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Delivering Well in an Economical Way for Marginal Field by Maximizing Co-Activity Operation and Mastering Drilling Practices in Swamp Drilling Operation

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Abstract. Limited remaining reserves is one of the challenges that is usually faced in mature field development. Swamp fields in Mahakam block are the examples in which field development become more marginal. Delivering wells more economically is one of the key points to survive in~~from~~ those conditions. Rig operation ~~which has~~with a significant daily expenditure could be a way for improvement ~~is one of the windows that can be improved~~ to yield~~deliver~~ economic wells.

In general, efficient rig operation will deliver well in a shorter duration and more economically. Two aspects can be improved to deliver well in shorter duration such as performing co-activity operation to shorten the horizontal time (preparation time) and mastering drilling practices to shorten the vertical time (drilling time). In co-activity operations aspect, swamp drilling team has successfully implemented various initiatives such as more rigless operations, batch drilling, offline activities, and other initiatives. While in drilling practices aspect, swamp drilling team have also successfully implemented ~~enhance~~ drilling parameter enhancement, high bit HSI, bit best selection, fast string connection, and team motivation to reduce the duration and well cost.

Implementing massive co-activity operations and best practices have demonstrated a significant time saving of 24% for Shallow Light Architecture (SLA) well and 27% for Extended Light Architecture (ELA) well. Those practices have also make a new record of fastest well completion in 2.17 days and highest drilling ROP for 141 m/hr with drilling 2303 m in the first 24 hrs that was recorded as the world best performance of Rotary Steerable System (RSS) BHA as per DD Company worldwide record. As a result, the 2020 average cost of SLA well wa~~i~~s 2.6 MUSD while ELA well wa~~i~~s 4.1 MUSD.

Those massive co-activity operations and drilling practices have been successfully implemented since 2019 without any safety incident and related Non-Productive Time (NPT). This positive result leads us to deliver more wells for future development in swamp fields asset.

Keyword: co-activity operation, drilling practices, economical, marginal field

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1 Introduction

Mahakam block has had operated and developed for more than 50 years. This block is divided into 2 big areas, Swamp and Offshore. The biggest challenge for the mature field in Mahakam is to maintain production while facing the depletion of the reservoir itself. A massive drilling campaign is conducted to maintain a declining production profile. Initiative and optimization are also conducted during Mahakam field development as well to achieve well economic for field development.

In swamp asset itself, the reservoir is divided into two types intervals, main zone and shallow zone. Main zone is located on interval between 2,200 – 5,000 mSS depth with the characteristic of consolidated sand while shallow zone is located on interval between 700 – 1,500 mSS depth with the characteristic of un-consolidated reservoir.

Initial field development was started in the early '80s and resulted in several optimizations. Starting from the introduction of tubingless completion (S. Oumer, 2012) in 2000 which reduces well duration by 33% from average 55 days to 34 days until the introduction of Light Architecture (LA) in 2010 where well duration reduced furthermore by 58% down to average 14 days. LA for shallow zone, called Shallow LA (SLA), then replaced standard Gravel Pack (GP) completion to squeeze well cost (AI. Handoko, 2017). Figure-1 shows a comparison between GP and SLA architecture.

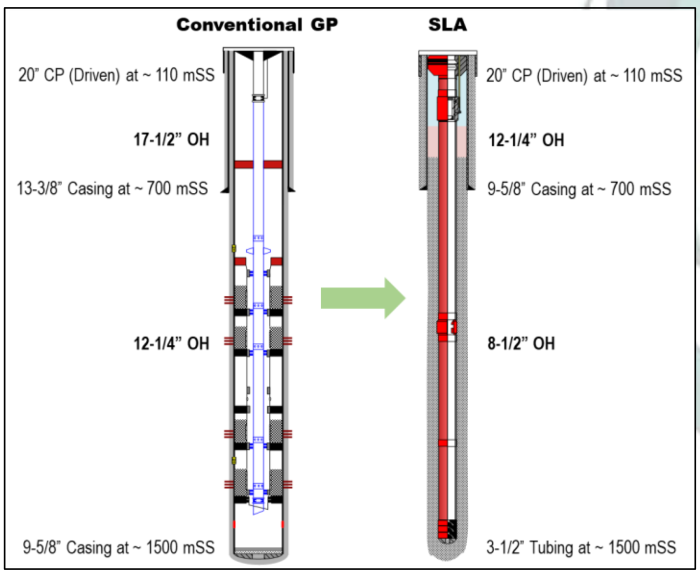


Figure.1 GP and SLA architecture comparison

LA was then industrialized and it was consisted of a two-hole section, 12-1/4" and 8-1/2". Nowadays, swamp fields use two types of LA wells, shallow well (<2000 mTVD) with Shallow

Light Architecture (SLA) and deep well (<4400 mTVD) with Extended Light Architecture (ELA) (MD. Maulana, 2019).

