University of Basrah

College of Engineering

Department of Petroleum

2020-2021

4th Year

Casing Wear

“ Names of Students ”

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Abstract

In some situations, while drilling through severe doglegs, drill strings are inevitably touching the inner wall of casing, which may wear casing harshly. For instance, this is a frequent problem in wells drilled in Bohai Bay basin in East China. In large dogleg sections of the well, casing is subjected to a dual-wear accumulation contributed by the tool joint and drill pipe (alternate wearing). Non planar geometry of the hole and complex geometry of the rotating drill pipe may add to the complexity of the wear process. Here, we propose a mathematical model to calculate the loss of wall thickness of the casing due to the dual wear. A finite element model is developed to incorporate wearing of the casing alternating between the tool joint and the drill pipe. Arbitrary Lagrange-Eulerian (ALE) adaptive meshing and remapping technique is utilized to specify the ablation velocity vectors at the inner casing surface. Our numerical results show that the dual wear contributions and ever-changing contact geometry in alternate wearing intensifies the rate of the casing wear 150% faster than that of the single wear models. Additionally, the curvature at point with maximum wear depth has been found to significantly impact the maximum stress of worn casing. This paper provides an accumulative wear model for accurate prediction of the casing wear and its residual strength before running the casing through the dogleg section.

Field tests indicate that this casing wear monitoring technique based on detection of tool joints can calculate the well casing wear volume (or weight) at any depth easily, its monitoring and computation are simple and the process has no impact on drilling, so it is suitable method for field operations.

Introduction

In recent years, drilling directional and horizontal wells with complicated trajectories and large doglegs have become a common practice especially for exploration and development of unconventional hydrocarbon reservoirs. However, directional drilling has also been used for various purposes such as drilling relief wells, drilling multiple wells from a single pad, or sidetracking from the wells with fishing problems. Therefore, the increasing complexities of directional wells escalate the potential risks for casing integrity, which may lead to well leakage or even well plugging and abandonment before starting production. Therefore, accurate prediction of the casing wear in large doglegs can be critical to save the well and avoid unnecessary costly aftermaths. Bradley et al. (1975) was one of the early references that documented the severe casing wear problem in directional wells, and conducted casing wear experiments under different operational conditions. Through the laboratory and field studies, the rotation of drill string is identified as the major reason for casing wear, and wear volume may obviously increase due to the concentrated contact loads in the doglegs. Best (1986) classified casing wear caused by drill string rotation as typical adhesive wear and abrasive wear. Through lab testing in field conditions, Best proposed that smooth, round and uniform surface of tool joint hard facing may help to achieve a maximum contact area at minimum contact stress. Additionally soft solid particles of drill mud may form a layer in the tool joint/casing contact region to avoid the metal-to-metal contact. White and Dawson (1987) used the full-scale wear-test machine to conduct the casing wear experiment for different steel grades, drilling fluid properties and contact loads. He proposed a linear casing wear-efficiency model that is based on the frictional work loss of the casing metal during the wear process. After75 times eight-hour casing wear tests, Hall et al.

Causes of Casing Wear

To analyze the forces behind casing wear, we need to study the torque and drag (T&D) of the drill pipe during drilling operations. The basic mathematical and physical model of T&D has not changed significantly since Johancsik et al. published their paper on T&D prediction. Any pipe movement in the deviated wellbore produces T&D along the pipe. Basically, axial movements such as drilling ahead or tripping creates drag, while rotation produces torque. The magnitude of T&D is determined by the combination of these two movements. While tripping operation causes drag. pipe rotation shifts the resistance from drag to torque.

Since the so-called vertical well virtually does not exist (the whirring action of the bit always creates a micro-helical shape of the well path), the contact of the drill pipe and its tool joint with the casing ID is unavoidable. The gravitational force acting on the drill pipe is always trying to pull the pipe to the lower side of the wellbore, while the axial tension on the drill pipe, in a build-up section, tends to push the pipe to the upper side of the wellbore. Depending on the pipe weight, dogleg severity, and axial force along the pipe, the drill pipe either touches the upper or lower side of the wellbore.

Typical T&D analysis starts by dividing the pipe into small elements. Calculation begins from the bottom element of the pipe, where weight on bit (WOB) and torque on bit (TOB) are expected. For each element, force and torque are balanced and the T&D at the top of the element are calculated. From bottom to top, calculations are performed for each pipe element, until it reaches the rig floor. This step-by-step calculation also determines the direction and magnitude of the side force, which pushes the drill pipe against the wellbore as shown in Figure 1.

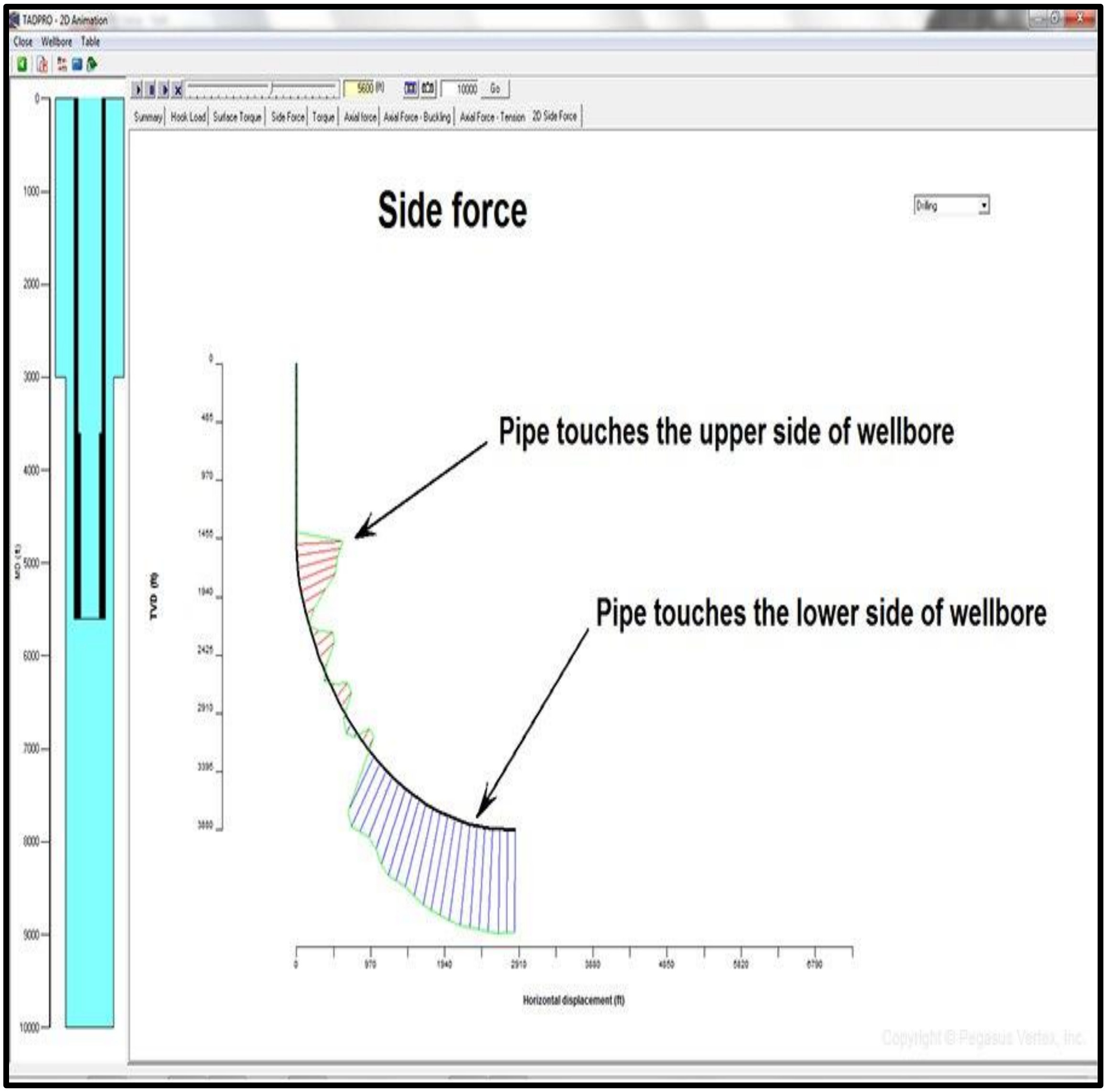


Figure1. Snapshot of side force along a drill

Prediction

1. Wear Mechanism

The casing wear model applied in CWPRQ (casing wear prediction software developed by PVI) assumes that the metal volume worn away in a wear groove section is proportional to the frictional energy transmitted to the casing by a rotating tool joint as shown in Figure 2.The transmitted frictional energy is defined in this formula:

$$\mathbf{E = \mu \times SF_{dp} \times SD}$$

Where:

E= Frictional Energy, Ib-ft

μ = Friction factor, dimensionless

SF_{dp} = Side force on tool joint per foot, lbt/ft

SD = Sliding distance traveled by the tool joint against casing wall, in

The volume of casing wall removed per foot in time t hours is mathematically expressed in the equation:

$$\mathbf{WV = WF \times SF_{dp} \times \pi \times D_{tj} \times 60 \times N \times t}$$

Where:

WV=Casing wear volume per foot, in^3/ft

WF = Wear factor, E-10psi^{-1}

SF_{dp} = Side force on drill pipe per foot, Ibt/t

D_{tj} = Tool joint OD, in

N= Rotary speed, rpm

t= Rotating time, hr

For a typical water-based mud, WF can vary as follows:

Normal or low: 3-7

Medium: 8-13

High: 14 -20

WF above 20 can be considered as very high and may cause severe casing damage.

Prediction

2-Wear Geometry

A typical wear groove is shown in the following figure:

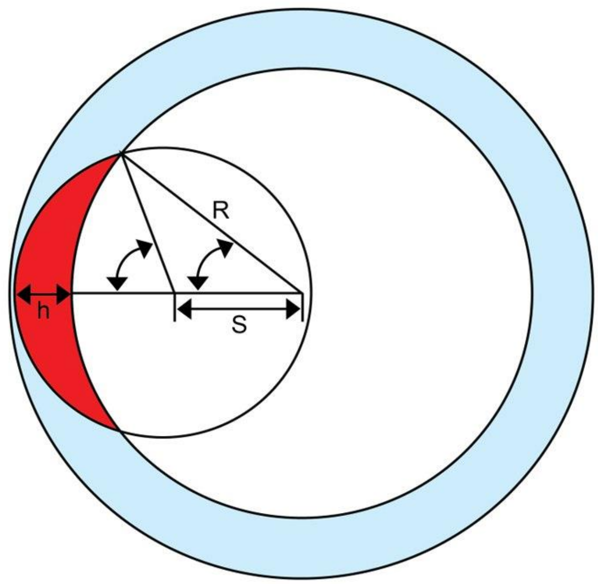


Figure2. Casing Wear Groove

The relationship between wear depth and casing wear volume is:

$WV=12(\beta r^{2}+ (P(P- R)(P-r)(P-S)-aR^{2}))^{2}$

Where:

WV = casing wear volume per foot, in^3/ft

h= wear depth, in

r=tool joint outer radius, in

R= casing inner radius, in

$S=R-(r - h)$, in

$P= (R+r+S)/2$, in

$\cos a = (R^{\circ}+S^{2}-r^{2})/2RS$

$B= \arctg(R x \sin a/R \ x \cos a-S)$

Prediction

3-Wear Factor

The definition of wear factor is the ratio of friction factor to specific energy, which is the amount of energy required to remove a unit of steel. The unit for wear factor is E-10psi; therefore, when a wear factor is reported as 8, the actual value used in casing wear calculation is $8E\text{-}10psi^{-1}$.

Quite a few experiments were conducted to find the casing wear factors under different mud systems, tool joint materials, casing interior and drill string protectors. Among them, Maurer Engineering Inc. conducted a joint-industry project DEA-42. It was reported that more than 300 laboratory tests were performed under DEA-42 to determine the wear factors for various drilling conditions.

The following is a schematic drawing of a casing wear testing machine.

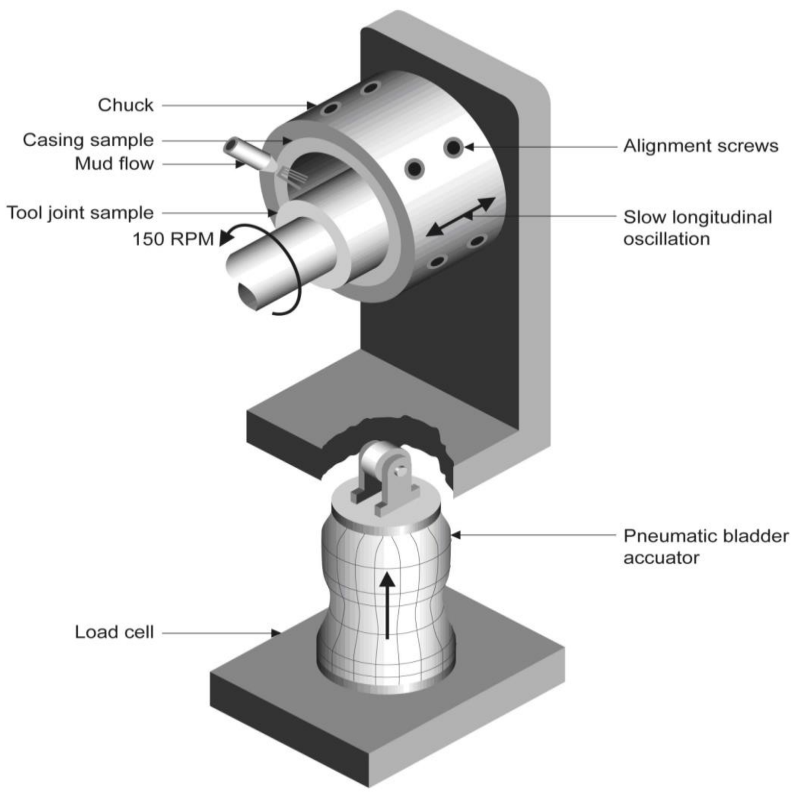
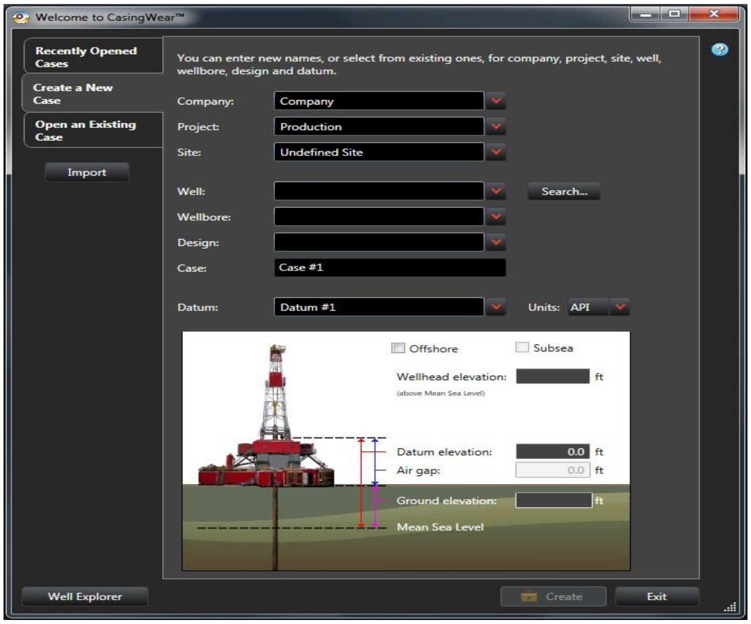


