D-Series Software

D-ROCK

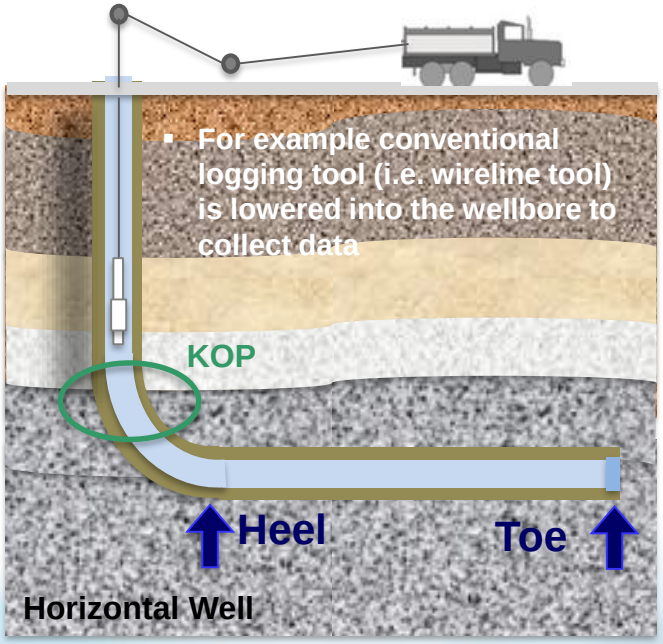
Outline

- 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

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

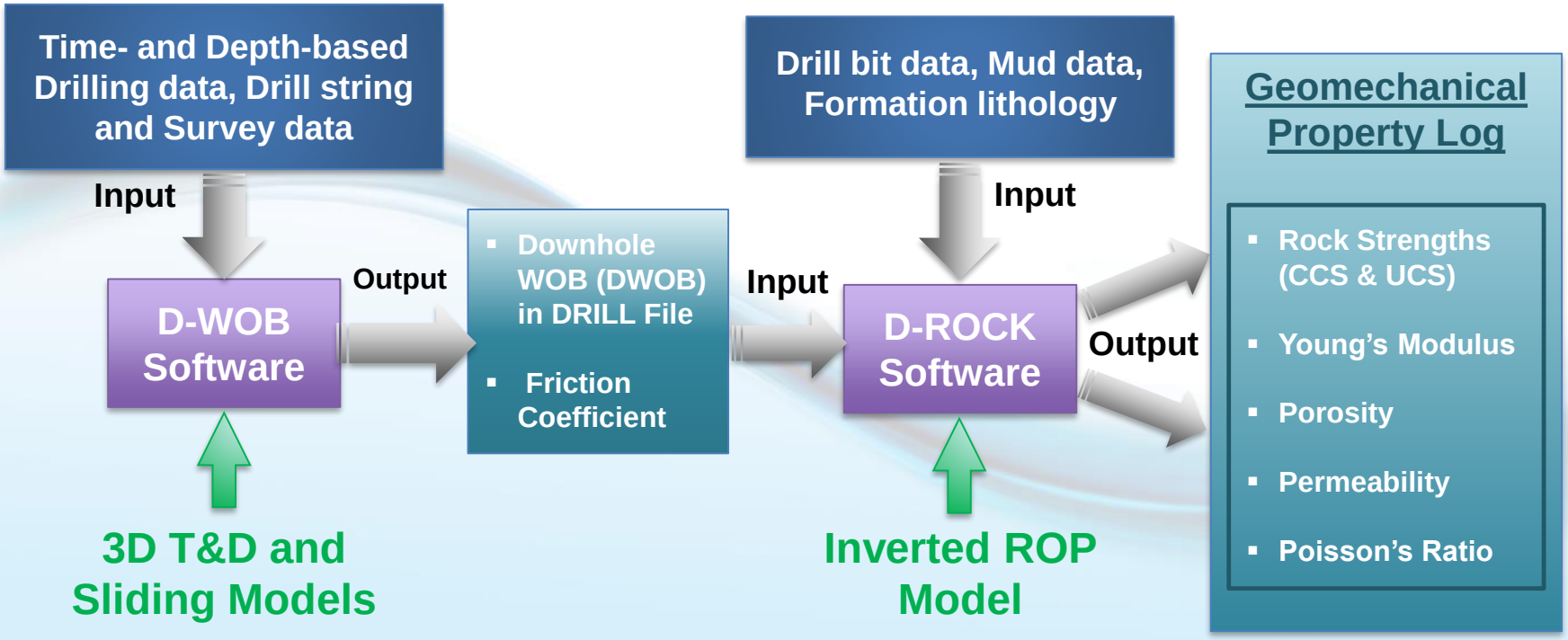
Introduction and Benefits

- 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

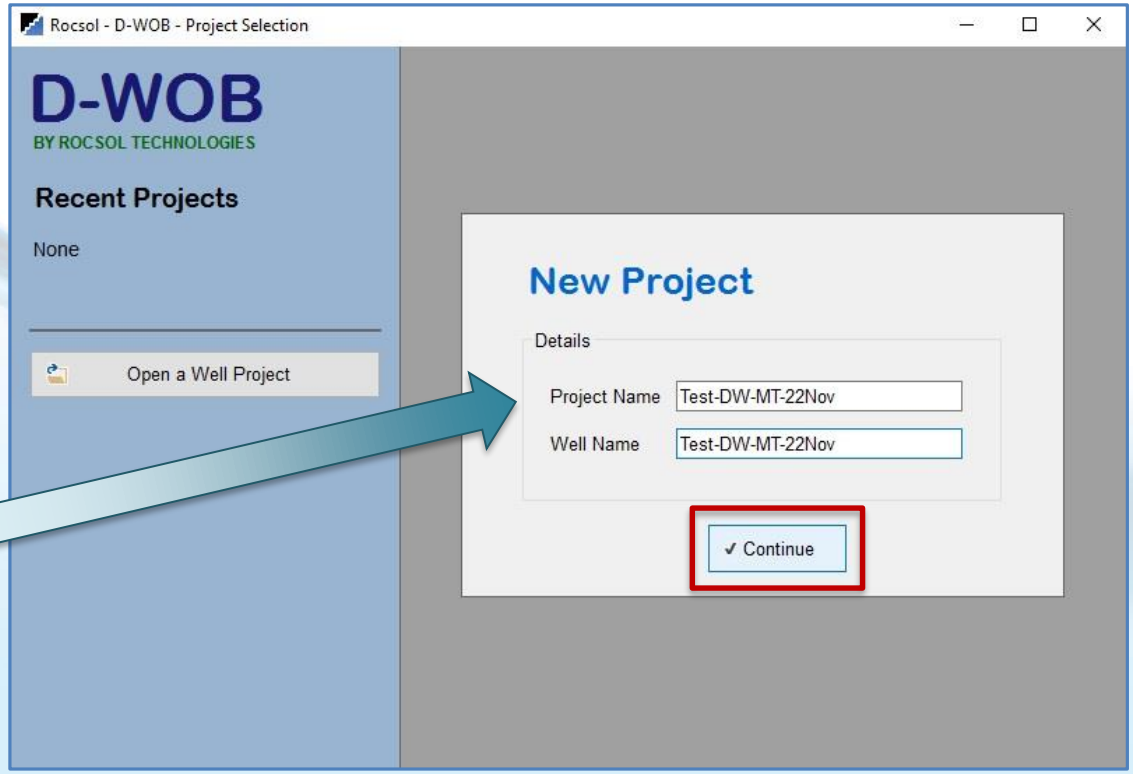
- **Input Files:**
  a) Drill data input file (default file extension: **.DRILL**) – From D-WOB output
  b) Drill bit input file (default file extension: **.Bit**)

- **Data saved in D-ROCK's Database**
  a) Bit constants
  b) Formation constants

