



Outperforming the High-Performance Drilling in Mahakam Delta: Enhanced Parameter and Fast Connection Practice Application in 8-1/2" Section Drilling Operation

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Abstract. Performance has always been the heart of Mahakam Delta drilling operation, particularly on Tunu Main Zone (TMZ) development. The struggle to maintain an economic value on the marginal reserves leads to the never-ending discovery of continuous improvement initiatives that successfully reduce the overall well duration and maintain sustainability of the project. Currently the 8-1/2" section drilling performance has reached plateau for almost 5 years and the Operator is challenged to create a step change. The initial TMZ performance benchmark is to drill 1400m within 24 hours. The PHM record was kept unbroken.

One improvement called "Enhanced Parameter and Fast Connection" has finally overcome this plateau. As the name suggests, the core of Enhanced Parameter and Fast Connection lies on the application of higher standard in drilling parameter as well as the reduction in connection time. Proper hydraulic design of an aggressive bit makes the application become more effective. On top of that, the most importance factor is a teamwork.

The Enhanced Parameter and Fast Connection Practice have created a new record in 8-1/2" TMZ with the current record sitting at 2303 m drilled in 24 hours. A new on-bottom and average Rate of Penetration (ROP) record was also achieved, and allowing a savings of 1.7 rig days compared to average performance.

Keyword: Drilling Performance, World Record, Fast Connection, Enhanced Parameter, Drilling Optimization



1 Introduction

Tunu is a giant mature gas field located in swamp area of Mahakam Delta, East Kalimantan, Indonesia. The gas field has been discovered in 1977 and production started in 1990. Year to date, more than 1300 wells have been drilled in this area (**Fig 1.1 and Fig 1.2**).

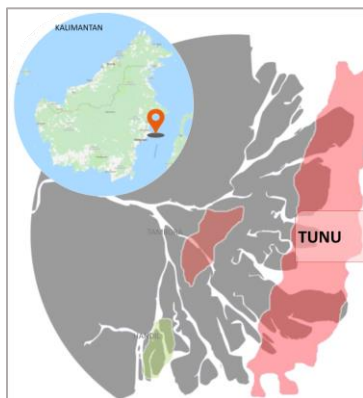


Figure 1.1. Tunu Field Location Map

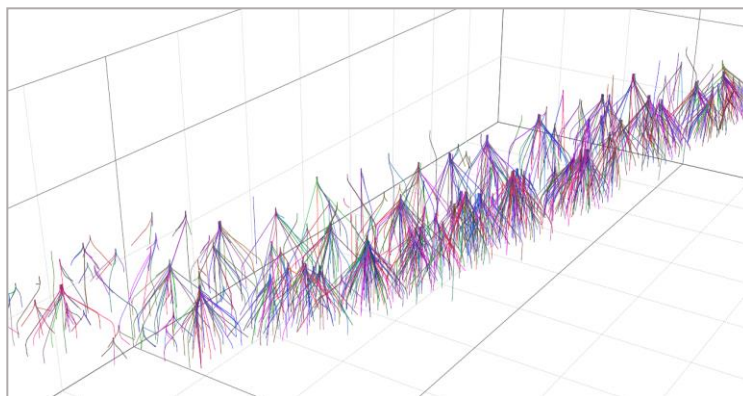


Figure 1.2. Tunu Well Trajectory Crowdedness

Tunu field reservoir consists of well-connected delta plain channels and isolated sand bars deposited in the deltaic environment [1]. Source of gas bearing reservoir can be divided into two intervals:

1. Tunu Main Zone (TMZ); Located in interval between 2,200 – 5,000 mSS depth with reservoir characteristic consolidated sand.
2. Tunu Shallow Zone (TSZ); Located in interval between 700 – 1,500 m SS depth with reservoir characteristic un-consolidate sand with strong aquifer support. This reservoir requires sand control mechanism.

Tunu current development has reached maturity, where finding new and economic targets are considered challenging such as low or marginal reserve (< 1 bcf). In addition, due to downturn of oil and gas in 2014, completing these marginal wells with standard approach make the well uneconomical.

Since last 5 years, Optimization and performance become the important parts of drilling operation particularly in Tunu. Sustainable optimization and performance mindset become a culture in the drilling team.

A lot of initiatives have been created by the drilling team to optimize well duration, e.g. rigless operation, well architecture simplification, simultaneous activities, batch drilling and well clustering. These initiatives have successfully reduced well duration and maintain continuous drilling operation in Tunu.

Uneconomical TSZ wells have been successfully optimized by implementation of shallow light architecture (**Fig 1.3**) which adopting the proven architecture of tubingless completion (**Fig 1.3**) in TMZ which combined with sand consolidation treatment as sand control method replacing Gravel Pack (GP) completion [2]. Year to date, TSZ wells are able to be completed with average 6.8 drilling days.



For TMZ well, in spite of the several optimizations implemented in 8-1/2" section, the drilling performance has already reach its plateau for the last 5 years and the record was kept unbeaten (**Fig 1.4**). The initial 8-1/2" section drilling TMZ record performance benchmark is to drill 1400m within 24 hours. In order to gain more economical benefit, the drilling performance has to be challenged by having other novel drilling method.

