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Use of Real-Time Rig-Sensor Data To Improve Daily Drilling Reporting, Benchmarking, and Planning—A Case Study

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Abstract

State of the art drilling operations analysis is mostly dependent on conventional daily activity reporting. However, these activity reports are based on human observations and judgment. This fact implies a number of limitations such as the coarse level of detail and subjective coding systems. To overcome these problems a rule-based system has been applied to autonomously analyze real time surface sensor data. The system evaluates the sensor data stream and acquires crucial process information as a basis for further analysis.
Scope of the system is the recognition of drilling operations, such as tripping, making connections, reaming, washing etc. to extend and enhance standard reporting. This way a standardized and objective categorization of the drilling process can be achieved at a level of accuracy and detail not reached so far.

Another benefit is the automated reporting feature. By the recognition of the rigs current state, the system is able to propose an impartial process description. This automatism leads to a reduction of the time spent on reporting and leaves more time to focus on unexpected events and lessons learned.
Analysis of field data allowed introducing new key performance indicators (e.g. wellbore treatment time per depth interval) for benchmarking, which are determined automatically during the evaluation process. This type of benchmarking does not rely on company specific activity coding systems. This way cost and time-consuming data management effort e.g. to compare operated and non-operated wells are eliminated.
The new system was applied to wells drilled in the Vienna Basin during the past year. As a conclusion it can be stated that the application of this system significantly improves the accuracy and resolution of the drilling process description reducing data management effort. The objective categorization of process information is a key enabler for benchmarking specifically when identifying hidden lost time.

Introduction

Most papers discussing drilling activity performance analysis start with three simple questions [1, 2, and 3]:

- What is the current level of performance?
- What is the benchmark?
- How can this gap be closed?

To increase performance all of these questions have to be answered properly. As already discussed by Thonhauser G. [4] the basis for most drilling performance analysis work performed is the daily activity breakdown with all its drawbacks:

- Analysis based on subjective human observations
- Coarse level of detail
- Time consuming data-entry and quality control process
- etc.

In addition to these drawbacks the current available personnel numbers and demographics in the petroleum industry leave very little room for extended analysis due to very tight time schedules. Experienced drilling engineers simply do not have the required time to do proper analysis but have to keep the business running on one hand. On the other hand young, maybe just graduated engineers do not have the experience and knowledge to do so. Bond and Scott [1] stated: “The exercise of extracting removable time analysis was very time consuming (up to 2 man months for the eight wells reviewed) and required a high level of drilling/completion knowledge.”

In difference to these known but often ignored facts operating companies often try to reduce cost by using performance driven contracts with drilling contractors without having any possibility to evaluate and benchmark the service they get.

And yet if done, the costs spent on

- Quality Control (QC)
- Performance Analysis
- Benchmarking

is substantial and is not often worth the investment effort.

Well Time

The time spent to drill a well is typically split up into different groups like productive time, non-productive time, etc. In Figure 1 a refined graphical representation of Bond and Scott [1] is presented.

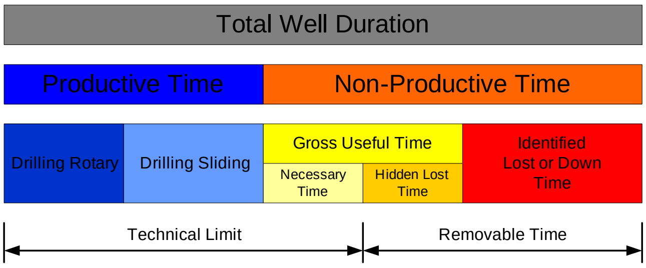

Figure 1 - Graphical representation of well time

Ultimate goal of all optimization efforts is to minimize the non-productive time. But since one part of the non-productive time, the necessary time, can not be prevented, one must identify the lost time. Lost time is divided into two parts, the identified and the hidden lost time.

The first part is relatively easy to take action against since someone already recognized a problem, reported the problem and took action against it. It is likely that in a similar situation the problem will be identified earlier or may be prevented completely. The second part of the loss time (the hidden loss time) is not identified yet, so actions for prevention require very experienced engineers, a lot of time and is sometimes hardly possible because the basis for the analysis are the daily drilling reports with their coarse level of detail.

Automated Operation Recognition

To overcome the drawbacks of the daily drilling operations breakdown a system to perform Automated Operation Recognition was developed. The industry identified the necessity for such a system, which was emphasized by the top vote for operational improvements during an industry forum on “Flat Time Reduction” [5, 6].

The used system gives a very detailed description of the drilling process by analyzing the surface measurement of the mud logger. For more information the reader is referred to [4].

The result of the software is a list of tasks, which define the operations start and end time as well as start and end tool, resectively hole depth. With the help of these tasks a broad variety of activity and analysis reports can be generated. Due to the fact that also the tool depth is stored as a result, very interesting analysis results like wellbore treatment time along the measured hole depth are possible.

The advantage of automated operations recognition with a completely automated and objective description of the drilling process forms the basis to derive benchmarks and to track the drilling process. The problem of low reporting granularity combined with traditional operations classification using manual coding is eliminated this way.

It is now possible to plan a well using the results of benchmarking based on automated operations recognition and then track planned versus actual process using the same technology.

Reporting

The results of the Automated Operation Recognition are not very suitable for direct analysis and visualization since the result table contains several 10.000 task records per day, depending on the operations going on. In the Appendix a selection of reports is given. The different report parts are described in the following on the example of the well *Demowell 7* in the *Vienna Basin*.