Start New Project with D-WOB

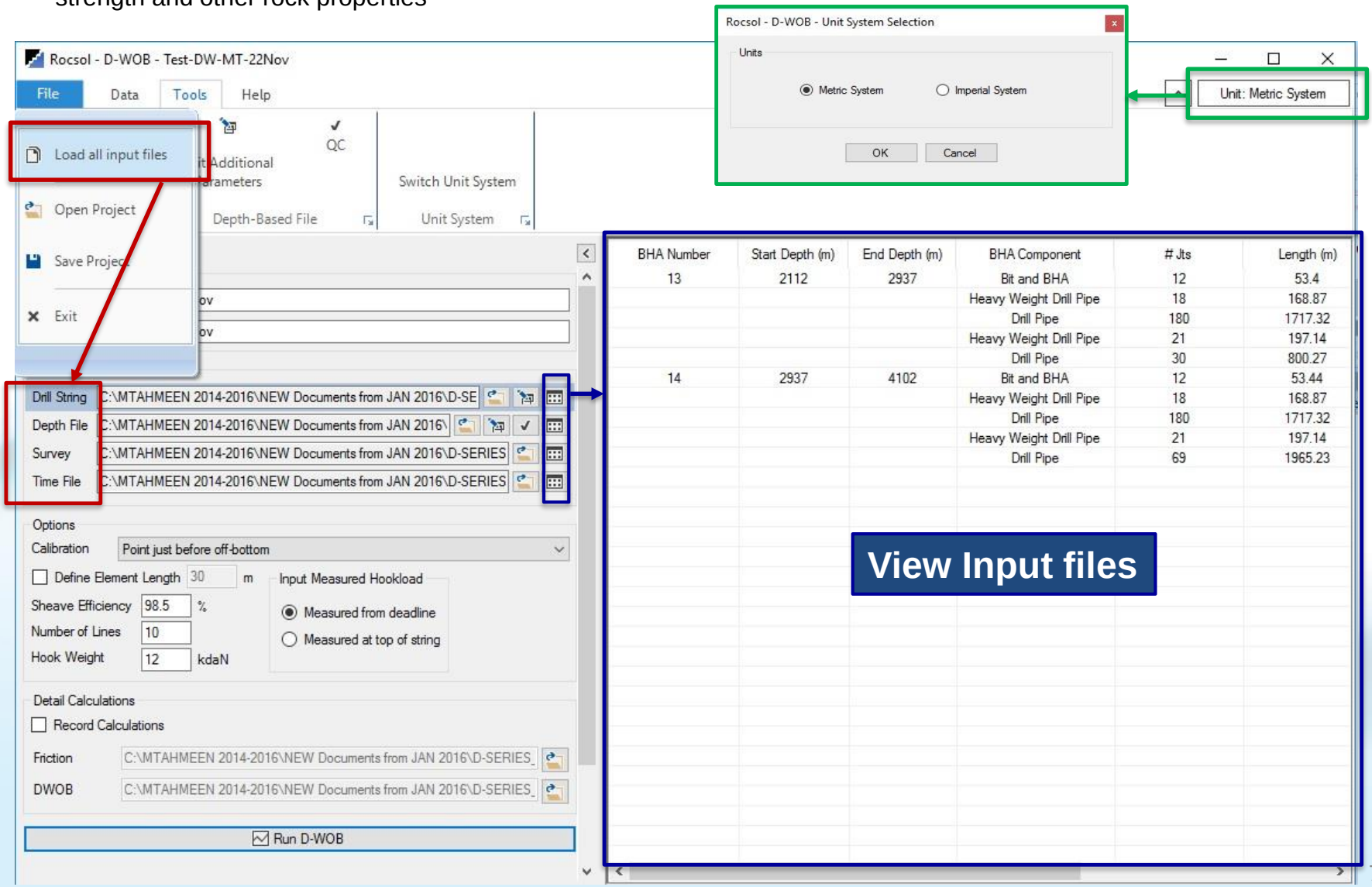
D-WOB Splash Screen

To start a new D-WOB project



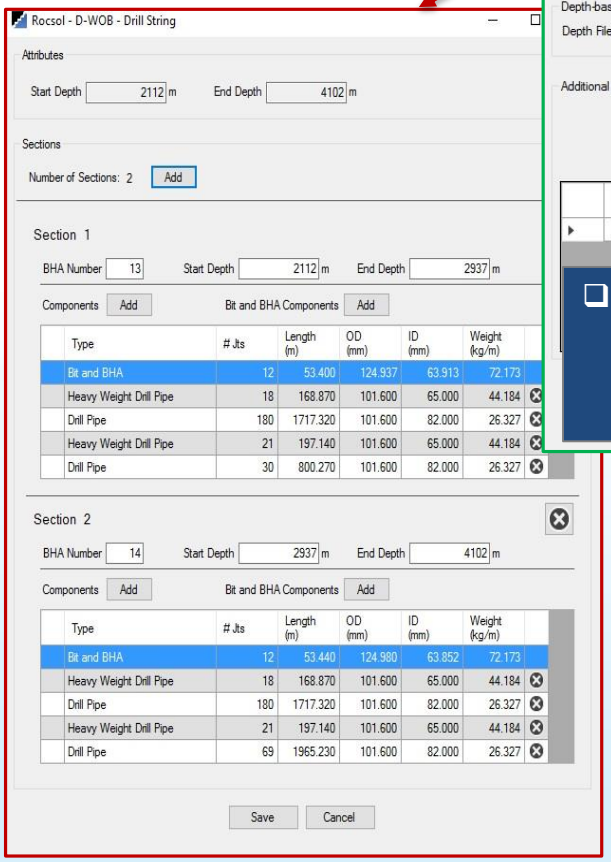
D-WOB Software

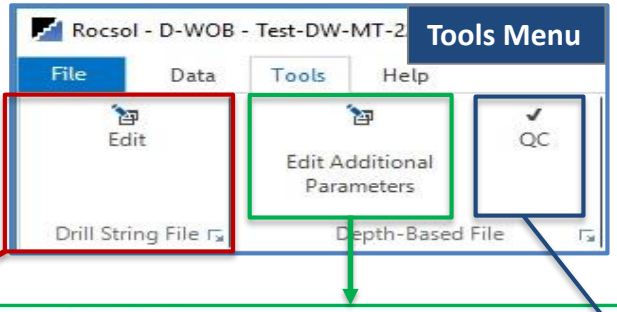
- Select Unit system for drilling parameters. Load and view 4 drilling input files
- **D-WOB** calculates downhole weight on bit (DWOB) which is used in Inverted ROP models to accurately predict rock strength and other rock properties

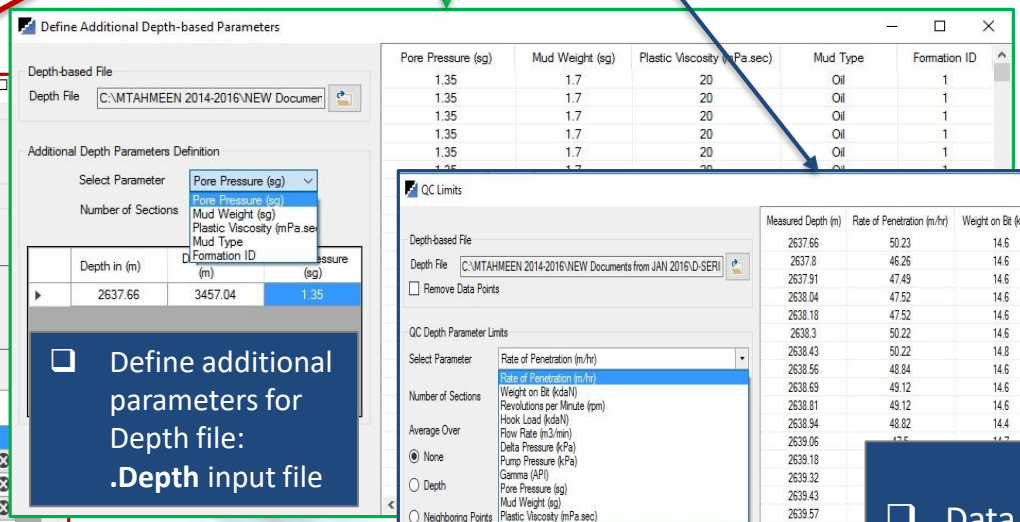


D-WOB – Tools

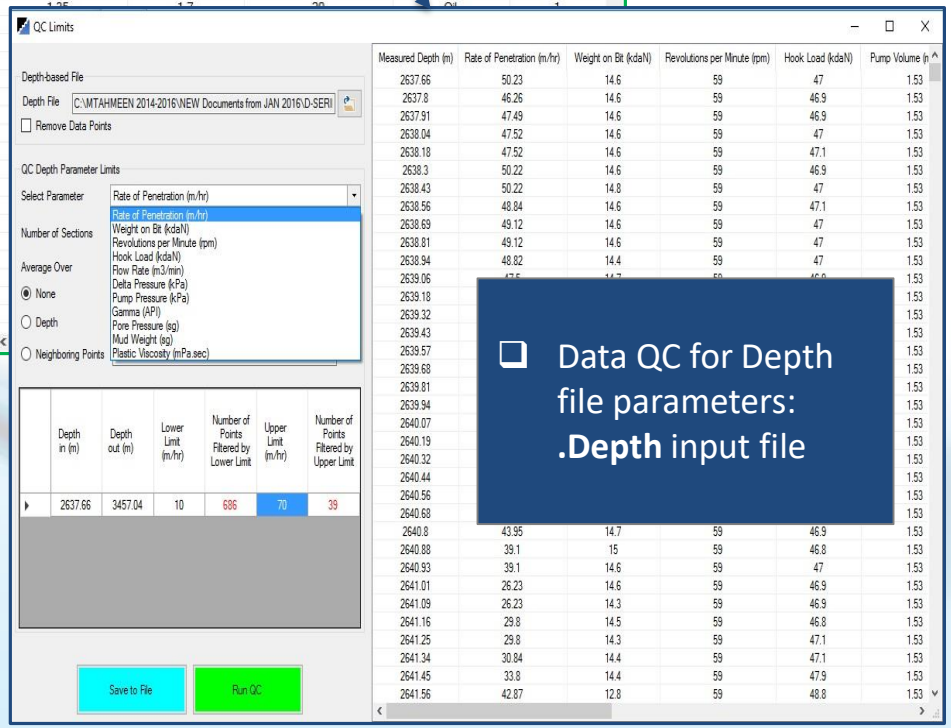
- Edit/create BHA (drill string) file: **.Bha** input file







