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Screening Tool for Rotary Steerable Candidate Selection

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Abstract

Rotary steerable tools are in use for drilling deviated as well as vertical wells. They provide certain advantages over alternative technologies such as bent-housing motors or square motors. Careful analysis of offset data helps to screen suitable candidates for the use of rotary steerable technology. The screening process has several aspects, such as the comparison of time, interval lengths, and rates of penetration in rotation and sliding; and review of nondrilling time, formation tendencies, and bottomhole assemblies.

Rig-based data-acquisition systems provide a good source of offset data. Most rigs in Western Canada use such a system for capturing typical drilling parameters at intervals of every 10 to 30 s. A dataset from such an acquisition system can be quite large. For a two-month well sampled at a 10-s interval, the dataset can typically be about 50 Mb, which makes the use of commonly available spreadsheet tools very inefficient. A new software program has been designed to help analyze offset data from rig-based electronic data-acquisition systems. This paper describes the key aspects of the algorithm used in this software for discerning useful information such as sliding versus rotating percentages and time breakdowns, which are derived from raw data in the form of drilling parameters such as pump pressure and hook load. In this paper, I also demonstrate the use of this software for calibrating torque and drag models.

Introduction

We live in the world of information technology. Every day lots of new data is captured and transmitted across the world. Drilling has also benefited from these technological advancements. Data-capture systems at the rigs capture key parameters that indicate the state of rig operations every 10 s and store them in huge databases. This data can form the basis of useful information for making fact-based decisions. It is, therefore, important that data is converted into useful information in a consistent and efficient manner.

The new software program (the program) provides a consistent and efficient mechanism for converting time-based, raw drilling data into useful information. Raw data is in the form of drilling parameters such as pressure, flow, rpm, torque, and weight on bit (WOB). Output from the program provides a time breakdown of rotary drilling, slide drilling, rate of penetration (ROP), tripping, reaming, and bottomhole assembly (BHA) handling operations. The time breakdown of BHA runs provides quick insight into the opportunities for optimization of drilling operations.

The program also breaks down data stream into manageable files of depth-based drilling data for each BHA run. These files can then be used for calibration of engineering models. One such application is the estimation of friction factors for drillstring design.

Conventional Data-Analysis Techniques

Conventionally, data is analyzed using spreadsheets. Spreadsheets offer a powerful environment with formulae for data manipulation and charting features. The main drawback is the amount of data that can be manipulated on a sheet. One sheet is limited to 65,536 rows of data. For data captured every 10 s, this limit is reached with 7.5 days of data acquisition. Most operations in Western Canada last a lot longer.

The second drawback of spreadsheets is that the speed of manipulation is an inverse function of the size of the dataset being manipulated. Interpretation of one row of drilling data can involve at least 13 decisions. Interpretation of one full sheet of data requires 845,000 decisions. This can take several hours of processing and still will only deliver information for one small part of a typical foothill's well.

The restriction on the number of rows and on the speed of processing makes the data analysis process inefficient to the point where it is not even attempted.

The New Program

The new program described here, which analyzes rig-based, electronically derived drilling data is a standalone program made in the Microsoft Visual C++ .net programming environment. It has the ability to batch process multiple drilling data files. These data files can be in one of three formats: comma-separated values (CSV), text file (TXT), or log ASCII standard (LAS). The individual fields of data can be comma-, tab-, or space-delimited. The program interprets the sequence of data to separate out the BHA runs and operational activity associated with each row of data.

Minimum Data Requirement

The time-based dataset for analysis must include the following parameters:

- Date and time
- Bit depth
- Hole depth
- Hook load
- WOB
- ROP
- Flow
- Standpipe pressure
- Rpm
- Torque.

The program does not take into account any units of measurements. All input is treated as dimensionless numbers.

Data Breakdown Algorithm

BHA Run Identification

Identification of BHA runs from time-based data is based on depth tracking. If data is captured without any breaks, the hole depth increases as the well progresses. Hole depth increases while drilling, whereas it stays constant while tripping. Bit depth, on the other hand, is a function of position of bit. It increases along with the hole depth while drilling but varies with the bit position while tripping. When tripping out, bit depth reduces and vice versa. Ideally, when the bit is at surface, bit depth should be zero. This relationship of hole depth and bit depth forms the basis of a simple logical model for BHA run identification from raw data.

I'll use a hypothetical example to explain this logic. Imagine a scenario in which a trip is about to commence. While drilling, hole depth is the same as bit depth, and both are steadily increasing at some rate related to the ROP. When drilling is stopped, hole depth becomes constant at the drilled depth. As trip is commenced, bit depth decreases with each successive row of data until it becomes zero at surface. As "tripping in" is commenced, bit depth starts to increase again until it gets to the same value as the hole depth, at which point, the bit is on bottom. A typical roundtrip dataset will exhibit the pattern outlined in Table 1.

Table 1: Pattern for BHA Roundtrips

Time	**Bit Depth**	**Hole Depth**	**Operation**
++	0	D1	Bit at surface
++	++	D1	Trip in
++	D1	D1	Bit on bottom
++	D1++	D1++	Drilling
++	--	D2	Trip out
++	0	D2	Bit at surface

++ indicates increment, -- indicates decrement

In reality, data is slightly more complicated because the bit at surface depth is not always captured as zero (see Figure 1). Instead, very often when *Bit Depth* is below a certain number, no data gets captured. That number varies with wells, data capturing system, rig operating practices, etc. The difficulty in interpretation is addressed by providing a calibration parameter *Bit-at-surface Depth.* When the *Bit Depth* is less than the *Bit-at-surface Depth*, bit is considered to be at surface. A new run is initiated when the *Bit Depth* goes past the *Bit-at-surface Depth* as it increases while tripping.