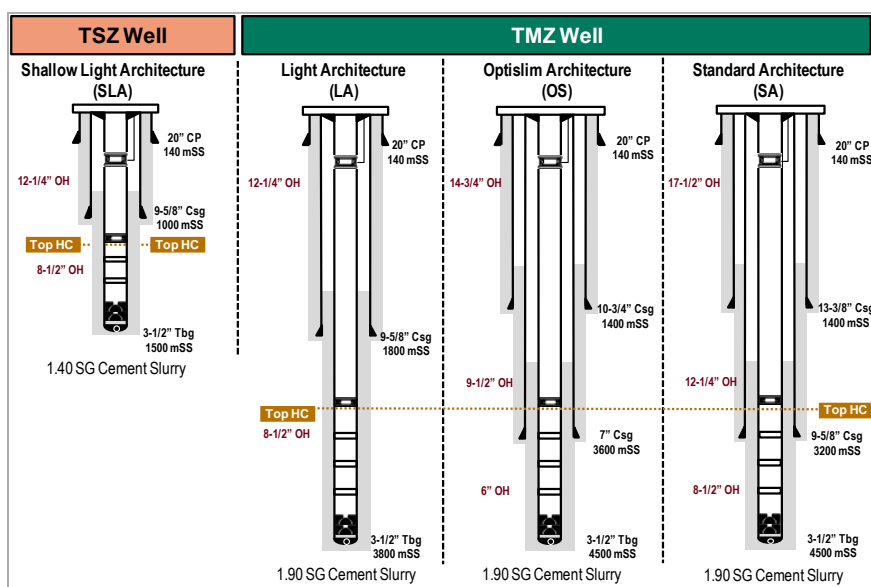


Figure 1.3. Tunu Field Location Map

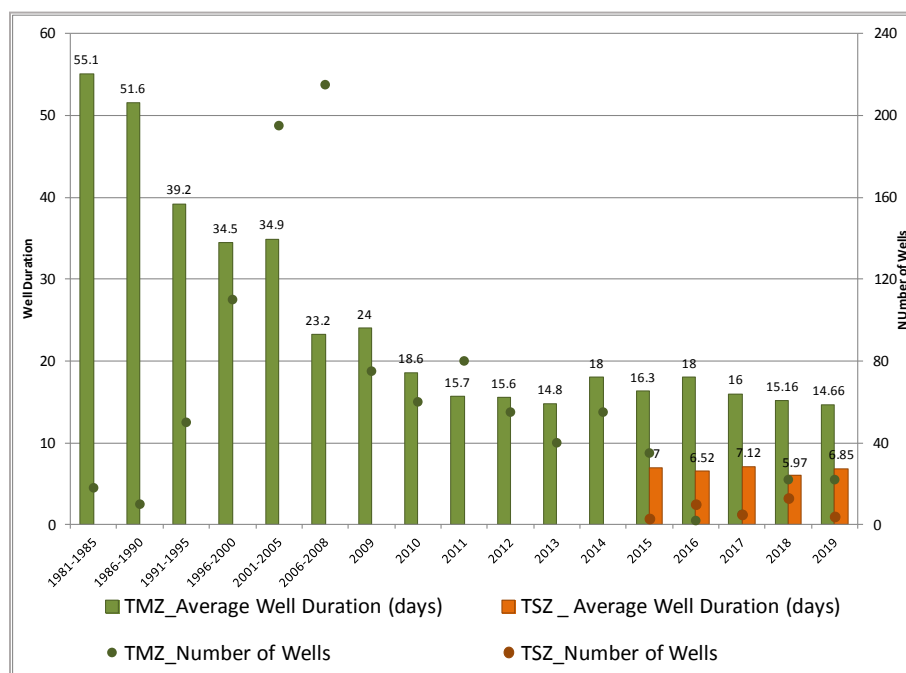


Figure 1.4. Average Well Duration and Numbers of Wells Evolution in Tunu Field for TMZ and SLA TSZ

Breakthrough has been taken and finally overcome the plateau. Improvement that combining skill as well as equipment optimization has been initiated. The “Enhanced Parameter and Fast Connection” technique has created multiple outstanding records in 8-1/2” TMZ drilling section.

2 Methodology

The spirit of Enhanced Parameter and Fast Connection technique lies on the application of higher standard in drilling parameter as well as the reduction in connection time. The technique is expected to become a solution to overcome the performance plateau.

The technique is created from team discussion among all the teams. Company as the leader, has to encourage and consolidate rig contractor and service companies. All the parties have to be in same direction to improve the drilling performance. The sense of belonging to the project becomes the success key of the technique.

Prior the technique implementation kick-off on the well, it had to be proven that the parameter enhancement is feasible to be done with current rig equipment and must not worsen the well hole condition. Several milestones as evident of “Enhanced Parameter” implementation feasibility are as (Figure 2.1).

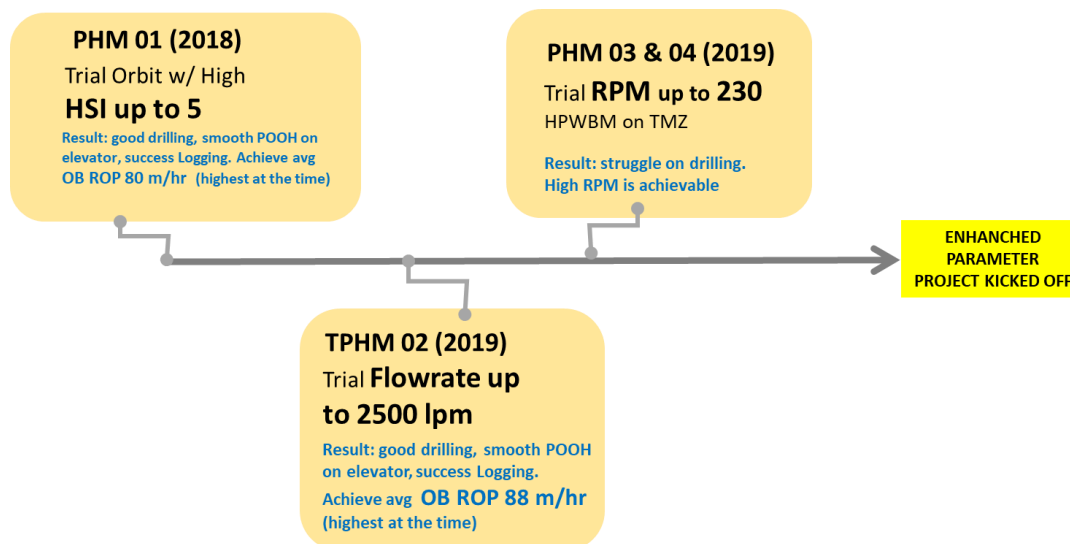


Figure 2.1. Enhance Parameter Pre-Kick-Off Milestones

High hydraulic horse power per square inch (HSI) with Orbit Schlumberger™ Rotary Steerable System (RSS) applied in Tunu that reached 5 Hp/in² has been recorded in 2008. The result proves the well could be completed with good drilling operation with 80 m/hr average On Bottom Rate of Penetration (OB ROP) -as the fastest at the time-, smooth 8-1/2” BHA pull out of hole (POOH) and the success of logging operation. In addition, there was no excessive wash out signature that made directional difficulty and severe hole cleaning condition.