Daily Drilling Tracking Report

24-Hour Summary

The first chart of this report covers the activities over time (see Figure 2). The activities are summed up for every full hour, so one bar represents one hour. The different colors within one bar represent the fraction of the activities within the hour. To improve the meaning of the chart the hole measured depth and the bit position are also displayed. The left y-axis gives the scale for the time of the bars, the left y-axis gives the scale for the hole and bit measured depth.

Using such a chart additional to the conventional daily drilling report gives much more detailed information about the time breakdown. The analysis based on the automated recognized process information reveals exact numbers about drilling ROP (net or gross), tripping speeds, connection time, etc.

Table 1 holds the time breakdown of a conventional daily drilling report. In contrast to this table Figure 2 shows the results for the same day gained by the evaluation of the surface measured mudlogging data.

Table 1: Daily Drilling Activity Report

Start MD	End MD	Start Date/Time	hrs	Description
3991	4017	2005-03-27 00:00:00	5	Drilling.
4017	4017	2005-03-27 05:00:00	0.5	Add DP, ream hole.
4017	4017	2005-03-27 05:30:00	0.5	MWD - measurement. Drilling in sliding mode from 3993m - 3997m. (3,5 hrs)
4017	4081	2005-03-27 06:00:00	10	Drilling
4081	4081	2005-03-27 16:00:00	1	Add DP, ream hole.
4081	4081	2005-03-27 17:00:00	1	MWD - measurement. SCR: Pump 1. 60 strokes 74 bar at 4042m Drilling in sliding mode: 4033m - 4037m, 4065m - 4068m.
4081	4105	2005-03-27 18:00:00	6	Drilling

The second chart of the report gives a summary of the time distribution for the whole day presented as pie chart. In the report also a table with the hours spent on each operation is presented (see Table 2).

Table 2: Daily Operation Statistics

Operation	Total [hrs]	Total [%]
Drilling rotating	11.21	46.72
Drilling sliding	8.00	33.32
Ream And Wash downwards (into hole)	0.49	2.04
Ream and Wash upwards (backreaming)	0.55	2.31
Wash downwards (into Hole)	0.41	1.71
Wash upwards (out of hole)	0.92	3.83
Run in hole	0.01	0.05
Run Out Of Hole	0.04	0.16
Circulation on	0.81	3.36
Making Connection	0.36	1.52
Other Operations	1.19	4.96
Grand Total	**24.00**	**100.00**

7-Day Summary

Analog to the 24-Hour Summary this report covers the last 7 days of activities. The chart is basically the same, just the measured hole depth and bit position is left out for simplicity. Additionally there is a 7 day operation statistics again presented as a pie chart. It looks exactly like the 24 hour operation statistics.

BHA Run Report

The BHA Run Report starts with a chart (see Figure 3) where the run is split into its main operations like

- Trip In
- Drill Formation
- Treatment
- Trip Out

To get a better understanding the measured hole depth and the bit position (in MD) is also displayed on this chart.

After this chart the time statistics of the whole BHA run follows (see Figure 4). Depending on the type of the run (drilling run, casing run ...) information like gross ROP in the case of a drilling run is calculated and displayed automatically.

At the end of the report a time statistic of the different identified main operations follow (see Figure 5). Depending on the type of main operation further details, benchmarks and KPIs like net and gross ROP, tripping speed, etc. are automatically calculated and displayed.

End of Well Report

The first chart of the End of Well Report is very similar to the BHA Run Report, only that the time split is done by phase instead of the main operation (see Figure 6; please note that the recording of the mudlogging data started at the beginning of the 17in phase, so the phases before show no results).

To give an overview over the performed BHA runs the End of Well Report closes with one or more charts containing an overview over each BHA run (see Figure 7).

Benchmarking

In order to define a target performance level to generate the best possible plan benchmarking is used. The data set available from automated operations recognition is used to define the key elements which define overall drilling performance. In the context of this work the following operations where investigated:

- Time to handle and make-up BHA components
- Tripping speeds
- Connection times
- Drilling time
- Wellbore treatment time (reaming, washing, circulating the hole)

Based on the result of the evaluation of these parameters a well is then planned assembling a planned time versus depth curve.

Wellbore Treatment Time along Depth

As already mentioned in the introduction it is possible to allocate operation times to the depth where the time was spent. So far this was obvious for drilling, but not possible for other operations like reaming, washing etc. because there is hardly ever coded information in the daily reports which could be processed by a program. With the results of the Automated Operation Recognition the bit position is also automatically assigned to the process tasks, so these kinds of reports are easily possible now.

In Figure 8 the wellbore treatment time is visualized. The four charts represent the total wellbore treatment time (which is the sum of the next three charts), circulation time, washing time and reaming time. The dashed red horizontal lines mark the casing shoe position.

At the casing shoes increased wellbore treatment time is obvious. Not so clear are the peaks marked by the three red shaded zones. These peaks mark potential trouble formations since increased wellbore treatment time was necessary there. These peaks do not only consist of the time spend in that depth after drilling, but every time the bit passed this zone. So even if the driller recognized some little trouble in this formation each time he passed the section during tripping he might not found it worth to report e.g. 15 minutes of reaming washing or circulation. But the necessary treatment time accumulates as drilling goes on with each trip and is an indicator for trouble formations. With this indication from the operation time statistics a closer look or a technical analysis might save time for the next well.

Figure 9 show the same chart type with other operations allocated to the depth. A detailed overview of necessary drilling time per depth interval is given (basically the inverse to the ROP). In this chart again the three red shaded areas mark the same trouble formations as in the latter figure. With the help of this additional chart the analysis gets further high quality information. Comparing the trouble areas 1 and 3 to the trouble area 2 it gets obvious that in the areas 1 and 3 the necessary wellbore treatment time was spent during drilling whereas in area 2 the treatment time was not spent during drilling. This can be seen on the fact that the necessary time to drill the interval is increased in area 1 and 3, but not in area 2.