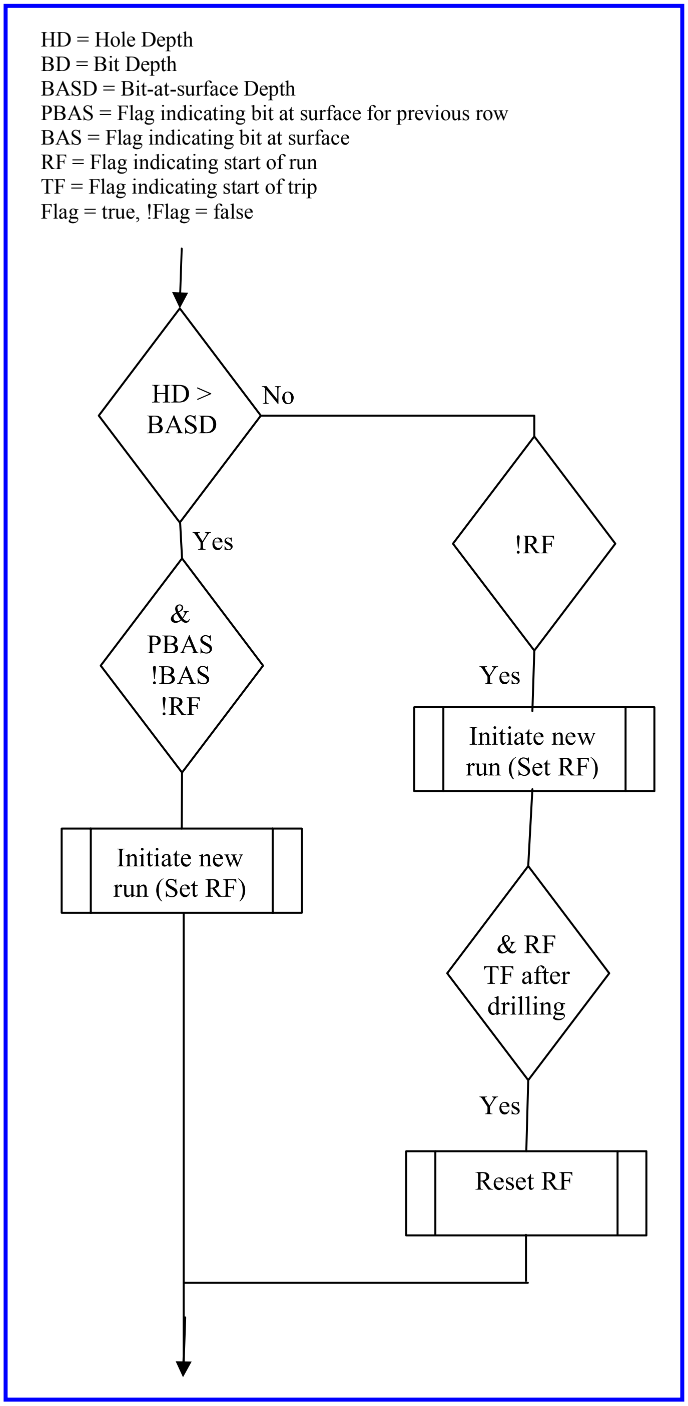


Figure 1: Flow chart for run identification.

The method of initiating a new BHA run by comparison with *Bit–at-surface Depth* works fine when the *Hole Depth* is greater than the *Bit-at-surface Depth*. When the *Hole Depth* is less than the *Bit-at-surface Depth*, each row of data represents a *Bit-at-surface* state. The simple logic of the new BHA run initiation will erroneously generate new BHA runs for each row of data. To avoid this, two flags are introduced, *Run Flag* and *Trip Flag*. The *Run Flag* is enabled when *Bit-at-surface* condition becomes true. So, this flag is enabled for all rows of data in which *Hole Depth* is less than *Bit-at-surface Depth.* When *Run Flag* is enabled for the first time, a new BHA run is initiated. The *Run Flag* is enabled for the first time when *Trip Flag* is set. *Trip Flag* is set when bit is off bottom for tripping. This outlines the mechanism for new BHA run initiations. However, the logic is still flawed and will go into perpetual run-flag set-reset cycle when tripping at hole depths shallower than the *Bit-at-surface Depth* value. To avoid these cycles, *Run Flag* is reset only if *Trip Flag* is set after a certain distance has been drilled with bit on bottom.

The main drawback of the logic is that for *Hole Depth* less than *Bit-at-surface Depth*, if the BHA is tripped out without drilling, it will not be counted as a new BHA run. This can be managed by suitable selection of *Bit-at-surface Depth* parameters. The program has set the default at 400 m. The user should decide if this depth is adequate for the data being analyzed and change it accordingly.

For the well interval in which *Hole Depth* is greater than *Bit-at-surface Depth*, the logic of a new BHA run initiation is relatively simple. A new run starts as the BHA is tripped in and the bit goes past the *Bit-at-surface Depth*. To test this condition, bit depths for two consecutive rows of data are compared with the *Bit-at-surface Depth*. As *Bit Depth* in the later row of data goes past *Bit-at-surface Depth* while the previous row does not, a new run is initiated.

Determining Operational Activity

Once decided which BHA run the row of data belongs to, the next step is to determine the activity associated with each row. The following modes of operational activity are recognized by the program:

- Rotary drilling
- Slide drilling
- Connection
- Tripping
- Reaming while tripping
- Reciprocating while tripping
- Reaming while drilling
- Surveys
- Others.

The operational activities are derived from the combination of two things.

- Fundamental activities: circulation and rotation.
- Status flags: bit on bottom, making hole, tripping, bit at surface, slip set, off-bottom reaming, weight on bit, and drill flag.

The fundamental activities are based on rig parameters and the logic is explained briefly in the following text.

Fundamental Activities

Circulation can be determined from either flow or standpipe pressure. Data captured from rigs have this redundancy. The program uses flow by default but gives user the choice to change the parameter to identify circulation. When the value of that parameter is greater than a threshold value, it is assumed that fluid is being circulated through the well. The threshold value is determined by the user. The default thresholds are 0.005 for flow and 200 for pressure. In an ideal world, these thresholds will be zero. But in the real world, all sensors exhibit certain play that results in a nonzero number when it should read zero. This necessitates the use of thresholds.

Rotation can be determined from either surface revolution per minute (RPM) or surface torque. Data captured from rigs have this redundancy. The program offers the choice of which parameter to use for rotation. When the value of that parameter is greater than a threshold value, it is assumed that the drillstring is being rotated from surface. The threshold value is determined by the user. The default thresholds are 0.5 for RPM or 50 for torque. The thresholds account for inaccuracies in sensor measurements when reading zeros.

Status Flags

The status flags are determined from the sequence of data and the comparison of parameters; their logic is explained as follows.

- *Bit on Bottom*: This flag is true when the difference between *Bit Depth* and *Hole Depth* is less than a threshold value. The default value for threshold is 0.1. User can override the default value.
- *Making Hole*: This flag becomes true when ROP is greater than a threshold, which is 0.1 by default.
- *Tripping*: This flag becomes true when the bit is off bottom by a distance greater than a threshold. The default for that threshold is 50. User can override this. This threshold takes into account the drilling practices such as reaming, surveying, or hole conditioning. The threshold defines the cutoff beyond which activity will be considered part of the tripping operation.
- *Bit at Surface:* This flag becomes true when *Bit Depth* is less than the user-defined threshold of *Bit-at-surface Depth*. The default threshold is 400.
- *Slip Set*: This flag is set when the hook load is less than the user-defined threshold of connection hook load.
- *Off-Bottom Reaming*: This flag is set when *Trip Flag* is not set and *On Bottom* flag is not set. Logic will be the equivalent of NOT (*Tripping* or *On Bottom*).
- *Weight on Bit*: This flag is set when the WOB is greater than the user-defined threshold of off-bottom WOB.
- *Drill Flag*: This flag is set when the bit satisfies the

Bit on Bottom criteria.

The algorithm flow chart (Figure 2) explains the logic used by the program to determine the operational activity for each row. The algorithm constitutes a six-level-nested if-else-if block. All decisions are mutually exclusive, which means that one row of data can only be attributed to one kind of operational activity. The criteria of decision at each level of if-else-if statement are also tabulated next to the flow chart. In the insert table in Figure 2, the “&” sign is a Boolean *AND* operator, and “NOT” is meant to be a Boolean *NOT* operator.

Program Outputs

This section provides some examples of outputs from the program.

Time Breakdown

Time breakdown is provided in a csv-formatted file for each well analyzed. The file contains a table of BHA runs along with time associated with each run, broken down by operational activities. This allows comparison of BHA performance in various wells, without the time-consuming exercise of reading through dailies and end-of-well reports. Such a comparison is helpful to identify areas of improvement.

Case Study 1

Table 2 shows part of the time breakdown for two wells. Well 1 was drilled first. Both wells were vertical to a depth of 2000 m and had a similar directional profile thereafter.