In other case, higher flow rate was applied to improve drilling performance. Flow rate was increased to 2500 lpm from initial 2400 lpm. The well was completed safely; good drilling operation, smooth BHA tripping and logging operation. Moreover, the well’s average OB ROP has become the fastest with 88 m/hr.

Optimized drill pipe rotation per minute (RPM) was applied on two wells to prove equipment (TDS) feasibility to handle RPM optimization. The results were negative for drilling operation yet it was due to High Performance-Water Based Mud (HP-WBM) trial implementation on the wells. In the other hand, the RPM implementation showed good result and the TDS was proven to cover the RPM range. There were no stall and overheating signature observed during the operation.

After those parameter optimizations and equipment were proven, these were combined to become one as “Enhanced Parameter” technique.

This was followed another technique called “Fast Connection”. This technique was started to be initiated based on connection performance review after “Enhanced Parameter” kick-off.



2.1 RPM Enhancement

RPM become one of the factors affecting drilling performance. RPM has direct effect on ROP especially on Polycrystalline Diamond Compact (PDC) bit application. Higher RPM produce higher depth of cuts capacity and more cutting to be removed. As result the ROP value could be improved.

Pipe rotation has significant effect on hole cleaning [5], with the fact that it gives mechanical effect of agitation to improve both cutting removal capacity and hole cleaning. Higher pipe RPM improves hole cleaning condition which indirectly improves ROP by minimizing pumping sweep and back reaming requirement. Better hole cleaning also improves BHA tripping speed, smooth open hole logging operation, and improves tubing running speed.

RPM working range is enhanced from the range of 150-200 rpm become 150 – 230 rpm. TDS working range result shown on below table:

Table-1: Enhance RPM Parameter

TDS Ampere	Max On Bottom Torque (klb.ft)	RPM (rpm)
30 A	15	230*
40 A	18	210
57 A	29	200

*note: if require directional works limit to 220 rpm for PD X6, 230 rpm for PD Orbit

TDS 4S™ with GE 752 High Torque Shunt Motor™ is utilized to drill Tunu wells in daily basis. There is no TDS upgrade requirement for RPM enhancement. The key of RPM optimization is correct Amps Field utilization based on actual torque load. The application is within the TDS 4S specification (**Figure 2.2 and Figure 2.3**).

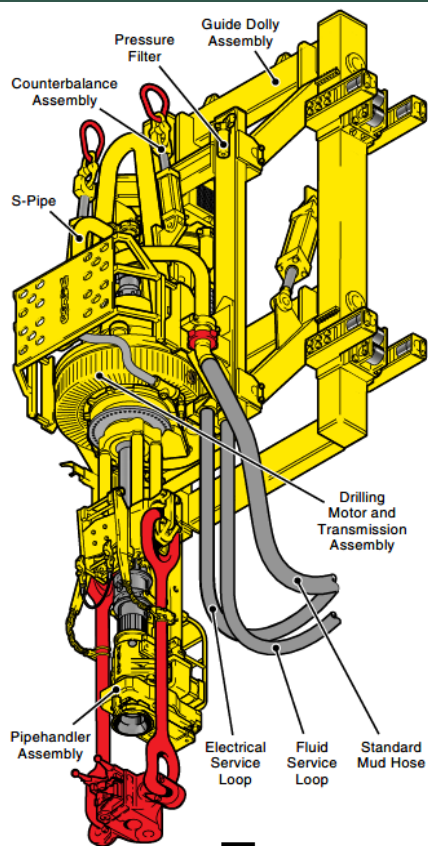
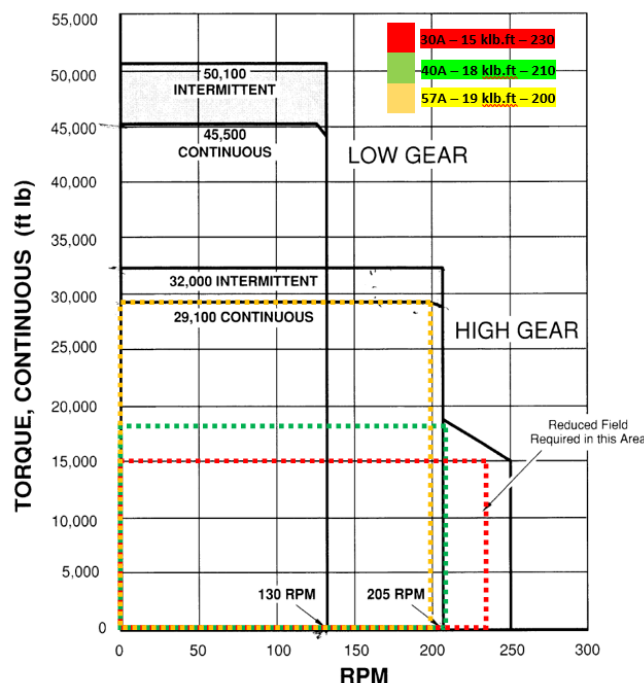


Figure 2.2. TDS 4S Major Component, taken from [7]

TDS-4S TOP DRIVE DRILLING SYSTEM

Drill Pipe Torque Vs. Speed GE 752 High Torque Shunt Motor



Continuous Torque Values are based on 1250 Armature Amps.
Intermittent Torque Values are based on stall at 1400 Amps with a 7 second maximum duration.
Reduced Field area is based on a 30 Amps Field.

Figure 2.3. TDS-4S TDS DP Torque V.S. RPM, taken from [7]

2.2 Flow Rate Enhancement

There are many variables which could affect cuttings transport. The most important variable is the in-situ liquid Velocity [9]. In-situ liquid velocity has direct correlation with drilling fluid flow rate. By having higher flow rate, liquid velocity can be improved as well as cuttings transport capacity and as consequence better hole cleaning could be achieved.