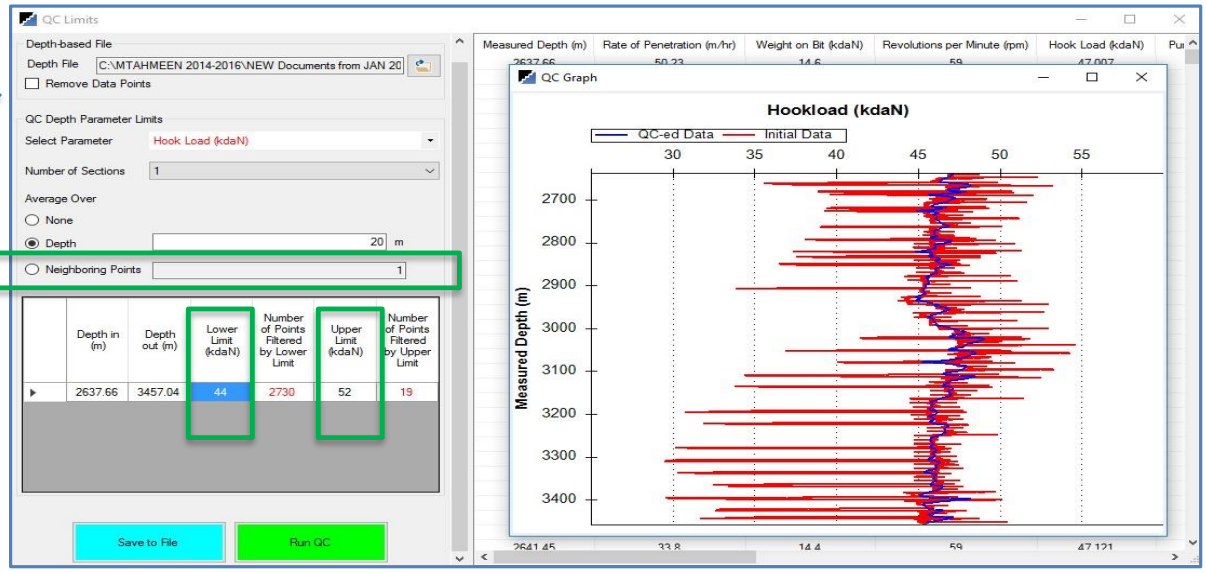
- Define additional parameters for Depth file: **.Depth** input file



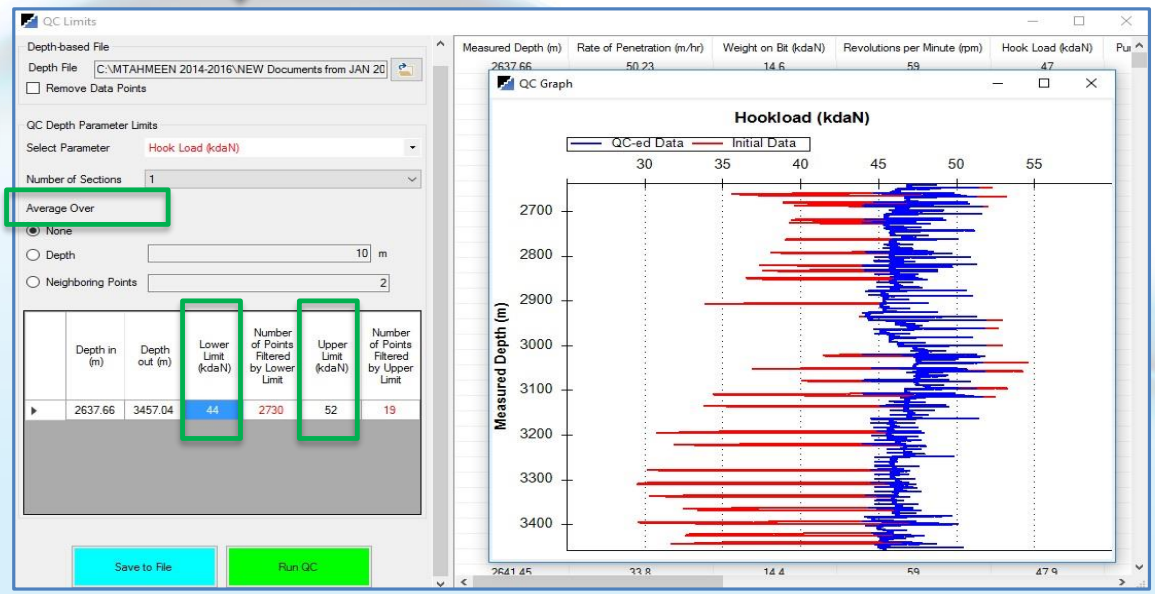
- Data QC for Depth file parameters: **.Depth** input file

D-WOB – QC Tool

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



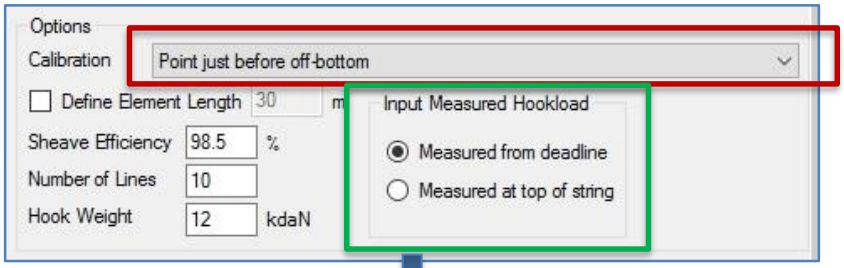
- QC based on set values of lower and upper limits without removing data points



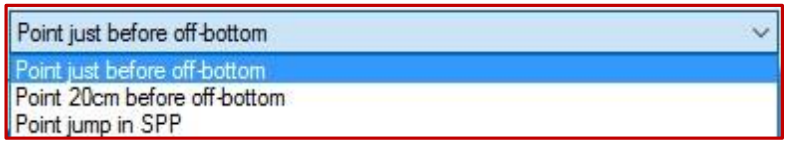
QC Options based on set lower and upper limits

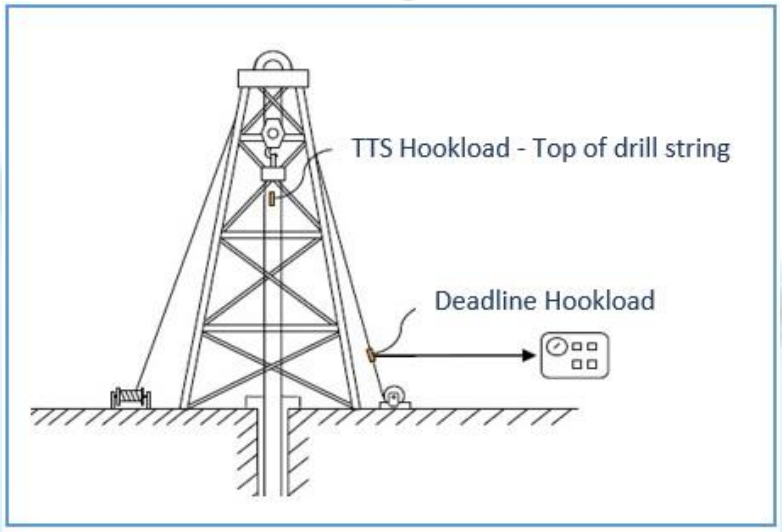
- Remove data points
- QC without removing data points
- Smoothing average over depth range
- Smoothing average over neighboring data points (1, 5, 10,…)

