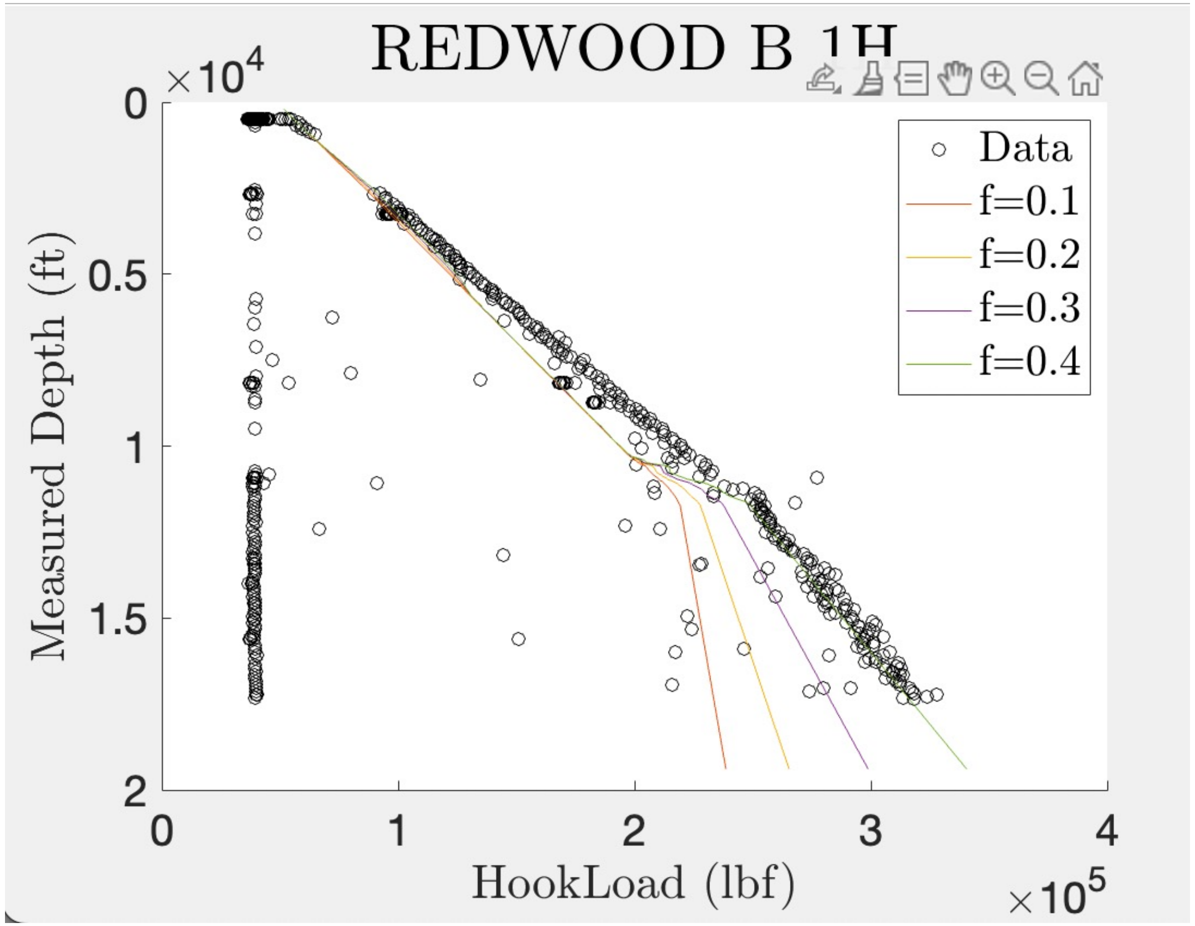
Model Output

- Axial forces tuned with different friction factors while tripping out compared to hook load from Pason for OZARK 1H.
- The tendency of the scatter data points from Pason are more aliened with the modeled curve with friction factor of 0.3.



