

D-Series Software

D-ROCK

Outline

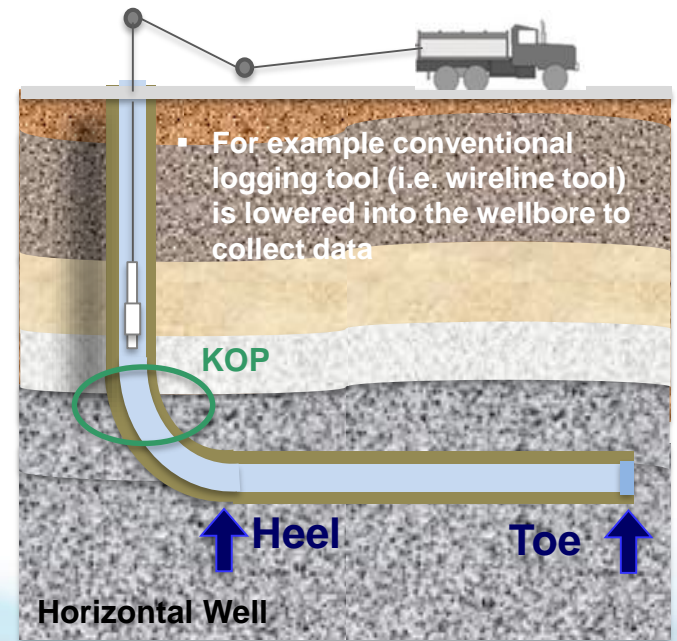
- ❑ Challenges of Horizontal Well Logging
- ❑ Introduction to D-Series Technology
- ❑ Required Inputs for D-Series Software
- ❑ Downhole WOB from D-WOB using Typical Drilling Data
- ❑ Geomechanical Property Log from D-ROCK Software

26 January, 2017

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Challenges of Horizontal Well Logging

- ❑ Conventional logging and rock mechanical testing are expensive (logging cost and rig time) and has uncertainties
- ❑ Continuous monitoring of rock mechanical and reservoir properties along the wellbore in horizontal wells
- ❑ In horizontal wells, the conventional logging tools can sometimes difficult to process (depth correlations and averaged data)
- ❑ Possible risks and concerns of trapping logging tools downhole
- ❑ Sometimes too late to make operational decisions and make changes in the drilling based on the information obtained using the conventional techniques such as, core analysis and well logging using sonic and resistivity image logs
- ❑ The conventional logging techniques are therefore not done on all unconventional wells (1 in 10 or 1 in 20) and mainly due to associated cost, uncertain and time consuming to process



A New Technology

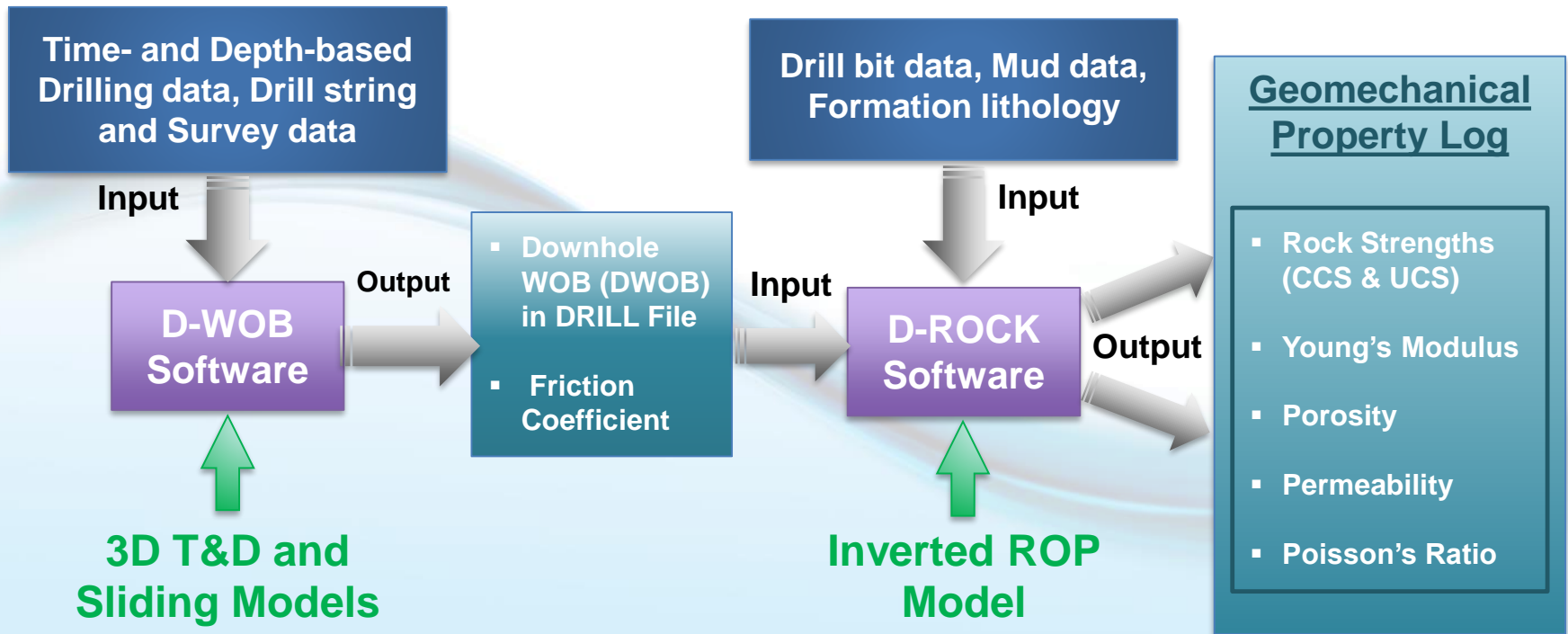
Introduction and Benefits

- ❑ A convenient logging technology composed of two D-Series software products: D-WOB and D-ROCK
- ❑ The software generates continuous rock mechanical and potential natural fracture property logs versus depth from drilling data collected during the drilling process (and some formation mapped correlations) and does not add cost
- ❑ The properties include confined compressive strength (CCS), unconfined compressive strength (UCS) and dynamic Young's modulus (E), porosity, permeability and Poisson Ratio
- ❑ The possible natural fractures and fracture zones can be identified from recognized behavior of the rock strengths (UCS) when penetrating the reservoir fractures at different depths
- ❑ UCS, Young's modulus, porosity, permeability and Poisson Ratio are key design parameters in unconventional fracture design software
- ❑ The rock mechanical logs and information on natural fractures in reservoir can be used to design an optimal stimulation (through selective perforation/zoning) treatment for maximum well productivity and NPT (Net Present Value)

D-Series Technology

□ D-Series Software

- **D-WOB** : Calculates friction coefficient (FC) and downhole weight on bit (DWOB) from drilling data, drill string information and wellbore survey measurement
- **D-ROCK** : Calculates rock strengths and Young's modulus, porosity, permeability and Poisson's ratio using the output from D-WOB software, drill bit information, mud data and formation lithology



Required Inputs for D-Series

□ For D-WOB

▪ Numeric Input:

- a) Single sheave efficiency percentage (%)
- b) Static hook weight – Metric System (kdaN)
Imperial System (klbf)
- c) Number of lines (dimensionless)

▪ Input Files:

- a) Depth-based file (default file extension: **.Depth**)
- b) Survey file (default file extension: **.survey**)
- c) Time-based file (default file extension: **.time**)
- d) Drill-string (BHA) file (default file extension: **.bha**)
- e) Lithology file (default file extension: **.lith**) – Optional for Abrasiveness calculation

□ For D-ROCK

▪ Input Files:

- a) Drill data input file (default file extension: **.DRILL**) – From D-WOB output
- b) Drill bit input file (default file extension: **.Bit**)