D-WOB Main UI – Options



❑ Options for friction coefficient calibration points





2

1

3

Off-bottom

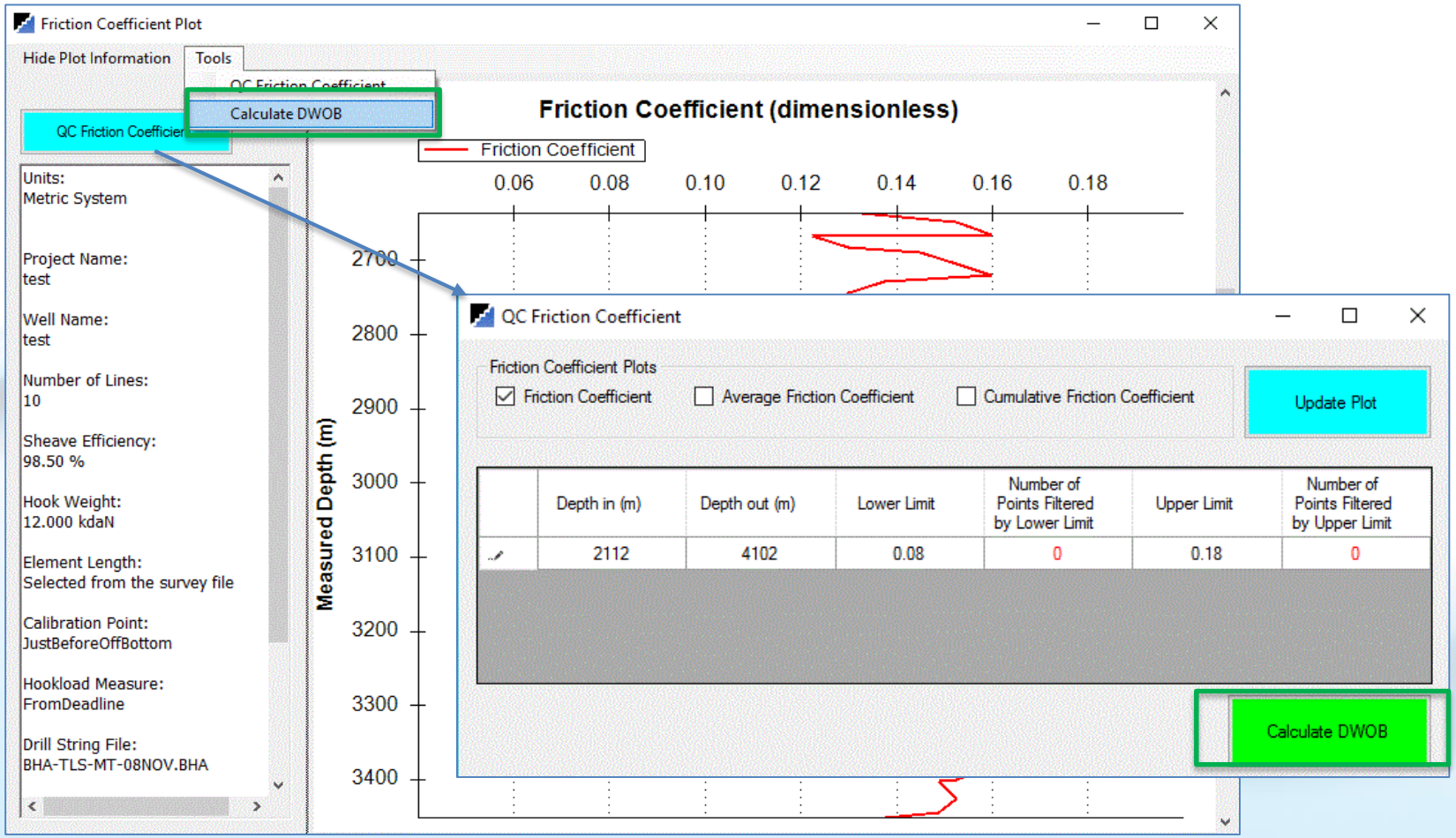
On-bottom

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	[illegible]	[illegible]	[illegible]	1.09	10182	0
[illegible]	1767.62	1767.9	[illegible]	[illegible]	[illegible]	1.09	10252	0
25-Sep-2011 02:16:40	1767.7	1767.9	[illegible]	[illegible]	[illegible]	1.09	10270	0
25-Sep-2011 02:16:50	1767.78	1767.9	42.9	1	50	1.09	10415	[illegible]
[illegible]	1767.85	1767.9	41.7	1.1	47	1.09	10958	0
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	[illegible]	[illegible]	[illegible]	1.09	11134	23.61
25-Sep-2011 02:18:10	1768.3	1768.3	[illegible]	[illegible]	[illegible]	1.09	11124	23.68
25-Sep-2011 02:18:20	1768.39	1768.39	[illegible]	[illegible]	[illegible]	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