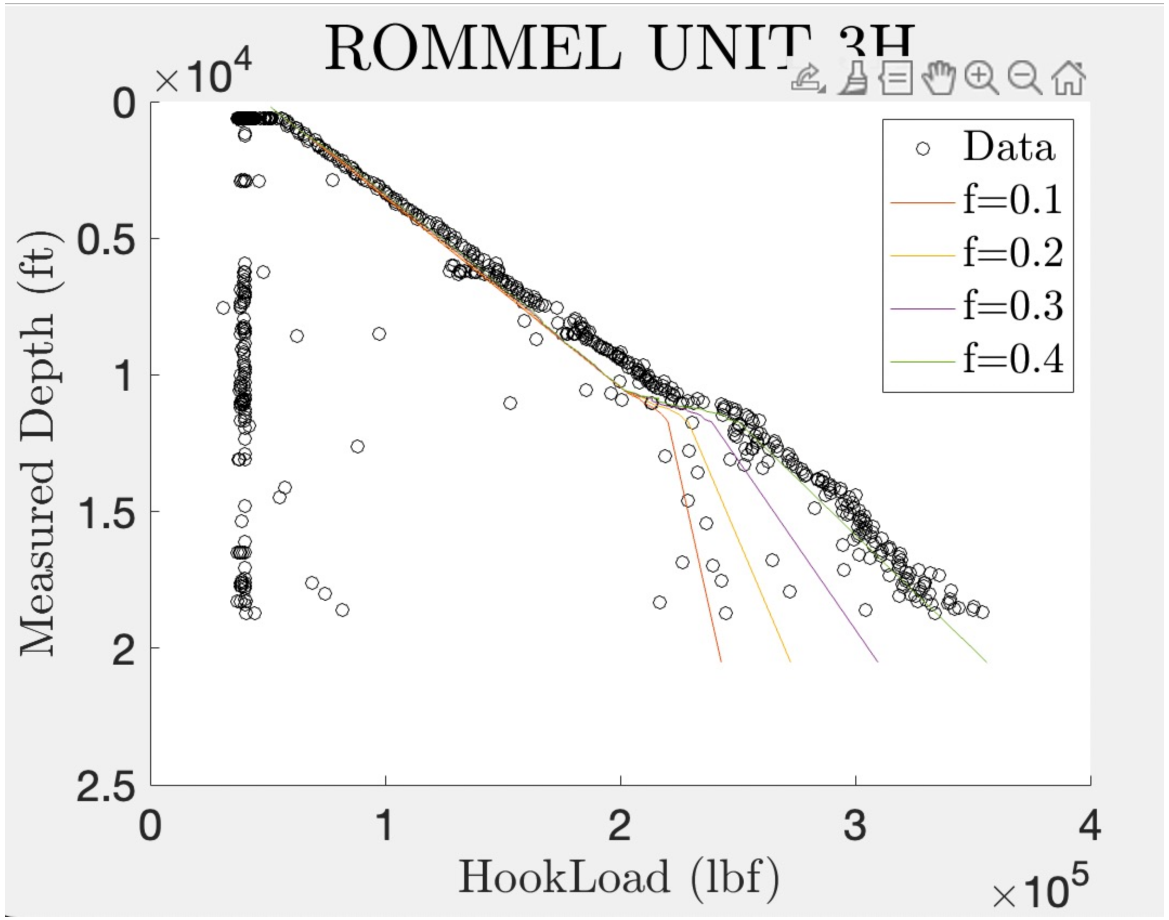
Model Output

- Axial forces tuned with different friction factors while tripping out compared to hook load from Pason for REDWOOD B 1H.
- The tendency of the scatter data points from Pason are more aliened with the modeled curve with friction factor of 0.4.