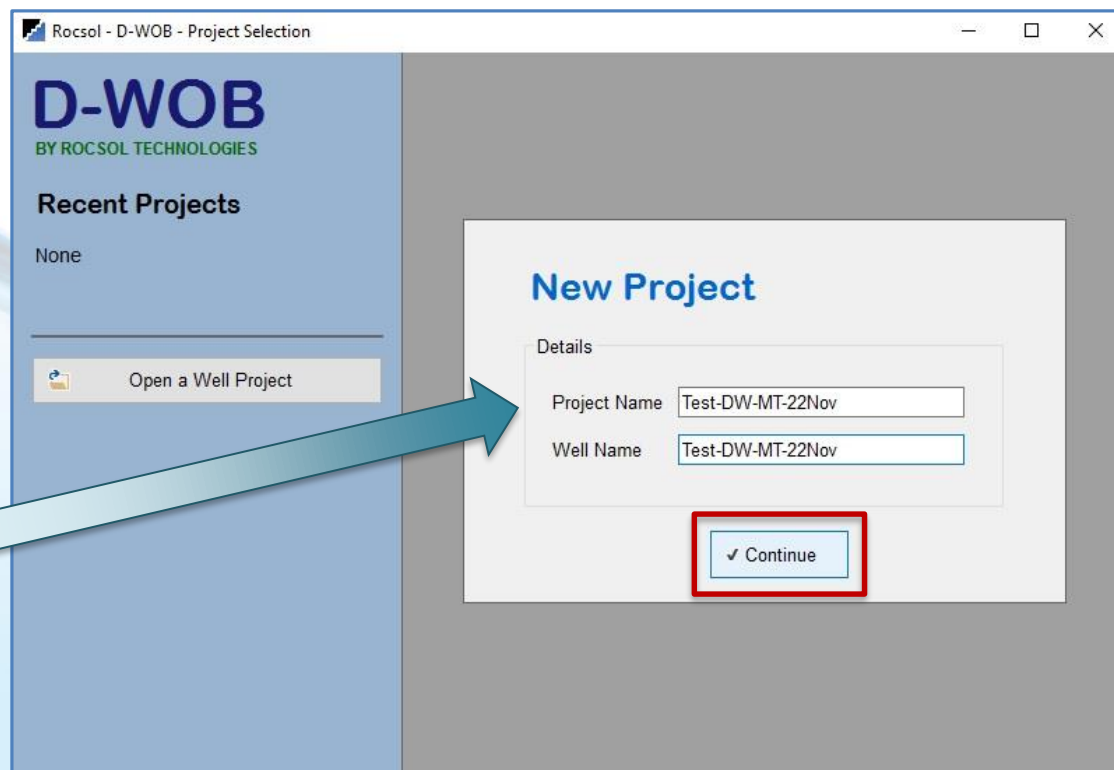
▪ Data saved in D-ROCK's Database

- a) Bit constants
- b) Formation constants

Start New Project with D-WOB



D-WOB Splash Screen



The "Rocsol - D-WOB - Project Selection" window shows the "D-WOB BY ROCSOL TECHNOLOGIES" header. Under "Recent Projects", it lists "None". A button labeled "Open a Well Project" is visible. A "New Project" dialog box is open, showing "Details" with "Project Name" and "Well Name" both set to "Test-DW-MT-22Nov". A red box highlights the "Continue" button at the bottom of the dialog.

To start a new D-WOB project

D-WOB Software

- ❑ Select Unit system for drilling parameters. Load and view 4 drilling input files
- ❑ **D-WOB** calculates downhole weight on bit (DWOB) which is used in Inverted ROP models to accurately predict rock strength and other rock properties

The screenshot displays the Rocsol D-WOB software interface. The 'File' menu is open, showing options like 'Load all input files', 'Open Project', 'Save Project', and 'Exit'. The 'Unit System Selection' dialog box is open, showing 'Metric System' selected. The 'Input Files' table is visible, showing data for BHA Number, Start Depth (m), End Depth (m), BHA Component, # Jts, and Length (m). A blue box highlights the 'View Input files' button.

Unit System Selection Dialog:

Units

☒ Metric System ☐ Imperial System

OK Cancel

Unit: Metric System

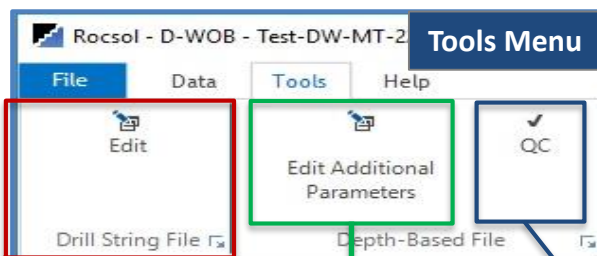
Input Files Table:

BHA Number	Start Depth (m)	End Depth (m)	BHA Component	# Jts	Length (m)
13	2112	2937	Bit and BHA	12	53.4
			Heavy Weight Drill Pipe	18	168.87
			Drill Pipe	180	1717.32
			Heavy Weight Drill Pipe	21	197.14
			Drill Pipe	30	800.27
14	2937	4102	Bit and BHA	12	53.44
			Heavy Weight Drill Pipe	18	168.87
			Drill Pipe	180	1717.32
			Heavy Weight Drill Pipe	21	197.14
			Drill Pipe	69	1965.23

View Input files

D-WOB – Tools

❑ Edit/create BHA (drill string) file:
.Bha input file



Define Additional Depth-based Parameters

Depth-based File
Depth File C:\MTAHMEEN 2014-2016\NEW Document

Additional Depth Parameters Definition

Select Parameter Pore Pressure (sg)
Pore Pressure (sg)
Mud Weight (sg)
Plastic Viscosity (mPa sec)
Mud Type
Formation ID

Depth in (m)	Formation ID	Pore Pressure (sg)
2637.66	3457.04	1.35

❑ Define additional parameters for Depth file:
.Depth input file

Pore Pressure (sg)	Mud Weight (sg)	Plastic Viscosity (mPa sec)	Mud Type	Formation ID
1.35	1.7	20	Oil	1
1.35	1.7	20	Oil	1
1.35	1.7	20	Oil	1
1.35	1.7	20	Oil	1
1.35	1.7	20	Oil	1
1.35	1.7	20	Oil	1
1.35	1.7	20	Oil	1

QC Limits

Depth-based File
Depth File C:\MTAHMEEN 2014-2016\NEW Documents from JAN 2016\D-SERI

☐ Remove Data Points

QC Depth Parameter Limits

Select Parameter Rate of Penetration (m/hr)
Rate of Penetration (m/hr)
Weight on Bit (kdaN)
Revolutions per Minute (rpm)
Hook Load (kdaN)
Flow Rate (m3/min)
Delta Pressure (kPa)
Pump Pressure (kPa)
Gamma (API)
Pore Pressure (sg)
Mud Weight (sg)
Plastic Viscosity (mPa sec)

Number of Sections

Average Over

☒ None
☐ Depth
☐ Neighboring Points

Measured Depth (m)	Rate of Penetration (m/hr)	Weight on Bit (kdaN)	Revolutions per Minute (rpm)	Hook Load (kdaN)	Pump Volume (m3/hr)
2637.66	50.23	14.6	59	47	1.53
2637.8	46.26	14.6	59	46.9	1.53
2637.91	47.49	14.6	59	46.9	1.53
2638.04	47.52	14.6	59	47	1.53
2638.18	47.52	14.6	59	47.1	1.53
2638.3	50.22	14.6	59	46.9	1.53
2638.43	50.22	14.8	59	47	1.53
2638.56	48.84	14.6	59	47.1	1.53
2638.69	49.12	14.6	59	47	1.53
2638.81	49.12	14.6	59	47	1.53
2638.94	48.82	14.4	59	47	1.53
2639.06	47.5	14.7	59	46.9	1.53
2639.18					1.53
2639.32					1.53
2639.43					1.53
2639.57					1.53
2639.68					1.53
2639.81					1.53
2639.94					1.53
2640.07					1.53
2640.19					1.53
2640.32					1.53
2640.44					1.53
2640.56					1.53
2640.68					1.53
2640.8	43.95	14.7	59	46.9	1.53
2640.88	39.1	15	59	46.8	1.53
2640.93	39.1	14.6	59	47	1.53
2641.01	26.23	14.6	59	46.9	1.53
2641.09	26.23	14.3	59	46.9	1.53
2641.16	29.8	14.5	59	46.8	1.53
2641.25	29.8	14.3	59	47.1	1.53
2641.34	30.84	14.4	59	47.1	1.53
2641.45	33.8	14.4	59	47.9	1.53
2641.56	42.87	12.8	59	48.8	1.53