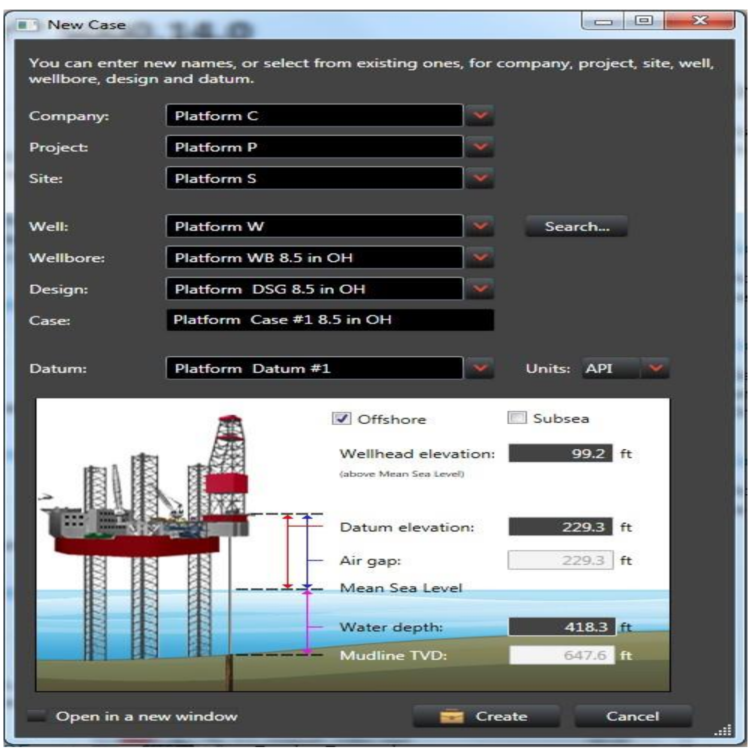
Figure- 4. Casing Wear Testing Machine

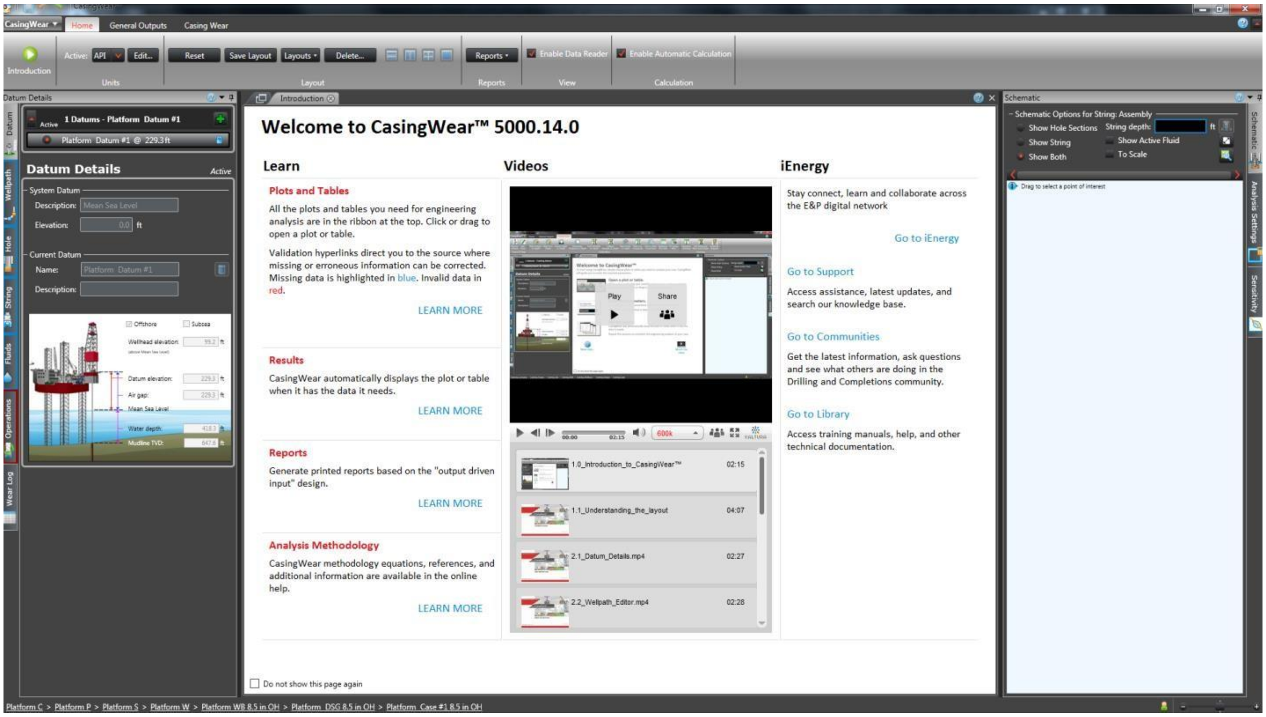
The Steps of Working Casing Wear

1-Select create a new Case

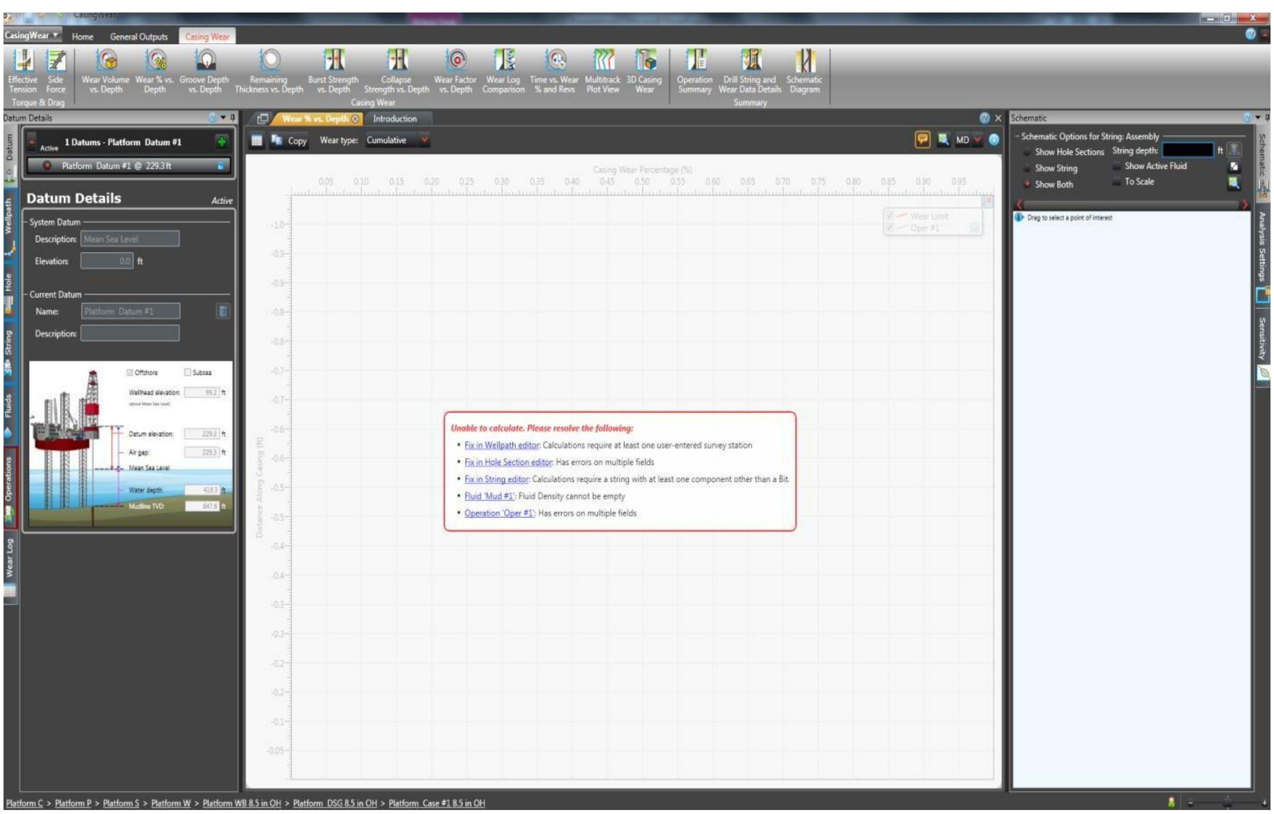


2- Define the well general information as shown below **> Click Create button** Note: **Use API units**

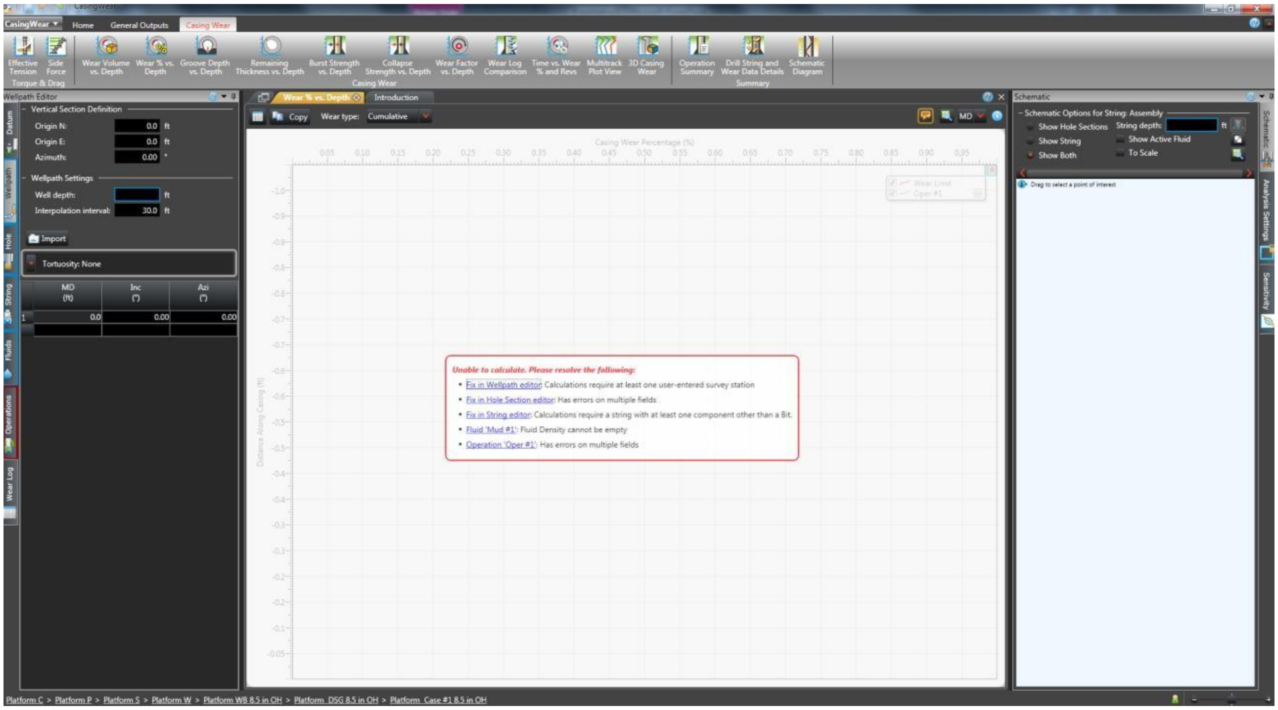


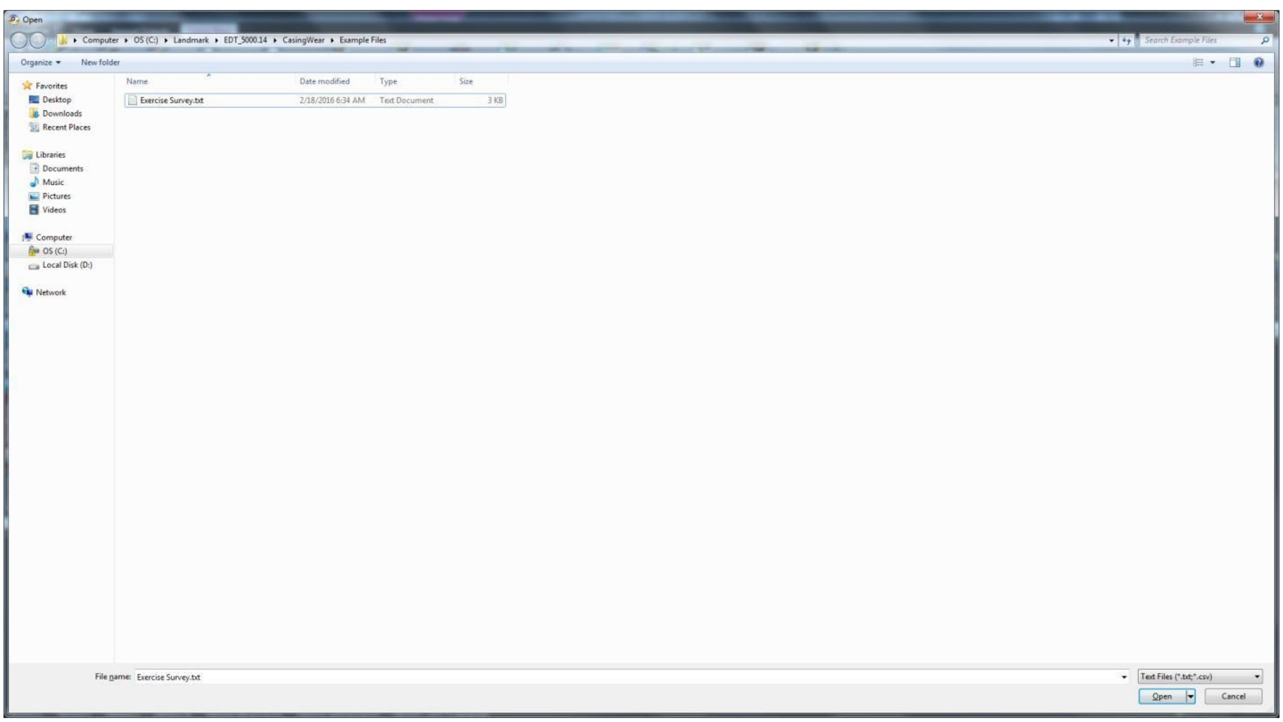


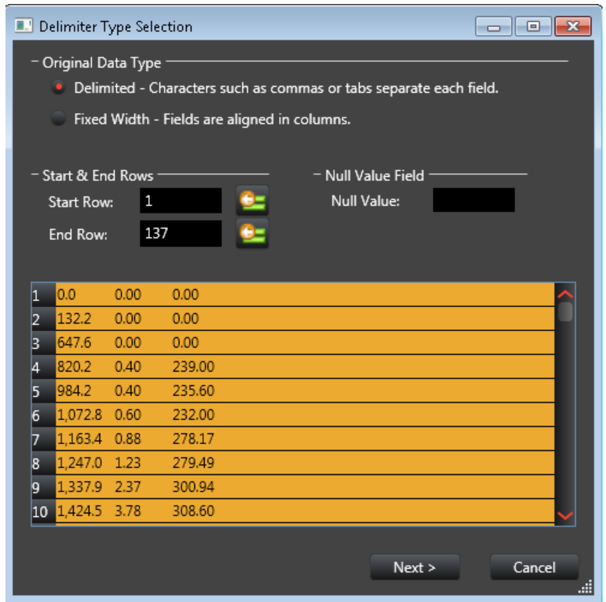
1- Select Casing Wear tab on the main application ribbon > Select Wear % vs. Depth Plot.



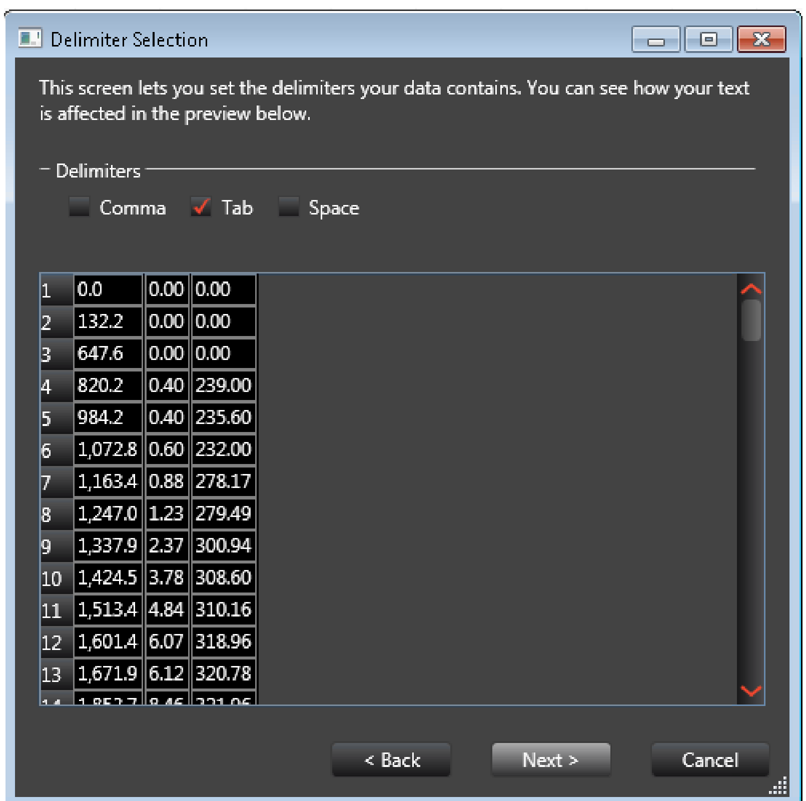
2-Select Fix in Wellpath Editor Hyperlink > **click on Import button**, find in C:\Landmark\EDT_5000.14a local Casing Wear Example files folder and select "Exercise_survey.txt" txt provided with this example.