Well 1 was drilled with a BHA comprising bent-housing motors. It can be seen that maintaining verticality was a significant challenge in Run 9 in Well 1 and required 31% sliding. Hole drag became evident even in the vertical part of the hole and required two dedicated reamer runs. Run 8 and Run 12 on Well 1 are reamer runs.

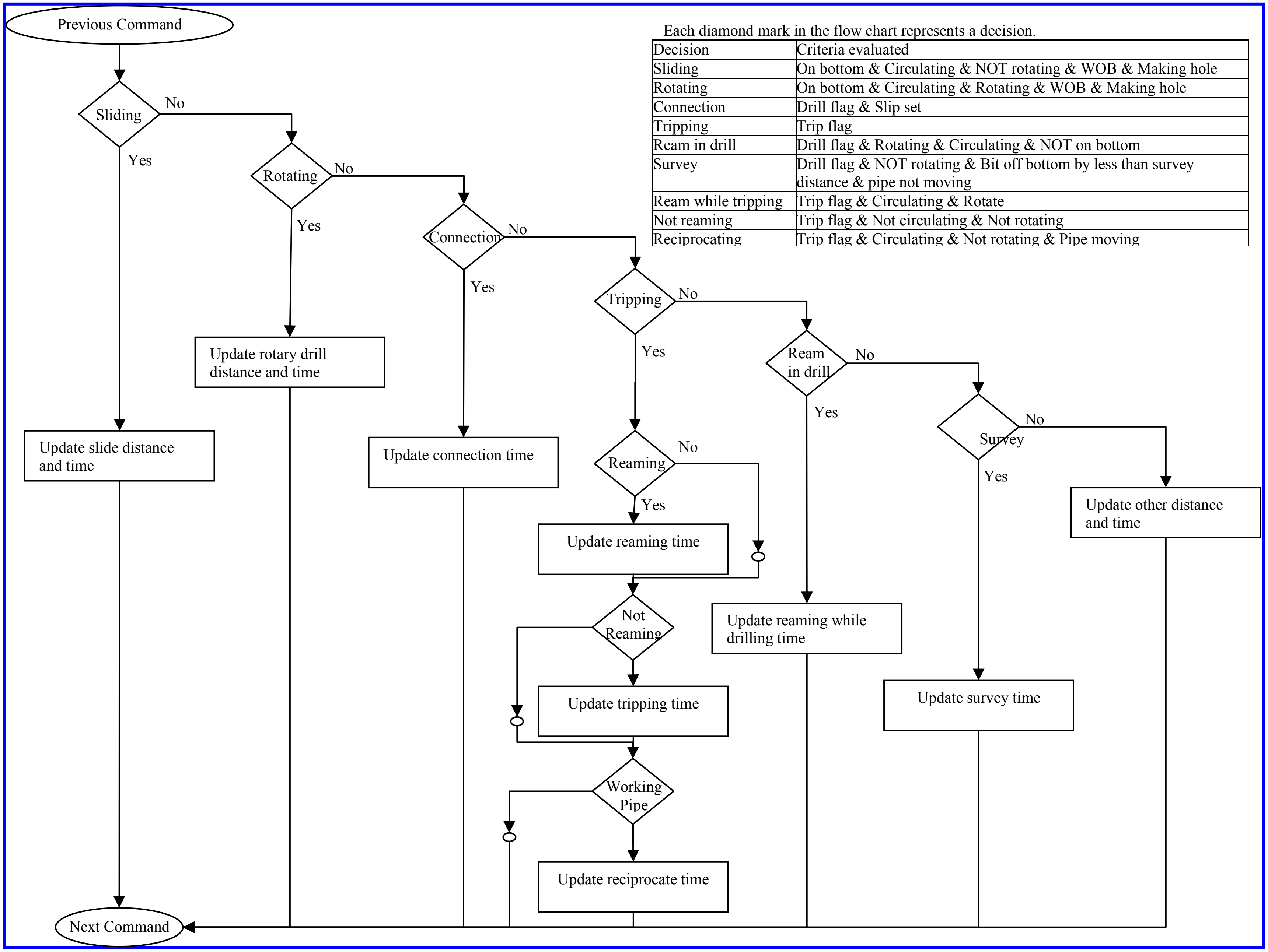
On the basis of results from Well 1, an RSS was used in Well 2, and more than 24 h was saved in drilling to the same depth. These savings become more appreciable when we take into account the ROP difference between the two wells. Related to softer formations, drilling in Well 1 enjoyed relatively faster penetration rates as opposed to those in Well 2. Total drilling time was 375 h and 407 h on Well 1 and Well 2, respectively. Despite the longer drilling time, Well 2 reached the same depth 24 h earlier than Well 1. The saving primarily came from the reamer runs, which were not required on Well 2.

BHA Run Files

The program offers the option of creating a *BHA Run File* for each row listed in the *Time Breakdown File*. The *BHA Run File* provides a listing of parameters as captured from the rig and filtered for the BHA run. The primary use of this data is to calibrate drilling engineering models against actual results. Case Study 2 illustrates the use of both the *Time Breakdown File* and the *BHA Run Files*.

Table 2: Case Study 1 time breakdown data (depth is expressed in meters and time in hours)

Run No.	Start Depth	End Depth	Rot Dist	Rot Time	Rot ROP	Slide Dist	Slide Time	Sliding ROP	Total Distance	Total Time	Average ROP	Slide %age	Survey Time	Connection Time	Reaming Time	Trip Reaming Time	Trip Time
Well 1																	
1	0	393.06	352.98	28.7667	12.27	0	0	0.00	352.98	28.77	12.27	0.00	4.32	10.60	8.95	0.01	0.00
2	393.06	633	228.79	48.7833	4.69	8.48	1.28611	6.59	237.27	50.07	4.74	3.57	3.63	3.12	4.78	4.19	10.39
3	633	633.08	0.82	0.008333	98.40	0	0	0.00	0.82	0.01	98.40	0.00	0.01	0.37	2.17	0.00	8.22
4	633.08	633.53	0	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	20.36	0.00	0.00	4.69
5	633.53	1300	601.42	46.7333	12.87	59.58	6.175	9.65	661.00	52.91	12.49	9.01	6.51	4.46	7.46	0.03	7.73
6	1300	1667.97	322.3	37.6083	8.57	41.62	9.17778	4.53	363.92	46.79	7.78	11.44	3.90	2.70	4.83	0.59	13.28
7	1667.97	1668.67	0.65	0.116667	5.57	0.03	0.013889	2.16	0.68	0.13	5.21	4.41	0.12	0.08	0.08	0.00	8.25
8	1668.67	1668.67	0	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.31	0.00	8.06
9	1668.67	2056.03	259.52	26.1611	9.92	120.65	19.025	6.34	380.17	45.19	8.41	31.74	5.90	1.95	5.66	2.87	17.35
10	2056.03	2222.3	90.86	18.3556	4.95	72.44	17.4167	4.16	163.30	35.77	4.56	44.36	6.88	1.37	3.41	0.15	9.48
11	2222.3	2495.4	174.06	29.5778	5.88	94.13	24.6528	3.82	268.19	54.23	4.95	35.10	6.23	1.82	4.31	2.83	15.76
12	2495.4	2495.4	0	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56	13.25
13	2495.4	2717.45	101.45	26.75	3.79	116.37	27.1028	4.29	217.82	53.85	4.04	53.42	5.54	1.34	4.61	0.51	21.69
Well 2																	
1	0	221.5	189.09	12.2944	15.38	0	0.052778	0.00	189.09	12.35	15.31	0.00	0.72	31.03	3.86	0.00	0.01
2	221.5	453.21	230.23	15.8139	14.56	0	0	0.00	230.23	15.81	14.56	0.00	1.52	1.67	2.47	4.76	14.30
3	453.21	630	175.26	19.5528	8.96	0	0	0.00	175.26	19.55	8.96	0.00	1.73	1.21	2.64	0.00	1.84
4	630	630.04	0	0.002778	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.09	0.00	10.83
5	630.04	630.85	0	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.96	28.71	0.00	0.00	5.48
6	630.85	1103.17	469.4	60.0583	7.82	0	0	0.00	469.40	60.06	7.82	0.00	4.16	2.33	4.85	0.00	3.03
7	1103.17	1103.17	0	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49
8	1103.17	1715.2	606.82	61.525	9.86	0	0	0.00	606.82	61.53	9.86	0.00	5.62	2.82	9.25	0.00	8.54
9	1715.2	2083.62	365.43	58.2667	6.27	0	0	0.00	365.43	58.27	6.27	0.00	5.88	1.86	5.77	0.78	12.38
10	2083.62	2350.72	262.53	53.2917	4.93	0	0	0.00	262.53	53.29	4.93	0.00	7.32	1.77	5.99	0.00	11.93
11	2350.72	2540	186.88	61.4333	3.04	0	0	0.00	186.88	61.43	3.04	0.00	5.23	0.57	4.06	0.28	10.43
12	2540	2703.73	162.65	59.0833	2.75	0	0	0.00	162.65	59.08	2.75	0.00	4.96	1.18	7.88	0.76	13.71