However, low oil and gas prices and limited remaining reserves in swamp fields pushed the drilling team to further squeeze well duration in order to support well economic and continue drilling operations. Several co-activities operation and drilling practices have been introduced to furthermore reduce well duration which directly impacts the well cost. Those implementations have demonstrated significant time saving and well cost reduction which is proven by lower average well duration and cost.

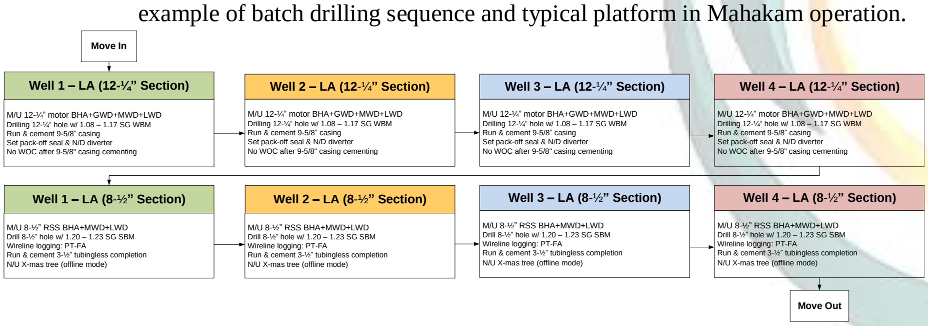
2 Methodology

In general, efficient rig operation will deliver well in a shorter duration and more economic. Two aspects can be improved to deliver well in shorter duration such as performing co-activity operation to shorten the horizontal time (preparation time) and mastering drilling practices to shorten the vertical time (drilling time). Driven by the low oil and gas price, several initiatives are introduced to reduce the well duration.

2.1 Co-activity Initiatives

2.1.1 Batch Drilling Sequence in a Platform

Batch drilling was introduced in Mahakam drilling sequence in which drilling activity up to 4 wells in a platform. This initiative significantly reduced well duration by eliminating extra rig move, platform preparation, drilling and mud preparation. Furthermore, the batch drilling sequence in a platform allowed us to do more co-activity operation to squeeze the well duration. Figure-2 shows the example of batch drilling sequence and typical platform in Mahakam operation.



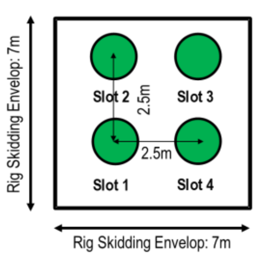


Figure 2. Batch drilling campaign in a platform

2.1.2 Rigless Conductor Pipe (CP) Driving and Compact Wellhead (CWH) Installation

20” CP was driven directed to trajectory azimuth and CWH was installed by rigless operation prior to rig arrival on each well slot to be drilled. This initiative could reduce rig time since CP driving job and CWH installation have been delivered by rigless barge. Figure-3 shows actual CP and CWH condition after installation.

Figure 3. Rigless CP driving and actual CP & CWH after installation

2.1.3 Take Conductor Pipe Survey while Cleaning Out It

Gyro while Drilling (GWD) was attached in the surface section Bottom Hole Assembly (BHA) to ensure actual inclination and azimuth in the CP shoe. Once cleaning out CP has been completed, GWD could take the survey and continued drilling. This initiative could reduce operation time which previously we had to prepare slickline equipment and run Gyro wireline inside the drill pipe to take the CP survey. BHA configuration itself can be seen in Figure-4.

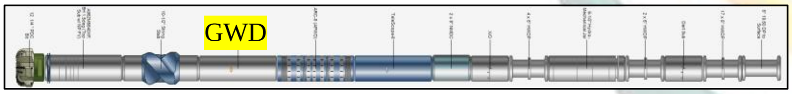


Figure 4. BHA Configuration for Surface Section

2.1.4 Pre-Installed Wellhead – No WOC

A pre-installed wellhead was the first step to conduct no Wait on Cement (WOC) operation. This step allowed the connection between the pin connector and the landing ring to be tested directly. The next steps were to run the casing hanger, performed surface cementing job, and 9-5/8” pack-off installation. Those operations permitted the well to be temporarily suspended since the annulus sealing area has been secured. Thus, the rig may skid to another batch well to continue drilling activity. Figure-5 shows the pre-installed wellhead configuration to perform No WOC activity.

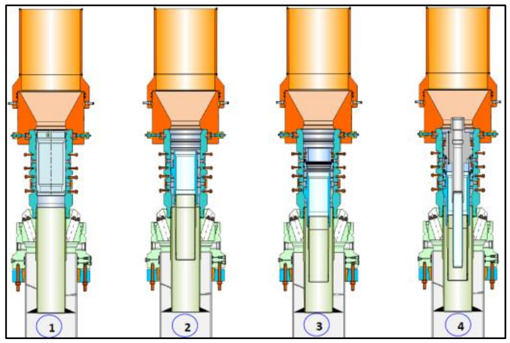


Figure 5. Pre-installed wellhead

2.1.5 Offline Surface Casing Cementing

Offline surface casing cementing was conducted to save rig time by performing two simultaneous jobs at the same time. This activity was performed directly on the platform instead of the rig floor during standard cementing. By utilization of pre-installed wellhead, offline surface casing cementing could be performed. After surface casing was landed, 9-5/8" pack-off can be installed directly to secure the annulus sealing area, and offline surface casing cementing could be conducted. The offline cementing activity was independent of other activities on the rig floor. Therefore, activity on the rig floor such as skid rig, M/U drill pipe, and BHA for the next phase can be conducted.