Flow rate enhancement is expected to improve ROP by improving cutting removal capacity ahead the bit. As the result, “re-grinding cutting” effect can be minimized and followed by increasing of bit shearing formation effectiveness. Based on trial prior “Enhanced Parameter” technique kick-off, the flow rate can be increased from 2400 lpm to 2500 lpm which give a significant average OB ROP improvement.

High Flowrate is set at maximum 2600 to 2900 lpm while common practice flowrate utilized in Tunu Field is 2400 lpm. To handle this enhanced flowrate, MWD turbine has to be upgraded to higher flow rate configuration. Initial MWD turbine 400-800 GPM is replaced by 500-1000 GPM MWD turbine (TeleScope

Schlumberger™) as per **Table-2**. The main reason of MWD turbine replacement is to have wider working range flowrate. As a result, MWD turbine can works safely during “Flowrate Enhancement” (**Figure 2.4**).

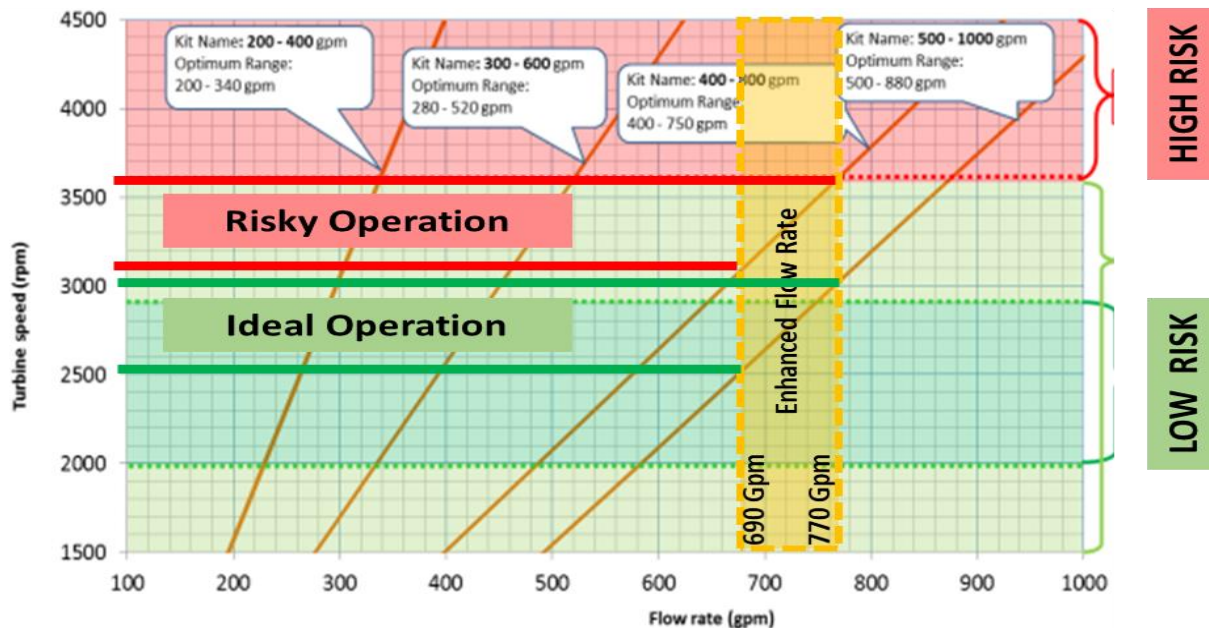


Figure 2.4. Optimum MWD Flow rate configuration

Table-2: Turbine Kit

Tool size (in)	Flow Kit Name (gpm)	Optimum Flow Range (gpm)
5.1	200 – 400 ²	200 - 340
	300 – 600	280 - 520
	400 – 800	400 - 770
	500 - 1,000 ³	500 - 880

2.3 HSI Enhancement

The main objective of HSI is to ensure bit cleaning in order to avoid ballooning that might happen in front of the cutter and the junk slot. In other hand, the bit cleaning also improves cutter efficiency to create penetration on formation.

High HSI design provides us high velocity jetting from bit nozzles. The high velocity jetting fluid makes “Hydraulic Drilling Effect” to the formation. Formation is being weakened by jetting force of the drilling fluid. The “Jetting Drilling Effect” is very effective during drilling in the upper part of TMZ formation (1800 – 3000 mSS) which have relatively softer formation characteristic than lower part of TMZ (**Figure 2.5**). Therefore, BHA is set with ge 4-5 hp/in² HSI ran by utilization of Total Flow Area (TFA) within range 0.73-0.85 in² at the bit.