Increased Accuracy for existing Analysis Procedures

The results of the Automated Operation Recognition are also very useful to support existing drilling performance analysis procedures. If the results are properly prepared they can be exported into other drilling analysis and management tools. An interface to the software used in papers [2 and 3] already exists and will be used in a pilot test until quarter 2 in 2006.

Connection Time Analysis

With the help of the results of the Automated Operation Recognition a new benchmark was possible to analyze: The average connection time per well. Basis of the analysis were 15 wells drilled by OMV in the *Vienna Basin* during a period of one year. Two rigs were involved in the drilling activities, *Rig A* and *Rig B*. Connnections with durations longer than 15 minutes and bit depth below 300m were not taken into consideration because they would falsify the result (BHA/HWDP connections). The total number of connections analyzed was 16.045.

Figure 10 summarizes the results. The two colors red and blue represent the two different rigs. The white numbers display the average connection time of the well, the white numbers in parenthesis the number of recognized connections. The black lines show the tendency for the two rigs.

If we take the majority of the wells into consideration the connection time is quite stable with a small downward tendency for recent wells. If we calculate the loss time for these wells, with the best historic performance as basis (2.1 minutes per connection) the overall saving potential is about 5.5days for all wells together (total well time was about one year, this leads to approximately 1.7% saving potential in terms of rig days). This is not very much in this case because the target MD for most of the wells is around 3000m.

A similar analysis done on 12 wells of a different operator in a different field where targe MD was in average around 6000m showed a saving potential of as much as 8% of the rig time if best historic performance could be achieved. The total number of recognized connections was more than 200.000 for all wells. The first conclusion is not very surprising: The deeper the well, the more does the connection/tripping time influence the time consumption. The more unexpected conclusion is the saving potential of as much as 8% of the rig time if this KPI kept in mind.

Planning

Use of real time data for automated/semiautomated benchmarking and performance ansalysis gives the engineer not only the chance to review large data sets in a short time but also offers a widespread source of information to plan for new wells.

The introduction of several new parameters during this case study made it possible to plan a new well and after drilling compare this plan with the actual well construction process. Parameters used for planning the time versus depth curve included bit life, tripping speed, connection time, job duration for BOP work, logging and cementing normalized with depth, productive/non-productive time, wellbore treatment time, time to handle tools and ROP.

The most difficult parameter to evaluate was ROP as definitions of it vary greatly in the industry. Most mud logging companies report ROP as the time needed to drill a certain depth interval, which is usually a few centimeters. Within this depth interval real ROP could vary greatly. For a better understanding several different ROP's have been introduced during this work. These ROP's ranges from a coarse level as high of giving a whole BHA run one single ROP down to the calculation of ROP at the sampling rate of sensors at the rig, which is commonly one hertz. As an outcome several ROP's have been defined:

1. Project ROP: Project ROP is the depth of the well versus the time needed for completion of the well construction.
2. Phase ROP: As the Project ROP the Phase ROP is the depth of a single phase of the project versus the time needed for its completion. It includes all operations needed for completion of the phase.
3. Gross Run ROP: The Gross Run ROP gives an overview of on the success of a single BHA run. Basically it includes all operations, like tripping, making connections, the drilling itself, reaming, washing, etc. needed to drill a certain depth interval during one single BHA run. Trends show that if no problems are encountered during the run the Gross Run ROP decreases with depth, but for the presented case is approximately the same on all 6 investigated wells.
4. Main Operation Gross ROP: Gross Run ROP still includes time needed for tripping and making connections. The Main Operation ROP recognices start and end of the main operation of the BHA run, basically its intention, and describes the depth drilled during this single run versus the time needed for finishing the main operation.
5. Drilling ROP: The Drilling ROP describes the productive time during a drilling run. Once the automated operation recognition defines an operation as drilling the Drilling ROP is calculated as depth drilled devided by the time it takes to drill this interval.

The combination of the several introduced ROP's gives the engineer a good picture on rates he can expect for either a whole well or one single drilling operation. Using the benchmarking and combining the expected drilling ROP with

- time to handle and make-up BHA components
- tripping speed,
- connection times,
- wellbore treatment time,
- casing running time,
- logging time,
- BOP handling time

allows to simulate the duration a single tubular assembly run up to a complete hole phase, as shown in the case study. Based on this operations plan it is then possible to define the required resources (human, equipment, materials, services), thus expected well cost.

As mentioned above an investigation on 6 reference wells in the Vienna Basin has been done to be able to plan time versus for a seventh well (Figure 11). This well has then been drilled and the planned time versus depth cuve was compared with the plan (Figure 12).

Results show that the planned time of 174 hours for the intermediate section and the actual time of 179 hours needed for completion of it match quite close. Still there is room for improvement. But comparison of planned and actual scenario gives the engineer the opportunity for comparison and search for improvement areas.

As a second step for example the best in class scenario could be played, which means not average numbers for ROP, connection time, tripping speed, etc. but the best performance of any of these parameters on any well would be used for well planning (Figure 13). Also a minimum of BHA runs is then planned taking maximum bit life into consideration. By doing so the Intermediate section of the planned well should only take around 142 hours.

As can be seen there is quite a high potential for improvement in drilling of this well section. Having now a detailed plan, which is based on measured data and not subjective human observations, enables the engineer to analyze the drilling process and take active measures to improve constantly the well construction efforts to optimize invested time and expenditures.