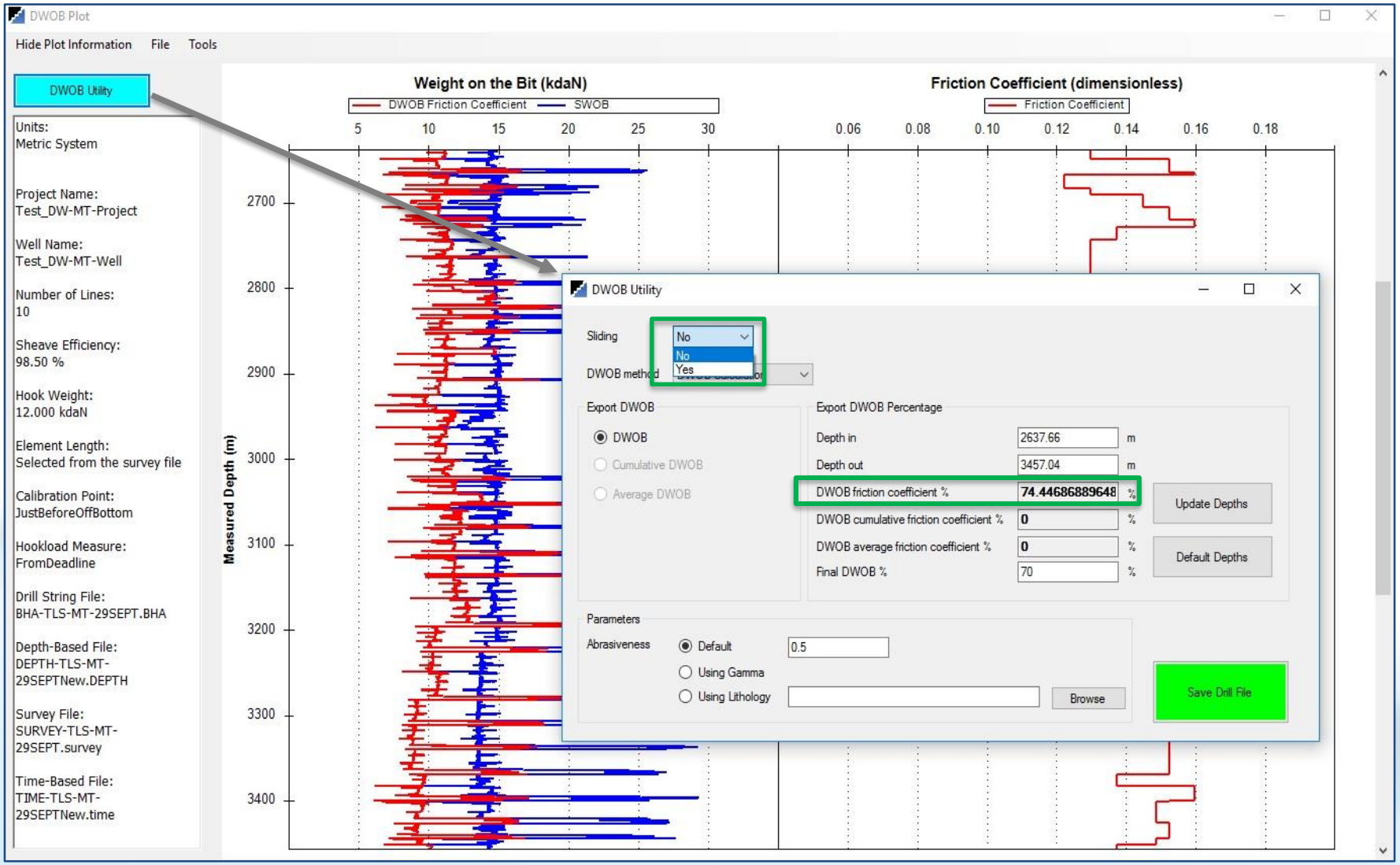
❑ Options of hook load measurement

Run D-WOB from Main UI

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

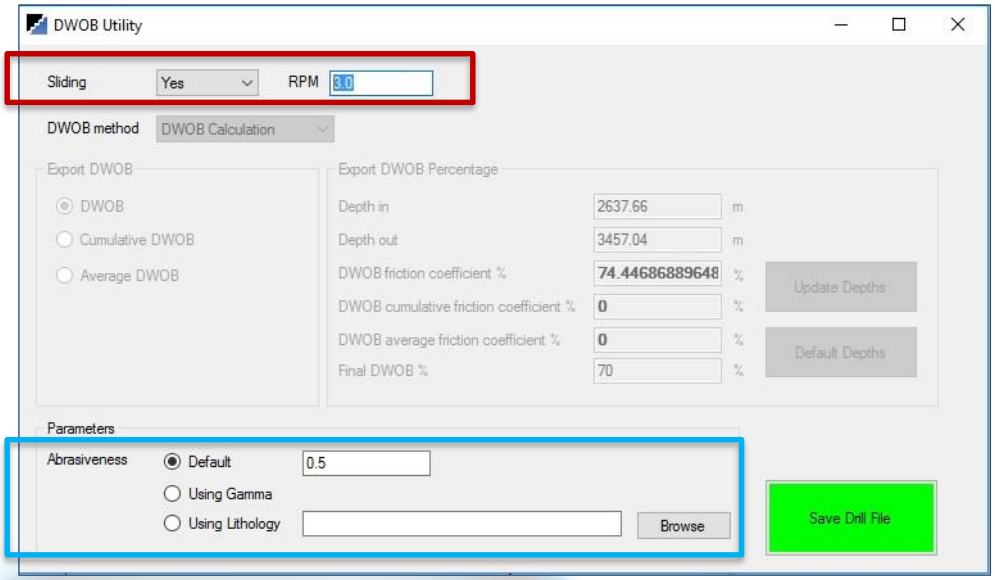


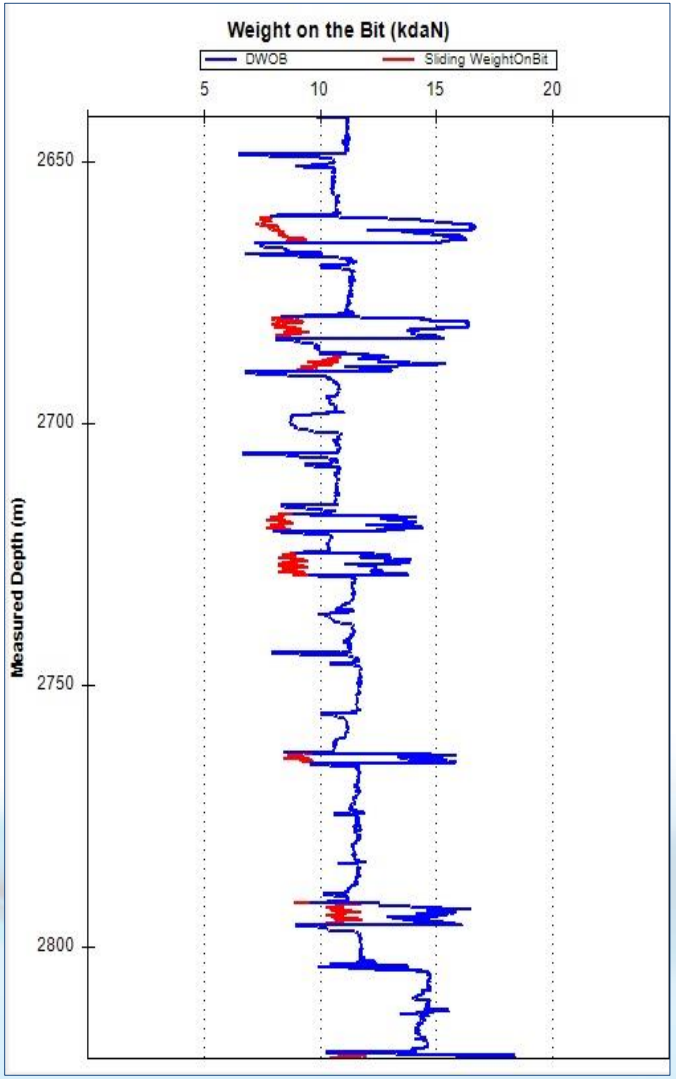
DWOB Calculations



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

DWOB Calculations – Sliding: Yes

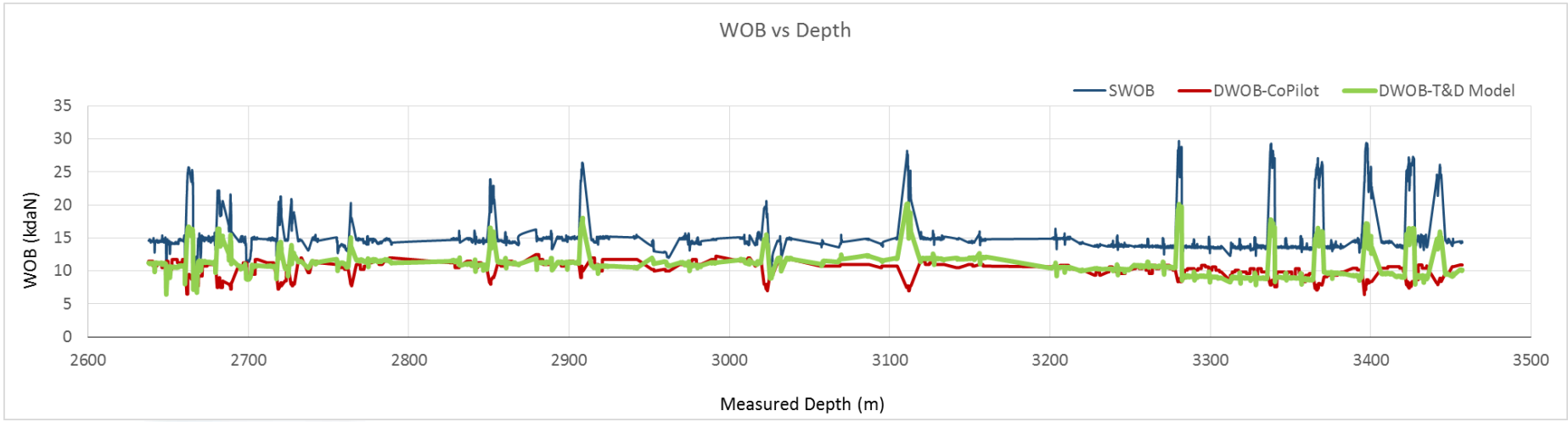




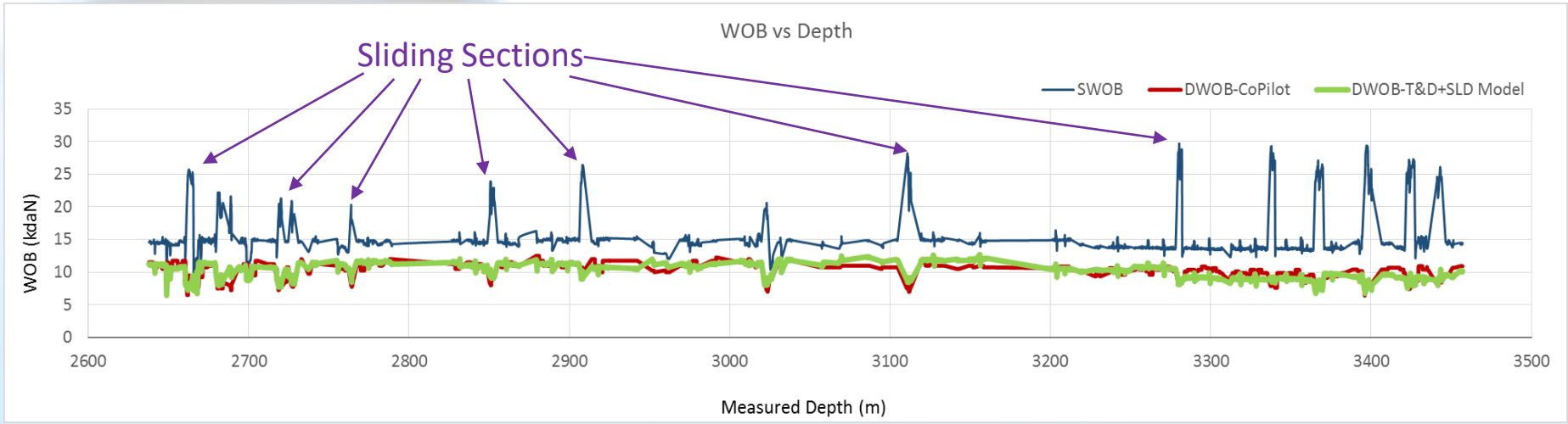
- **Sliding – Yes:** T&D model for rotating sections and sliding model for sliding sections
- Option to set sliding RPM
- Options to calculate abrasiveness
- **Save Drill file** for D-ROCK

D-WOB Validation

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



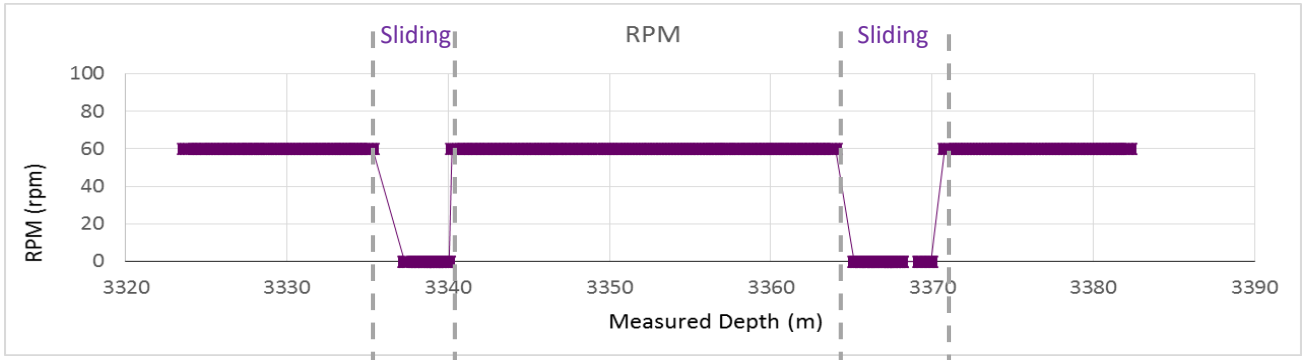
- **If D-WOB Sliding option : Yes** (both T&D and Sliding models)



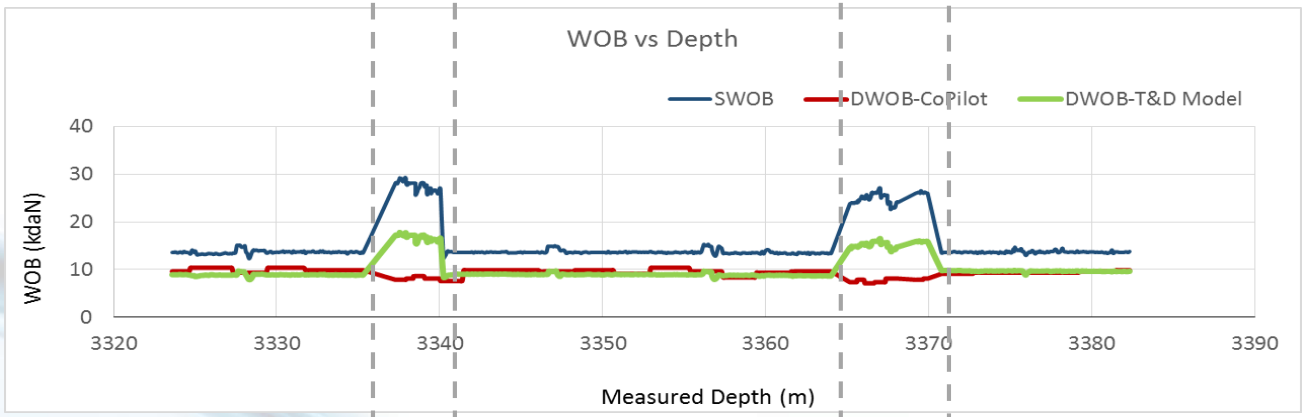
- Validation with downhole measuring tool – Co-Pilot