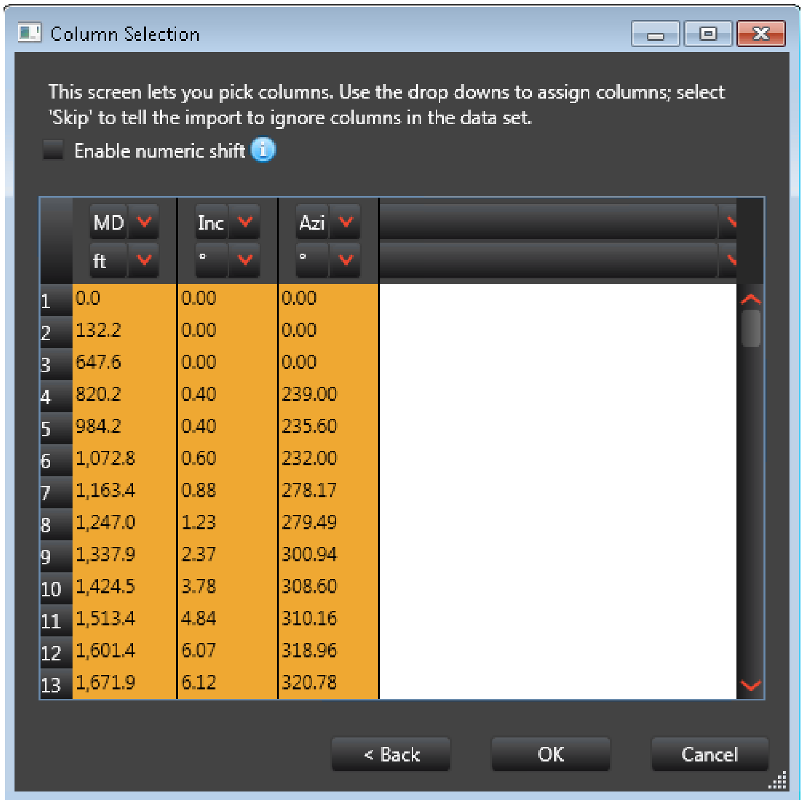




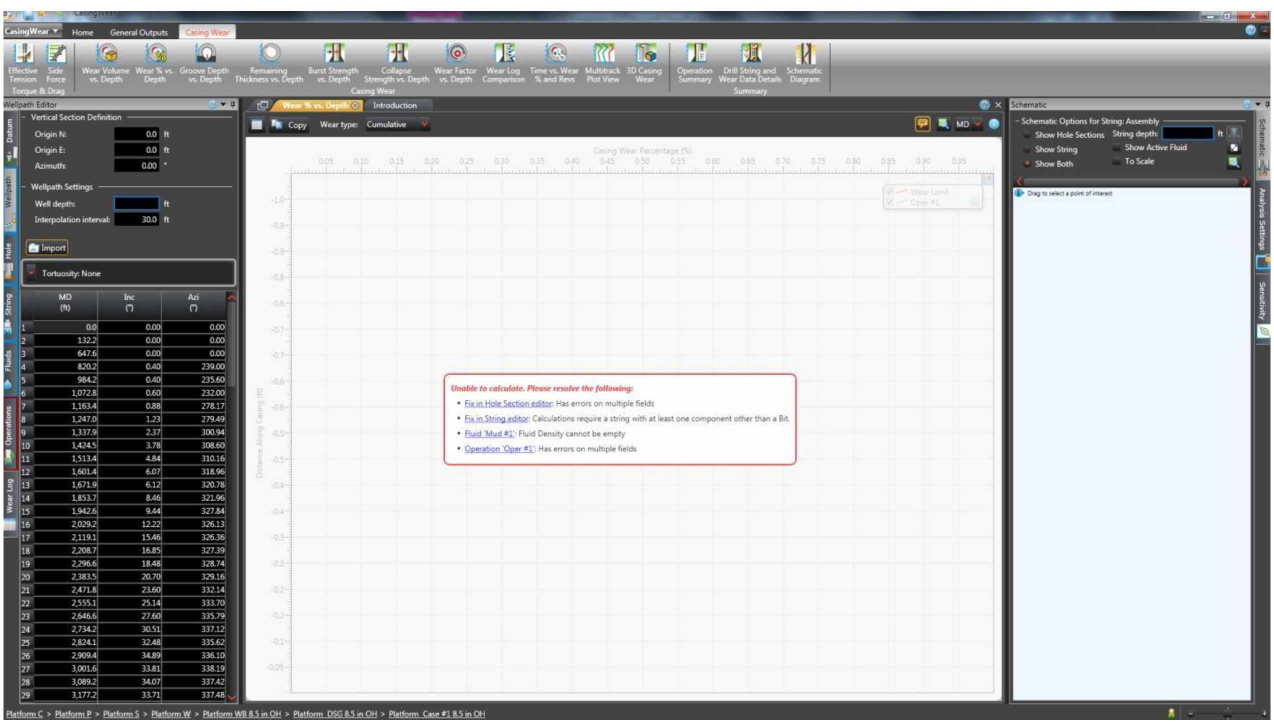
Observe: data text presentation while a tab delimiter is applied. **Click Next button**.



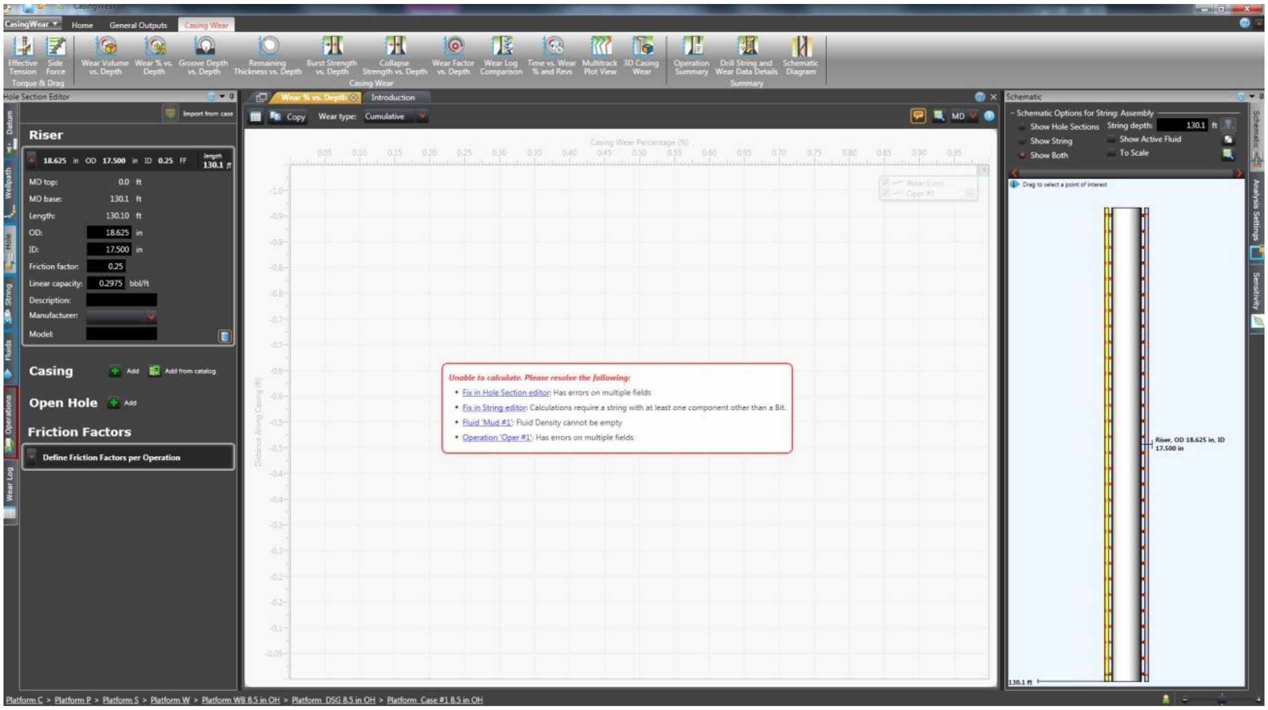
3-Select columns that represent MD (**ft. units**), Inclination and azimuth (**degrees units**) as shown below, **click OK button**



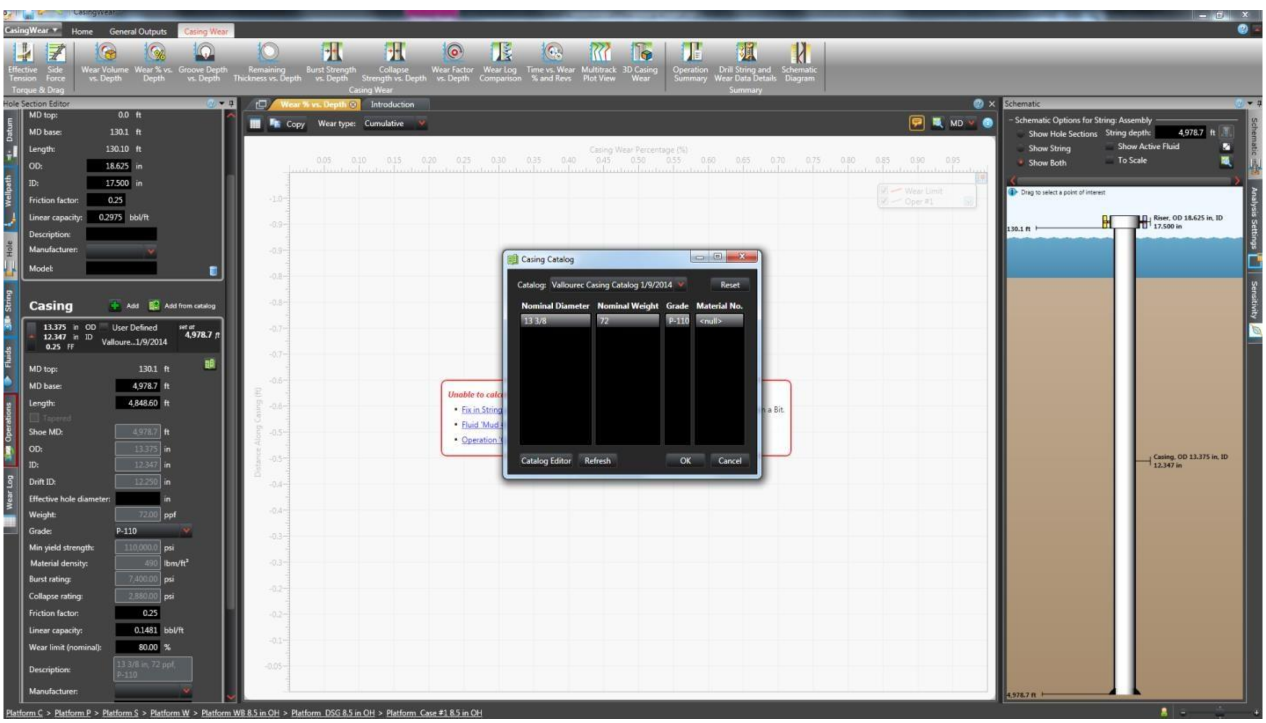
Select Fix in Hole Section editor hyperlink



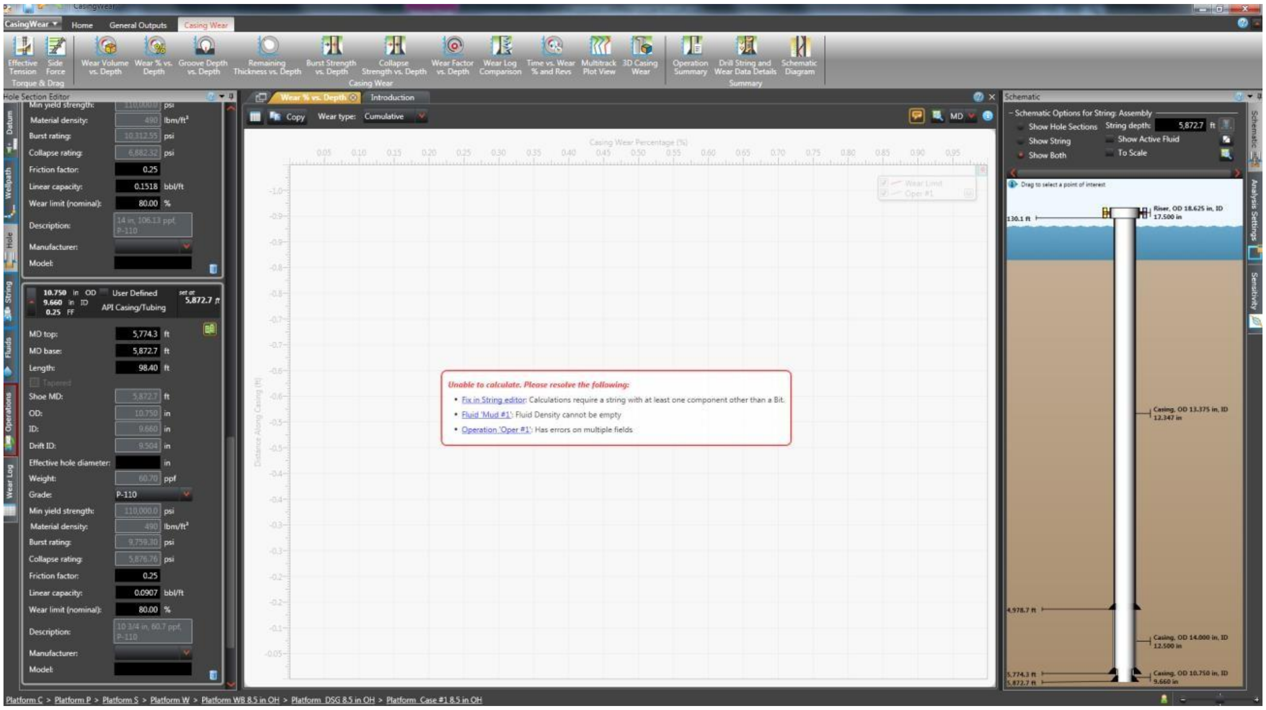
4-Click Riser "+" > Enter a short pipe section as shown below.



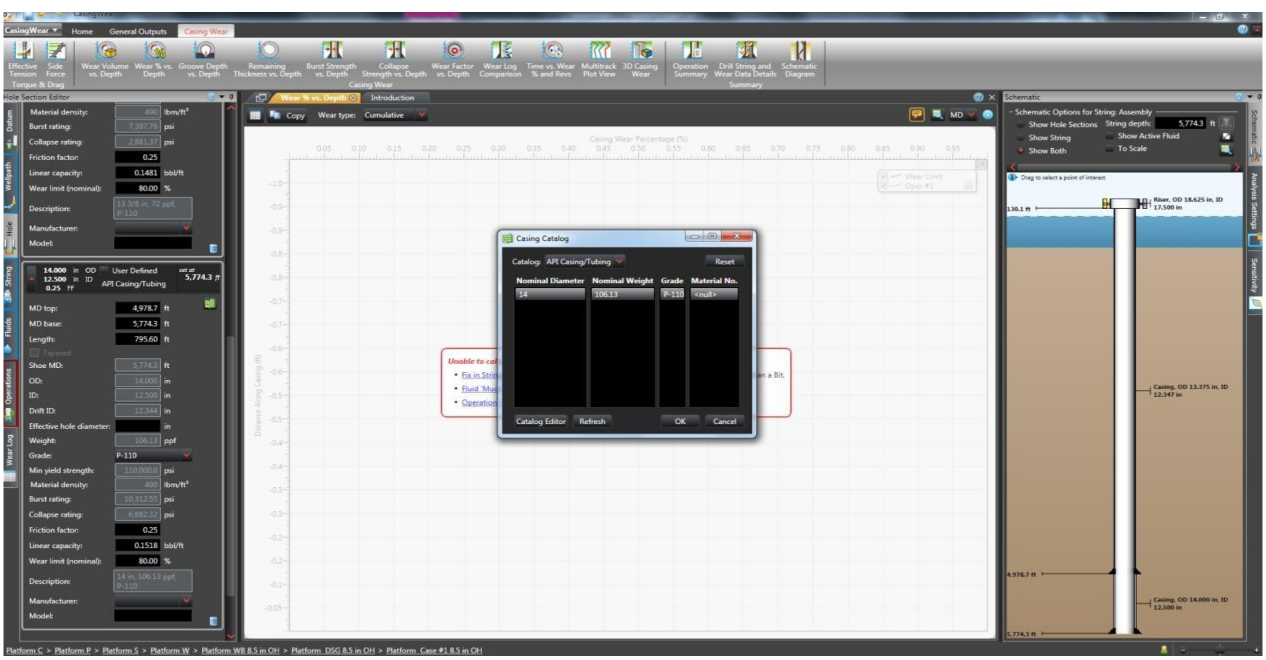
5-Click Casing "+" > enter a casing section MD TOP 130.10 ft.; MD base : 4978.7 ft. Use the catalog editor (API Casing/Tubing catalog) and select a 13 3/8" in OD, 72 ppf weight, P-110 Grade Casing as shown below; once selected click OK button



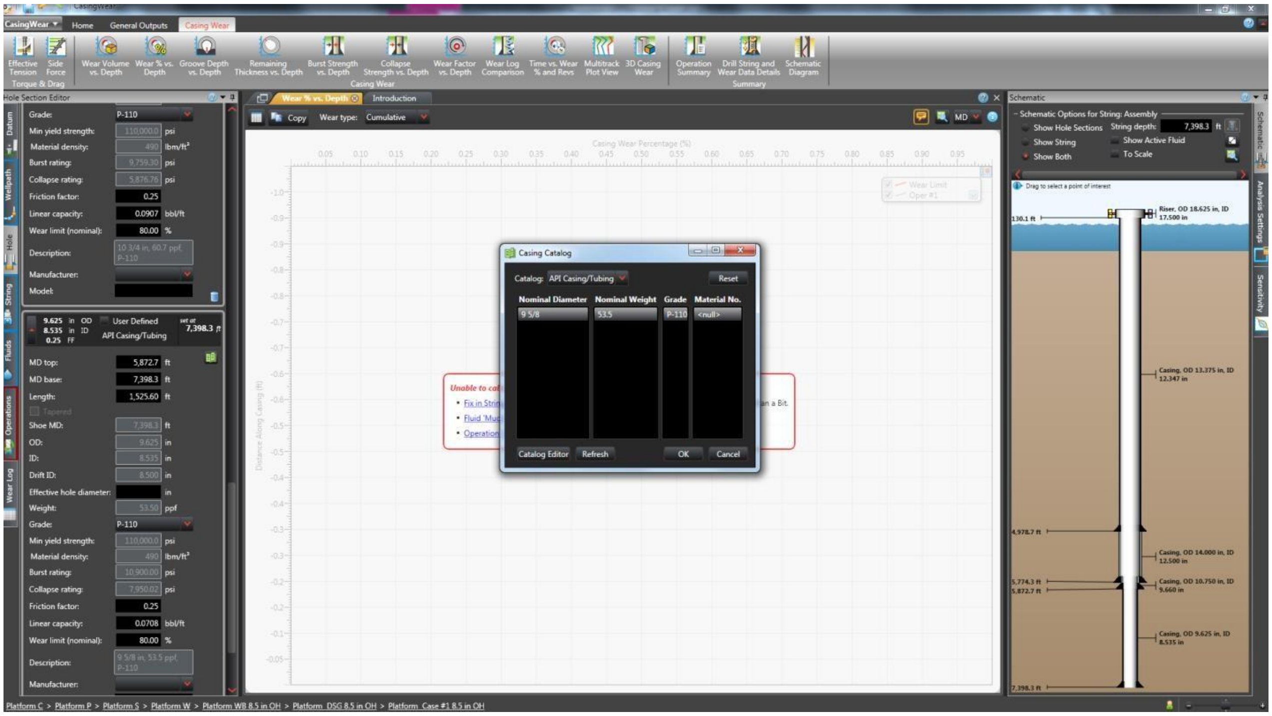
7-Click Casing "+" > enter a short top liner section MD Top: 5774.3 ft.; MD Base: 5872.7 ft. Use the catalog editor and select a 10 3/4 in OD, 60.7 ppf weight, P-110 Grade pipe as shown below