❑ Data QC for Depth file parameters:
.Depth input file

Rocsol - D-WOB - Drill String

Attributes
Start Depth 2112 m End Depth 4102 m

Sections
Number of Sections: 2

Section 1
BHA Number 13 Start Depth 2112 m End Depth 2937 m

Components Bit and BHA Components

Type	# Jts	Length (m)	OD (mm)	ID (mm)	Weight (kg/m)
Bit and BHA	12	53.400	124.937	63.913	72.173
Heavy Weight Drill Pipe	18	168.870	101.600	65.000	44.184
Drill Pipe	180	1717.320	101.600	82.000	26.327
Heavy Weight Drill Pipe	21	197.140	101.600	65.000	44.184
Drill Pipe	30	800.270	101.600	82.000	26.327

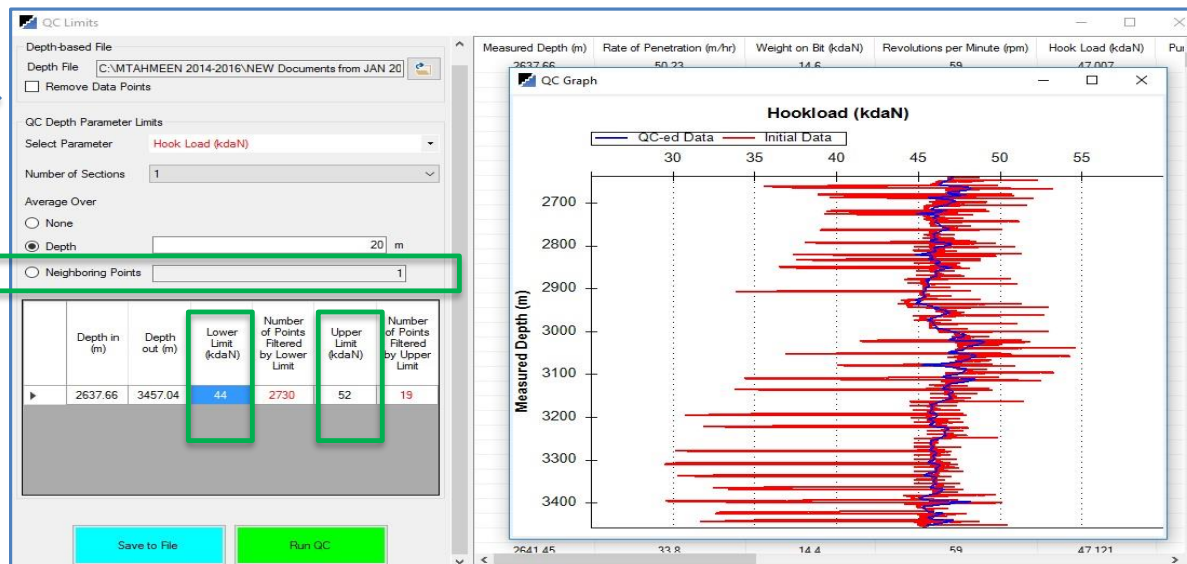
Section 2
BHA Number 14 Start Depth 2937 m End Depth 4102 m

Components Bit and BHA Components

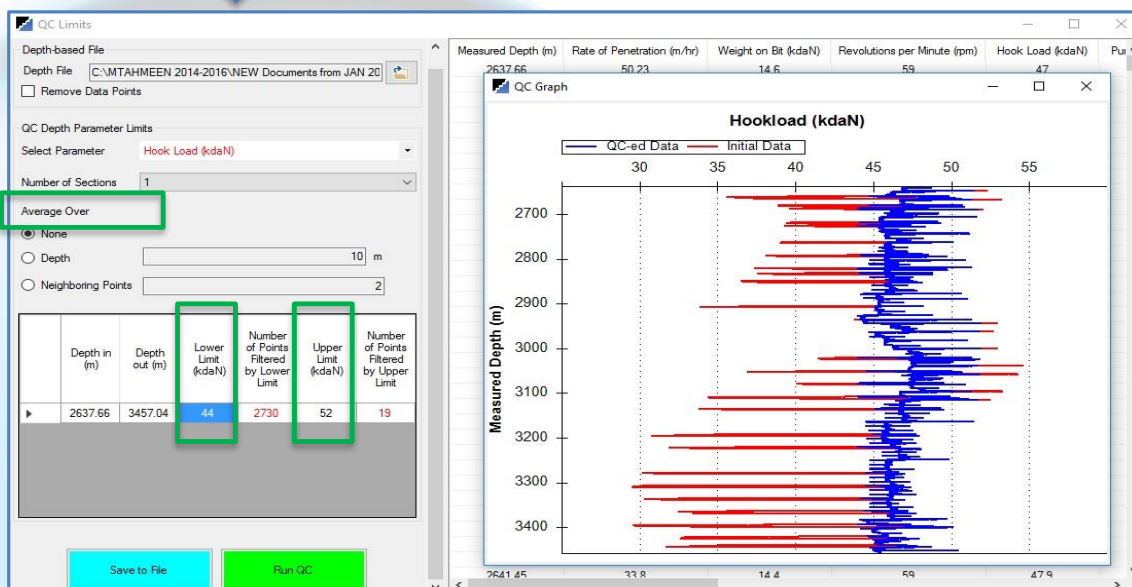
Type	# Jts	Length (m)	OD (mm)	ID (mm)	Weight (kg/m)
Bit and BHA	12	53.440	124.980	63.852	72.173
Heavy Weight Drill Pipe	18	168.870	101.600	65.000	44.184
Drill Pipe	180	1717.320	101.600	82.000	26.327
Heavy Weight Drill Pipe	21	197.140	101.600	65.000	44.184
Drill Pipe	69	1965.230	101.600	82.000	26.327

D-WOB – QC Tool

- ❑ Smoothing average over 20m depth range and based on set values of lower and upper limits



- ❑ QC based on set values of lower and upper limits without removing data points



QC Options based on set lower and upper limits

- ❑ Remove data points
- ❑ QC without removing data points
- ❑ Smoothing average over depth range
- ❑ Smoothing average over neighboring data points (1, 5, 10,...)

D-WOB Main UI – Options

Options

Calibration Point just before off-bottom

☐ Define Element Length 30 m

Sheave Efficiency 98.5 %

Number of Lines 10

Hook Weight 12 kdaN

Input Measured Hookload

☒ Measured from deadline

☐ Measured at top of string

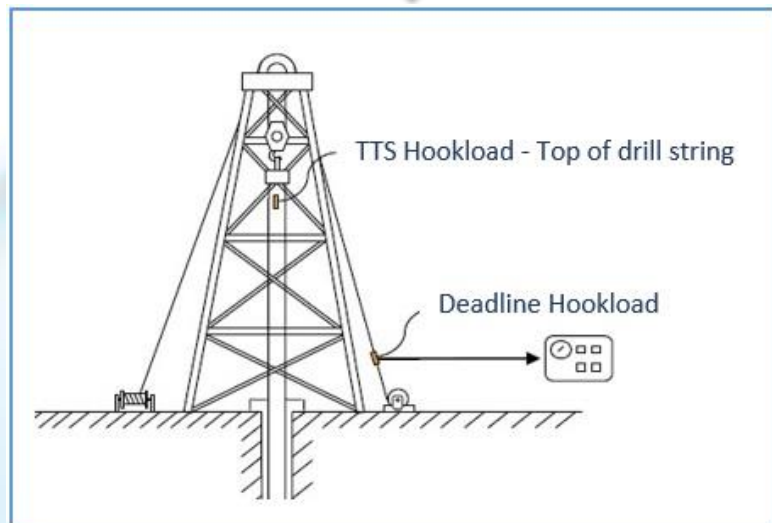
Options for friction coefficient calibration points