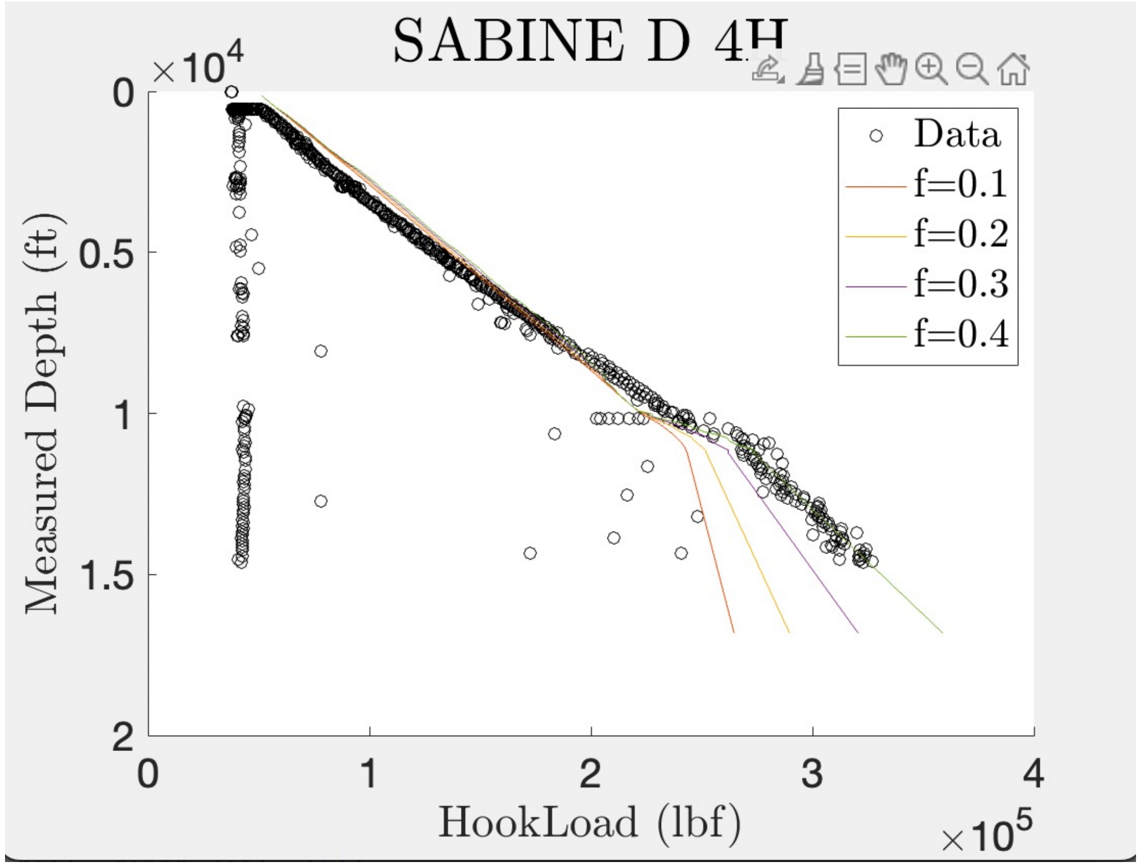
Model Output

- Axial forces tuned with different friction factors while tripping out compared to hook load from Pason for ROMMEL UNIT 3H.
- The tendency of the scatter data points from Pason are more aliened with the modeled curve with friction factor of 0.4.



Model Output

- Axial forces tuned with different friction factors while tripping out compared to hook load from Pason for SABINE D 4H.
- The tendency of the scatter data points from Pason are more aliened with the modeled curve with friction factor of 0.4.



Torque Sensitivity Analysis

- For the sensitivity analysis used to determine the Lateral length we use parameters of the wells (F.F., DP Yield, OD, ID, X-SECTION and more) were used in order to have greater accuracy. The value of the Lateral length was increased until we reach the torque limit in this case.
- We found values of torque that are really close to the real Data, between 19.9 – 23.7 kf-lbf.

WELL	PASON TORQUE DATA (Kf-lbf)	LL (ft)	MODEL TORQUE (Kf-lbf)	Increase in LL	
Ozark Unit 3H	19.9	**7,183**	19.03	5,197	ft
FF=0.3		9,950	22.42	42.0%	
		10,745	25.41		
		12,380	28.99		
ROMMEL UNIT 3H	20.4	**8,699**	21.49	2,311	ft
FF=0.4		8,980	22.82	21.0%	
		9,210	25.90		
		11,010	29.00		
SABINE D4 H	23.7	**5,521**	19.28	3,709	ft
FF=0.4		6,800	21.05	40.2%	
		8,100	24.19		
		9,230	29.00		
SIERRA H 08	22.3	4,275	18.33	6,020	ft
FF=0.35		6,800	20.96	58.5%	
		8,100	24.12		
		10,295	29.00		
BIGHORN PLAINS 02	23.6	8,249	20.79	2,851	ft
FF=0.27		9,000	22.63	25.7%	
		10,200	25.97		
		11,100	28.98		