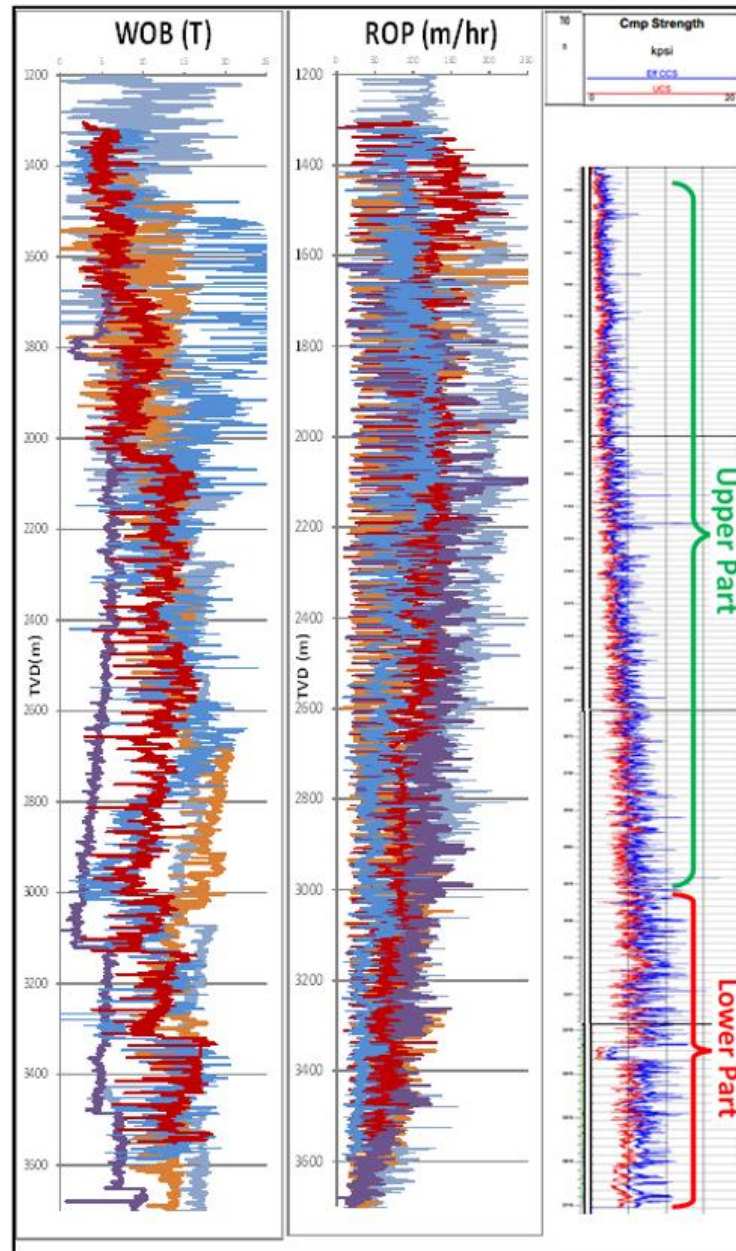


Figure 2.5. General WOB, ROP, and Formation Compressive Strength Profile in Tunu Field

2.4 Fast Connection Practice

Drilling connection contributes more than 30 percent of drilling duration on 8-1/2" section TMZ drilling. Improving connection time instantly reduces drilling duration since no correlation with rate of penetration.



Based on connection post-monitoring on some wells drilled with “Enhanced Parameter” technique, connection time was not consistence and can be improved. Initially, general recorded connection time is 10-13 minutes with some crews could achieve below 10 minutes in average (**Figure 2.6**).

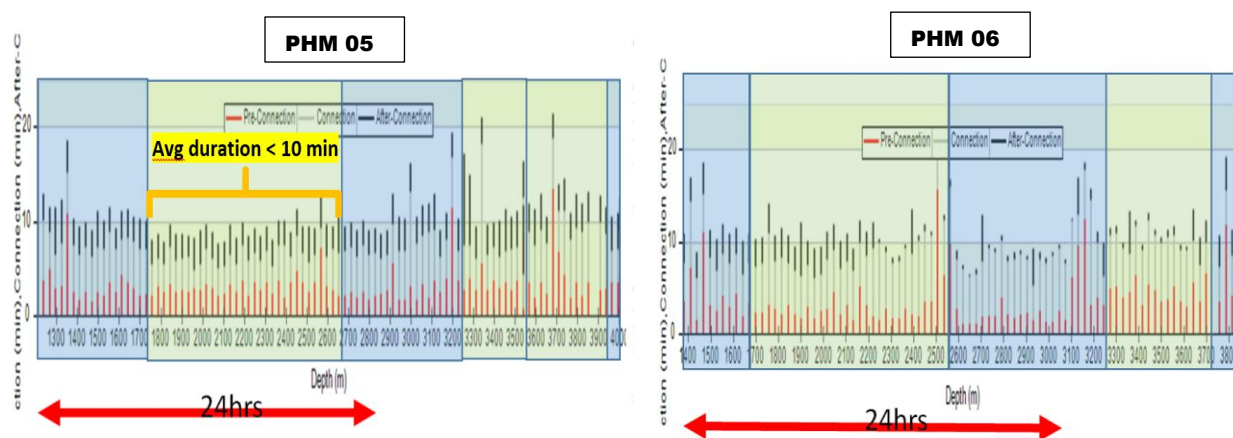


Figure 2.6. Old Connection Technique Duration with average duration 10-13 min

The keys of reducing connection duration are reducing pre-connection duration and survey time. Since hole cleaning theoretically has been improved by parameter enhancement, back reaming length and T&D monitoring frequency could be reduced. Survey time is reduced by performing survey on slip. No more waiting time for sync and good survey confirmation is done in the practice but waiting for 30 seconds only. “Fast Connection” technique consists of bellow steps.

Table-3: Fast Connection Steps

Conn Steps	Fast Connection
1	Backream 0.5 -1 single*
2	Take T&D every 3-5 stands*
3	Set on slip
4	Pump off, Break out connection
5	Clean elevator (took 0-1 mins)
6	P/U new stand, Make up connection
7	Pump on with drilling FR directly just after the DPs are connected.
8	Wait for MWD-LWD theoretical sync (30 Sec), no need to wait Sync & Survey confirmation
9	Release slip
10	Drill ahead

* Adjusted as per hole dictated

“Enhanced Parameter and Fast Connection Practice” is feasible and practical to be implemented. The Technique has been implemented in several TMZ wells in Tunu Field without any difficulties and failure.



2.5 Proper Bit Design

In order to satisfy high ROP need, generally 8-1/2” bit needs to be designed with aggressive cutter back rake angle and good hydraulic design. Depth of cut limiters should be decreased to improve the aggressiveness. However, bit stability is a must in order for the bit could stand to TD with acceptable ROP.

HSI enhancement also produces erosion risk for the bit. Therefore, the bit needs to be erosion resistance. Matrix body bit is recommended to be utilized for “Enhanced Parameters” application. However, a bit with steel body and proper hydraulic design has been run on “Enhanced Parameters” well with acceptable erosion signature.

Some bit features that have been implemented with “Enhanced Parameters” application to achieve drilling records are as followed (**Figure 2.7**).