Conclusion

The following conclusions can be drawn

- It is possible to utilize rig sensor data for automated drilling process description as basis for operations analysis.
- The problems inherent to the classical drilling operations breakdown, as part of morning reporting, can be overcome by automatically generating a high quality and objective description of the drilling process.
- Benchmarks can be derived, which form the basis for planning future wells and allow identifying potential performance improvements.
- Drilling operations plans can be substantially improved by clearly defining target tripping, connection and drilling times etc. – supporting technical limit approachs.
- Lost time can be identified more accurately.
- Permanent tracking of the actual process against the plan, respectively benchmarks allow identifying hidden lost time.
- A combination of this type of drilling process monitoring with cost control within an integrated project management approach will allow to track operations of an intire rig fleet in an highly automated way.

Acknowledgement

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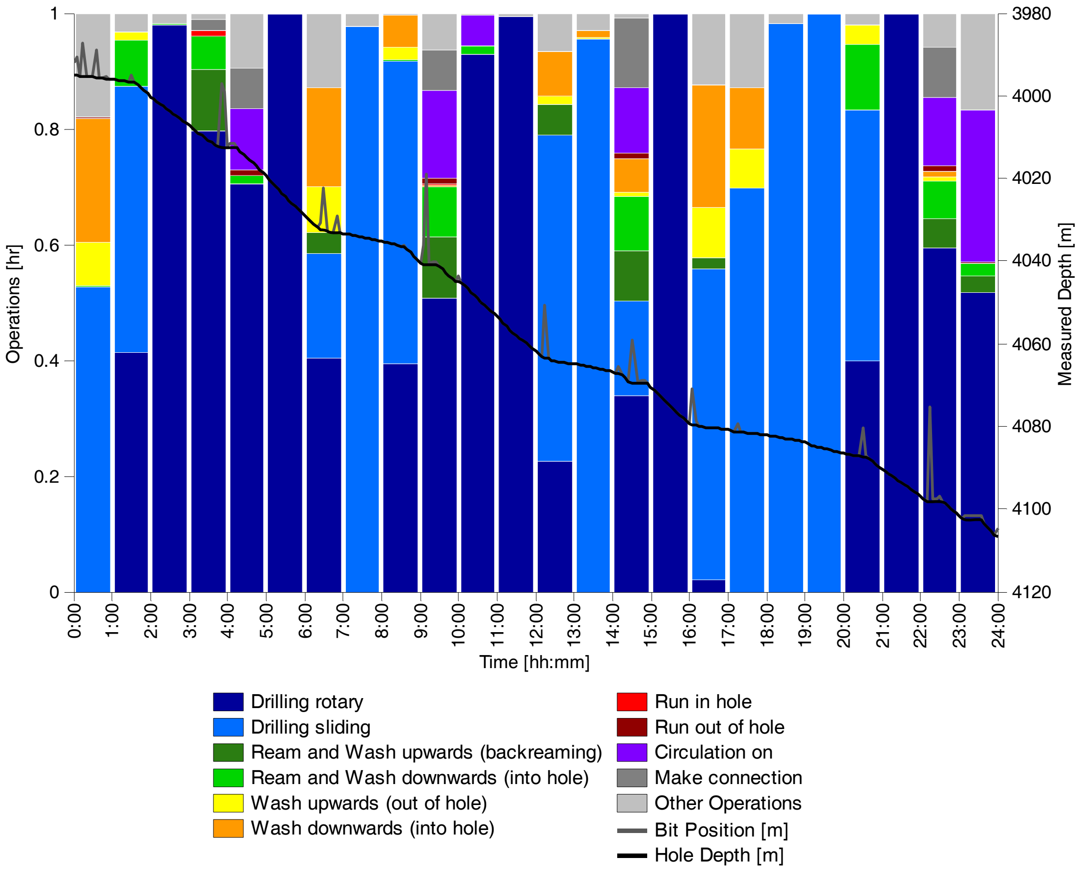