Each diamond mark in the flow chart represents a decision.

Decision	Criteria evaluated
Sliding	On bottom & Circulating & NOT rotating & WOB & Making hole
Rotating	On bottom & Circulating & Rotating & WOB & Making hole
Connection	Drill flag & Slip set
Tripping	Trip flag
Ream in drill	Drill flag & Rotating & Circulating & NOT on bottom
Survey	Drill flag & NOT rotating & Bit off bottom by less than survey distance & pipe not moving
Ream while tripping	Trip flag & Circulating & Rotate
Not reaming	Trip flag & Not circulating & Not rotating
Reciprocating	Trip flag & Circulating & Not rotating & Pipe moving

Figure 2: Algorithm for activity selection

Case Study 2

This well was drilled in western Alberta in the harsh foothill's environment. The well had its kickoff point (KOP) at approximately 2600 m. It was drilled with a verticality tool to 2000 m. Thereafter, strong formation tendencies required the use of a motor; the process of bringing the wellbore back to vertical resulted in some fairly severe doglegs (12°/30 m) in the hole. The target formation was at true vertical depth (TVD) of approximately 4000 m, and the well was required to be horizontal through the formation. Because of the severe doglegs at relatively shallow depths, it was decided to use a push-pipe BHA (Figure 3a). Uncertainty in geological information necessitated a sidetrack from this hole. As the sidetrack was being drilled, the ROP became exceedingly slow coupled with difficulties in sliding and with surface torque in excess of pipe makeup torque. A study was undertaken using the electronic data captured from the rig. The new software program was used to analyze that data. The *BHA Run Files* provided the "as drilled" hook loads and surface torques for calibration of friction factors. These calibrated friction factors were used to design the drillstring and BHA, and we took into consideration the drillpipe torque, yield strength, buckling, and rig equipment limitations. The redesigned BHA and drillstring delivered 50% more penetration rate and saved 25% trip time to result in an overall saving of 110 h ($380 thousand).

A plot of actual tripping hook-loads superimposed on modeled tripping loads is shown in Figure 4. From the plot, axial friction factors close to total depth (TD) can be estimated as 0.35. Using this friction factor, both push-pipe and conventional BHAs were modeled for buckling. The results are shown in Figure 5 and Figure 6. It was obvious that the push-pipe arrangement results in the buckling of the drillpipe and possibly explains the slow ROPs. It was decided to drill with a conventional BHA as outlined in Figure 3b.

The formations at the depths ranging from 3700 to 4060 m were drilled twice because of the sidetrack—once with the push-pipe BHA and the second time with the conventional BHA. Tables 3 and 4 provide the ROP in both cases. These tables were constructed from the *Time Breakdown File* generated by the new program.

Sliding ROPs were improved by approximately 50% on the average. If no changes had been made to the BHA and if a 200.52-m hole was drilled at 0.95 m/h, it would have taken 211 h to drill the sidetrack. The new BHA configuration saved 73 h (211 h minus 137 h) of drilling time and two bit trips (one bit only lasts for about 35 drilling hours in that area).

The second part of the puzzle was that surface torque exceeded the drillpipe makeup torque when attempting to back ream. This was creating operational difficulties when tripping out. Tripouts were longer than necessary. To counter this problem, the drillstring axial load and torque were modeled using the friction factors as mentioned previously. The torque plot indicated modeled torque in excess of makeup torque in the push-pipe arrangement drillstring. The drillpipe was re-configured; S-135 grade pipe was placed across the severe doglegs, and heavier grade S-135 pipe was picked up to surface. Details of the drillstring are shown as part of the conventional BHA in Figure 3b. With this new drillstring, it was possible to increase the rig top-drive-system torque-limit setting. The new torque limit allowed the drillstring to be reamed out-of-hole at the start of the trip and, thus, saved rig time. Figures 7 and 8 show the surface torques while back reaming along with the top drive system torque limit. Tables 5 and 6 provide trip times with the push-pipe drillstring and the redesigned drillstring.

Table 3: Time Breakdown
Push-Pipe BHA (Original Hole)

Depth Range	Rotary Distance	Rotary Time	Slide Distance	Slide Time
3723–3757	13.22	11.26	21.27	26.60
3757–3804	27.4	28.20	18.10	21.50
3804–3845	15.16	13.2	24.60	28.70
3845–3888	6.97	4.15	34.64	37.90
3888–3892.8	4.82	2.96	0	0
3892–3948	36.18	20.06	18.77	13.53
3948–3996.5	44.9	32.30	3.24	2.80
3996.5–4024	26.95	21.76	0	0
4024–4061	31.45	23.88	6.82	3.56
Total	207.00	157.00	127.00	134.60
Average ROP	1.32 m/h		0.95 m/h	

Table 4: Time Breakdown
Conventional BHA (Sidetrack Hole)

Depth Range	Rotary Distance	Rotary Time	Slide Distance	Slide Time
3777–3854	77.7	47.75	0	0
3854–3910	23.3	10.02	32.32	12.74
3910–3989	21.5	32.33	54.94	23.39
3989–4020	12.96	10.16	18.14	10.23
4020–4066	22.8	16.38	22.59	13.89
4066–4114	23.8	15.52	23.6	15.59
4114–4153	15.31	12.83	22.53	40.15
4153–4193	27.72	24.09	10.81	6.89
4193–4225	15.01	15.86	15.59	14.72
Total	240.14	184.95	200.52	137.72
Average ROP	1.30 m/hr		1.46 m/hr	

The new drillstring design consumed time to lay down and picking up the new pipe. However, investment in time was not wasted and paid off over the next bit runs by saving about 25% of the rig time on each trip.