D-WOB Validation – Cont'd

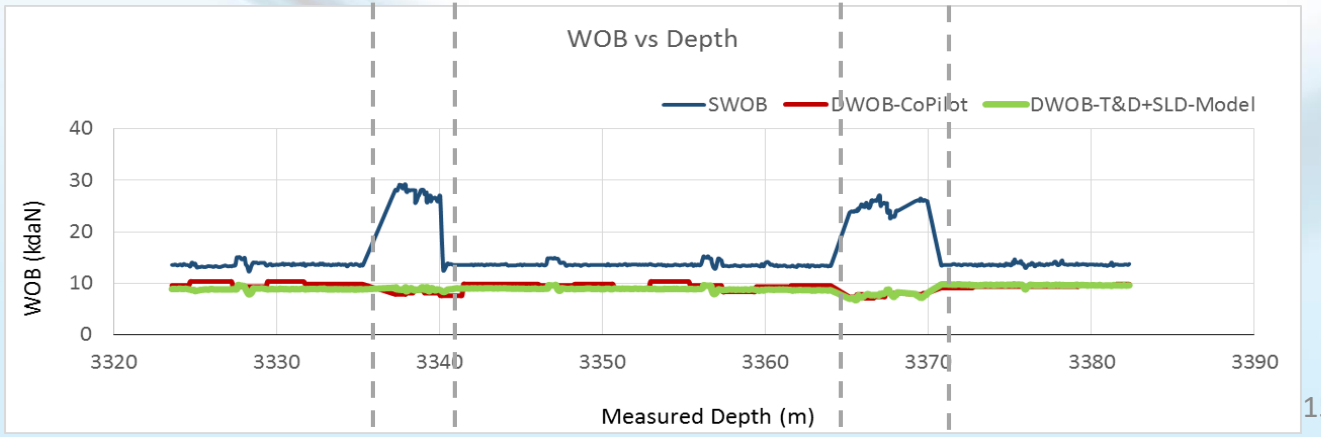
RPM



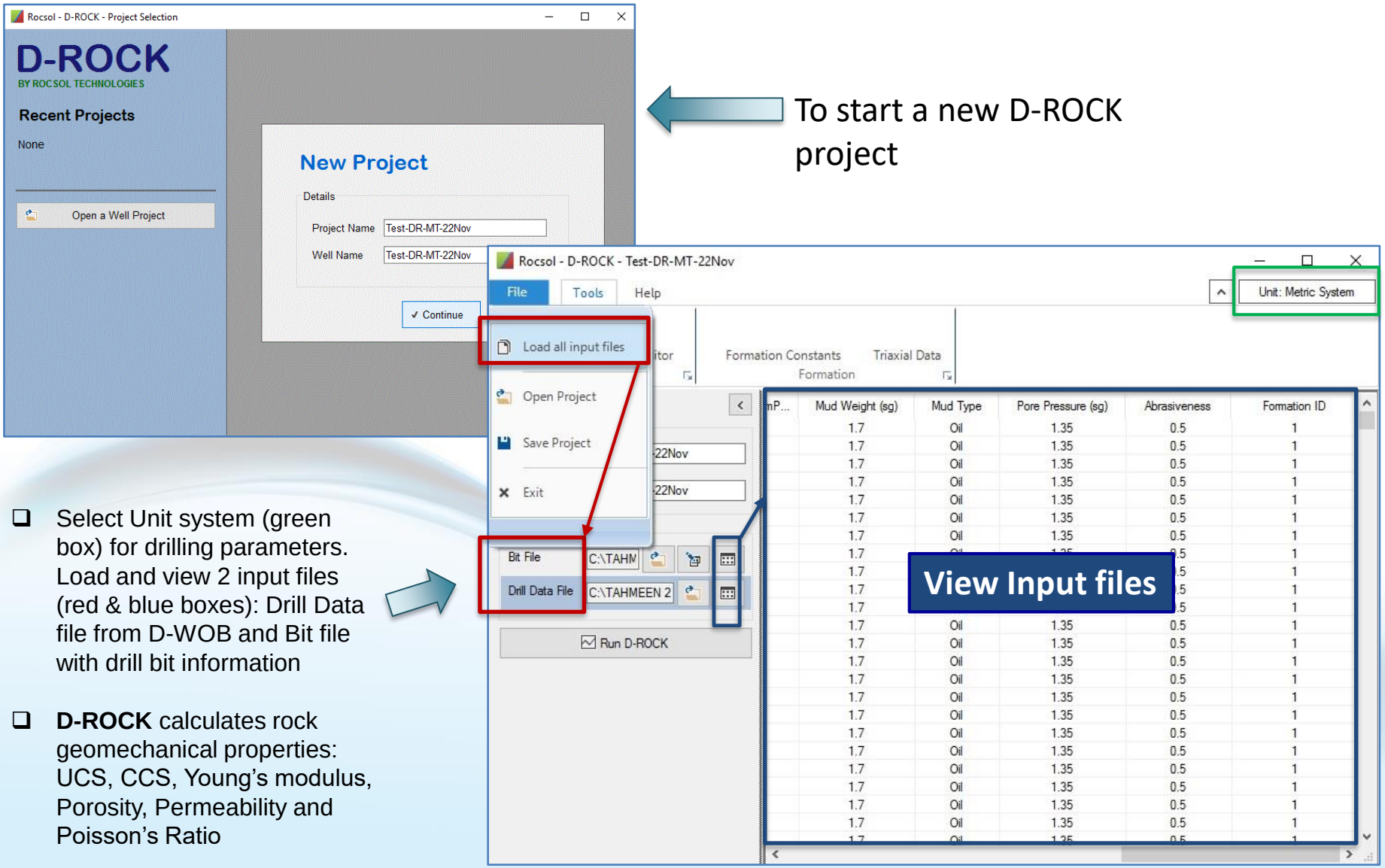
Sliding: **NO – T&D Model**



Sliding: **YES – SLD Model** for sliding sections



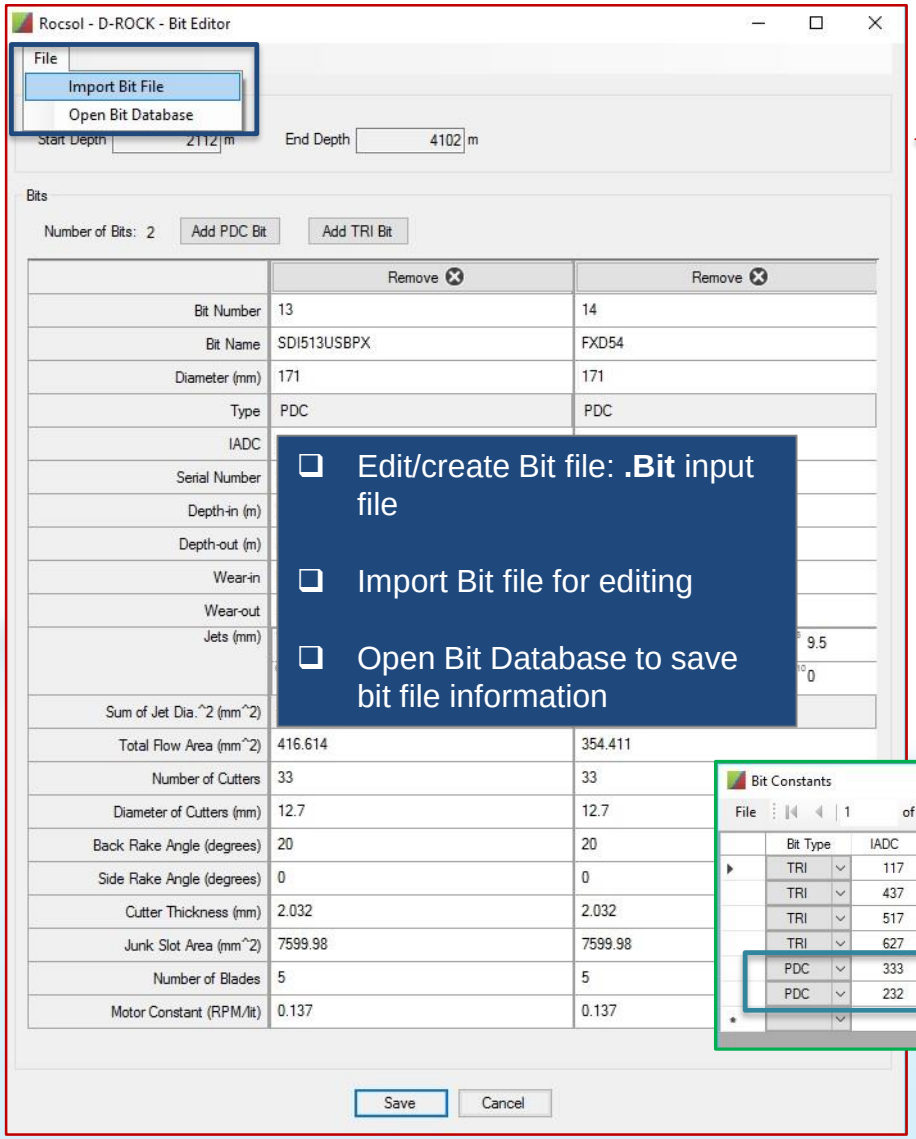
Start New Project with D-ROCK



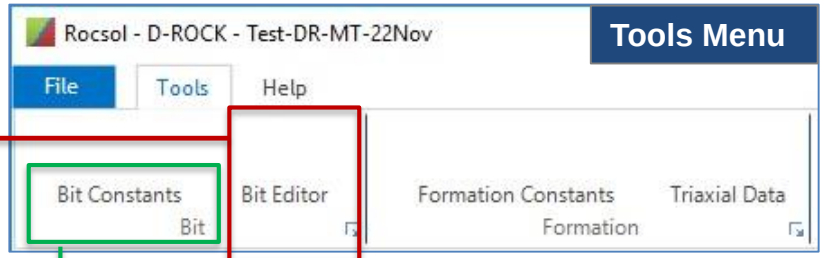
To start a new D-ROCK project

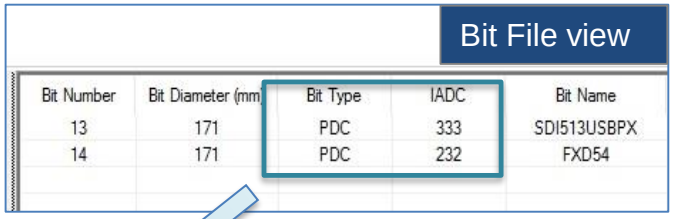
- Select Unit system (green box) for drilling parameters. Load and view 2 input files (red & blue boxes): Drill Data file from D-WOB and Bit file with drill bit information
- **D-ROCK** calculates rock geomechanical properties: UCS, CCS, Young's modulus, Porosity, Permeability and Poisson's Ratio