Hook load Sensitivity Analysis

- For the sensitivity analysis used in the hook load, a similar methodology was used, the value of LL was increased to find the maximum possible HL, using the tool.
- We found values of hook load between 306,832 – 384,804

WELL	OZARK UNIT 1H	
YIELD STRENGTH	135,000	
CROSS SECTION	4.56	
DRILL STRING LIMIT	135,000.0	
SAFETY FACTOR	1	NO SAFETY FACTOR
MD	HOOKLOAD	HL/XS
20,437	375,064	82,194
23,363	387,501	84,919
24,437	392,235	85,957
25,790	400,001	87,659
Actual LL	7,183	ft
New LL	**12,536**	ft
Increase In LL	**5,353**	ft
Lateral Increase	**42.70%**	

WELL	SIERRA H 08	
YIELD STRENGTH	135,000	
CROSS SECTION	4.56	
DRILL STRING LIMIT	135,000.0	
SAFETY FACTOR	1	NO SAFETY FACTOR
MD	HOOKLOAD	HL/XS
15,122	306,832	67,241
17,122	328,123	71,907
19,122	348,381	76,346
24,220	399,999	87,658
Actual LL	4,275	
New LL	**13,373**	
Increase In LL	**9,098**	ft
Maximum lateral Incr	**68.03%**	

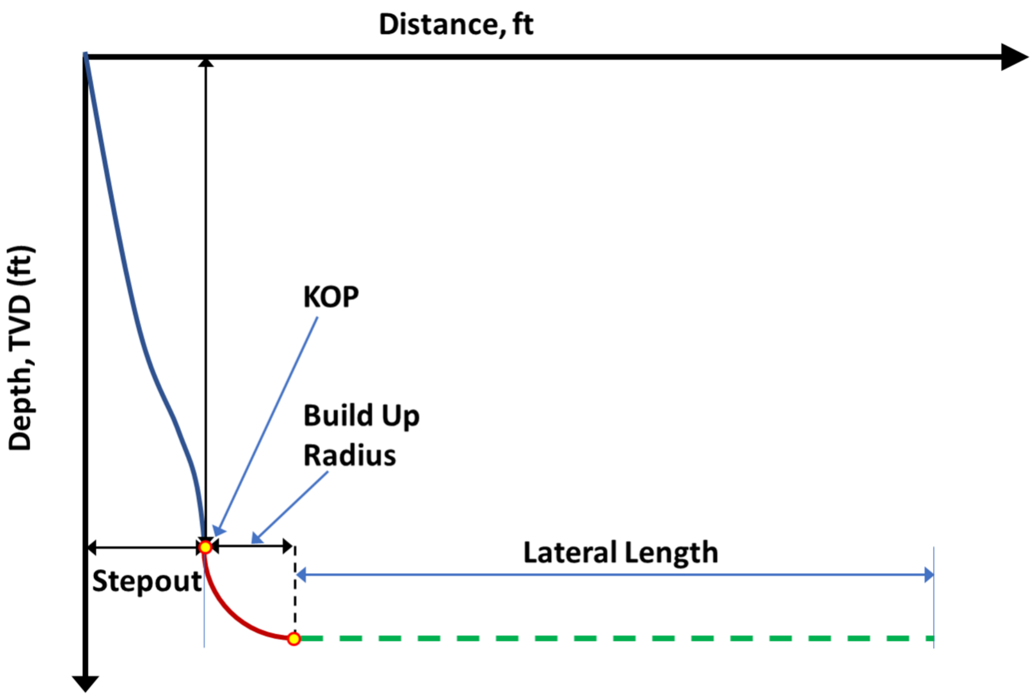
WELL	ROMMEL UNIT	
YIELD STRENGTH	135,000	
CROSS SECTION	4.56	
DRILL STRING LIMIT	135,000.0	
SAFETY FACTOR	1	NO SAFETY FACTOR
MD	HOOKLOAD	HL/XS
20,514	384,804	84,328
21,654	388,675	85,177
22,700	396,289	86,845
23,753	400,000	87,658
Actual LL	8,699	
New LL	**11,938**	
Increase In LL	**3,239**	ft
Maximum lateral Inc	**27.13%**	