Table 5: Tripping Time with Push-Pipe Drillstring

Depth (m)	Roundtrip Time (h)
3777	33.4
3854	27.7
3910	23.6
3989	33.
4020	31.1

Table 6: Tripping Time with Redesigned Drillstring

Depth (m)	Roundtrip Time (h)
4066	19.6
4114	19.1
4153	20.5
4193	17.7
4225	17.8

Graphical Outputs

The program also provides several graphical outputs, which include:

- Time-depth chart (Figure 9a)
- ROP versus depth (Figure 9c)
- WOB versus depth
- Slide/rotate versus depth (Figure 10)
- Drilling/ reaming torque versus depth
- Tripping/ drilling hook loads versus depth (Figures 4 and 9b)
- Mechanical Specific Load (MSL) versus depth (Figure 9d).

Batch analysis allows parameters from all wells analyzed together to be plotted on the same chart. Figure 9 (a, b, c, and d) shows some typical graphical outputs. The program also creates a correlation file, which contains links to the graphical data. That makes it possible to revisit previously analyzed data without having to rerun the analysis.

The Mechanical Specific Load (MSL) is an adaptation of the Mechanical Specific Energy (MSE) concept presented by Dupriest and Koederitz.[1] They defined MSE as

$$\text{MSE} = [(480 \times \text{Tor} \times \text{RPM}) / (\text{Dia}^2 \times \text{ROP})] + [(4 \times \text{WOB}) / (\text{Dia}^2 \times \Pi)] \quad (1)$$

Electronic data-capturing systems typically do not capture the hole diameter (Dia). The term MSL was adapted from MSE with the following relationship:

$$\text{MSL} = \text{MSE} \times A_c, \quad (2)$$

whereby A_c *is the cross sectional area*

$$A_c = \text{Dia}^2 \times \Pi /4. \quad (3)$$

This makes MSL independent of hole size. It still retains the character of an abrupt change when reaching the founder point. Figure 9d shows the MSL-versus-depth chart for three bit runs of a well. The first bit run experienced excessive stick-slip. This is consistent with the spiky character of the plot for the first run. The second and third run, however, are more steady and are characterized with abrupt changes (founder points) towards the end of the bit runs. The interbedded nature of the foothill's formations certainly masks the very presence of founder points.

A detailed correlation of MSL to different formations and founder points is beyond the scope of this paper. The discussion above was just to provide an introduction to one of the program outputs.

Rotary Steerable Candidate Selection Process

The selection of a suitable candidate involves analysis of offset wells for performance while sliding, sliding percent, and hole-conditioning time. Hole conditioning can be wiper trips, dedicated reamer runs, or reaming the slides, etc. Case Study 3 presents a case whereby use of an RSS can yield substantial savings.

Case Study 3

Well A was drilled in the northeastern British Columbia. It had an S-profile with a departure of about 180 m from surface location. The KOP was at an approximate depth of 1550 m, and the well was brought back to vertical starting from 2200 m. The well was finished at a TD of about 2500 m with a 6° inclination. The well was drilled to the KOP without any directional tools. The time breakdown for the BHA runs from the KOP to 2500 m is presented in Table 7 and Figure 10.

Well B is to be drilled in the same area with a similar profile. If on Well B, the entire section (1400–2500 m) is drilled in the rotary mode, the savings in time are about 62 h based on the difference in sliding and rotating ROPs (refer to Table 7). Typically, when rotary steerables are used, there is no need to ream because the string is always in rotation. For a total reaming time of 13.5 h (Table 7), the total potential savings that rotary steerable tools can bring to Well B are 62 to 75 h, which is equivalent to a dollar savings of $129 thousand to $156 thousand. Such an analysis helps to quantify the benefit of rotary steerable tools and, hence, makes the selection process easier.

Conclusions

The new software program provides quick and efficient means for analysis of drilling data captured from rig operations by electronic data-recording systems.

The *Time Breakdown File* provides a measure of performance and, hence, allows comparison between wells or BHAs.

The *BHA Run Files* provide data pertaining to single BHAs and can be used for calibrating the drilling engineering models.

The time breakdown helps to quantify the benefit in utilizing rotary steerable tools.

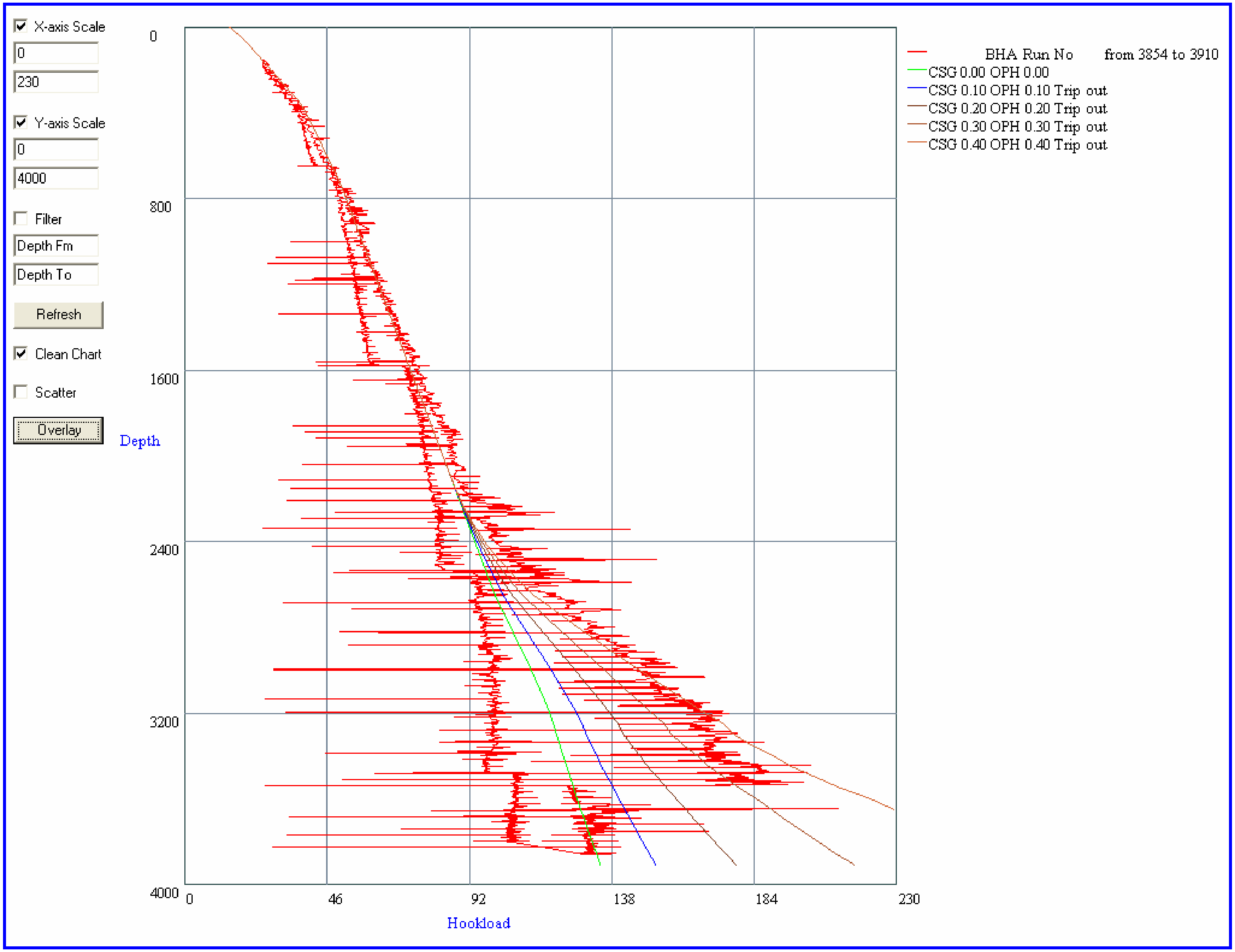
Nomenclature

AND = Boolean AND Operator which results in a Boolean value of true if and only if both operands are true
NOT = Boolean NOT operator results in Boolean Inverse of the operand

References

1. Dupriest, F. E., and Koederitz, W. L.: "Maximizing Drill Rates with Real-Time Surveillance of Mechanical Specific Energy, SPE/IADC 92194, Amsterdam, February 23–25, 2005.