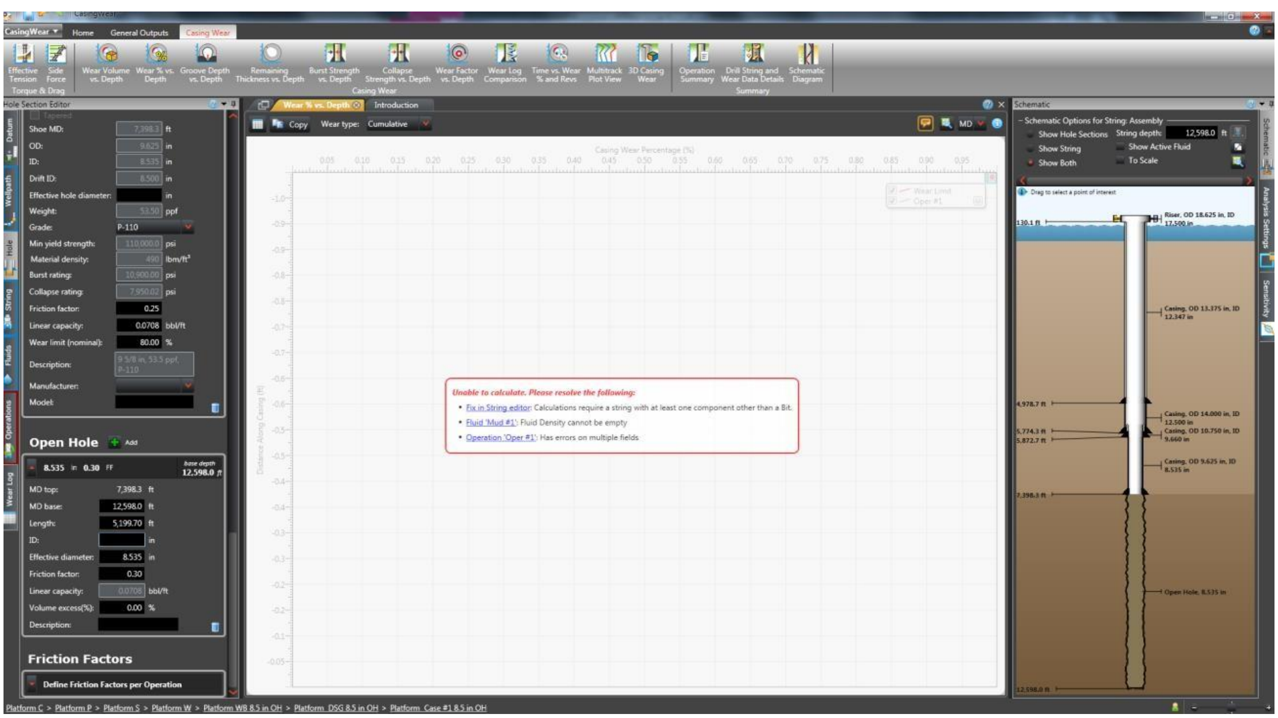
6-Click Casing "+" > enter a casing section #2; MD Top at 4978.7 ft.; MD Base at 5774.3 ft. Use the catalog editor and select a 14 in OD, 106.13 ppf weight, P-110 Grade pipe as shown below.



8-Click Casing "+" > enter a lower liner section MD Top: 5872.7 ft.; MD Base: 7398.3 ft. Use the catalog editor and select a 9 5/8" in OD, 53.5 ppf weight, P-110 Grade pipe as shown below.

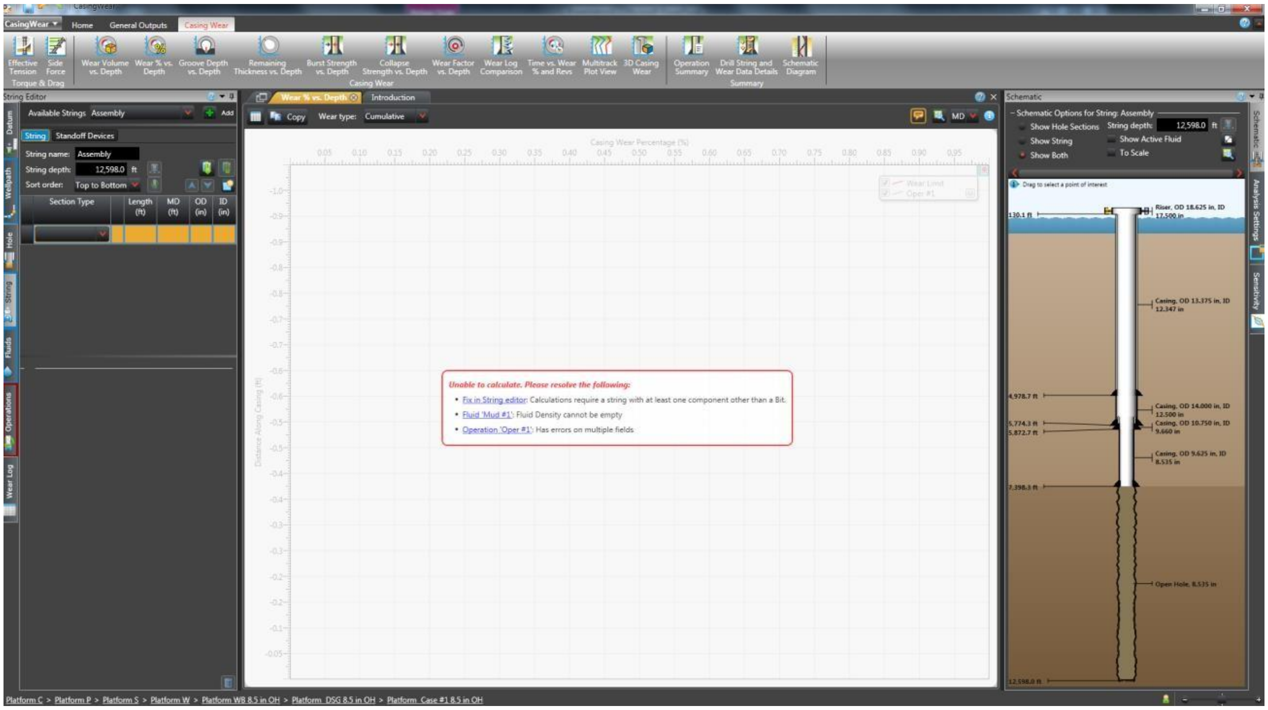


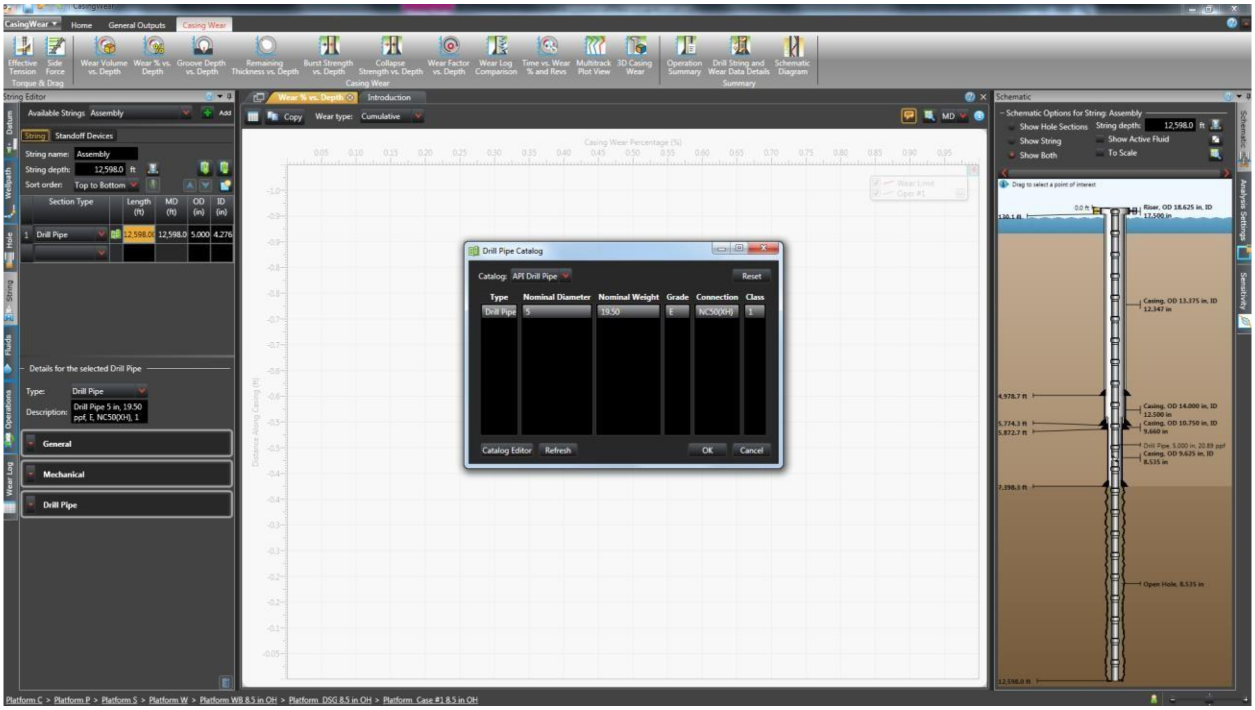
9-Click "+" Open Hole > define an open hole MD base to 12,598.4 ft.

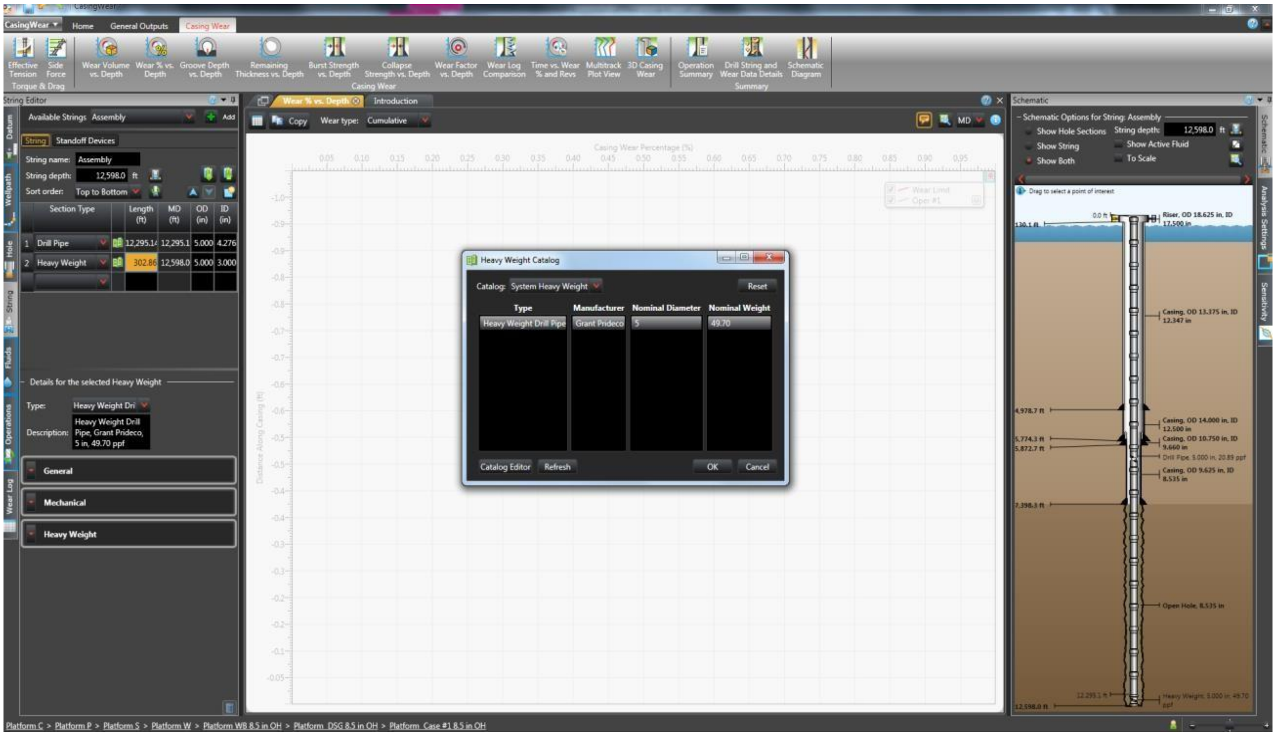


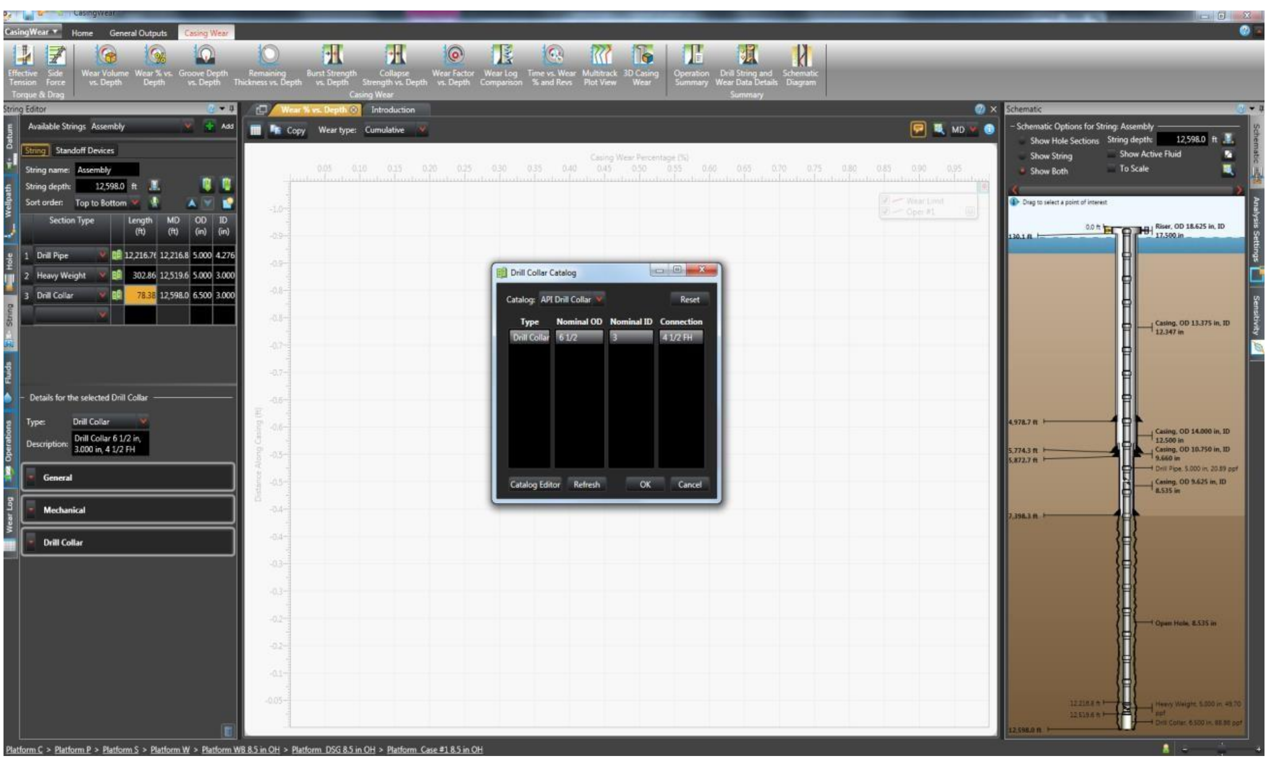
10-Click Fix in String editor hyperlink; define a drill string configuration.