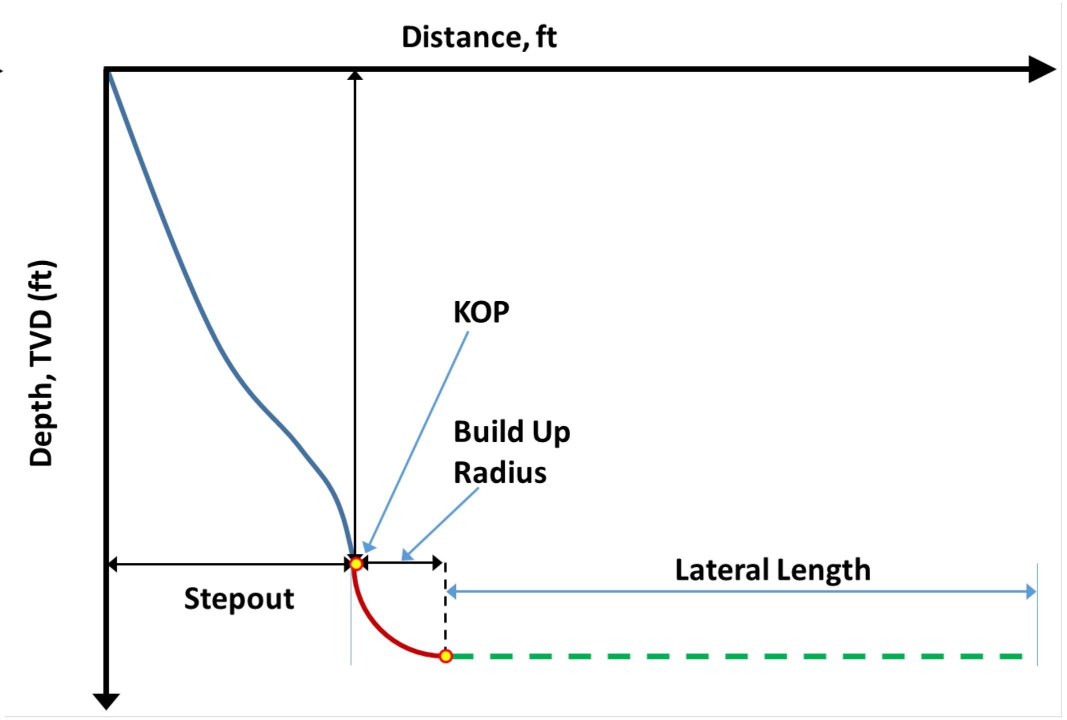
WELL	BIGHORNE PLAINS 02	
YIELD STRENGTH	135,000	
CROSS SECTION	4.56	
DRILL STRING LIMIT	135,000.0	
SAFETY FACTOR	1	NO SAFETY FACTOR
MD	HOOKLOAD	HL/XS
18,929	316,286	69,313
20,929	330,622	72,455
25,929	375,678	82,328
29,303	400,010	87,661
Actual LL	4,275	
New LL	**14,649**	
Increase In LL	**10,374**	ft
Maximum lateral Incr	**70.82%**	

WELL	SABINE D4 H	
YIELD STRENGTH	135,000	
CROSS SECTION	4.56	
DRILL STRING LIMIT	135,000.0	
SAFETY FACTOR	1	NO SAFETY FACTOR
MD	HOOKLOAD	HL/XS
16,820	351,047	76,931
18,820	371,456	81,403
20,820	397,933	87,206
20,964	399,997	87,658
Actual LL	5,521	
New LL	**9,665**	
Increase In LL	**4,144**	ft
Maximum lateral Inc	**42.88%**	