Point just before off-bottom

Point just before off-bottom

Point 20cm before off-bottom

Point jump in SPP

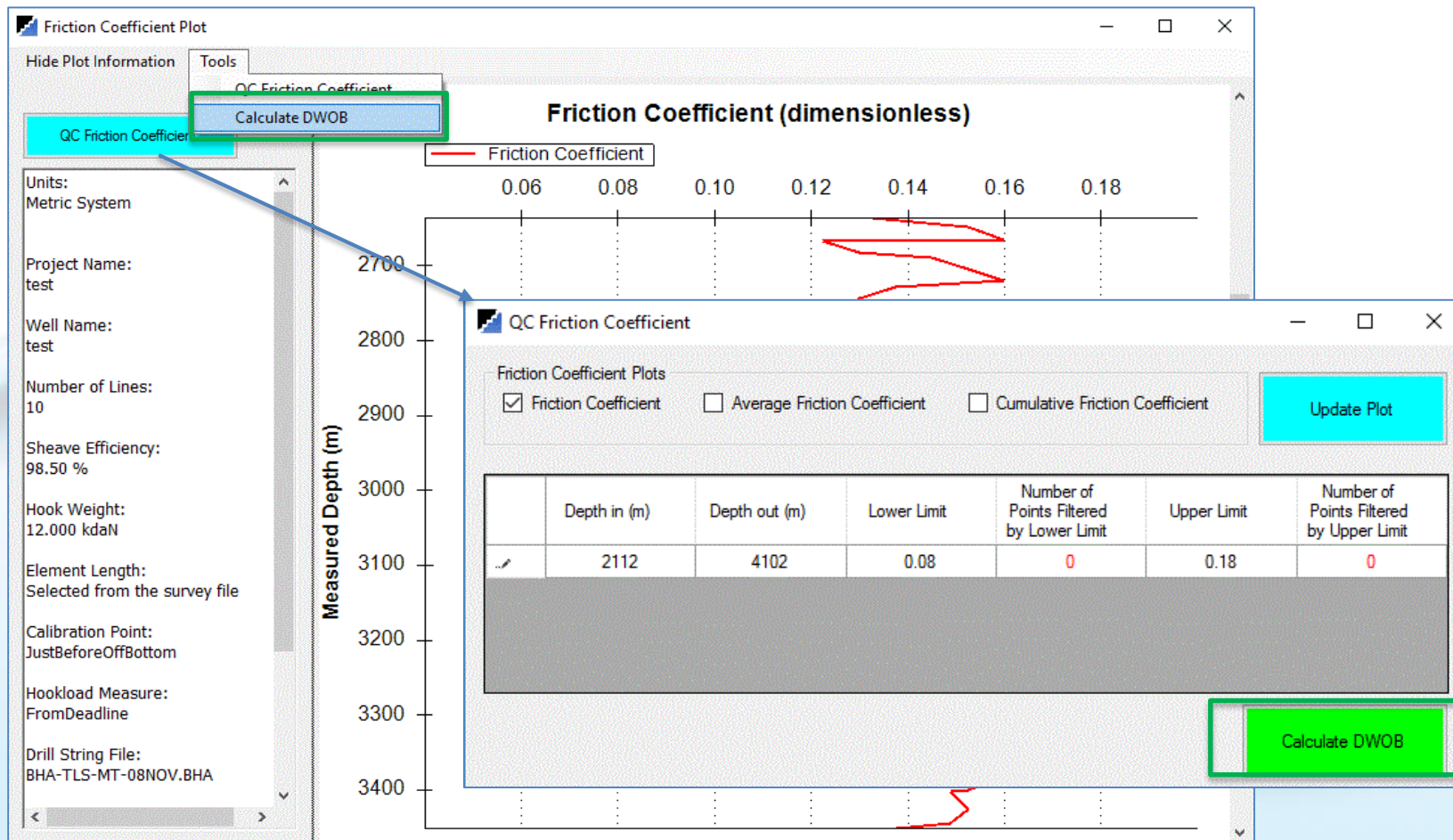


	Date	Depth - Bit	Total Depth	Hookload	Weight on Bit	Top Drive RPM	Flow In	Pump Pressure	ROP Depth/Hour
	25-Sep-2011 02:15:40	1766.84	1767.9	42.7	4.8	50	1.09	10362	0
	25-Sep-2011 02:15:50	1767.1	1767.9	42.8	5	50	1.09	10493	0
	25-Sep-2011 02:16:00	1767.42	1767.9	43.6	6.7	51	1.09	10256	0
	25-Sep-2011 02:16:10	1767.46	1767.9	43.1	0.1	51	1.09	10316	0
	25-Sep-2011 02:16:20	1767.53	1767.9				1.09	10182	0
	25-Sep-2011 02:16:30	1767.62	1767.9				1.09	10252	0
	25-Sep-2011 02:16:40	1767.7	1767.9	43.5	0	50	1.09	10270	0
	25-Sep-2011 02:16:50	1767.78	1767.9	42.9	1	50	1.09	10415	0
	25-Sep-2011 02:17:00	1767.85	1767.9	41.7	1.1	47	1.09	10958	0
1	25-Sep-2011 02:17:10	1767.91	1767.91	41.6	1.4	46	1.09	10948	6.52
	25-Sep-2011 02:17:20	1767.98	1767.98	41.6	1.4	47	1.09	10913	16.67
	25-Sep-2011 02:17:30	1768.04	1768.04	41.4	1.8	47	1.09	10967	23.07
	25-Sep-2011 02:17:40	1768.1	1768.1	41.2	1.8	45	1.09	10946	23.11
	25-Sep-2011 02:17:50	1768.17	1768.17	41.3	1.7	46	1.09	11065	22.7
	25-Sep-2011 02:18:00	1768.22	1768.22				1.09	11134	23.61
	25-Sep-2011 02:18:10	1768.3	1768.3				1.09	11124	23.68
	25-Sep-2011 02:18:20	1768.39	1768.39				1.09	11014	27.36
	25-Sep-2011 02:18:30	1768.46	1768.46	41.5	1.6	46	1.09	11039	29.3
	25-Sep-2011 02:18:40	1768.54	1768.54	41.1	2	46	1.09	11115	28.87
	25-Sep-2011 02:18:50	1768.6	1768.6	41.2	1.8	47	1.09	11237	27.18
	25-Sep-2011 02:19:00	1768.64	1768.64	41.4	2.4	46	1.09	11164	24.85
	25-Sep-2011 02:19:10	1768.71	1768.71	41.5	1.6	46	1.09	11100	21.93
	25-Sep-2011 02:19:20	1768.77	1768.77	41.5	1.6	47	1.09	11207	19.14