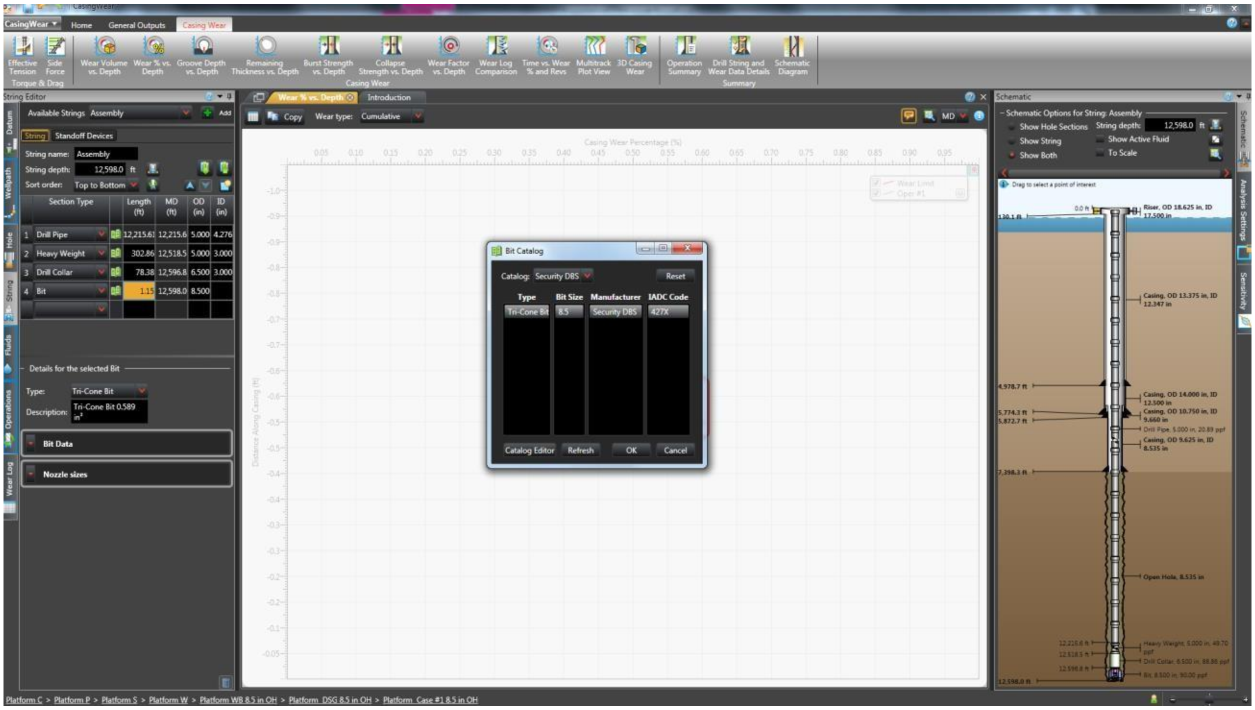
1. Define the following String components section types as shown below





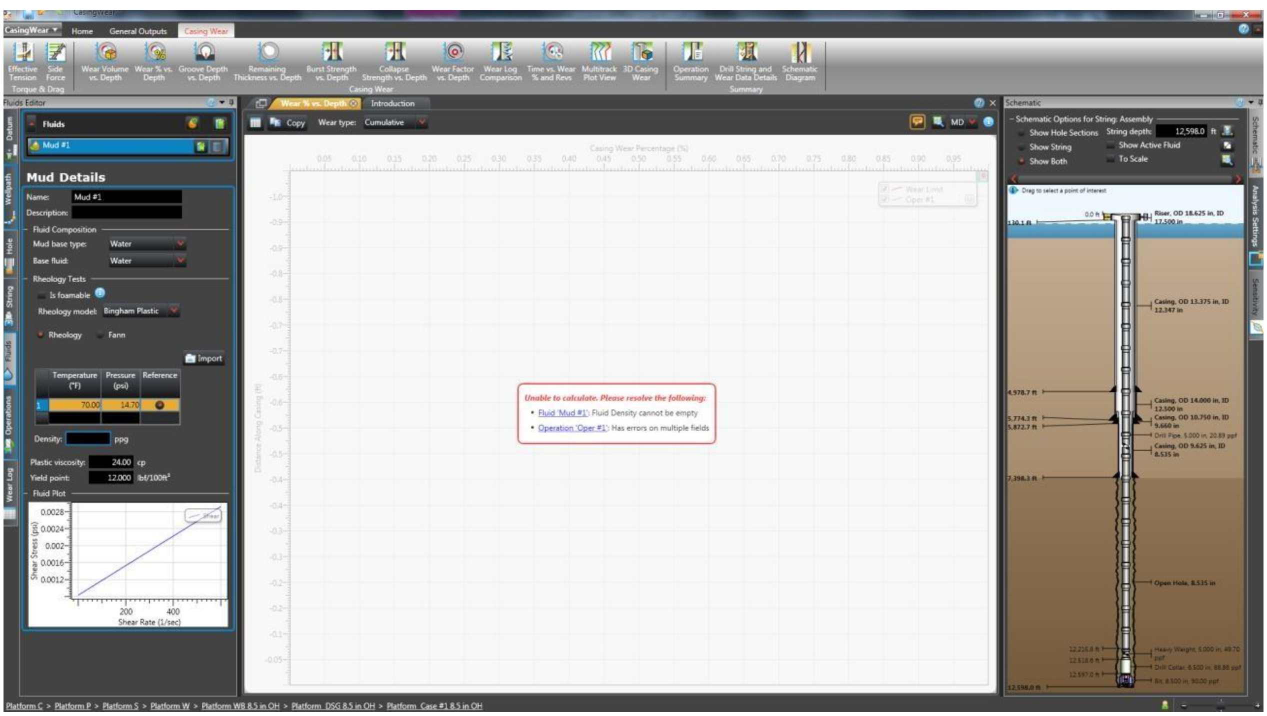

CasingWear
Home
General Outputs
Casing Wear
String Editor
Available Strings Assembly
String
Standoff Devices
String name: Assembly
String depth: 12,598.0 ft
Sort order: Top to Bottom
Section Type
Drill Pipe
Heavy Weight
Details for the selected Heavy Weight
Type: Heavy Weight Dri
Description: Heavy Weight Drill Pipe, Grant Prideco, 5 in, 49.70 ppf
General
Mechanical
Heavy Weight
Wear % vs. Depth
Introduction
Copy
Wear type: Cumulative
Casing Wear Percentage (%)
Heavy Weight Catalog
Catalog: System Heavy Weight
Reset
Type
Manufacturer
Nominal Diameter
Nominal Weight
Heavy Weight Drill Pipe
Grant Prideco
5
49.70
Catalog Editor
Refresh
OK
Cancel
Schematic
Show Hole Sections
Show String
Show Both
Show Active Fluid
To Scale
Platform C > Platform P > Platform S > Platform W > Platform WB 8.5 in OH > Platform DSG 8.5 in OH > Platform Case #1 8.5 in OH


CasingWear
Home
General Outputs
Casing Wear
String Editor
Available Strings Assembly
String
Standoff Devices
String name: Assembly
String depth: 12,598.0 ft
Sort order: Top to Bottom
Section Type
Drill Pipe
Heavy Weight
Drill Collar
Details for the selected Drill Collar
Type: Drill Collar
Description: Drill Collar 6 1/2 in, 3.000 in, 4 1/2 FH
General
Mechanical
Drill Collar
Wear % vs. Depth
Introduction
Copy
Wear type: Cumulative
Casing Wear Percentage (%)
Drill Collar Catalog
Catalog: API Drill Collar
Reset
Type
Nominal OD
Nominal ID
Connection
Drill Collar
6 1/2
3
4 1/2 FH
Catalog Editor
Refresh
OK
Cancel
Schematic
Show Hole Sections
Show String
Show Both
Show Active Fluid
To Scale
Platform C > Platform P > Platform S > Platform W > Platform WB 8.5 in OH > Platform DSG 8.5 in OH > Platform Case #1 8.5 in OH

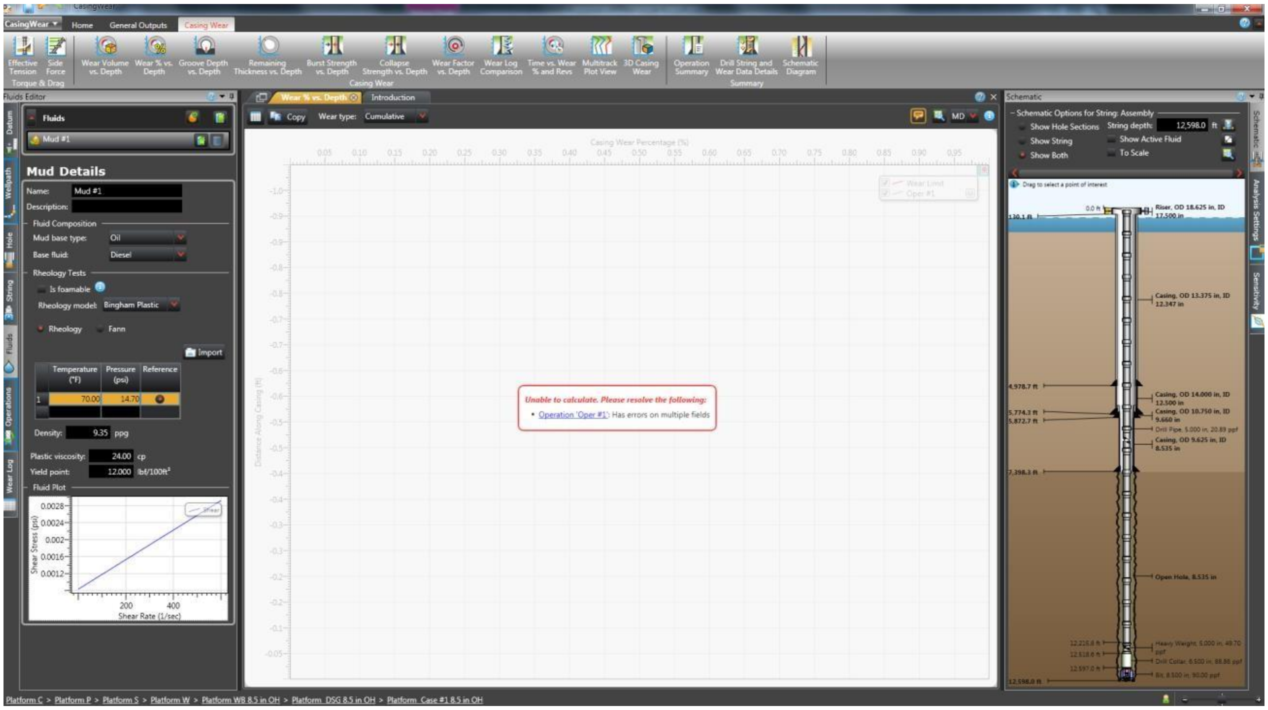


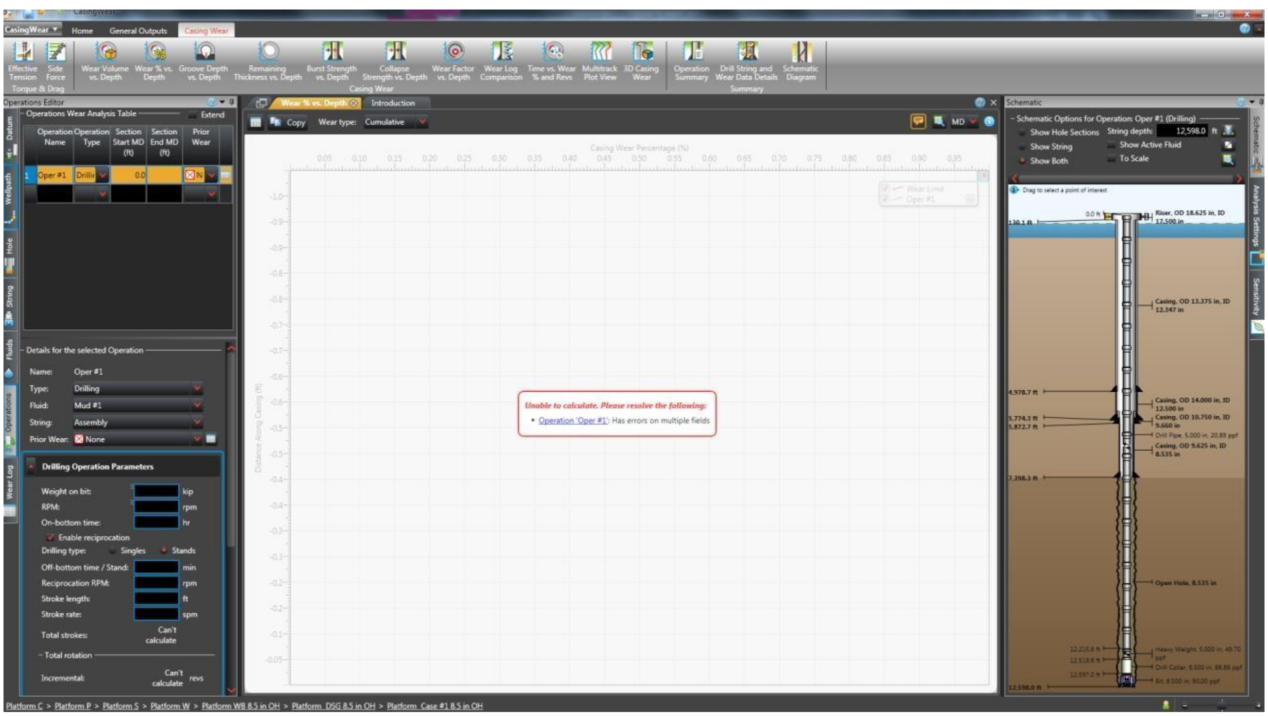
2-Click Fluid #1 hyperlink > define the 8.5" Open Hole drilling fluid density.

Enter Fluid name: Mud #1

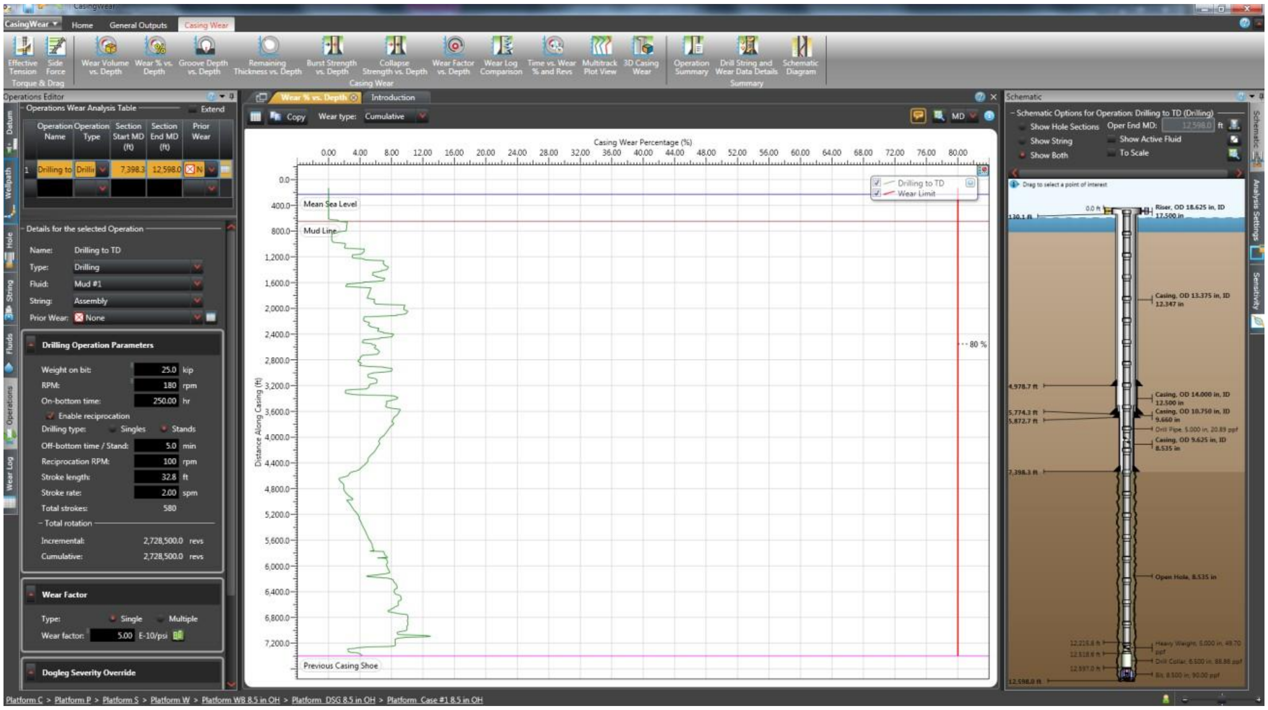


3-Click Operations Oper #1 hyperlink;