Figure 2: Daily Drilling Tracking Report – 24-Hour Summary, Operations over Time

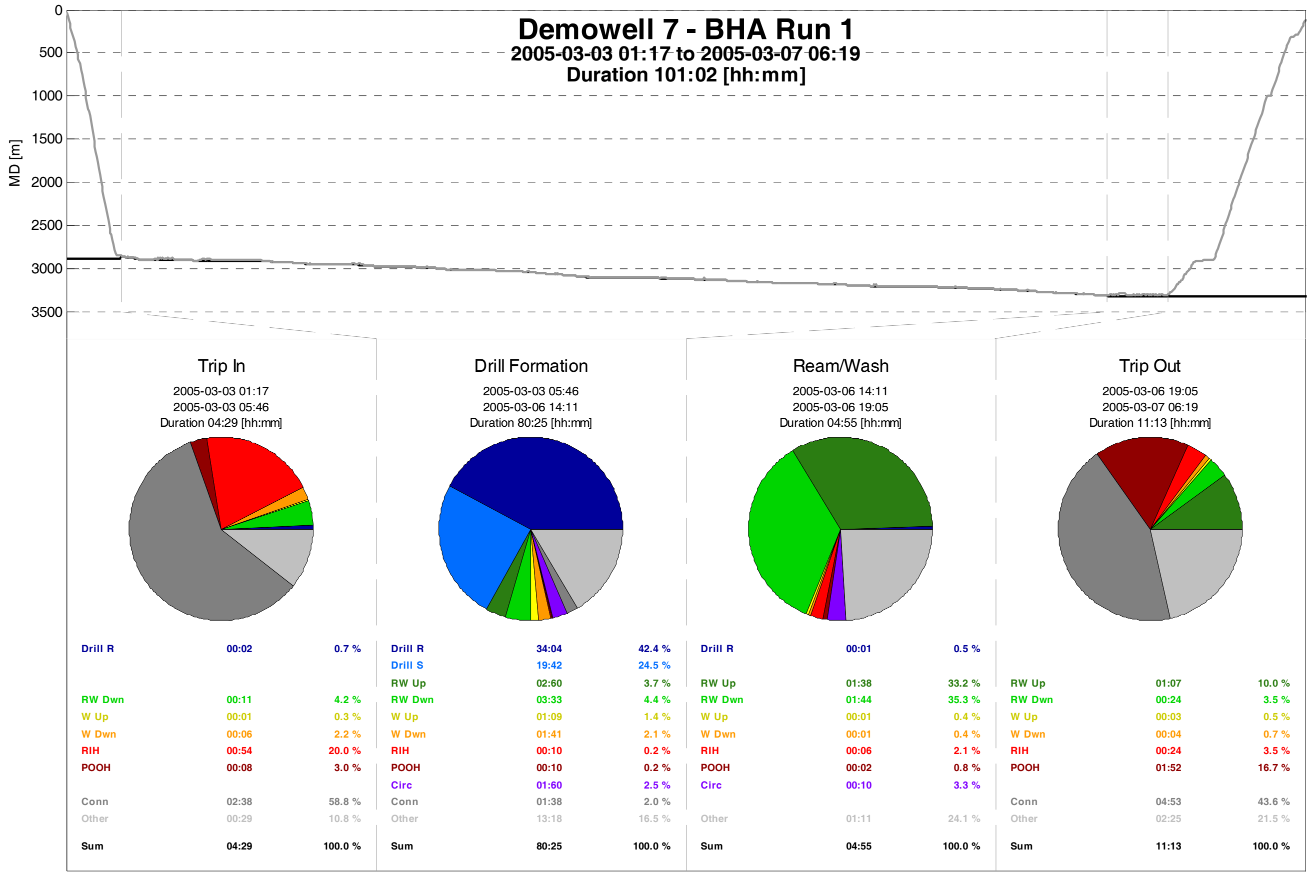
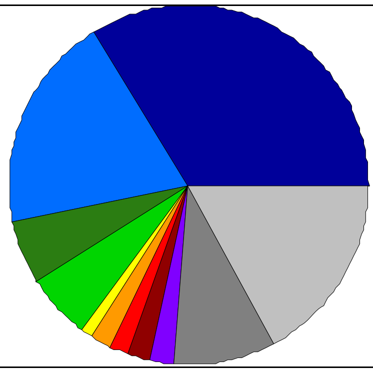


Figure 3: BHA Run Report - Run Details

BHA Run Overview

Start Time 2005-03-03 01:17:15 **End Time** 2005-03-07 06:19:15	**Duration [hh:mm]** 101:02
Start Bit MD --- **End Bit MD** ---	**Delta Bit MD** ---
Start Hole MD 2882.36m **End Hole MD** 3320.38m	**Delta Hole MD** 438.02m



Drill R	34:08	33.8%
Drill S	19:42	19.5%
RW Up	05:45	5.7%
RW Dn	05:52	5.8%
W Up	01:15	1.2%
W Dn	01:52	1.9%
RIH	01:34	1.6%
POOH	02:13	2.2%
Circ	02:09	2.1%
Conn	09:10	9.1%
Other	17:23	17.2%
SUM	101:02	100.0%

Special Analysis for Run Type “Drilling Run”

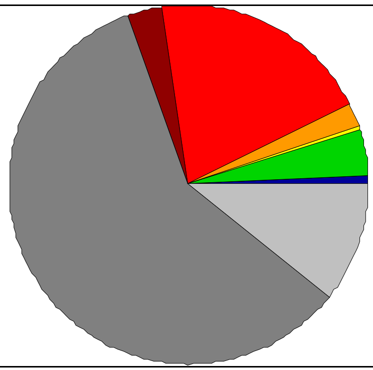
Average gross ROP 4.33m/h

Figure 4: BHA Run Report - BHA Run Overview

Operation Details

Trip In

Start Time 2005-03-03 01:17:15 **End Time** 2005-03-03 05:46:37	**Duration [hh:mm]** 04:29
Start Bit MD 21.17m **End Bit MD** 2855.45m	**Delta Bit MD** 2834.28m
Start Hole MD 2882.36m **End Hole MD** 2855.45m	**Delta Hole MD** -26.91m



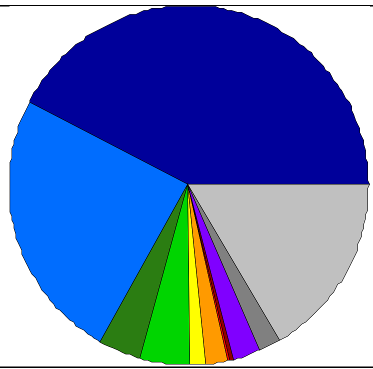
Drill R	00:02	0.7%
Drill S	00:00	0.0%
RW Up	00:00	0.0%
RW Dn	00:11	4.2%
W Up	00:01	0.3%
W Dn	00:06	2.2%
RIH	00:54	20.0%
POOH	00:08	3.0%
Circ	00:00	0.0%
Conn	02:38	58.8%
Other	00:29	10.8%
SUM	04:29	100.0%

Special Analysis for Trip In

Average gross tripping speed 631.32m/h
Number of recognized connections 99
Average connection time 1.82min