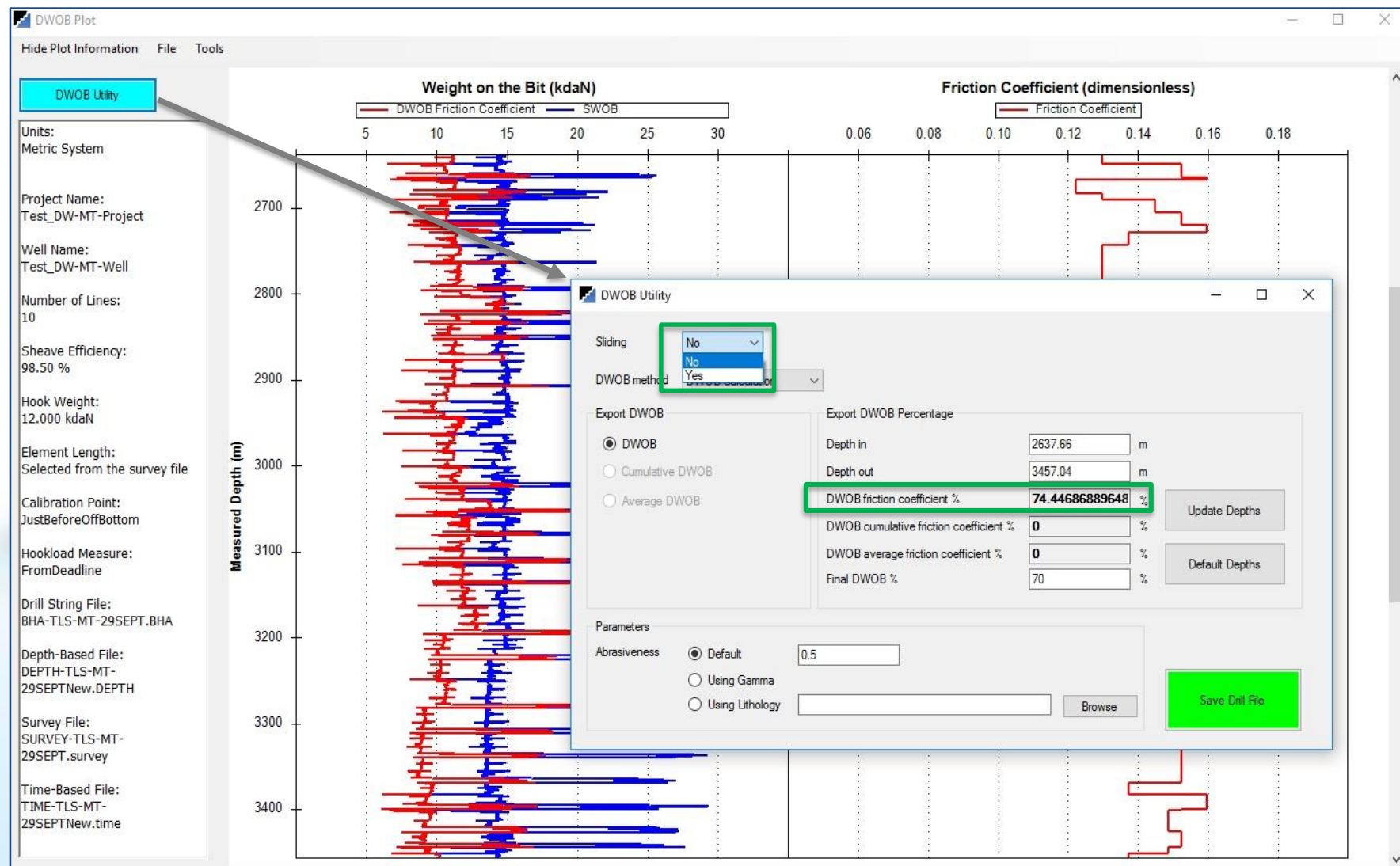
Options of hook load measurement

Run D-WOB from Main UI

- ☐ Calculate friction coefficient
- ☐ QC friction coefficient and update plot (optional)
- ☐ Calculate DWOB



DWOB Calculations



☐ **Sliding No:** Only T&D model for both rotating and sliding sections

DWOB Calculations – Sliding: Yes

DWOB Utility

Sliding: Yes RPM: 3.0

DWOB method: DWOB Calculation

Export DWOB:

- ☒ DWOB
- ☐ Cumulative DWOB
- ☐ Average DWOB

Export DWOB Percentage:

Depth in: 2637.66 m

Depth out: 3457.04 m

DWOB friction coefficient %: 74.44686889648 %

DWOB cumulative friction coefficient %: 0 %

DWOB average friction coefficient %: 0 %

Final DWOB %: 70 %

Parameters:

Abrasive: ☒ Default 0.5

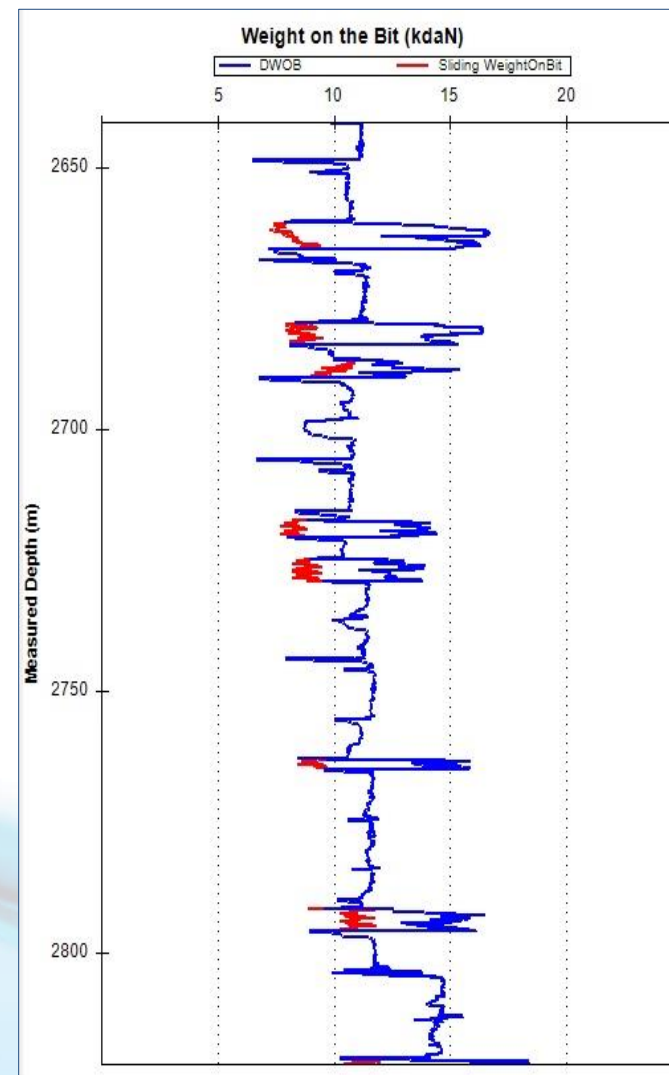
☐ Using Gamma

☐ Using Lithology

Update Depths

Default Depths

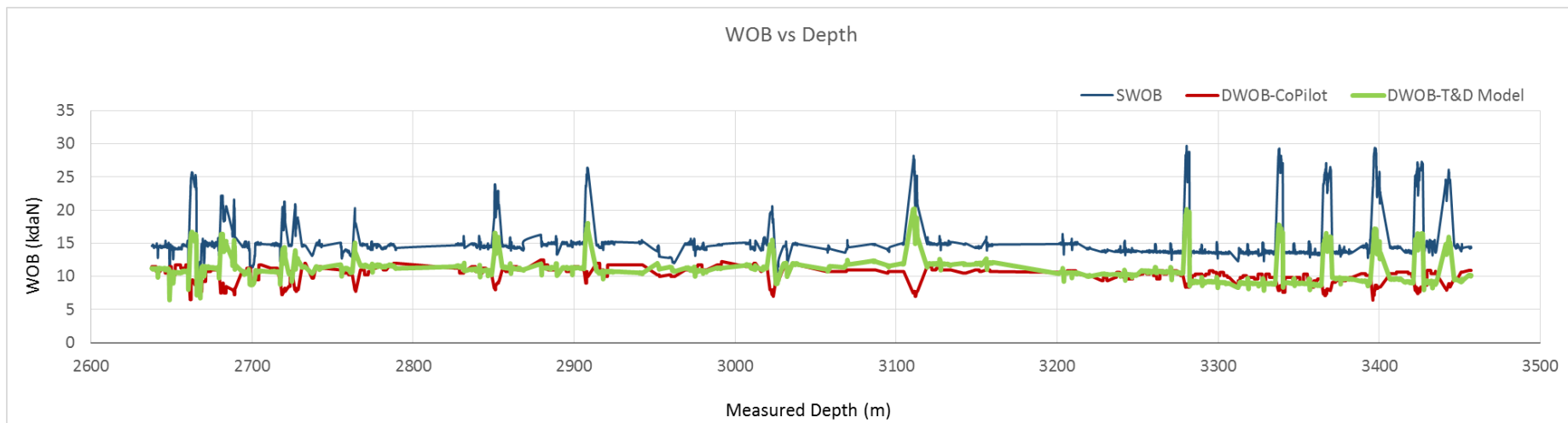
Save Drill File



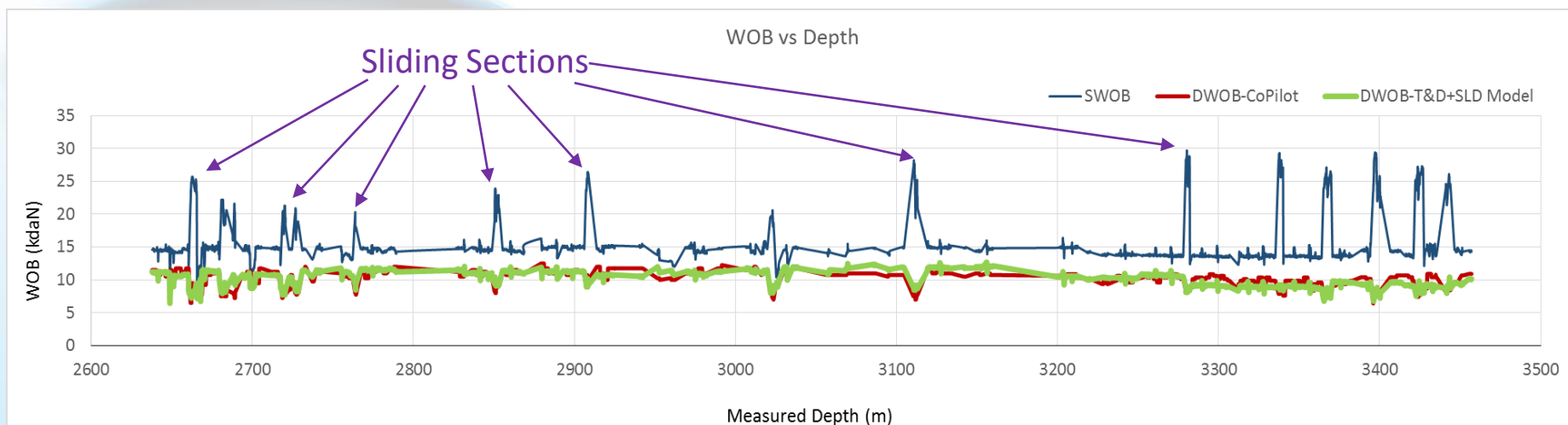
- ☐ **Sliding – Yes:** T&D model for rotating sections and sliding model for sliding sections
- ☐ Option to set sliding RPM
- ☐ Options to calculate abrasiveness
- ☐ **Save Drill file** for D-ROCK