Figure 4: Friction factor calibration chart (screen shot from software program. Depth is in expressed in meters and Hookload in kdaN)



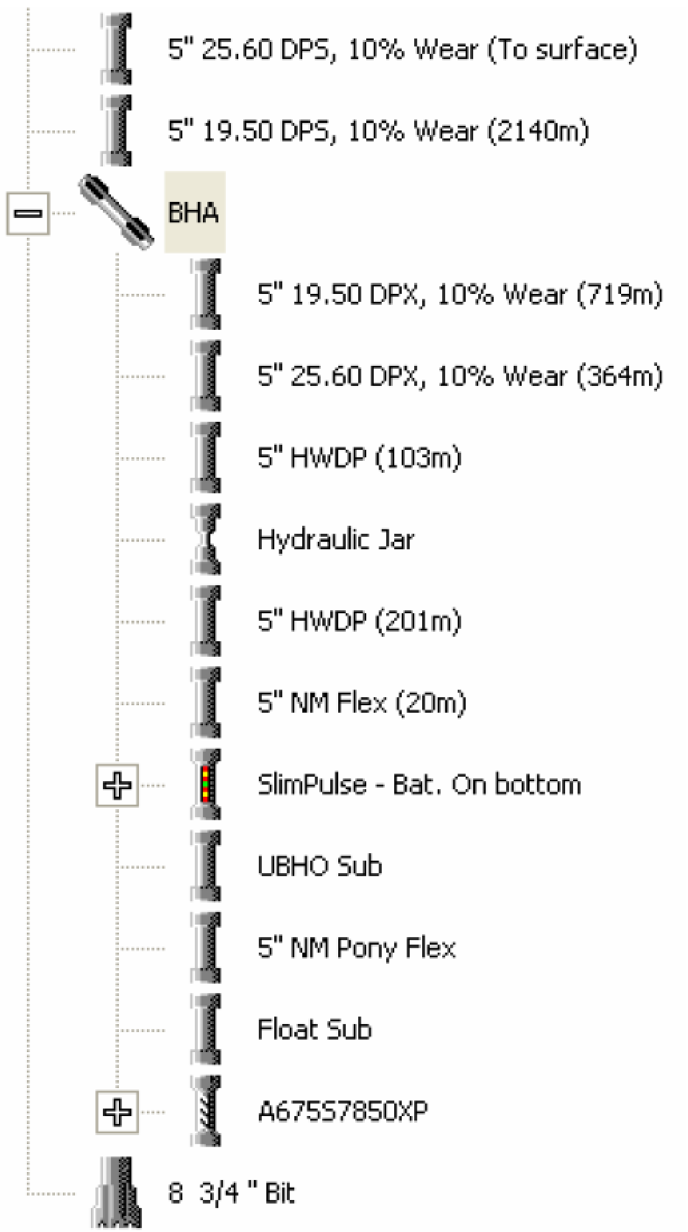
☑ X-axis Scale
0
230

☑ Y-axis Scale
0
4000

☐ Filter
Depth Fm
Depth To

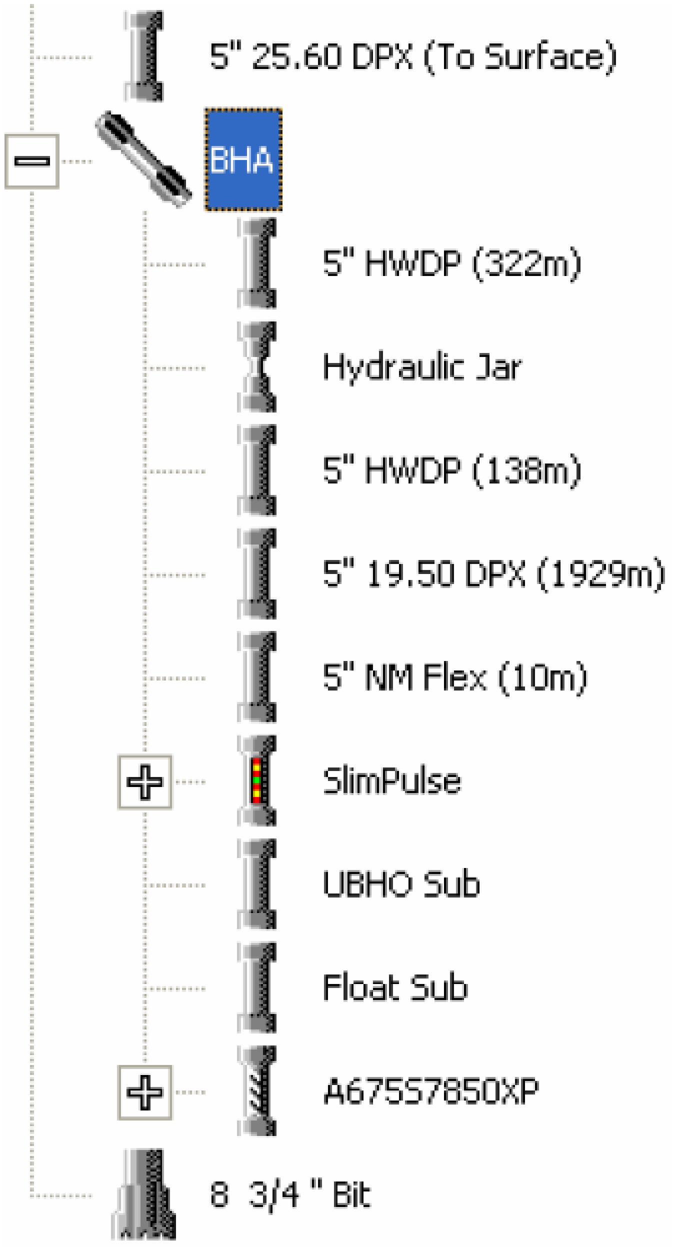
☑ Clean Chart

☐ Scatter



5" 25.60 DPS, 10% Wear (To surface)
5" 19.50 DPS, 10% Wear (2140m)
BHA
5" 19.50 DPX, 10% Wear (719m)
5" 25.60 DPX, 10% Wear (364m)
5" HWDP (103m)
Hydraulic Jar
5" HWDP (201m)
5" NM Flex (20m)
SlimPulse - Bat. On bottom
UBHO Sub
5" NM Pony Flex
Float Sub
A675S7850XP
8 3/4 " Bit

Figure 3b: Redesigned conventional BHA.