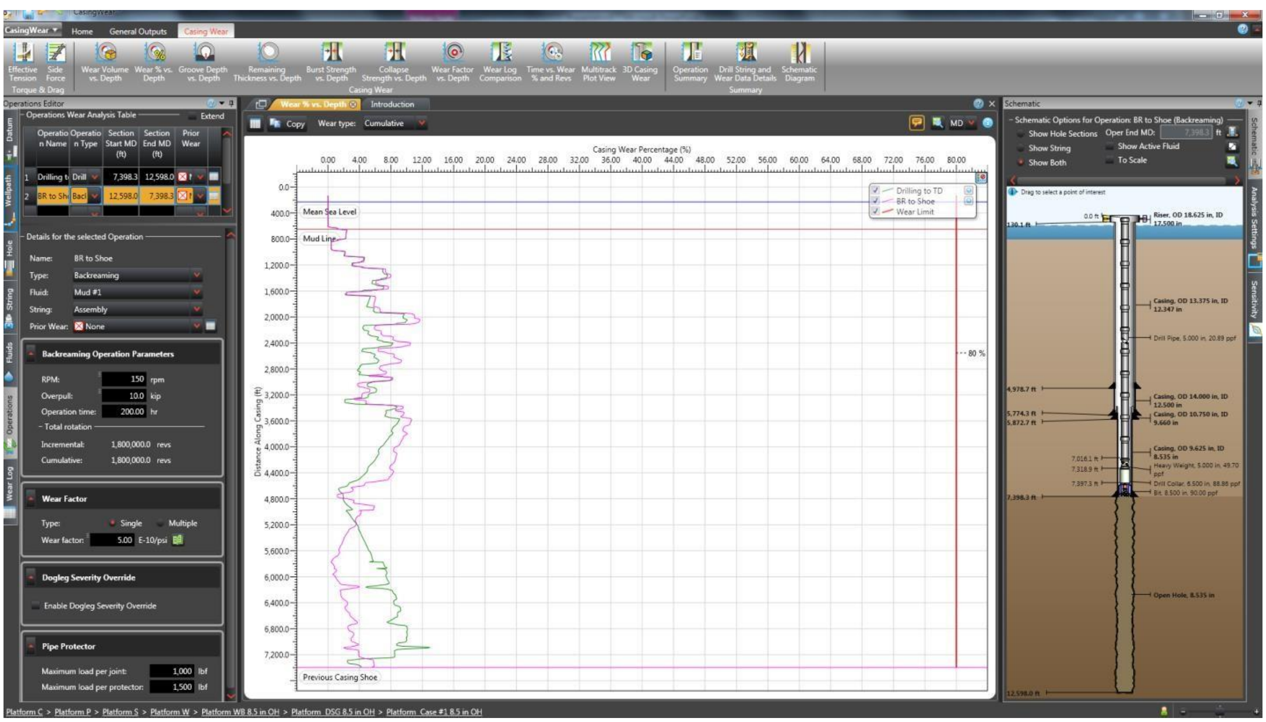




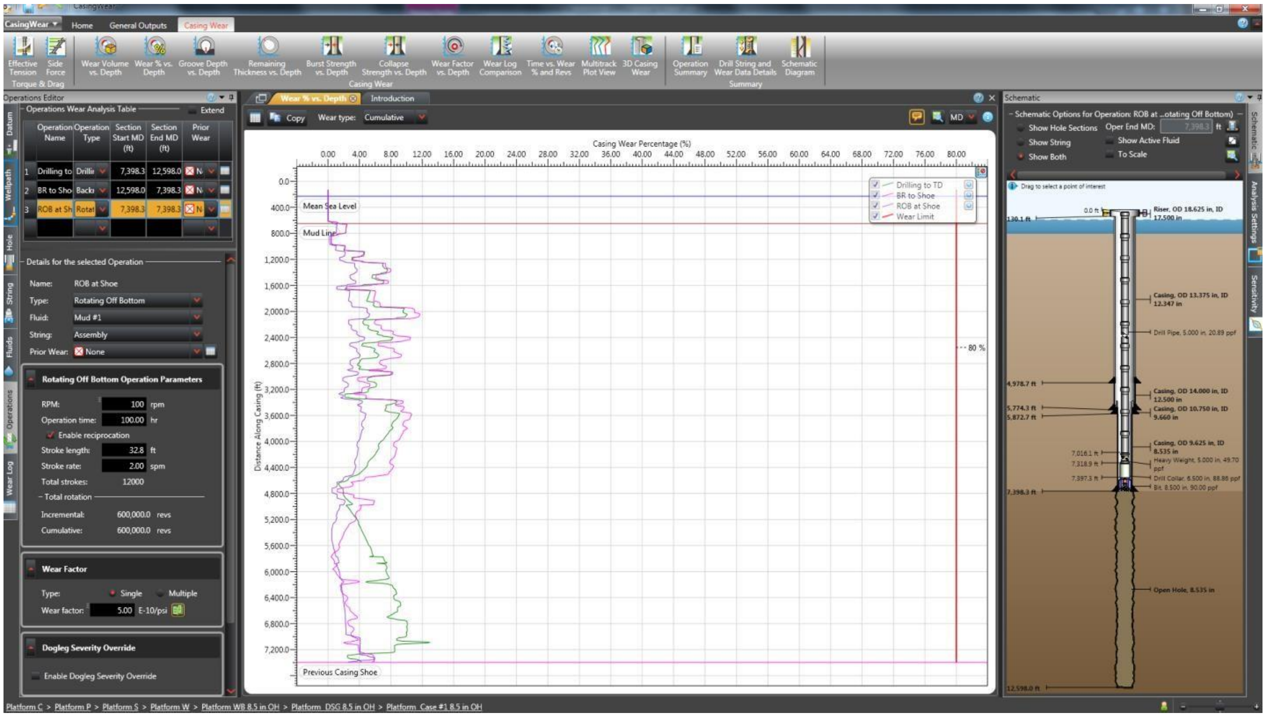
3-Enter Operation “**Drilling to TD**” Operation type Drilling, details as shown below



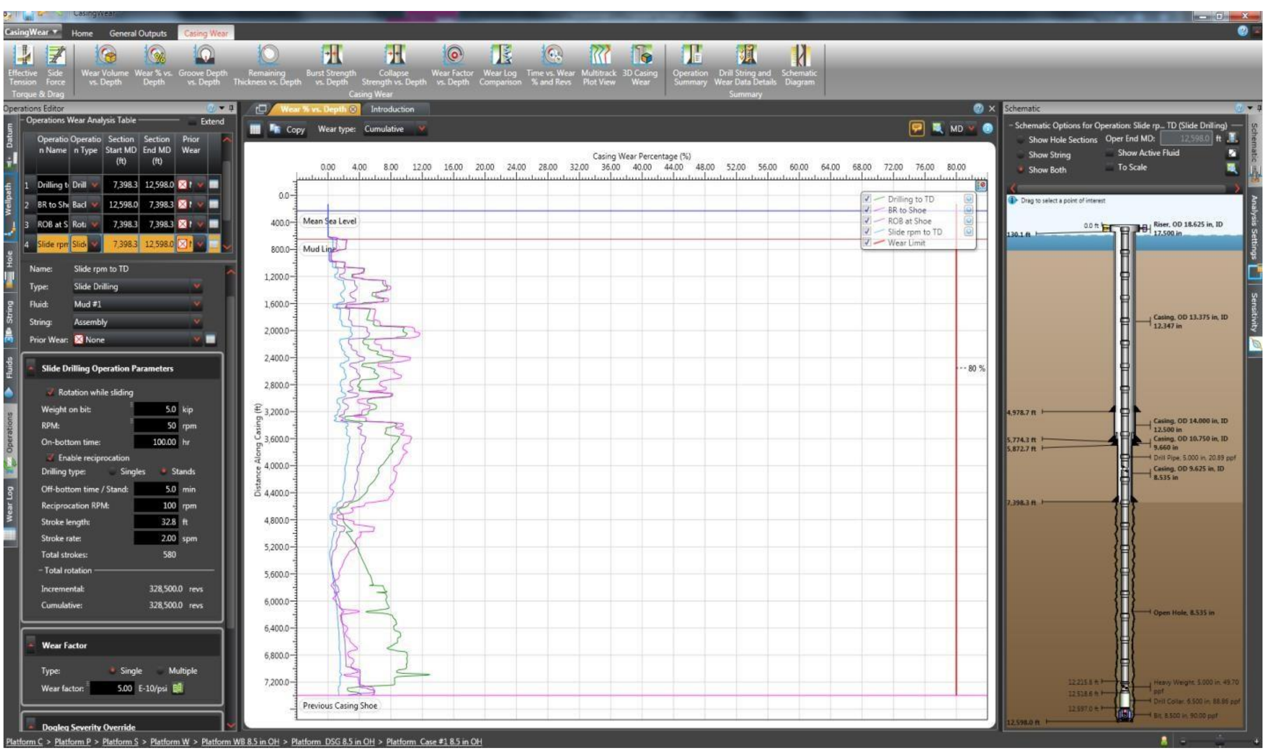
4-Enter Operation “**BR to Shoe**”, Operation type Back-reaming, details as shown below



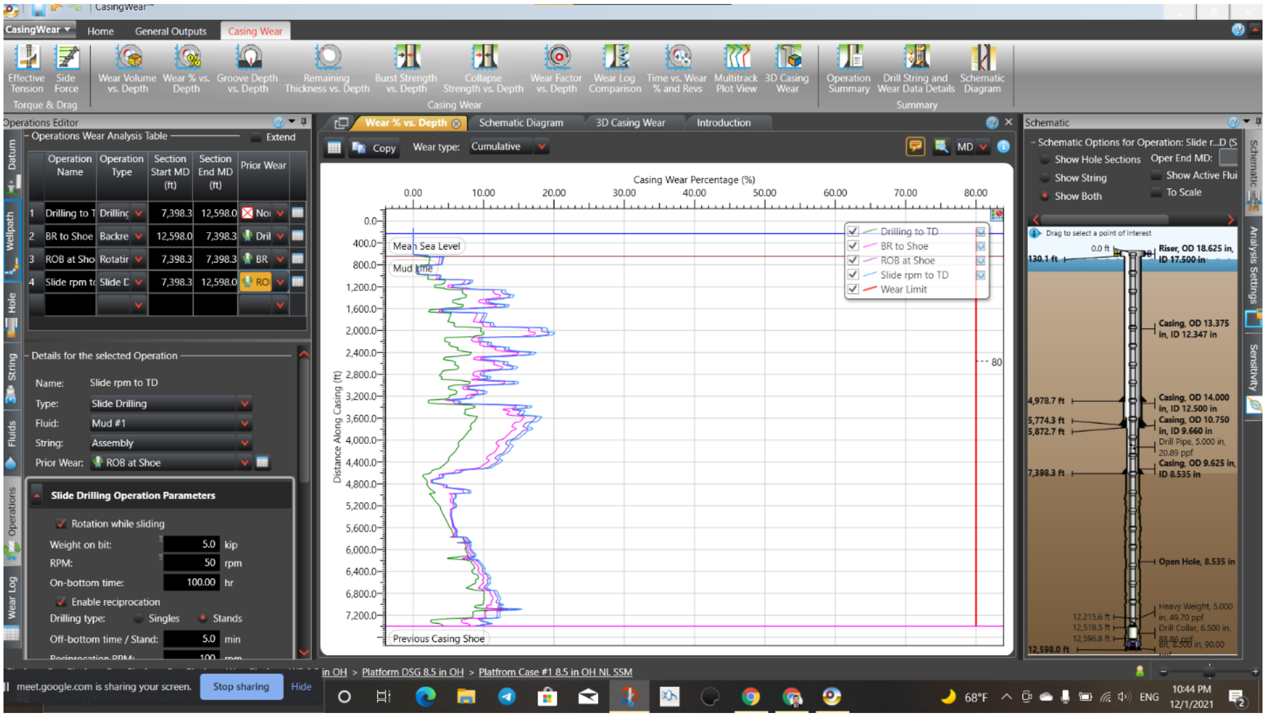
5-Enter operation "ROB at Shoe",



6-Enter operation "Slide rpm to TD", Operation type Slide; details as shown below

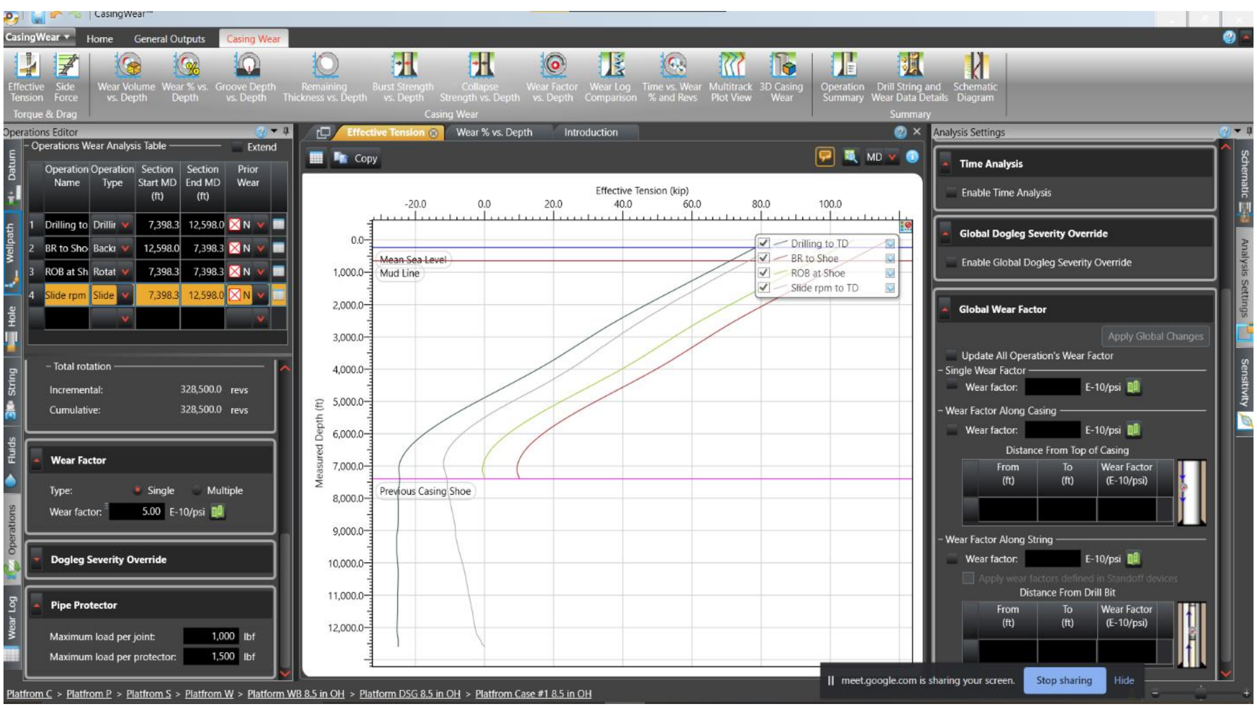


7-Click **Analysis Setting** on the right side of the Casingwear™ window.