D-WOB Validation

☐ If D-WOB Sliding option : No (only T&D model)



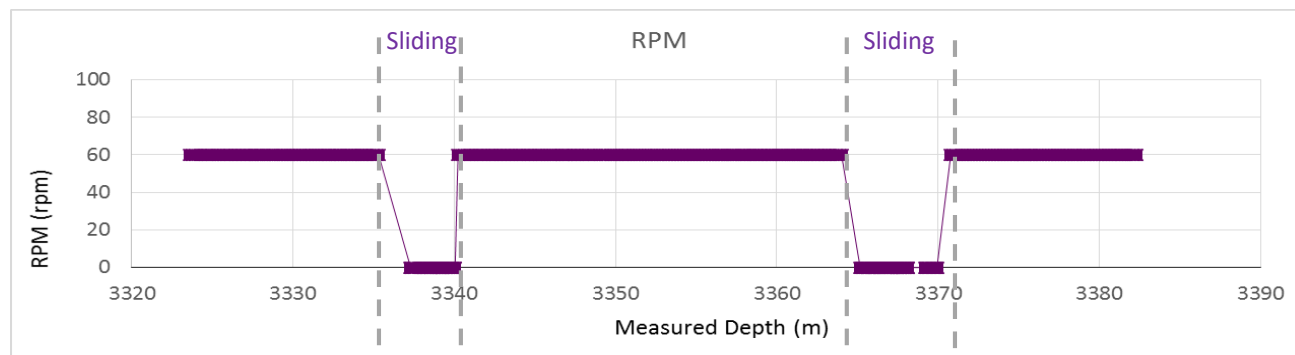
☐ If D-WOB Sliding option : Yes (both T&D and Sliding models)



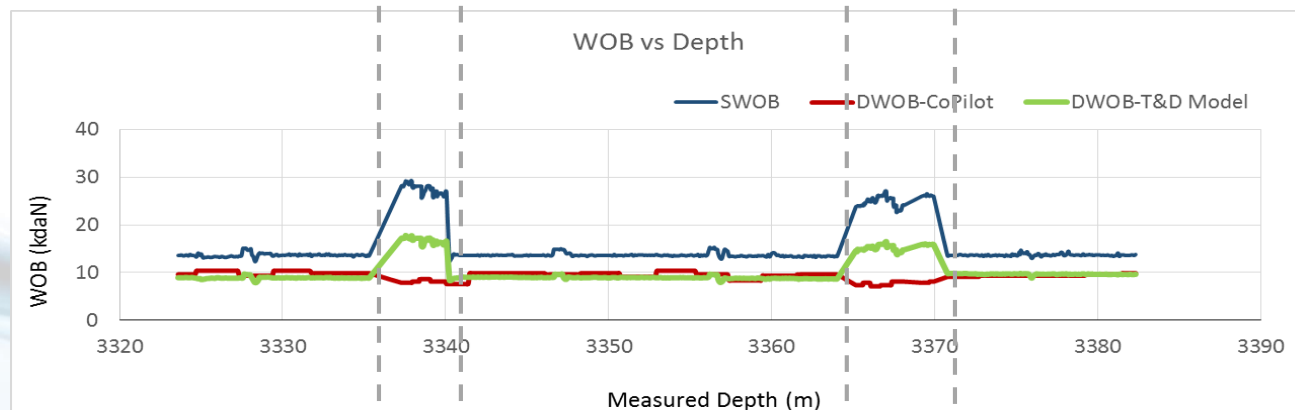
☐ Validation with downhole measuring tool – Co-Pilot

D-WOB Validation – Cont'd

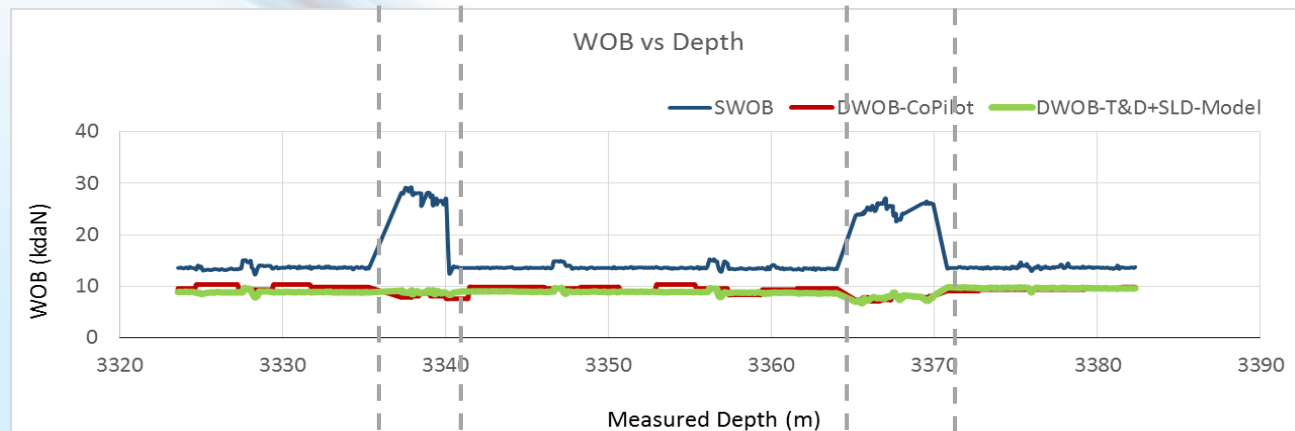
RPM

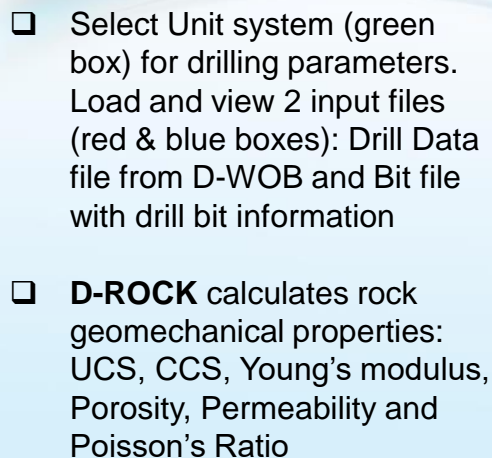


Sliding: NO – T&D Model



Sliding: YES – SLD Model
for sliding sections





D-ROCK Tool –Drill Bit and Data Information

Rocsol - D-ROCK - Bit Editor

File

Import Bit File

Open Bit Database

Start Depth 2112 m End Depth 4102 m

Bits

Number of Bits: 2 Add PDC Bit Add TRI Bit

	Remove X	Remove X
Bit Number	13	14
Bit Name	SDI513USBPX	FXD54
Diameter (mm)	171	171
Type	PDC	PDC
IADC		
Serial Number		
Depth-in (m)		
Depth-out (m)		
Wear-in		
Wear-out		
Jets (mm)		9.5
Sum of Jet Dia.^2 (mm^2)		0
Total Flow Area (mm^2)	416.614	354.411
Number of Cutters	33	33
Diameter of Cutters (mm)	12.7	12.7
Back Rake Angle (degrees)	20	20
Side Rake Angle (degrees)	0	0
Cutter Thickness (mm)	2.032	2.032
Junk Slot Area (mm^2)	7599.98	7599.98
Number of Blades	5	5
Motor Constant (RPM/lt)	0.137	0.137

Save Cancel

- ☐ Edit/create Bit file: .Bit input file
- ☐ Import Bit file for editing
- ☐ Open Bit Database to save bit file information

Rocsol - D-ROCK - Test-DR-MT-22Nov

Tools Menu

File Tools Help

Bit Constants Bit

Bit Editor

Formation Constants Formation

Triaxial Data

Bit File view

Bit Number	Bit Diameter (mm)	Bit Type	IADC	Bit Name
13	171	PDC	333	SDI513USBPX
14	171	PDC	232	FXD54

Bit Constants

File 1 of 6

	Bit Type	IADC	a1	c1	K	a2 water	a2 oil	b2	c2	a3	b3
	TRI	117									
	TRI	437									
	TRI	517									
	TRI	627									
	PDC	333									
	PDC	232									

Bit Constants Database

The screenshot displays the 'Triaxial Data' software interface. On the left, the 'Formation Constants' window shows a table with columns: Formation ID, AS Constant, BS Constant, AE Constant, and BE Constant. The table lists 8 formations, with Formation 9 selected. A blue box labeled 'Formation Constants Database' is overlaid on this table.