5" 25.60 DPX (To Surface)
BHA
5" HWDP (322m)
Hydraulic Jar
5" HWDP (138m)
5" 19.50 DPX (1929m)
5" NM Flex (10m)
SlimPulse
UBHO Sub
Float Sub
A675S7850XP
8 3/4 " Bit

Figure 3a: Push-pipe BHA.

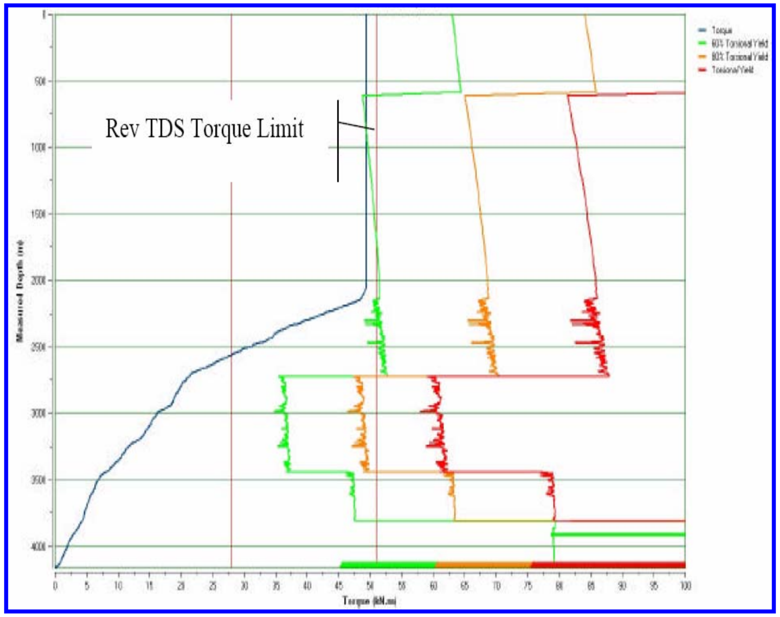


Figure 7: Surface torque while back reaming; conventional BHA.

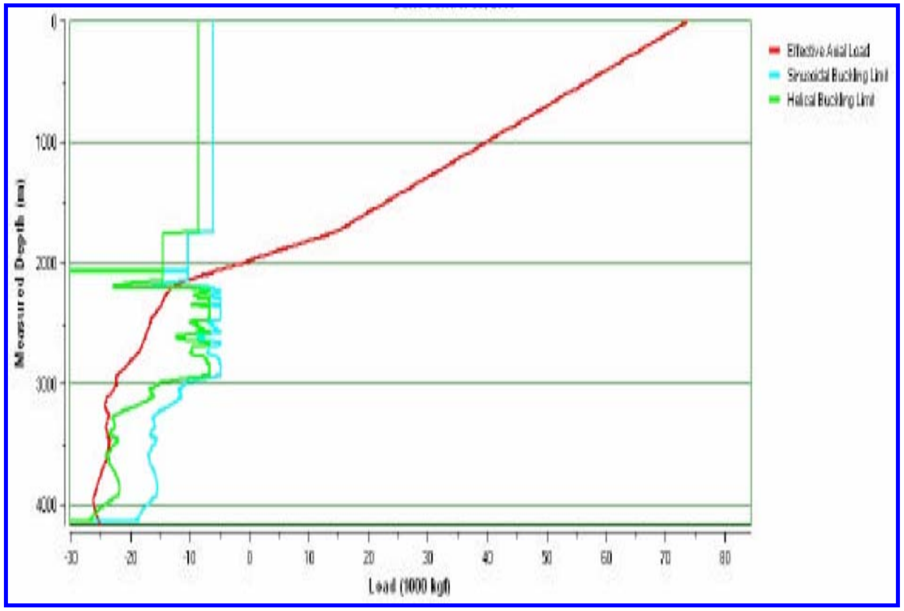


Figure 5: Buckling analysis while sliding; push-pipe BHA.

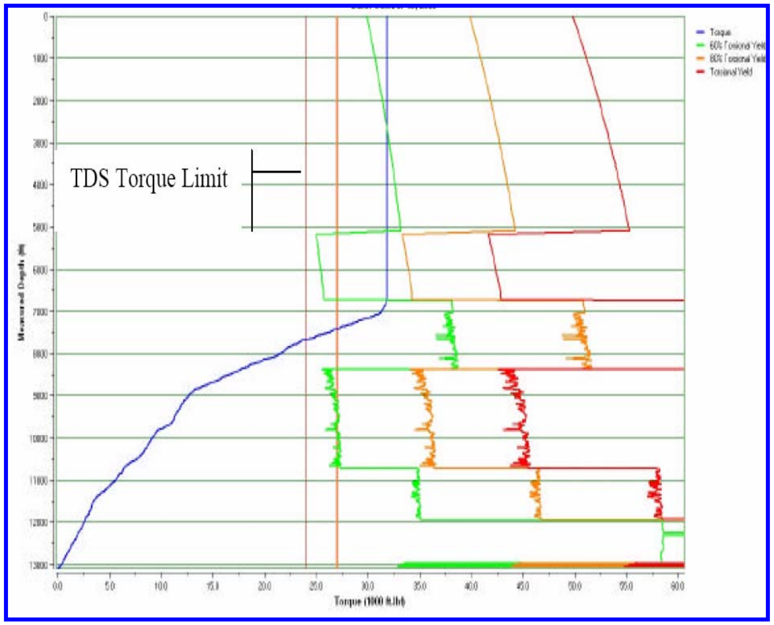


Figure 8: Surface torque while back reaming; pushpipe BHA.

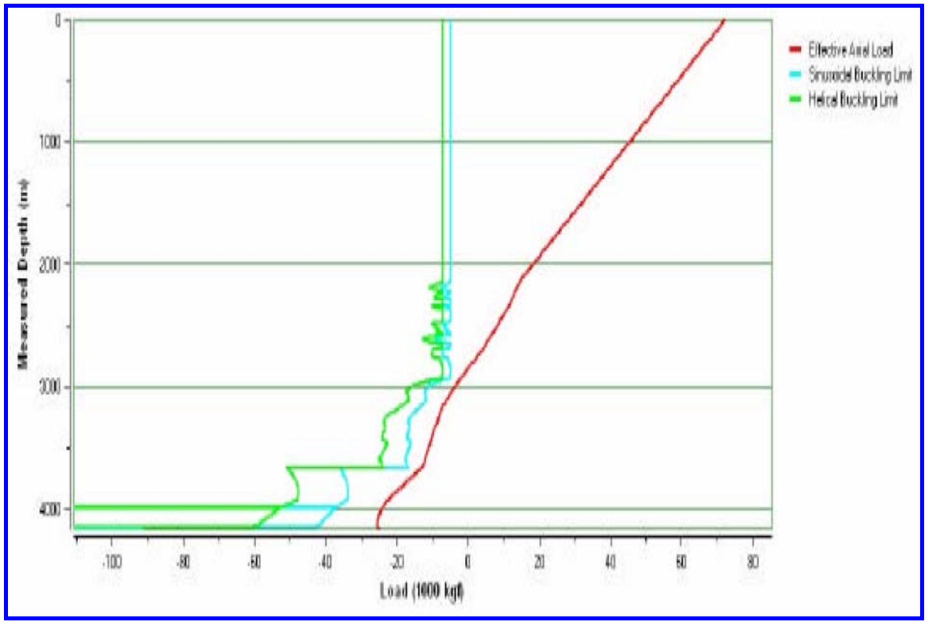


Figure 6: Buckling analysis while sliding; conventional BHA.