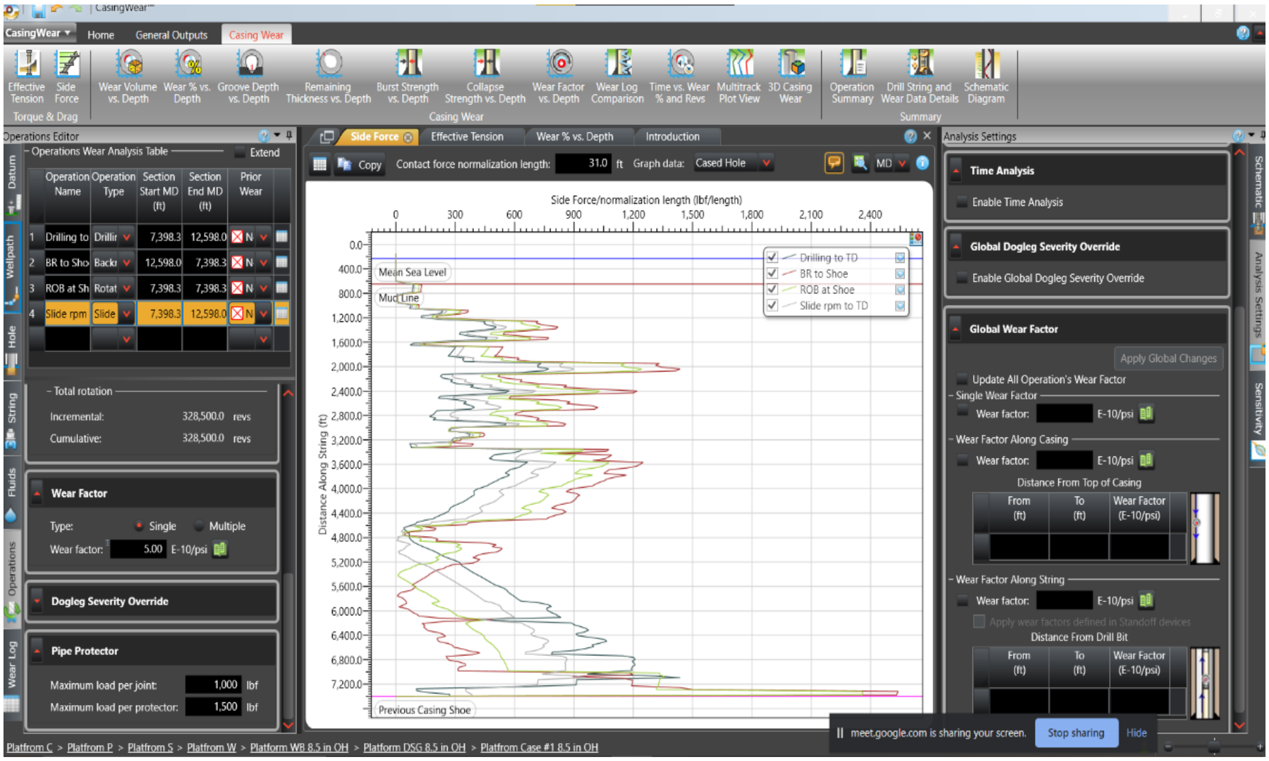


8-Casing Wear Plots

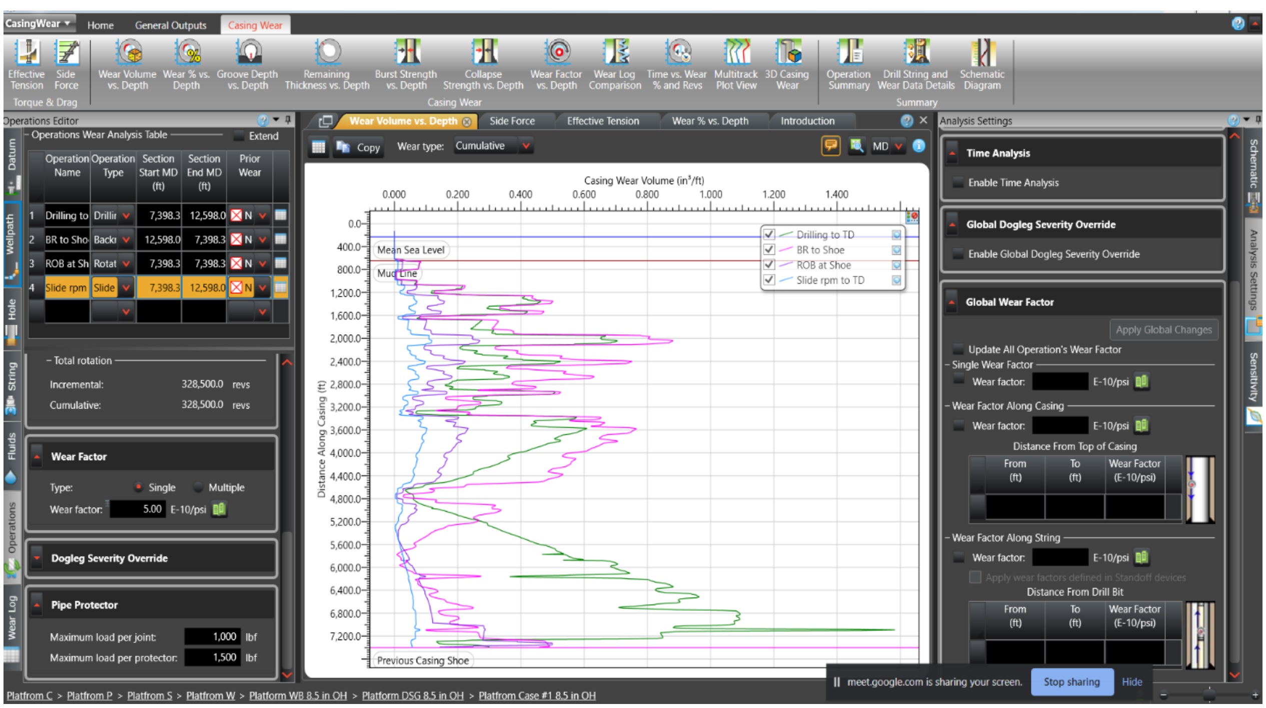
Select Effective Tension plot result



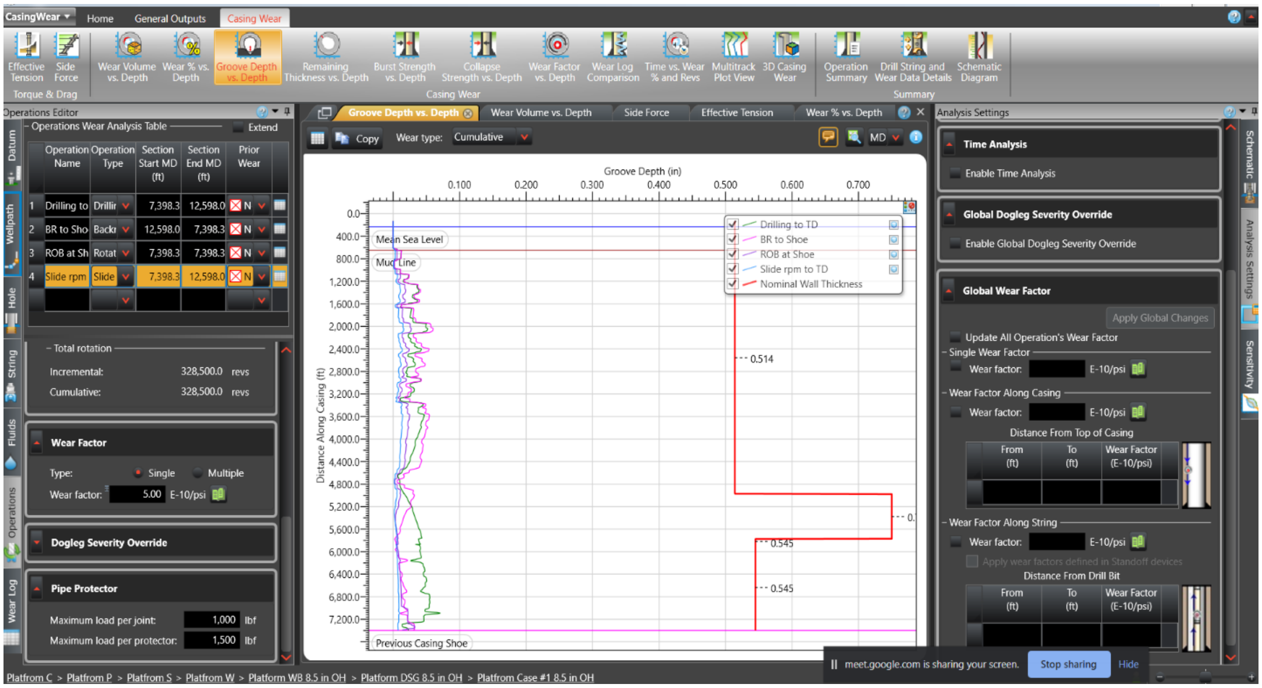
9-Select Side Force plot results



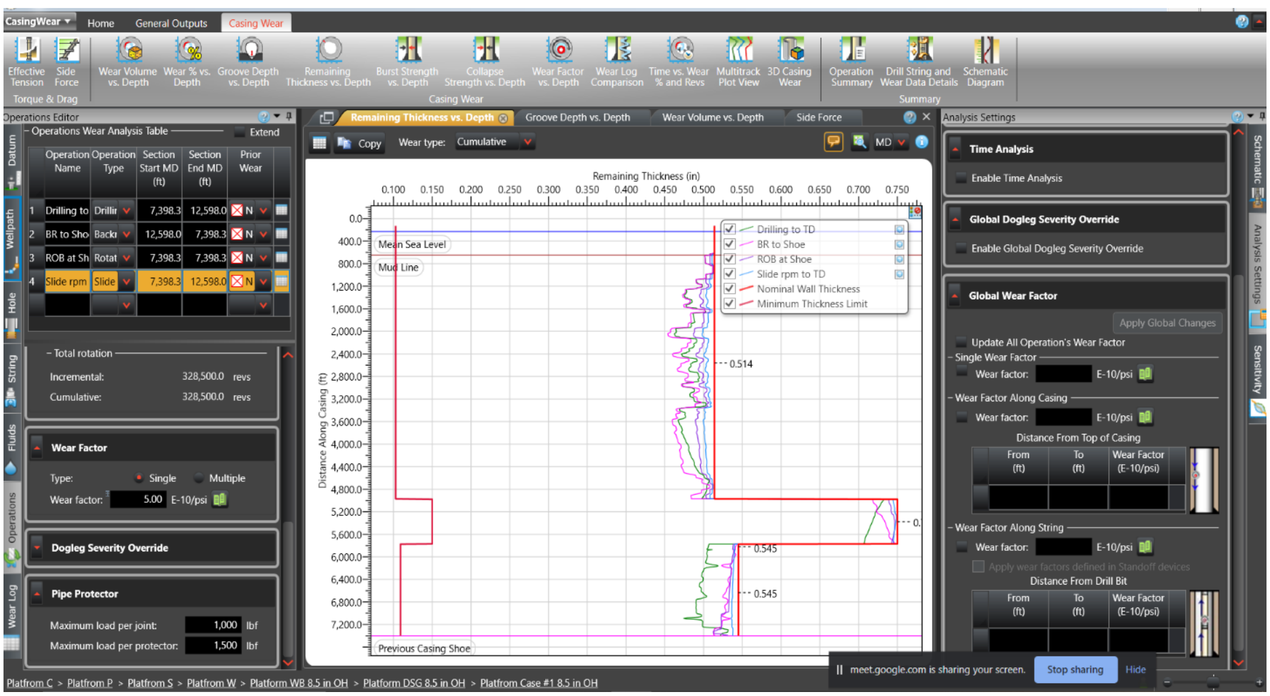
10- Select Casing Wear Volume plot result



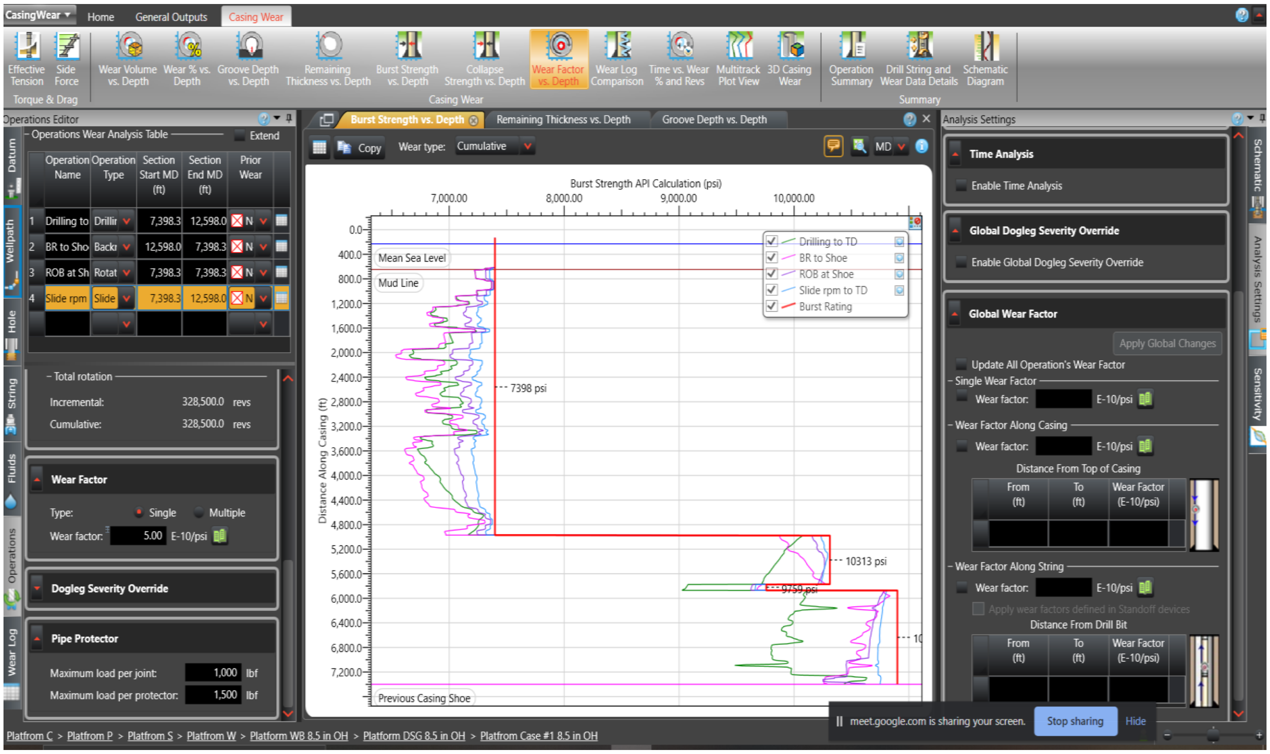
11-Select Groove Depth plot results



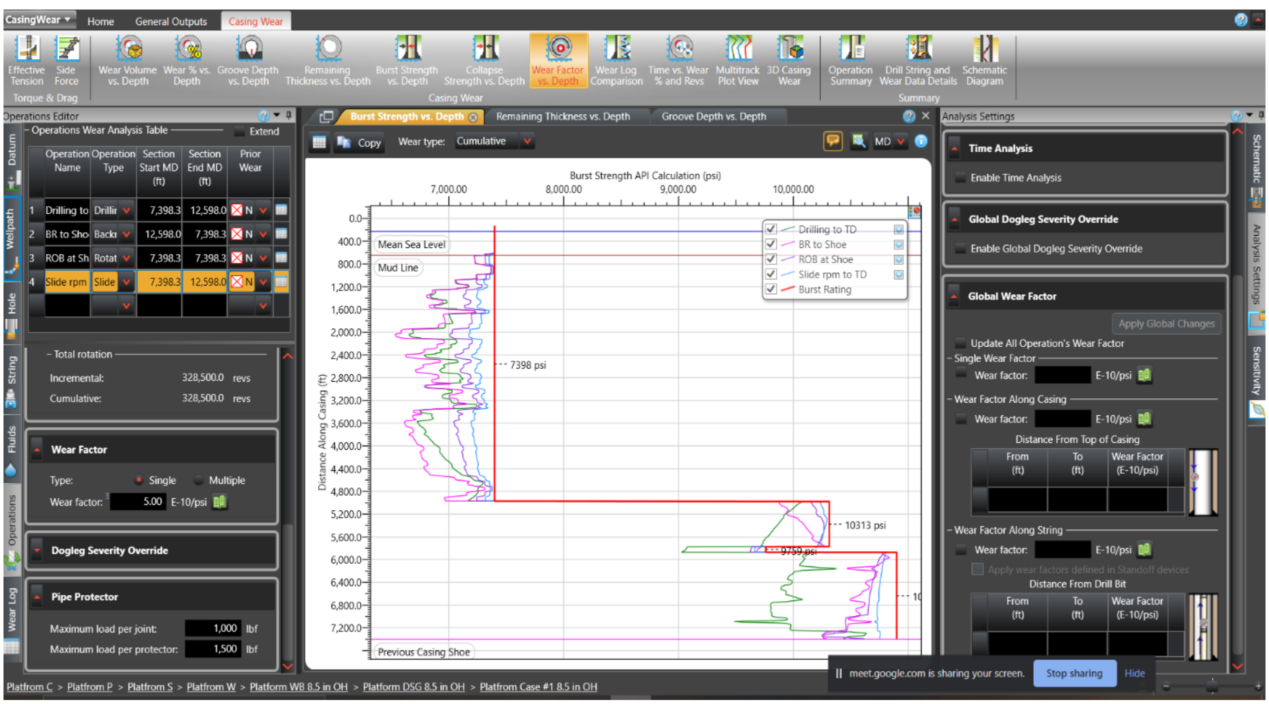
12-Select Remaining Thickness plot results