In the center, the 'Young's Modulus Constants' window shows a table with columns: Young's Modulus (E_c) in GPa, Confined Compressive Strength (CCS) in MPa, and Confining Pressure (P_c) in MPa. The table lists 6 data points. A blue box with two checkboxes is overlaid on this table:

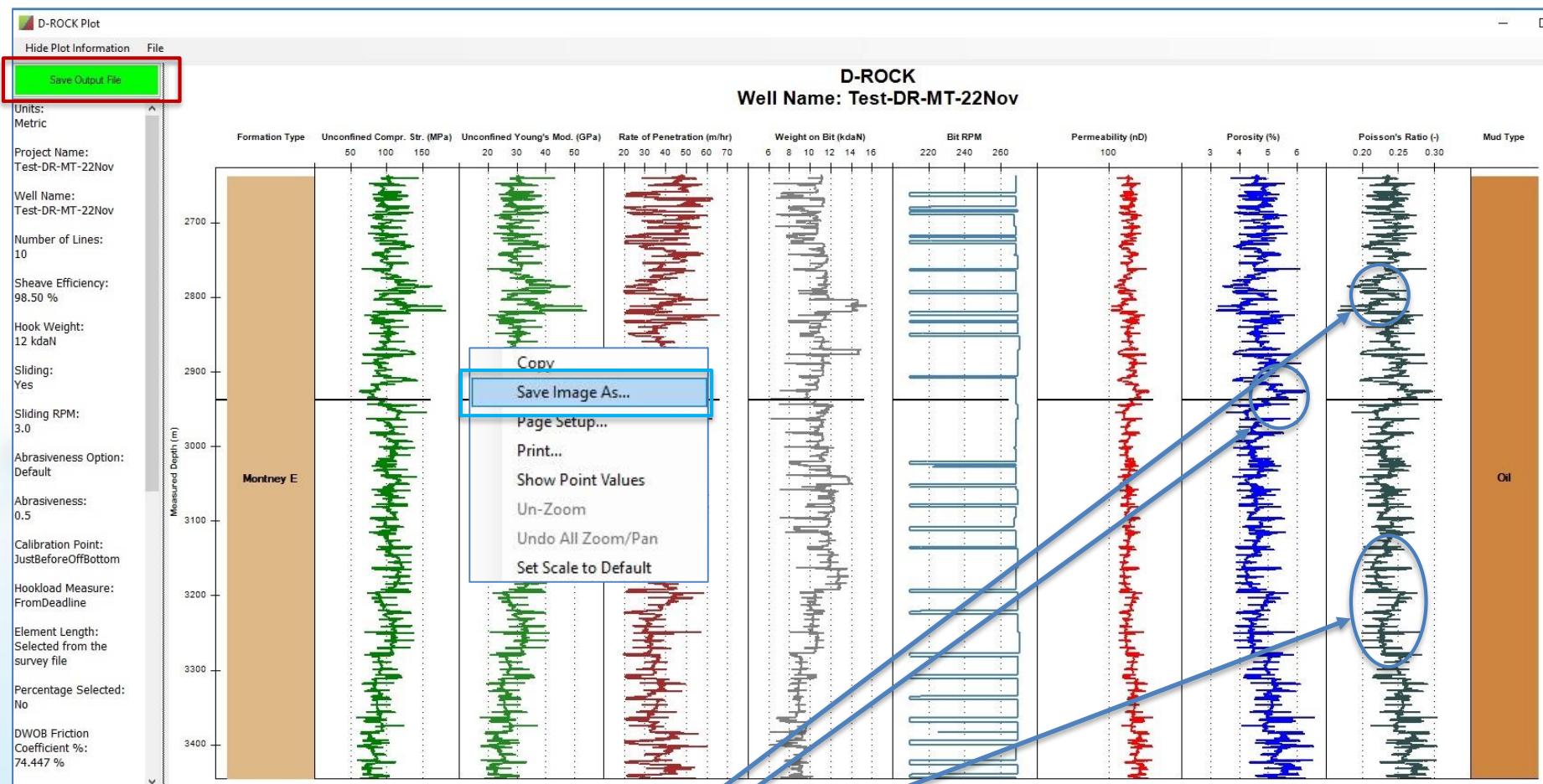
- ☐ Calculate constants AE and BE using Triaxial lab data
- ☐ Update Formation Constants Database

Below this table, a red box highlights input fields for 'aE' (0.275125) and 'bE' (-0.263955), with a green 'Calculate' button to the right.

On the right, a graph titled 'Young's Modulus over Confined Compressive Strength vs Confining Pressure' plots Young's Modulus (GPa) on the y-axis (0.08 to 0.28) against Confining Pressure (MPa) on the x-axis (0 to 35). The graph shows 'Lab Data' (blue circles) and 'Calculated Data' (red circles) connected by lines, showing a decreasing trend.

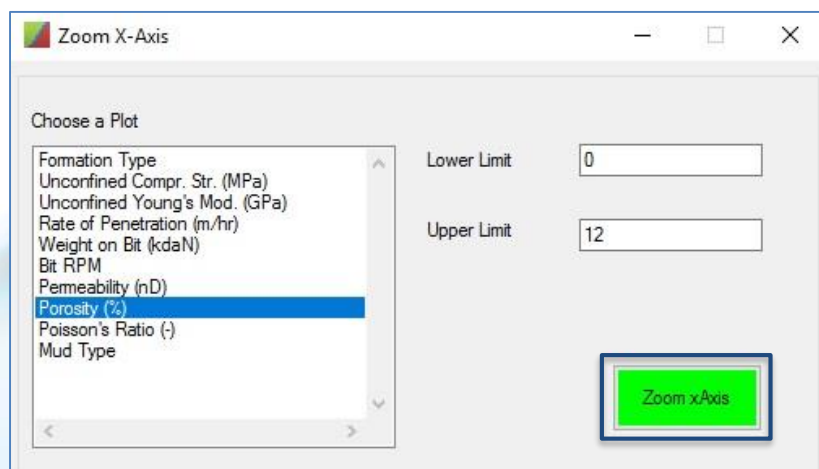
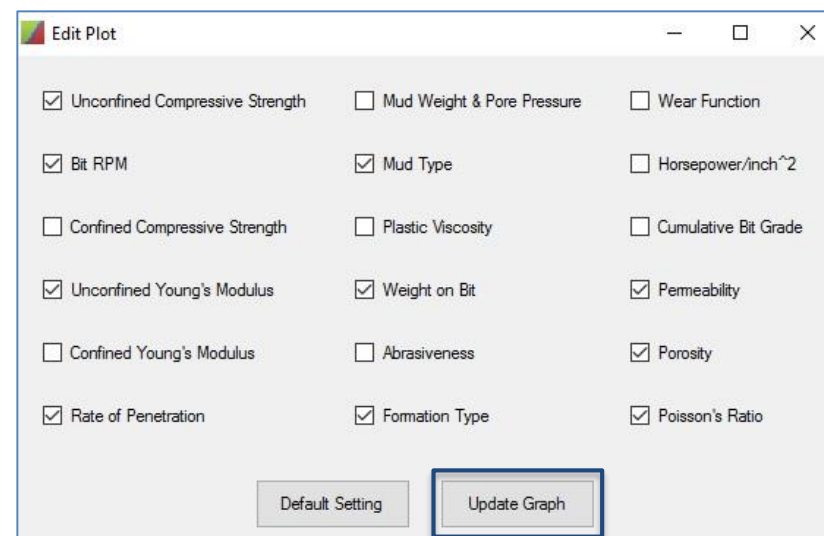
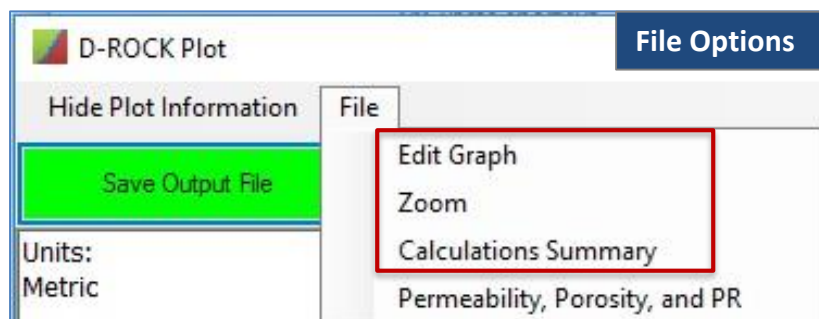
D-ROCK Outputs