Risk Matrix Development

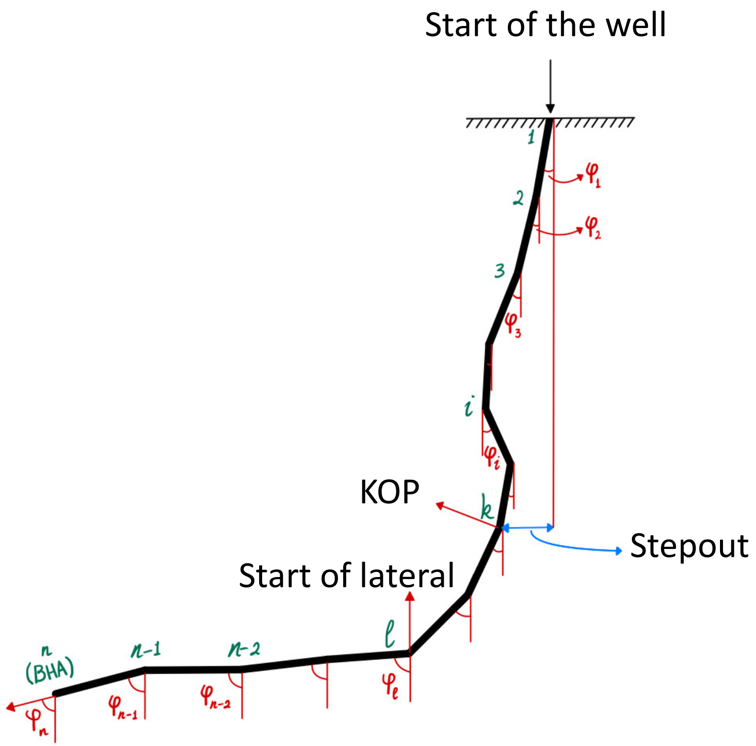
The risk matrix was developed based on an S chape well, with the consideration of various stepout distances.





Risk Matrix Development

When calculating the torque and the axial forces in the risk matrix, we considered a model of connected line segments to build the well trajectory



Risk Matrix Development

The risk matrix operates based on there types of contrains:

- Torque constraint
- Hook load constraint
- Pipe yield constraint

Torque Constraint												
Lateral Length, ft	Stepout, ft											
	0	300.0	600.0	900.0	1,200	**1,383**	1,500	1,800	2,100	2,400	2,700	3,000
3,000												
4,000												
5,000												
6,000												
7,000												
8,000												
9,000												
10,000												
11,000												
12,000												
13,000												
14,000												

Risk Matrix Development

Input of the risk matrix

Well Geometry		Drilling BHA and Block Weight		Equipment Limit	
KOP TVD, ft	10,000	OD, in	6.75	Yield Stress, 1000 psi	135.0
Planned Stepout, ft	750.0	Total Weight, 1000 lbs	9,000	Max Hook Load, 1000 lbs	289.2
Build Up Radius, ft	1,108	Block Weight, 1000 lbs	40,000	Max Surface Torque, 1000 ft-lb	24.00
Drilling Parameters		**Drill Pipe**		**Risk Matrix Format**	
Mud Type, **O**il or **W**aterbased	--	OD, in	4.50	Stepout Increment, ft	300.0
Mud Weight, ppg	8.90	ID, in	3.83	Lateral Section Increment, ft	1,000
Friction Coef, unitless	0.40	Weight, lb/ft	17.00		

Risk Matrix Development

The risk matrix operates by calculating the maximum lateral section length by while increasing the torque and hook load within the range allowed based on the pipe yield constraint gradually until reaching the first constraint. The risk matrix then halt the execution of any further calculations and output the results.

Customizable Risk Assessment

The risk matrix tool allows to customize the assessment of the risk within the risk matrix evaluation. We can choose one of two options for the risk assessment:

1. Risk assessment based on the percentage reached of the dominant constraint on the risk matrix.
2. Risk assessment based on the percentages reached of the maximum lateral section length considering the first constraint reached during the execution of the risk matrix.

Customizable Risk Assessment

Torque Constraint												
Lateral Length, ft	**Stepout, ft**											
	0	300.0	600.0	**750.0**	900.0	1,200	1,500	1,800	2,100	2,400	2,700	3,000
4,000												
5,000												
6,000												
7,000												
8,000												
9,000												
10,000												
11,000												
12,000												
13,000												
14,000												

Customizable Risk Assessment

Hook Load Constraint												
Lateral Length, ft	**Stepout, ft**											
	0	300.0	600.0	**750.0**	900.0	1,200	1,500	1,800	2,100	2,400	2,700	3,000
7,000												
8,000												
9,000												
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11,000												
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14,000												