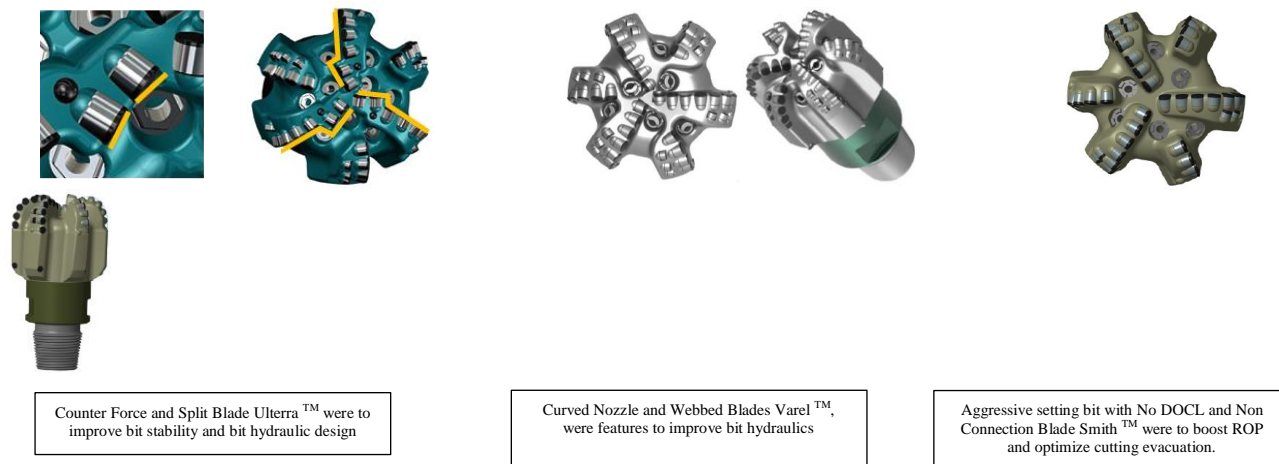


Figure 2.6. Some Bit Features that Implemented with Enhanced Parameter

2.6 Enhanced Rotary Steerable System

Currently, push-the-bit RSS BHA type is proven to be utilized for “Enhanced Parameter” application. Motor BHA is not recommended to be utilized due to rotation and flow rate limitation.

Enhanced-push-the-bit RSS BHA with mechanical pad seal is recommended to be utilized in “Enhanced Parameter”. The BHA provides higher rate of RSS back pressure and more robust pad seal that allows parameter optimization to be push from the beginning of the section. It overcome potential pad seal blown due to aggressive parameter applied.

2.7 Teamwork

Teamwork is the absolute success key of the technique application. The teamwork has to be built among the all parties. Persuasive and friendly approaches have to be implemented in order to create working conformance.



The sense of belonging to the project becomes a powerful factor to create great teamwork. Any initiative is welcomed and has always been discussed within the team. Company becomes an encouraging leader that actively digging ideas and any potential from all parties. Collaborative discussions are held during formal and informal forums such as social media group discussion, dinner talks, pre-spud meeting, etc.

Competitive culture among the rigs is created by the company. By this culture, rig team is always encouraged to be motivated to deliver their best performance for each project. Being “the best rig among the fleets” predicate is become a great honor to be chased. As the reward, Rig incentive is always implemented proportionally to the performance. A souvenir regarding record breaking performance has also been added to boost morale and maintain the team spirit.

Family has become the most effective factor in a team. Both social and religious relationships have to be well-preserved among the individual. A healthy psychological aspect improves physical fitness and shall add to better rig performance. Regular religion activities, monthly birth day celebration, futsal gathering, social charity, and during days off gathering onshore are done to build a Rig family. Some documentations could be seen on **(Figure 2.7)**.

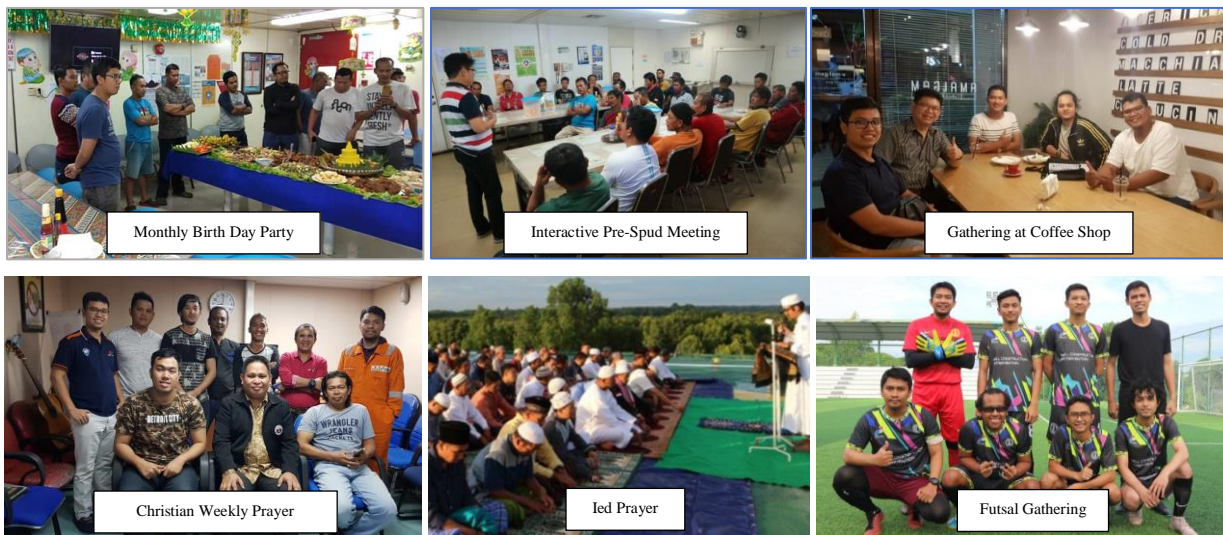




Figure 2.7. Some Team Gathering Documentations to Improve Teamwork

3 Result and Discussion

The first implementation of “Enhance Parameter” was commenced on June 2019 and instantaneously achieved record breaking of meter-age drilling in 24 hour. It achieved 1680 m in 24 hour (**Figure 3.1**).

In the second implementation of the technique, meter-age drilling in 24 hour record was broken again with 1704 m in 24 hour achievement. In this well, it was achieved 87 m/hr average OB ROP (**Figure 3.1**).