- ❑ Calculates CCS, UCS, Young's Modulus, Porosity, Permeability and Poisson's Ratio
- ❑ Outputs can be used in stimulations design, reservoir mapping (Earth model – Petrel/Landmark) or drilling simulation



Where do we stimulate?

D-ROCK Plot – File Options

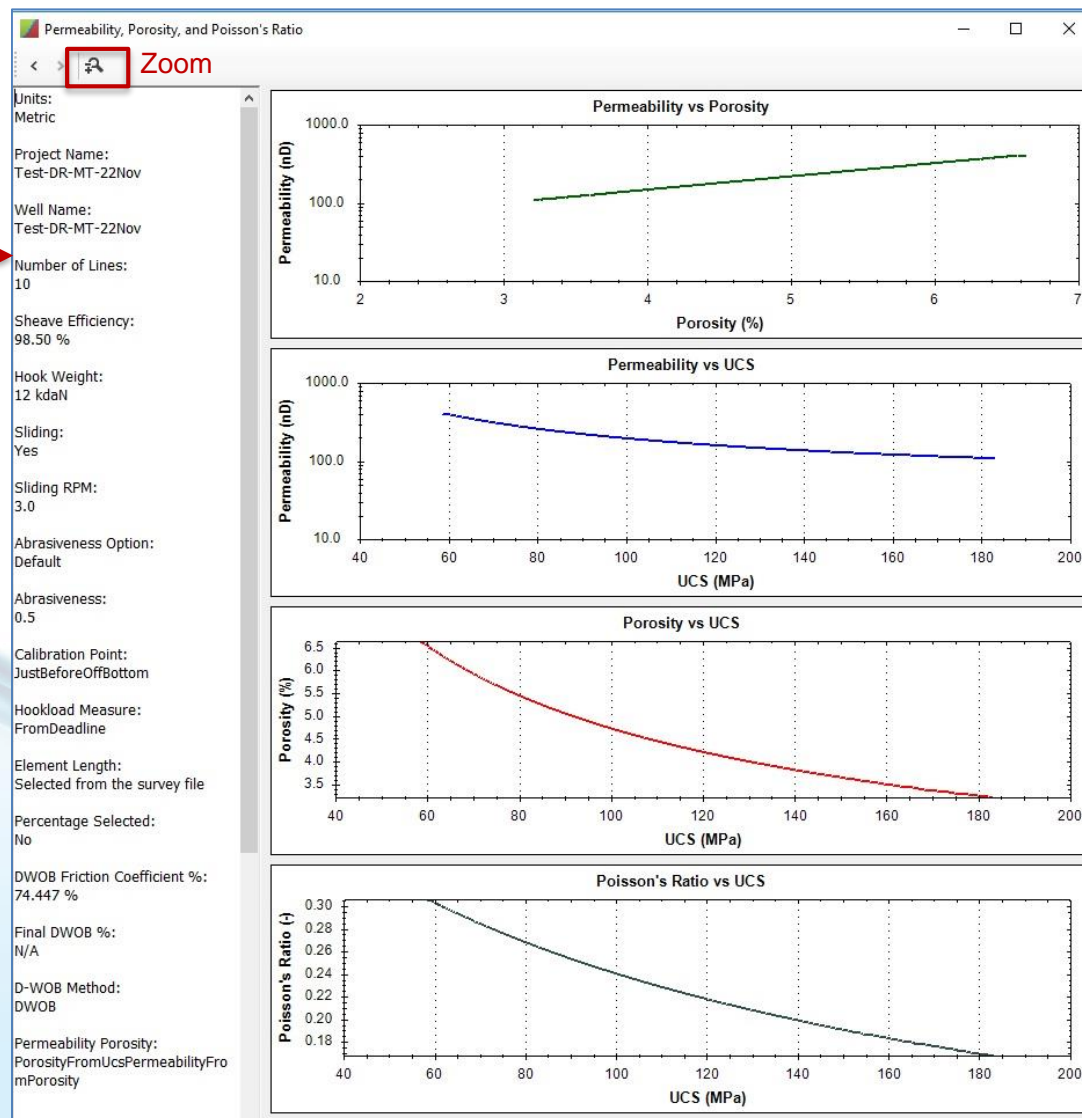
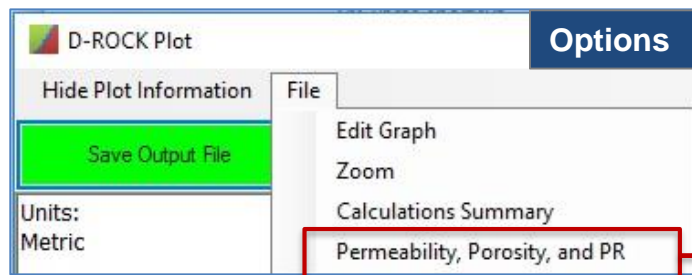


- ☐ **Edit Plot/Graph:** Parameter selection to view on D-ROCK Plot UI
- ☐ **Zoom X-Axis:** Zoom X-axis of any selected parameter
- ☐ **Calculation Summary:** Average of all parameters at bit run section

Calculations Summary

	Bit Name	Depth-in (m)	Depth-out (m)	Delta-Depth (m)	Average Rate of Penetration (m/hr)	Average Unconfined Compressive Strength (MPa)	Average Unconfined Young's Modulus (GPa)	Average Confined Young's Modulus (GPa)	Average Weight on Bit (kdaN)	Average Bit RPM (rpm)	Average Flow-Rate (lpm)	Average Mud Weight (sg)	Average Pore Pressure (sg)	Average Abrasiveness	Average Plastic Viscosity (mPa.sec)	Average Permeability (nD)	Average Porosity (%)	Average Poisson's Ratio (-)
▶	SDI513USBPX	2112	2937	825	34.98	105.77	31.49	23.29	10.64	249.5	1530	1.69	1.35	0.5	20	189.2	4.62	0.235
	FXD54	2937	4102	1165	35.25	99.92	29.75	22.05	10.25	252.1	1530	1.68	1.35	0.5	20	201.4	4.78	0.242

D-ROCK Outputs – Plot Options



Plot Options

- ☐ UCS versus Permeability and Porosity (Lower Eagle Ford formation)
- ☐ Poisson's Ratio from UCS and Mohr Failure Envelope

D-ROCK Verification

Results from a case study

Well Information

- ❑ Montney formation
- ❑ Montney: Dark grey siltstone with minor sandstone
- ❑ Porosity: 3 – 8%
- ❑ Poisson's Ratio: 0.22 – 0.28
- ❑ Horizontal section: 2600m – 4102m
- ❑ Oil and water based mud
- ❑ Smith drill bit: 171 mm
Haliburton drill bit: 171 mm

Results from Case Study

- ❑ Prediction on geomechanical properties are consistent with laboratory determined rock properties
- ❑ Average UCS: 99.92 – 106 MPa
Average Young's Modulus (YM): 29.75 – 31.49 GPa
- ❑ Similar analysis on an identical well yields average UCS around 109 MPa and YM around 32 GPa
- ❑ Average Porosity: 4.62 – 4.72%
Average Poisson's Ratio: 0.24