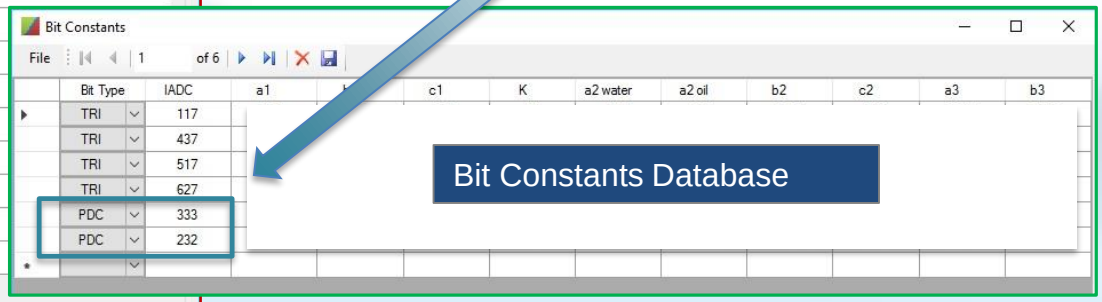
D-ROCK Tool –Drill Bit and Data Information



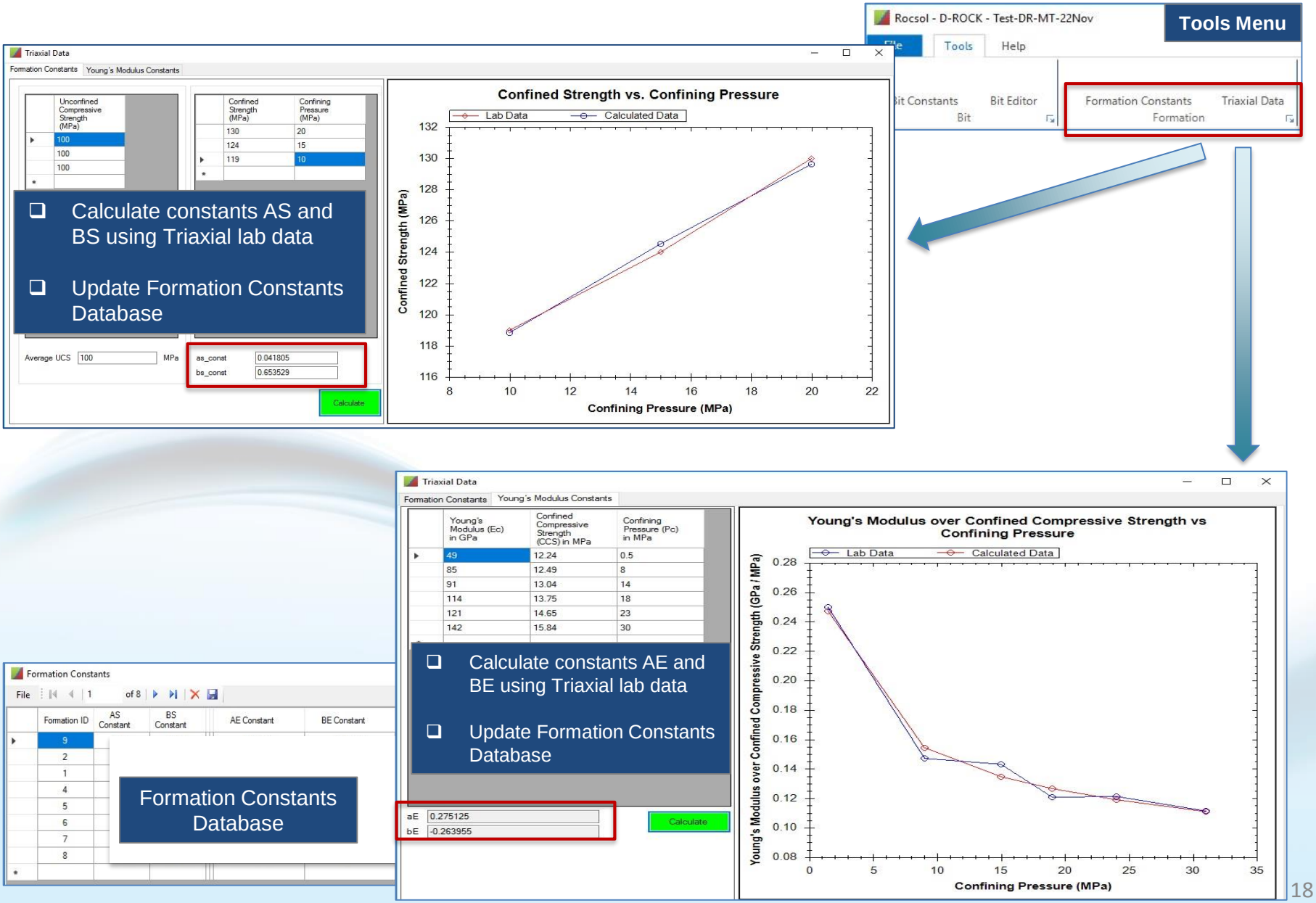
- Edit/create Bit file: **.Bit** input file
- Import Bit file for editing
- Open Bit Database to save bit file information