Drill Formation

Start Time 2005-03-03 05:46:37 **End Time** 2005-03-06 14:11:20	**Duration [hh:mm]** 80:25
Start Bit MD 2855.45m **End Bit MD** 3320.07m	**Delta Bit MD** 464.62m
Start Hole MD 2855.45m **End Hole MD** 3320.07m	**Delta Hole MD** 464.62m



Drill R	34:04	42.4%
Drill S	19:42	24.5%
RW Up	02:60	3.7%
RW Dn	03:33	4.4%
W Up	01:09	1.4%
W Dn	01:41	2.1%
RIH	00:10	0.2%
POOH	00:10	0.2%
Circ	01:60	2.5%
Conn	01:38	2.0%
Other	13:18	16.5%
SUM	80:25	100.0%

Special Analysis for Drill Formation

Gross ROP.. 5.78m/h
Net rotating ROP.. 11.73m/h
Net sliding ROP 2.86m/h

Figure 5: BHA Run Report - Excerpt of Operation Details

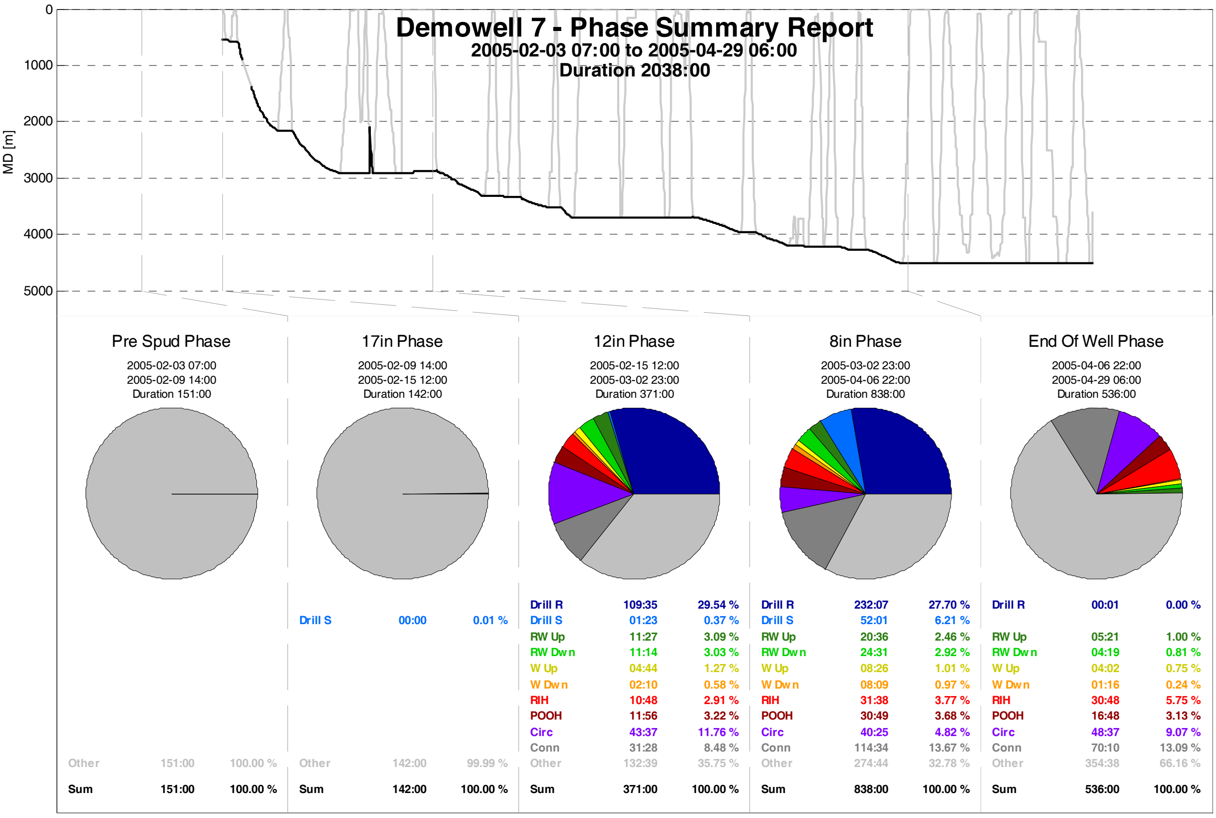


Figure 6: End of Well Report – Phase Summary Report

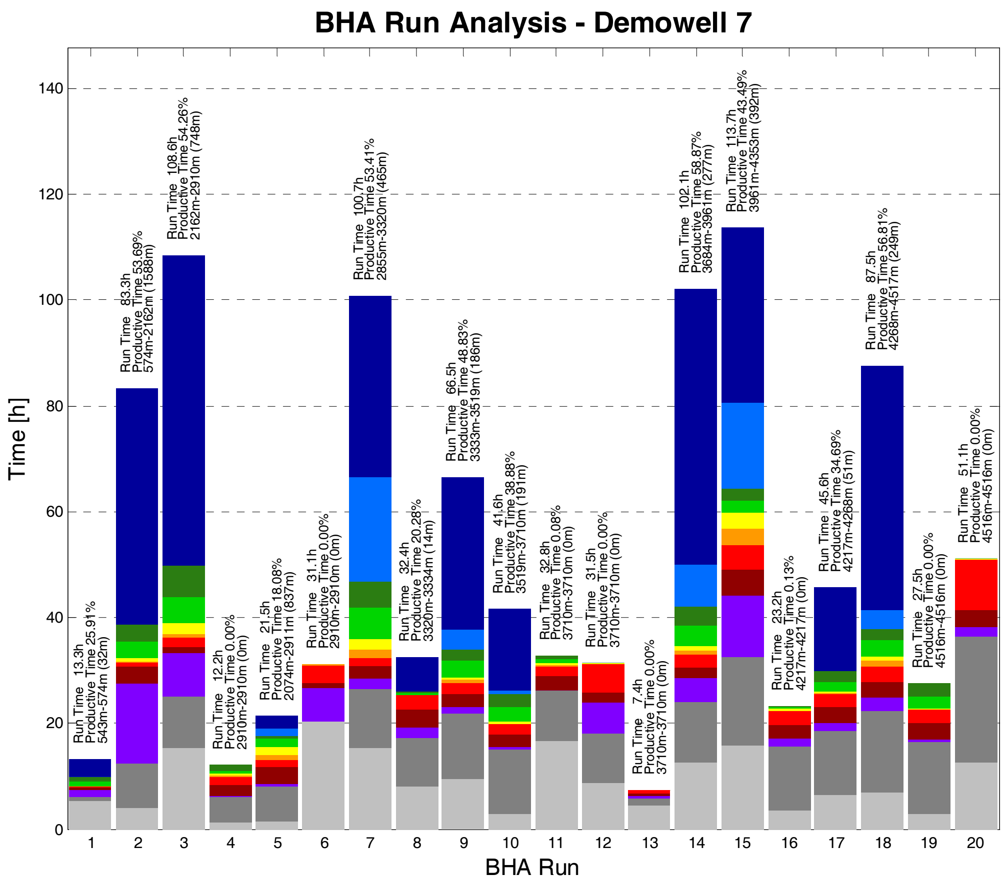


Figure 7: End of Well Report - BHA Run Overview

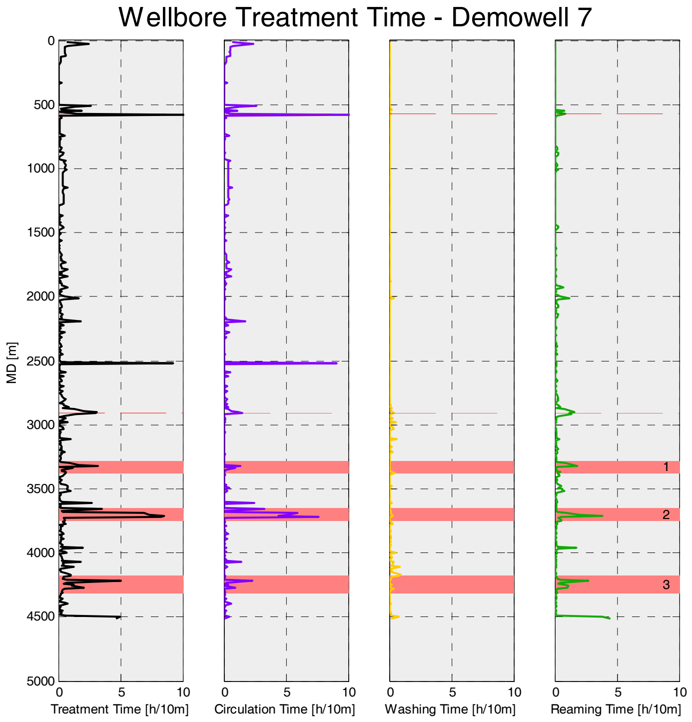


Figure 8: Wellbore Treatment Time - Conditioning Time

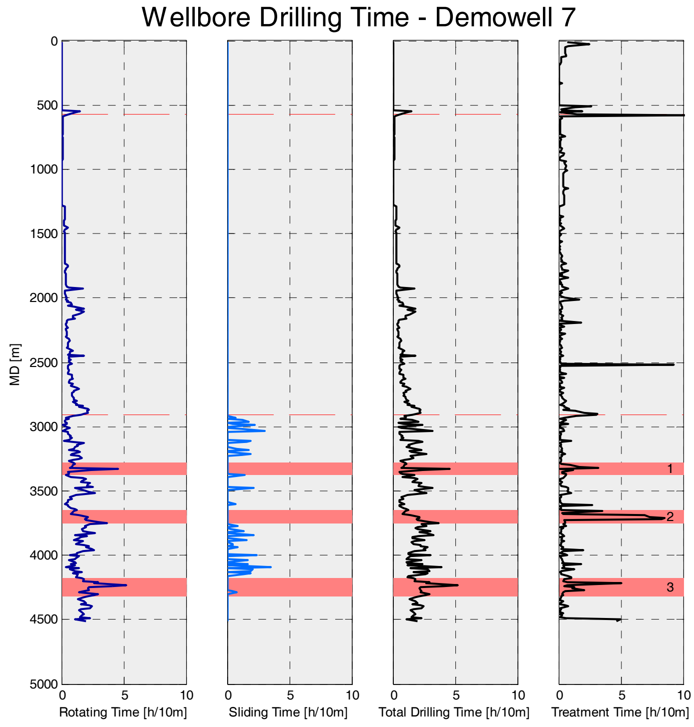