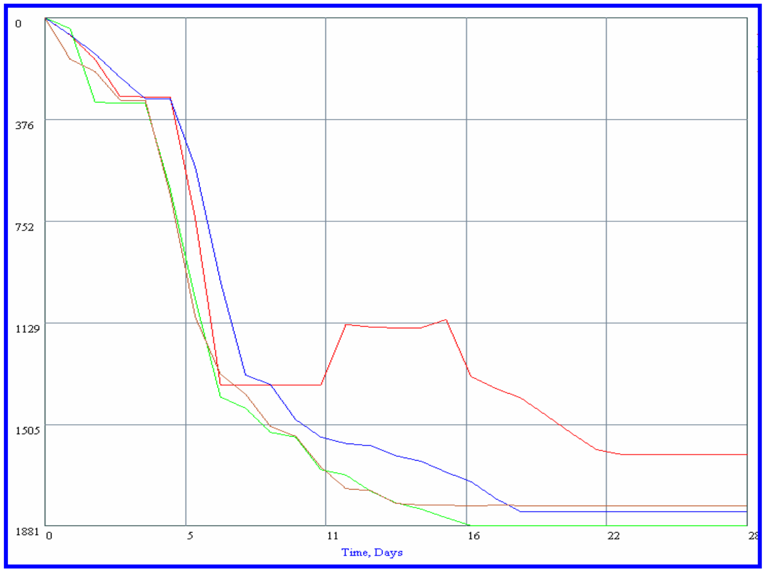


Figure 9a: Time-depth curves.

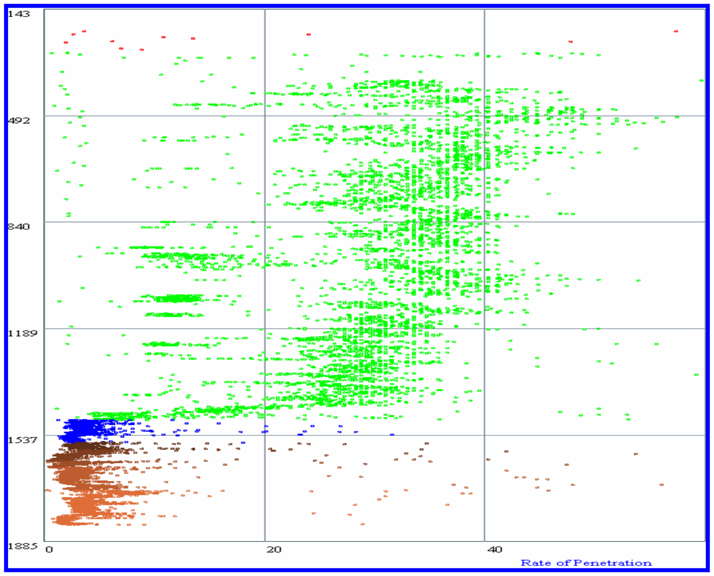


Figure 9c: ROP versus depth.

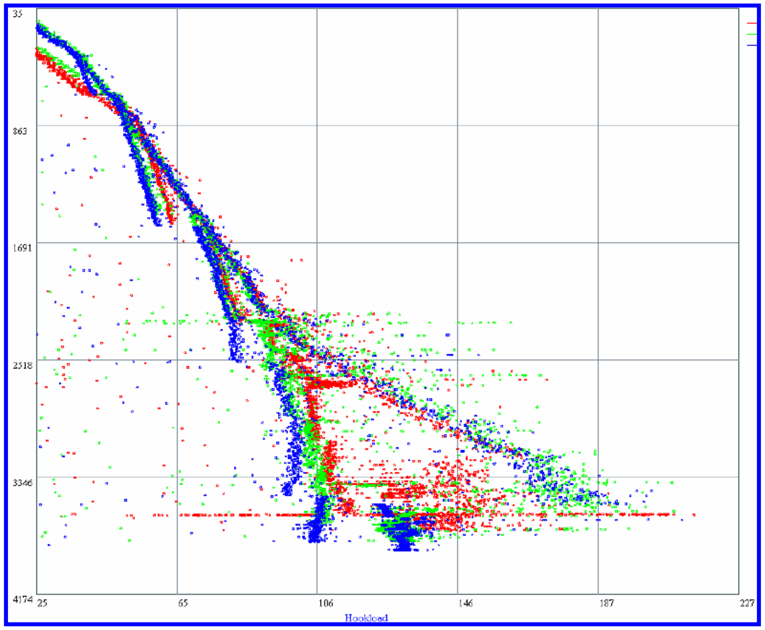


Figure 9b: Tripping loads for three trips.

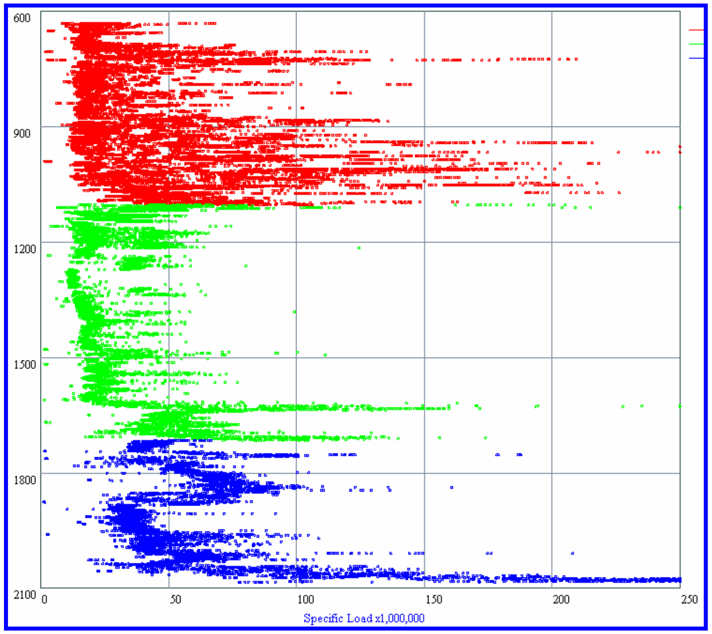


Figure 9d: MSL versus depth for three bit runs.

Table 7: Well A Time Breakdown (Case Study 3)

Well A Drilling Time Breakdown

Start Depth	End Depth	Rot Dist	Rot Time	Rot ROP	Slide Dist	Slide Time	Slide ROP	Total Distance	Total Time	Avg ROP	Slide %age	Reaming Time	Trip Time
1417.2	2260.3	597.18	31.52	18.95	264.44	40.51	6.53	861.62	72.03	11.96	30.69	5.34	10.70
2260.3	2528.2	194.58	15.74	12.37	79.26	41.93	1.89	273.84	57.67	4.75	28.94	8.17	11.20
									129.70				
Well B Potential Drilling Times													
1417.2	2260.3							861.62	45.47	18.95		5.34	10.70
2260.3	2528.2							273.84	22.14	12.37		8.17	11.20
									67.61				

Figure 10: Well A sliding versus rotating ROPs. Screen capture from the new software program (Case Study 3).