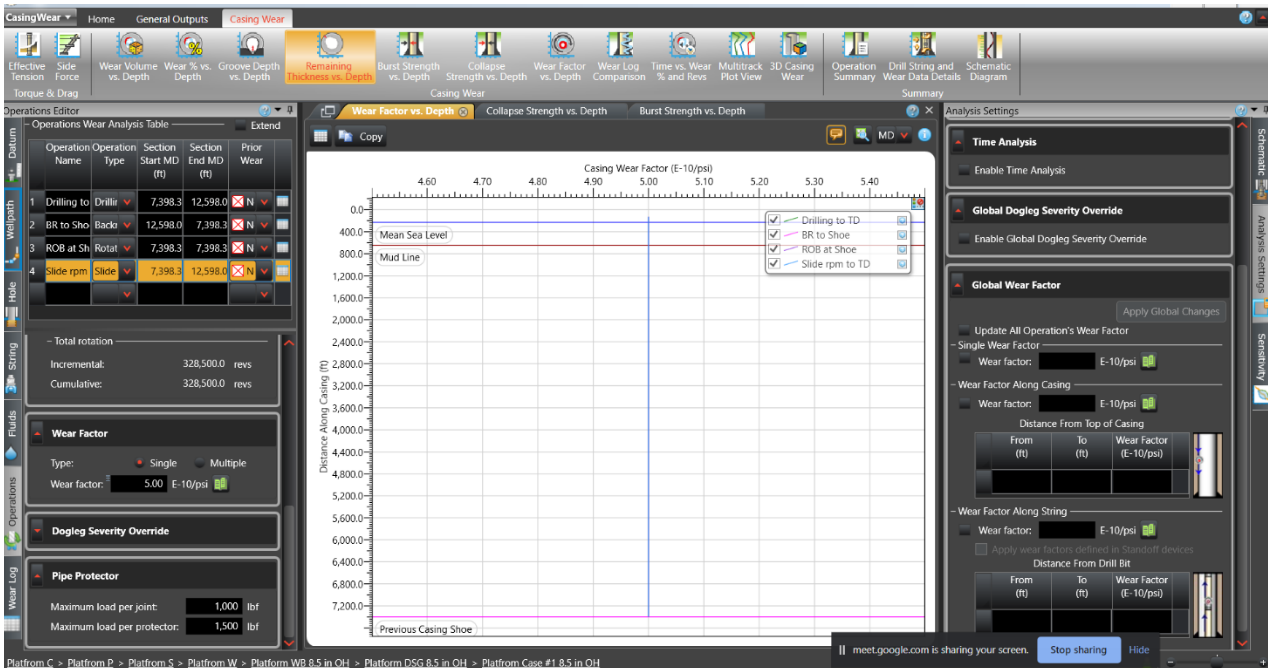
13-Select Burst Strength plot



14-Select Collapse Strength plot results

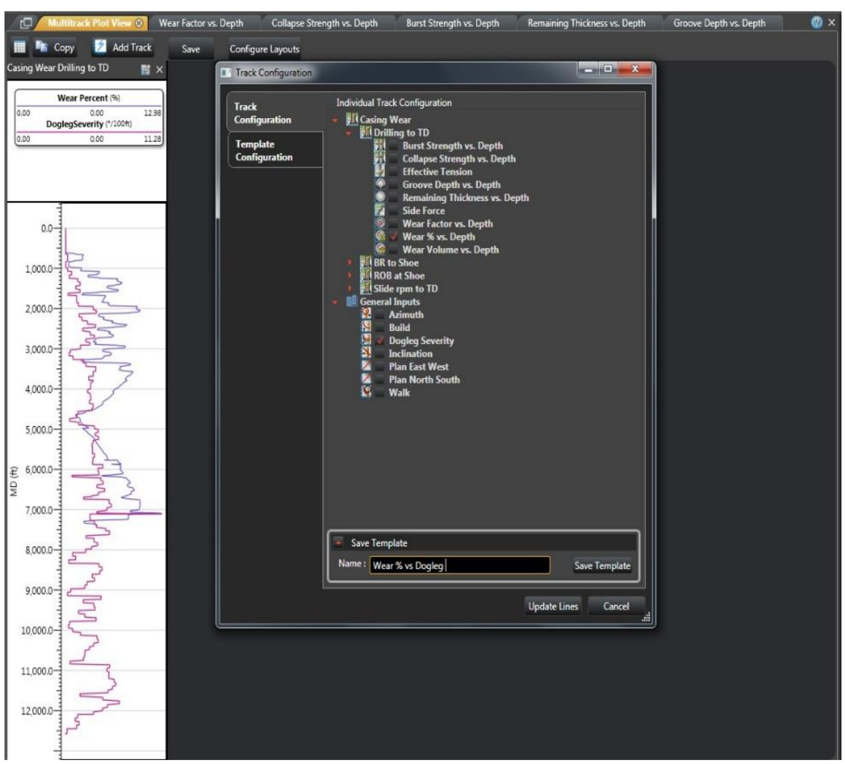


15-Select Casing Wear Factor plot results



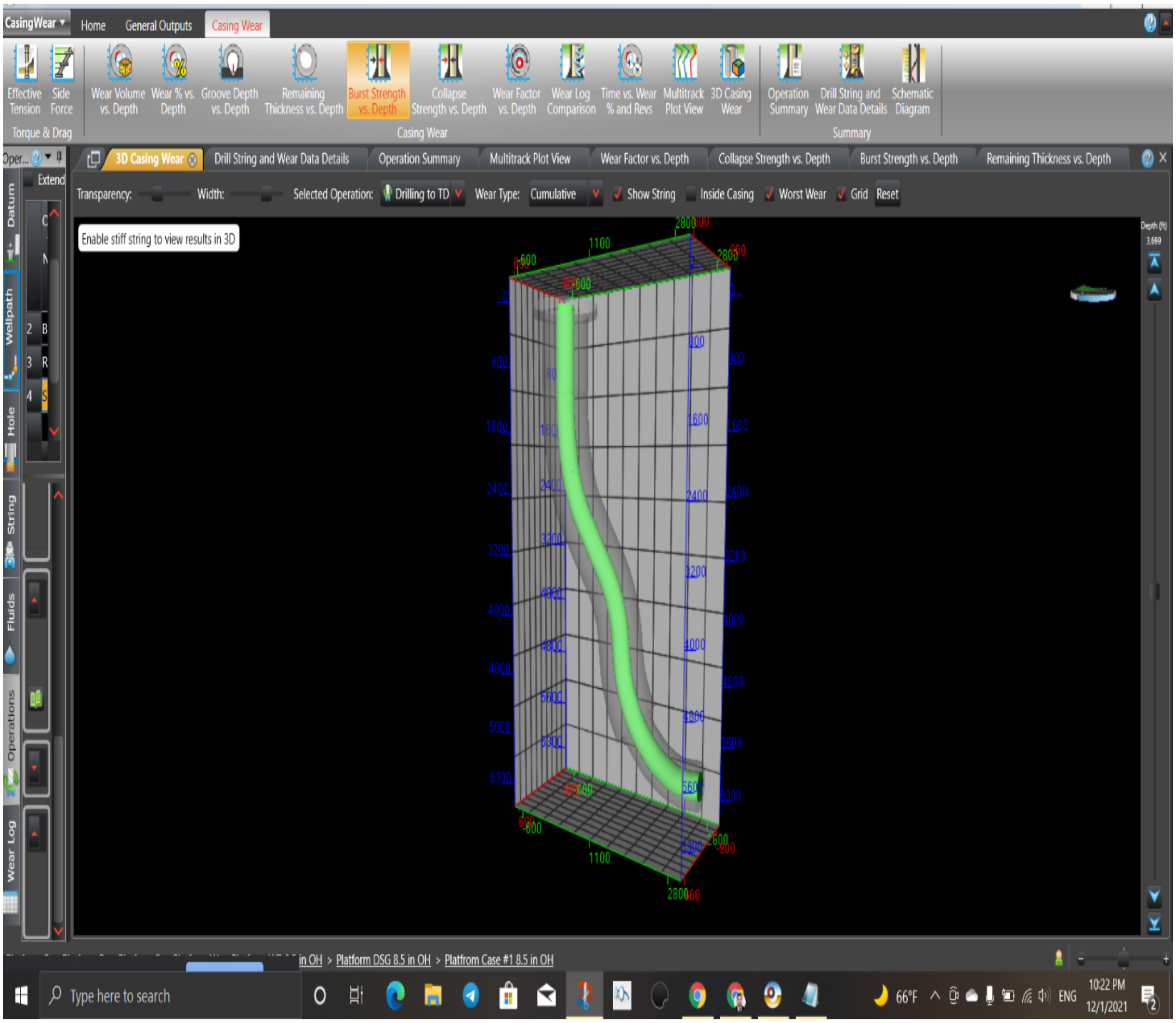
16-Select Multitrack Plot

- Select Add Track
- Combine Casing Wear % vs. Depth with General input Dogleg Severity
- Comment: Configurations can be saved for future.

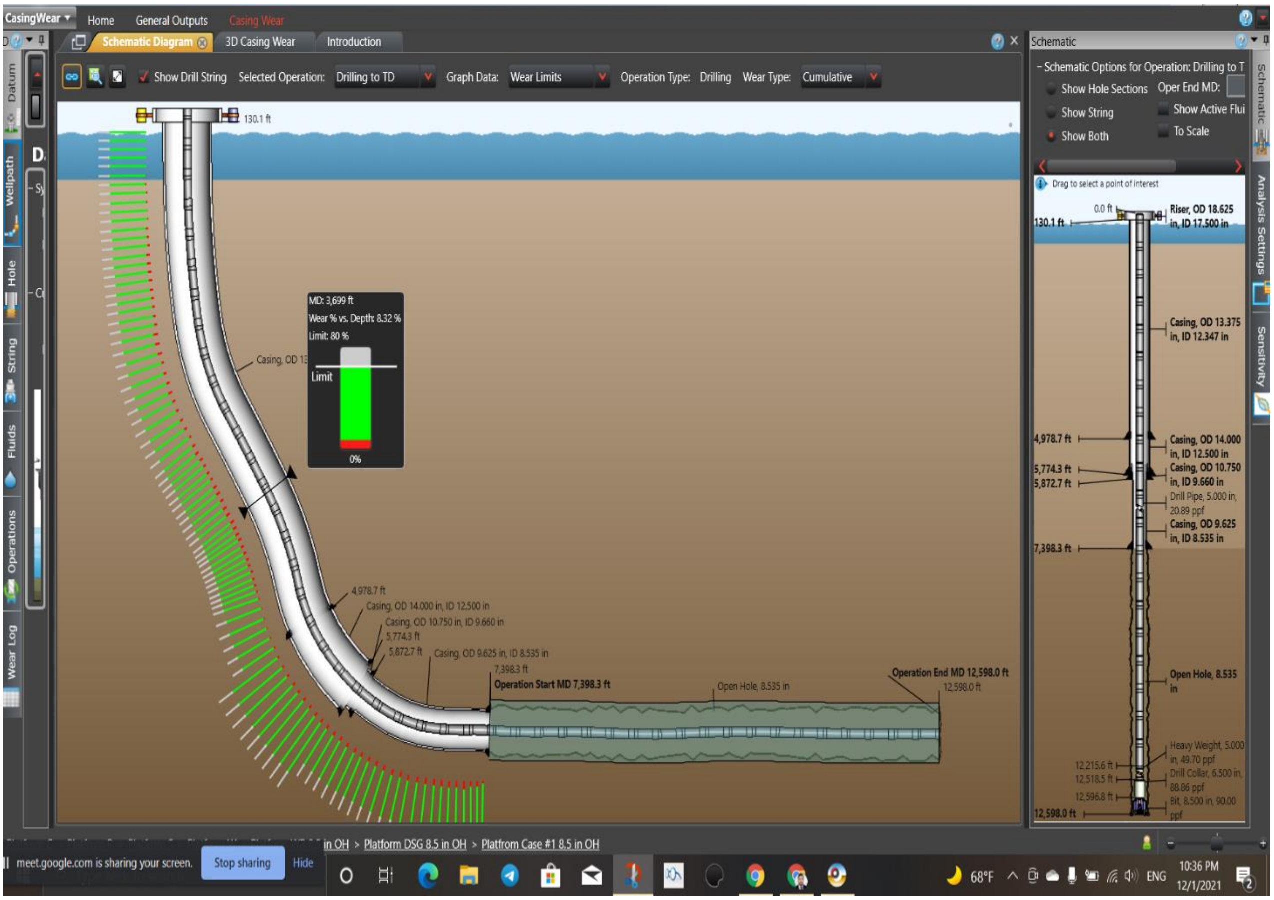


- Up to six track can be defined
- Supports the combination of Operation results and General results together in each track
- Operation Results per track shall be of same operation
- Each track supports a maximum of 4 parametersi
- Multitrack Layout configuration can be saved for future use
-

18-Select 3D Casing Wear

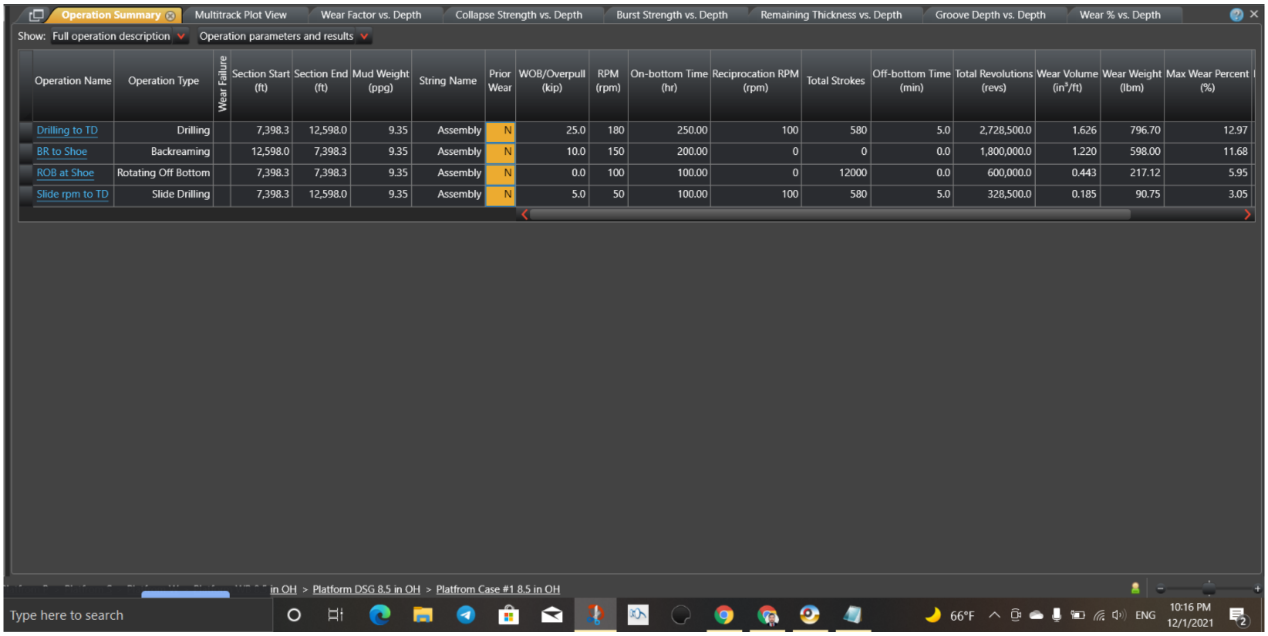


19-Select Schematic Diagram



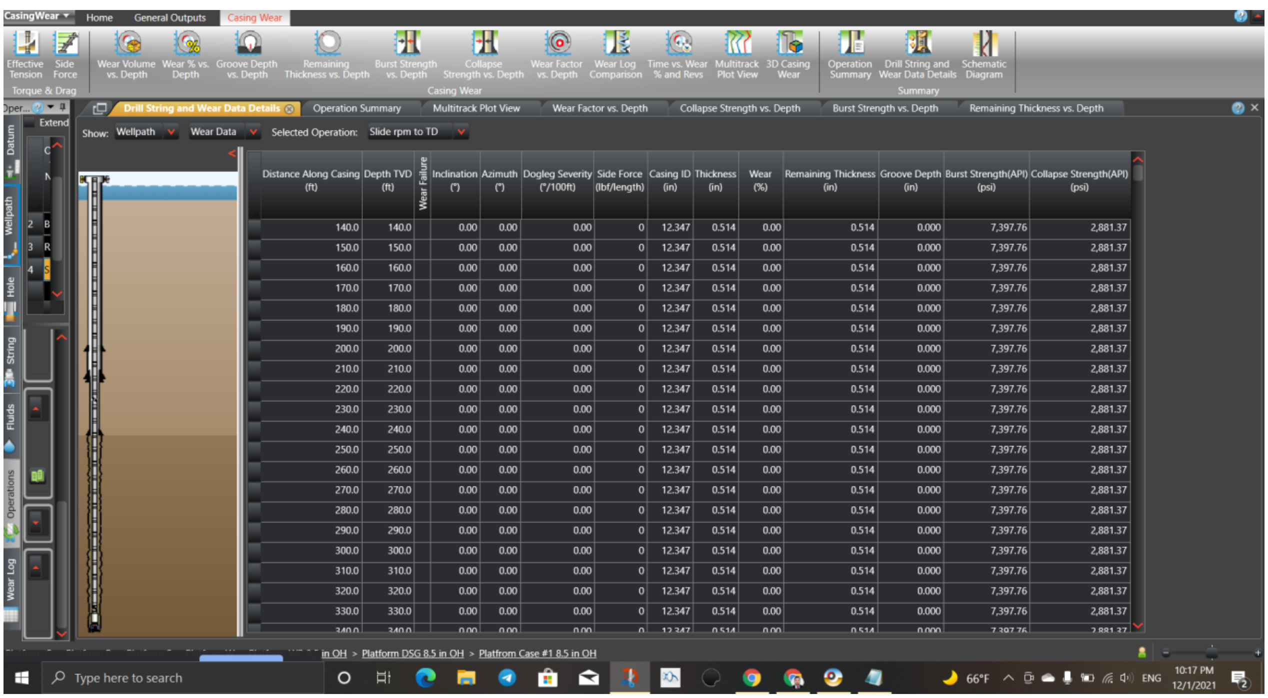
Results

1-Select Operation Summary



Operation Name	Operation Type	Wear Failure	Section Start (ft)	Section End (ft)	Mud Weight (ppg)	String Name	Prior Wear	WOB/Overpull (kip)	RPM (rpm)	On-bottom Time (hr)	Reciprocation RPM (rpm)	Total Strokes	Off-bottom Time (min)	Total Revolutions (revs)	Wear Volume (in³/ft)	Wear Weight (lbm)	Max Wear Percent (%)
Drilling to TD	Drilling		7,398.3	12,598.0	9.35	Assembly	N	25.0	180	250.00	100	580	5.0	2,728,500.0	1.626	796.70	12.97
BR to Shoe	Backreaming		12,598.0	7,398.3	9.35	Assembly	N	10.0	150	200.00	0	0	0.0	1,800,000.0	1.220	598.00	11.68
ROB at Shoe	Rotating Off Bottom		7,398.3	7,398.3	9.35	Assembly	N	0.0	100	100.00	0	12000	0.0	600,000.0	0.443	217.12	5.95
Slide rpm to TD	Slide Drilling		7,398.3	12,598.0	9.35	Assembly	N	5.0	50	100.00	100	580	5.0	328,500.0	0.185	90.75	3.05

2-Select Drill String and Wear Data Details



Distance Along Casing (ft)	Depth TVD (ft)	Wear Failure	Inclination (°)	Azimuth (°)	Dogleg Severity (°/100ft)	Side Force (lbf/length)	Casing ID (in)	Thickness (in)	Wear (%)	Remaining Thickness (in)	Groove Depth (in)	Burst Strength(API) (psi)	Collapse Strength(API) (psi)
140.0	140.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
150.0	150.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
160.0	160.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
170.0	170.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
180.0	180.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
190.0	190.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
200.0	200.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
210.0	210.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
220.0	220.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
230.0	230.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
240.0	240.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
250.0	250.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
260.0	260.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
270.0	270.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
280.0	280.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
290.0	290.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
300.0	300.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
310.0	310.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
320.0	320.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37
330.0	330.0		0.00	0.00	0.00	0	12.347	0.514	0.00	0.514	0.000	7,397.76	2,881.37

Discussion

casing wear creates more serious problems for operators due to its potential catastrophic incidents such as oil pills, blow out or loss of the well for that we have to take this problem seriously in field work developments (Drilling operations -Casing design) to reduce the cost of field developments as we can as possible.

To understand casing wear problem more clearly, we have to have a full understanding for the contributed conditions (well path and dogleg, Drill pipe weight, Tool joint coating, Mud and its additives and RPM and ROP) to take the best decision at the proper time, to get a good prediction for the problem and achieving well integrity.

In this research we have used a new an innovation of Landmark casing Wear software which provides a comprehensive solution to casing wear assessments. And as it shown in chapter three we applied our data gradually started with entering data of each section for each casing section ended with an open hole reaches to depth of 12,598.4 ft and then entering the data of each section of drill string (Drill pipe ,Heavy weight drill pipe , Drill collar and drill bit) ,Then drilling fluid to end finally with some other operations (Drilling TO TD , BR to shoe ,ROB at shoe and Slide rpm to TD), And then Analysis Settings to get our Data output (Casing wear plots) .

Prevention & Conclusion of Casing Wear

The knowledge we have acquired through decades of studies, lab testing. post-job analyses and computer modeling provides a good foundation for the following casing wear preventive measures:

• Minimize dogleg severity and expect real dogleg at least 1.5 times higher than the planned value
•Use casing friendly tool joint materials
•Reduce rotor speed and use downhole motor
•Increase ROP
•Select proper mud type and add lubricants to reduce wear and friction
•Use drill pipe protectors
•Use thick wall casing in the anticipated wear section area
•Use software to reduce risks.

At the steady-state wear stage, the wear-efficiency model can be used to predict the casing wear quantitatively. The inversion value of CWF from the survey data in the drilled wells can be used to predict the casing wear in the adjacent wells to be drilled under similar conditions and the predicted results are good.

Dynamic cumulation of the casing wear area and quantitative calculation of the casing wear location angle can be used to predict the groove depth and the locations of the casing string wear.

The geometry of a casing wear groove has a great impact on the wear groove depth. Size changes of drill strings may result in a sudden change in the casing wear mode even if the conditions of friction & wear are unchanged. Therefore, the effect of drill string size on the casing wear should be taken into account in the casing wear prediction because they are unavoidable in drilling & completion operations.

When simulating the casing wear in a planned well, it is necessary to make a reasonable correction to the predicted depth of the casing wear groove using scientific inversion of casing wear factor from the drilled well because there are differences between the actual drilled well and the planned well.

We have been noticing from this research the most important thing it's not the use of Landmark Casing Wear software itself with entering the required data to get the required plots and results but the most important thing is understanding the principles and contributed conditions beyond casing wear problem (well path (vertical, deviated or a horizontal well) and dogleg severity ,Torque and Drag and the types of movements which caused them, Dill pipe weight and the effect of gravitational forces which caused that occurred touching of drill string to the wall of casing ,Tool joint coating and the type of material ,roughness of it and its effect on the casing

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