“Fast Connection” was started to be implemented on 3rd well. The combination technique of “Enhanced Parameter and Fast Connection” created outstanding achievement of multiple record breaking. It broke meter-age drilling in 24-hour record, average OB ROP record, and average ROP record on 8-1/2” section TMZ Tunu Field. It reached 1804 m in 24 hour, 91 m/hr average OB ROP, and 58 m/hr average ROP (**Figure 3.1**).

“Enhanced Parameter and Fast Connection” was continued to be implemented in several wells with good result on drilling, BHA tripping, and logging operation.

“Enhanced Parameter and Fast Connection” implementation was optimized. Enhanced-push-the-bit RSS BHA was utilized to enhance flow rate limitation. By this BHA, flow rate could be optimized more than previous practice. Bit with aggressiveness, stability, and optimum hydraulic design was utilized to complete the technique.

During the technique implementation on 8th well, multiple records of meter-age drilling in 24 hour, average OB ROP, and average ROP on 8-1/2” section were broken again with **2132 m** in 24 hour, **92 m/hr** average OB ROP, and **61 m/hr** average ROP (**Figure 3.1**).

In February 2020 on 14th well, average OB ROP and average ROP records were broken again with **95 m/hr** average OB ROP, and **62 m/hr** average ROP (**Figure 3.1**).

“Fast Connection” practice is upgraded by significantly cutting survey waiting time to 30 seconds.

In the end, multiple records breaking could be achieved again on 19th well. In March 2020, it reached **2303 m** in 24 hour, **141 m/hr** average OB ROP, and **88 m/hr** average ROP as (**Figure 3.1**).

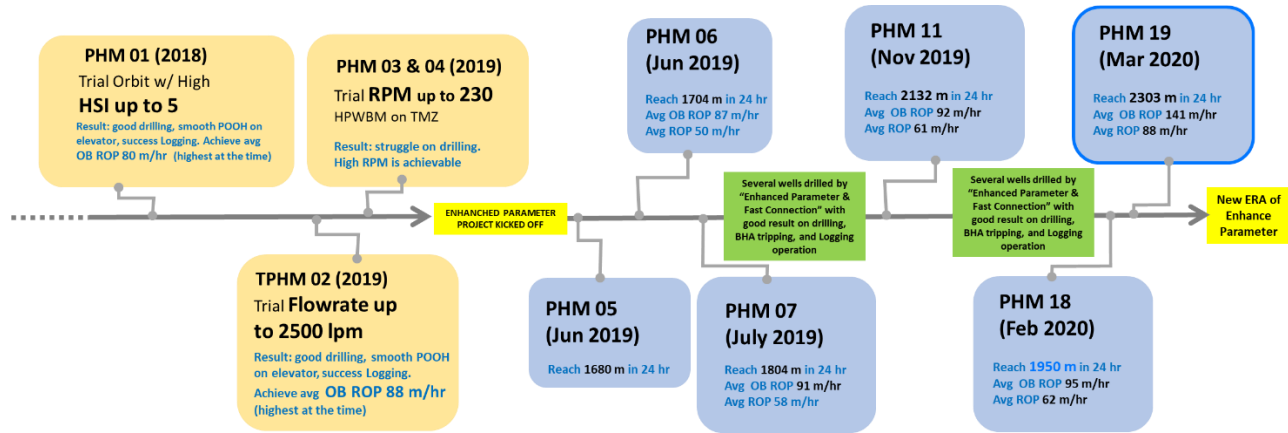


Figure 3.1. Enhanced Parameter & Fast Connection Milestones

3.1 Drilling Performance

Based on 8-1/2” section TMZ Tunu Field ROP database (**Figure 3.2**), “Enhance Parameter & Fast Connection” implementation create big success to overcome TMZ Tunu Field performance plateau. Some drilling performance records were broken with the current record sitting at **2303 m** drilled in 24 hours, **141 m/hr** average OB ROP, and **88 m/hr** average ROP. Compared to initial drilling performance (**52 m/hr** average OB ROP and **36 m/hr** average ROP), average OB ROP could be increased by **171%** and average ROP could be improved by **140 %**.