Figure 9: Wellbore Treatment Time - Drilling

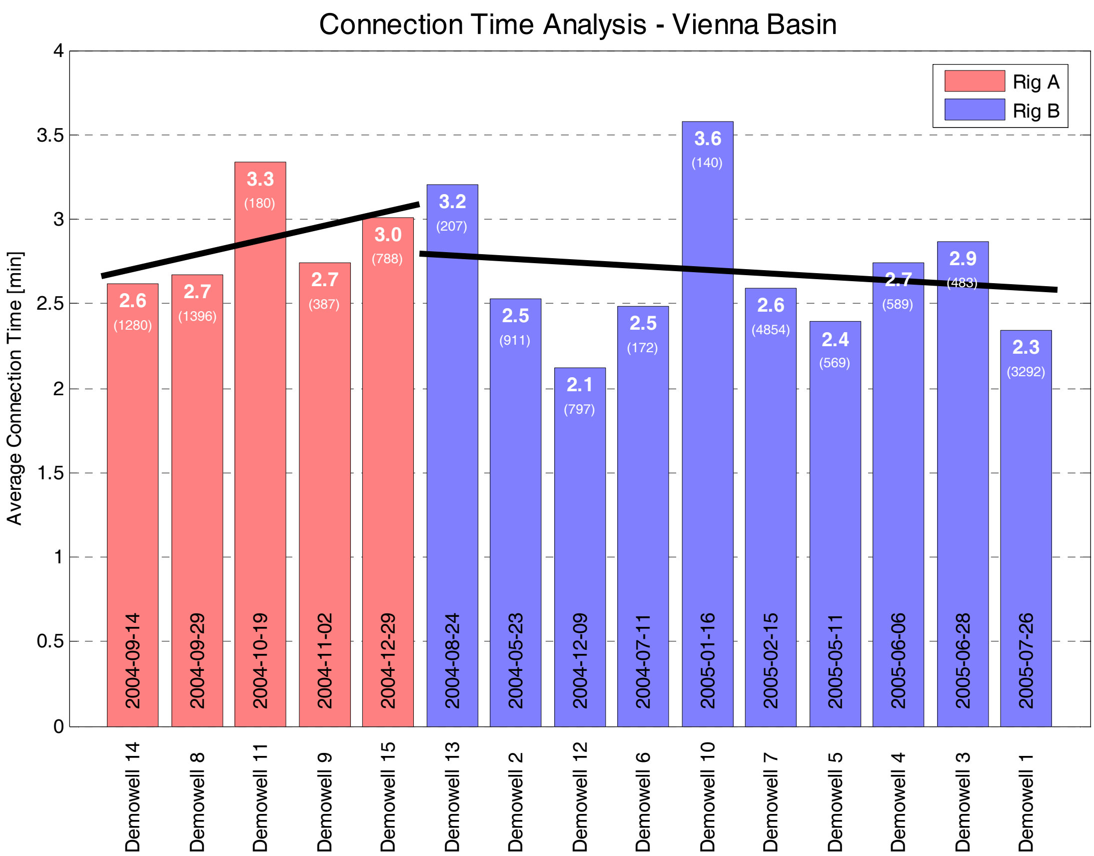


Figure 10: Conncetion Time Analysis - Vienna Basin

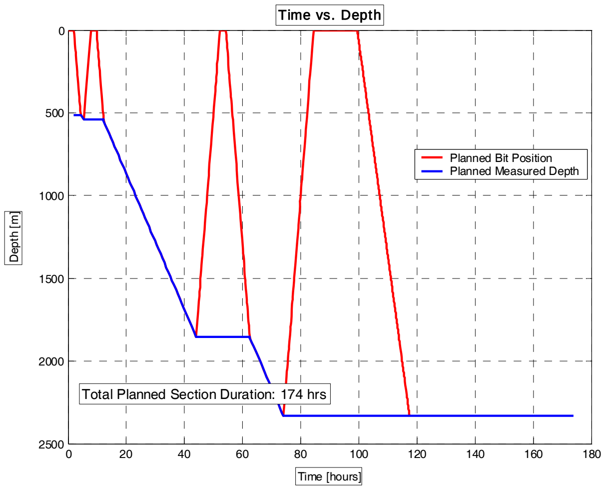


Figure 11: Planned Time versus Depth for Demowell - Bit Position and Measured Depth

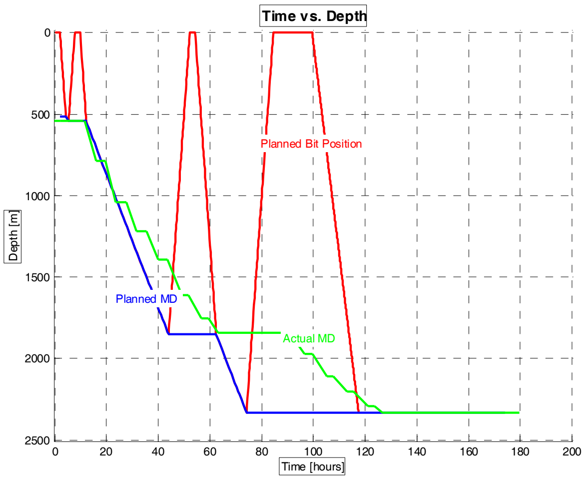


Figure 12: Planned versus Drilled Time versus Depth for Demowell

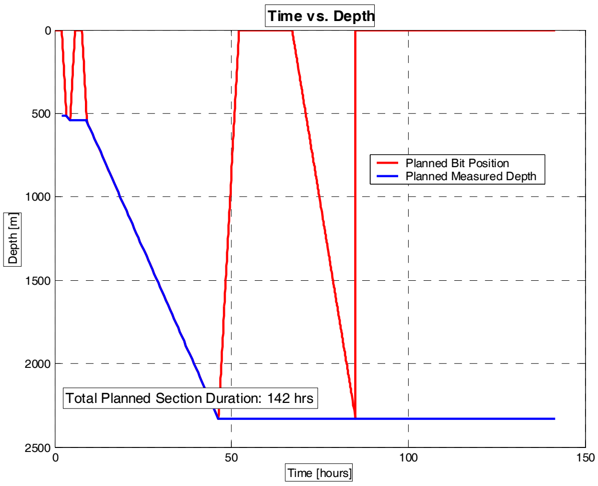


Figure 13: Time versus Depth for Best Performance Parameters