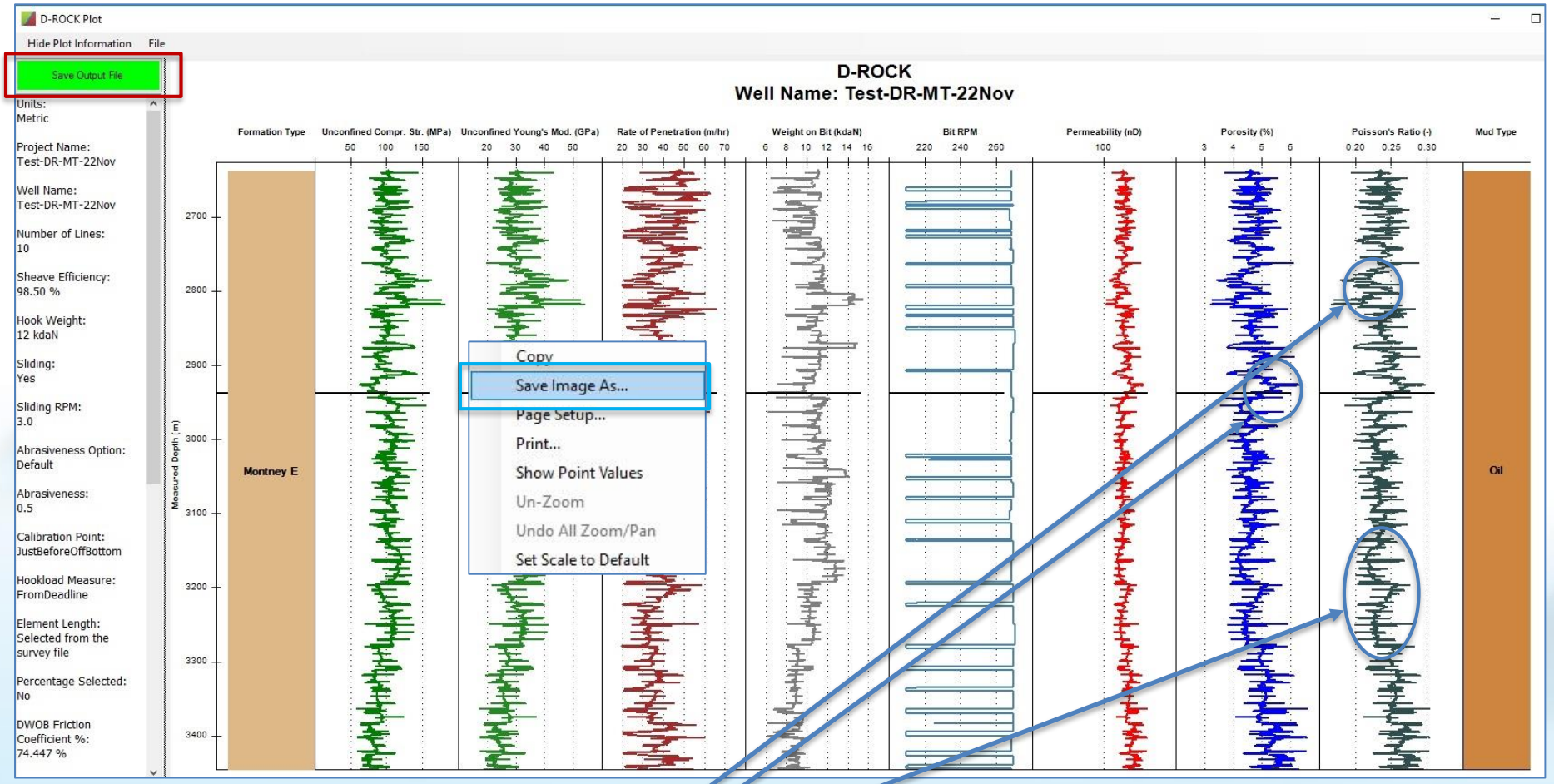


D-ROCK Tool – Formation Characteristics from Cores



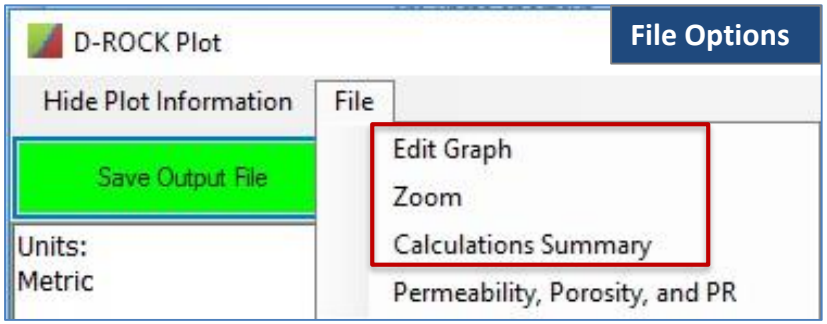
D-ROCK Outputs

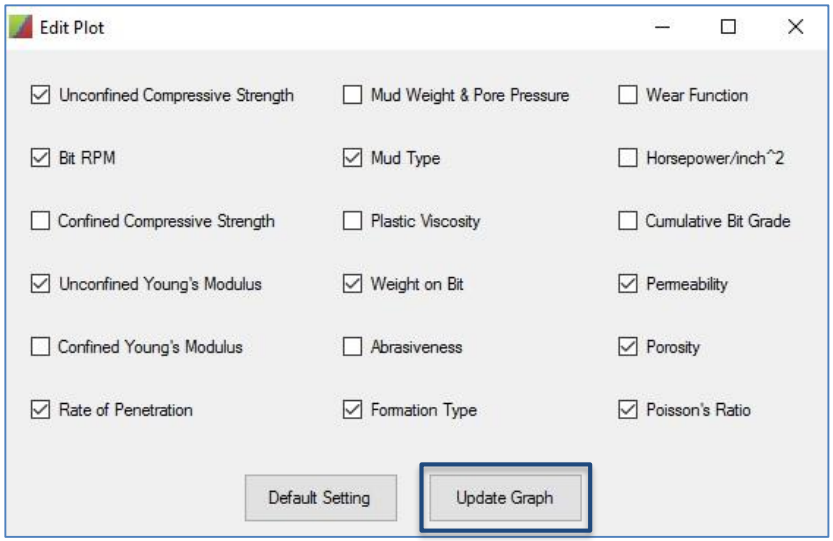
- Calculates CCS, UCS, Young's Modulus, Porosity, Permeability and Poisson's Ratio
- Outputs can be used in stimulations design, reservoir mapping (Earth model – Petrel/Landmark) or drilling simulation

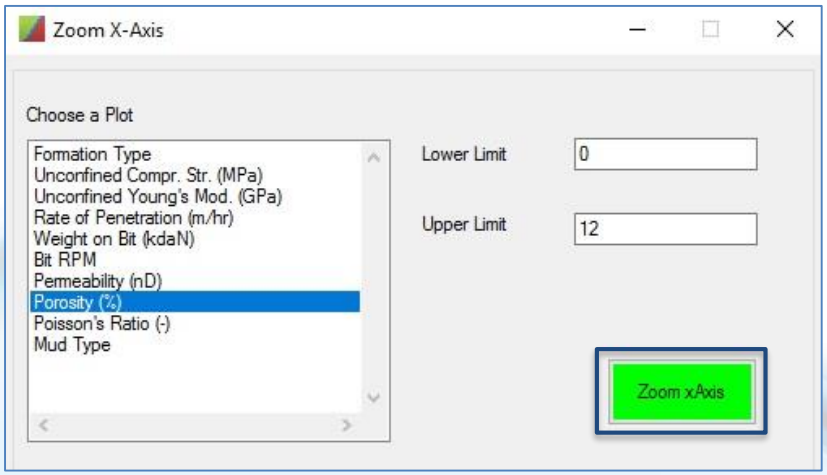


Where do we stimulate?

D-ROCK Plot – File Options





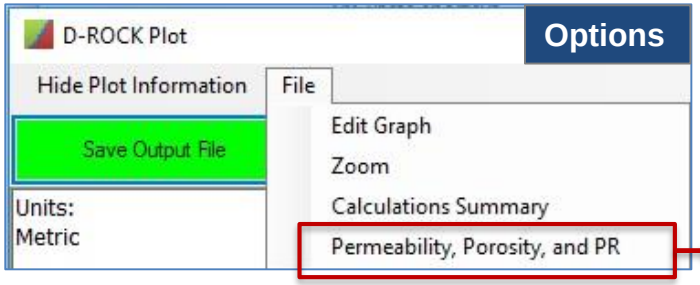


- **Edit Plot/Graph:** Parameter selection to view on D-ROCK Plot UI
- **Zoom X-Axis:** Zoom X-axis of any selected parameter
- **Calculation Summary:** Average of all parameters at bit run section

Calculations Summary

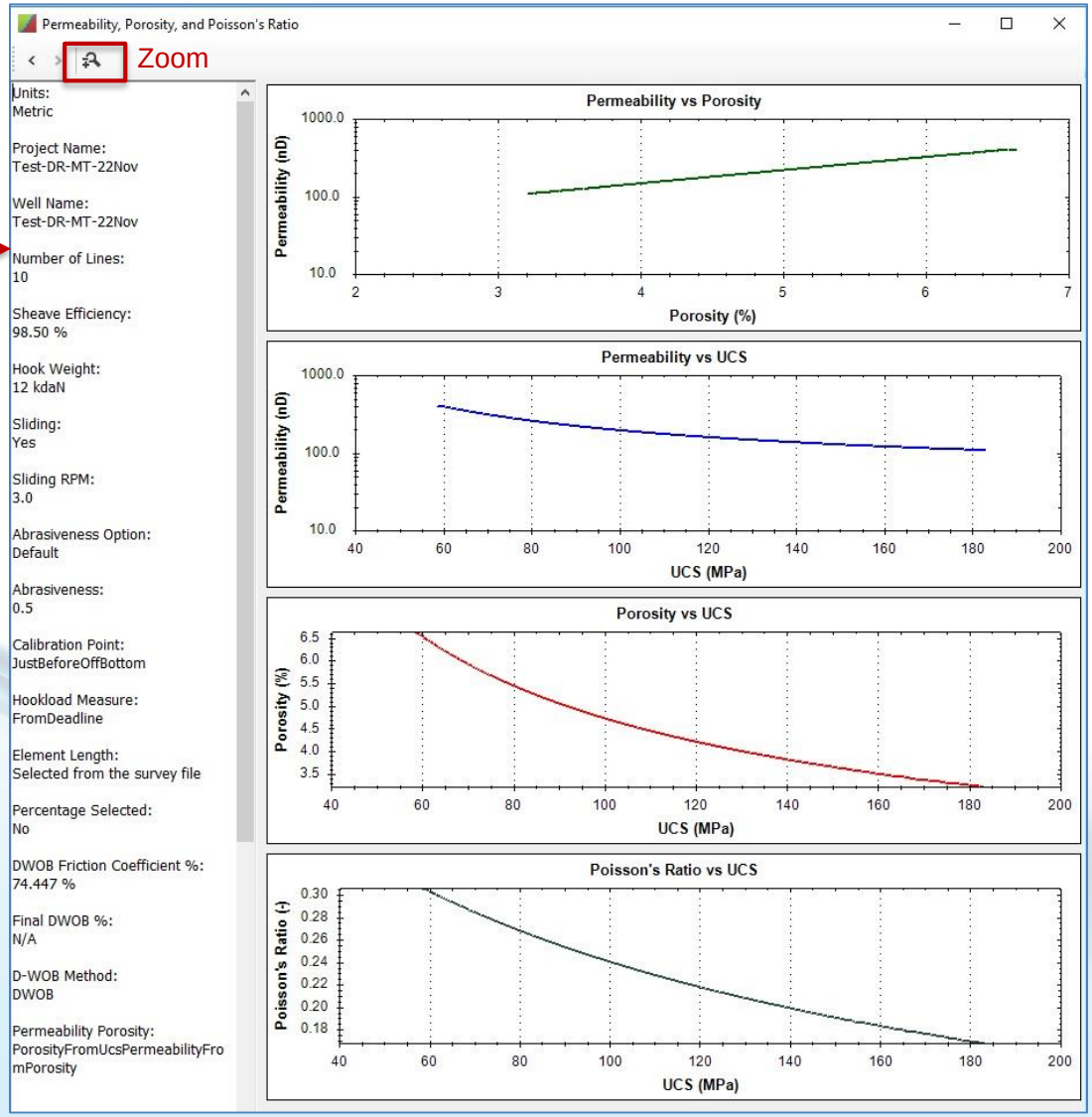
Bit Name	Depth-in (m)	Depth-out (m)	Delta-Depth (m)	Average Rate of Peneteration (m/hr)	Average Unconfined Compressive Strength (MPa)	Average Unconfined Young's Modulus (GPa)	Average Confined Young's Modulus (GPa)	Average Weight on Bit (kdaN)	Average Bit RPM (rpm)	Average Flow-Rate (lpm)	Average Mud 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