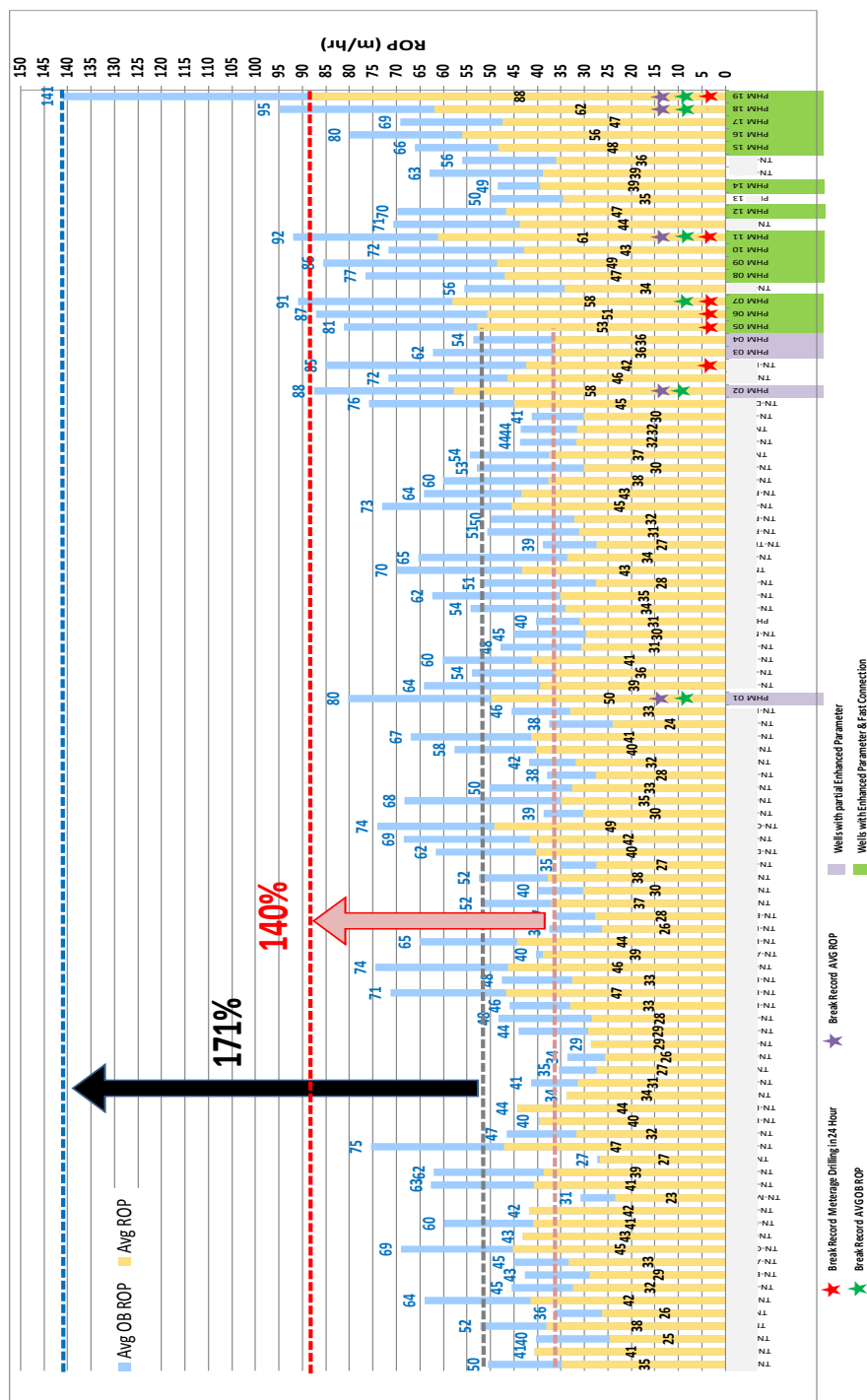


Figure 3.2. 8-1/2” Section TMZ TUNU Field ROP Data Base



3.2 Connection Performance

It is shown on Connection Duration comparison (**Figure 3.3**) that significant reduction on connection duration is observed. Moreover, the connection duration is consistently below 6 minutes. The duration could be reduced by ~ 7 minutes comparing to old connection method as per below table.

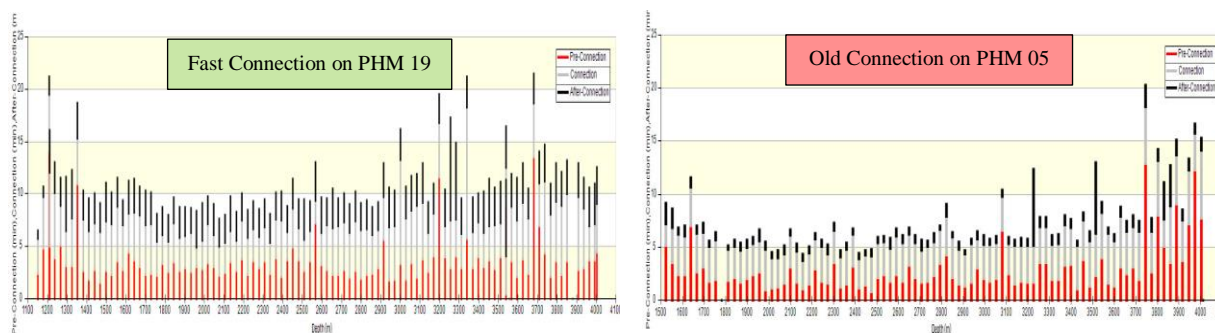


Figure 3.3. Old Connection V.S. Fast Connection Duration

Table-4: Old Connection V.S. Fast Connection Comparison

Conn Steps	Old Way	Fast Connection
1	Backream 1 single – 1 stand	Backream 0.5 -1 single*
2	Take T&D every stand	Take T&D every 3-5 stands*
3	Set on slip	Set on slip
4	Pump off, Break out connection	Pump off, Break out connection
5	Clean elevator (took 1-2 mins)	Clean elevator (took 0-1 mins)
6	P/U new stand, make up connection	P/U new stand, Make up connection
7	Pump on with low FR	Pump on with drilling FR directly just after the DPs are connected.
8	Release slip	Wait for MWD-LWD theoretical sync (30 Sec), no need to wait Sync & Survey confirmation
9	Increase FR to drilling FR	Release slip
10	Wait for survey result (3-5 mins)	Drill ahead
11	Drill ahead	
Cum Time	10-13 minutes	4-6 minutes

* Adjusted as per hole dictated

Based on field data, currently 100% survey was well received during “Fast Connection Practice” implementation. To be noted, each connection time was not systematically recorded through real-time monitoring. However, rig crews were fully aware of this practice and constantly deliver their best performance on each connection.



3.3 Duration Saving

By implementing the “Enhance Parameter & Fast Connection” well duration could be reduced by ~ 1.7 Days. In calculation for 2500 m open hole length drilling (typical length of 8-1/2” open hole length TMZ Tunu Field), ROP improvement contribute 41 hours. The duration saving is equivalent to ~ USD 255K. In addition, the improved hole quality allows a faster tripping speed and a safer subsequent operation.

4 Conclusion

The “Enhanced Parameter & Fast Connection” technique was proven to overcome TMZ Tunu Field performance plateau. The “Enhanced Parameter and Fast Connection” technique has created multiple outstanding records in 8-1/2” TMZ drilling with the current record sitting at at 2303 m drilled in 24 hours, 141 m/hr average OB ROP, and 88 m/hr average ROP.

The “Enhanced Parameter & Fast Connection” technique is proven to improve average OB ROP by 171% and average ROP by 140%. While the “Fast Connection” was proven to be done in 4-6 minutes with duration saving up to 7 minutes each connection.

The “Enhanced Parameter & Fast Connection” was believed to improve hole quality. Based on well database, smooth BHA tripping operation, smooth tubing running operation, and almost no open hole logging problem were observed.

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