To perform offline surface casing cementing, the diverter has to be nipple down after the casing hanger being landed and tested. The cementing head was used to perform the cementing job and installed above the wellhead. Return during circulation & cementing is closely monitored on active pit volume and visual on the shaker. Figure-6 shows the configuration of offline surface casing cementing.

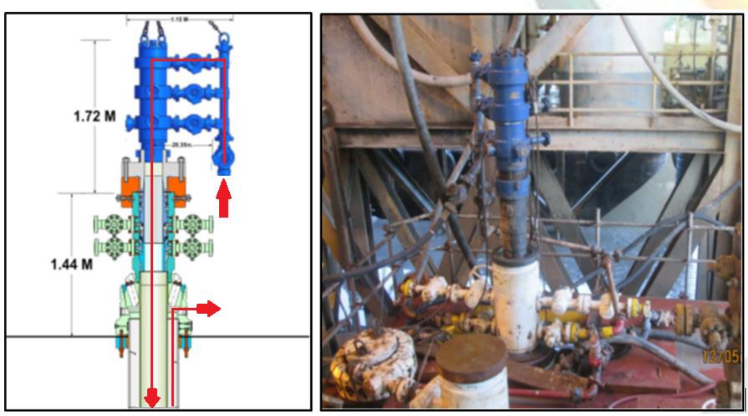


Figure 6. Offline surface casing cementing configuration

2.1.6 Offline BOP Test & Quick Test BOP Adapter

Offline BOP test is a familiar operation in Pertamina Hulu Mahakam. The procedure was to conduct the test on stump. This operation could lead us to do another co-activity such as makeup tubular on the rig floor. In addition~~Besides that~~, a quick test BOP ~~adapter~~ connection could be performed without set the tester plug first since the BOP adapter has been modified to have an o-ring and testing port. The modification of the BOP adapter itself allowed us to do a connection test through the testing port. In which previously, this activity required ~~us~~ to run a tester plug through a rotary table. Figure-7 shows the modification from the previous BOP adapter connection to the new one.

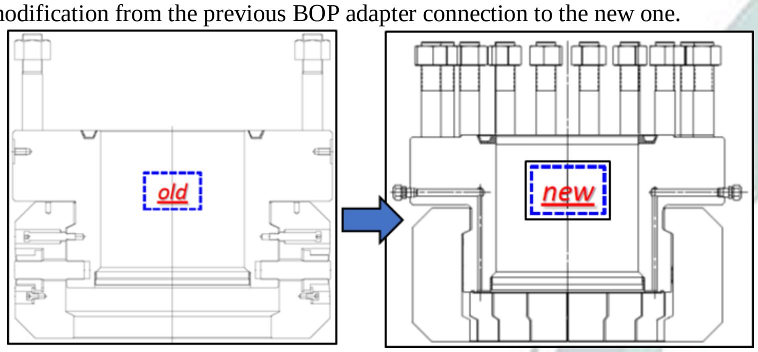


Figure 7. BOP adapter connection modification

2.1.7 Makeup 3-1/2" Tubing while Drilling

Makeup 3-1/2" tubing was performed during drilling activity. This co-activity was conducted in a rig-floor simultaneously with drilling activity by utilizing a single elevator and power tong to make up the tubing. Tubing was transferred by crane and being received by a single elevator. Tubing was then placed in an additional mouse hole and will be connected with another tubing. After 1 stand, 3 joints of R2 tubing, ~~of tubing~~ being made, that ~~tubing~~ stand could be rack back to the derrick. Figure-8 shows the co-activity of makeup tubing 3-1/2" tubing while drilling. This operation could be performed if the well has a tubingless completion program.

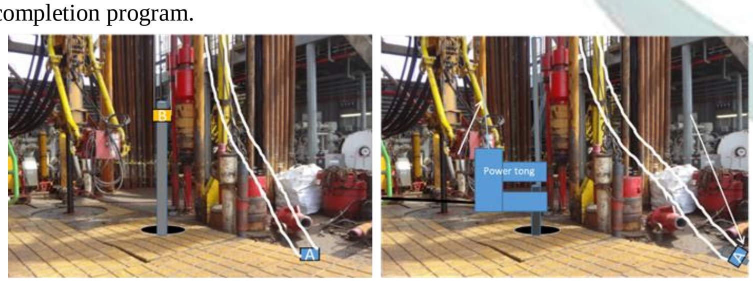


Figure 8. Makeup tubing 3-1/2" while drilling

As a result, after the reservoir section was drilled, the tubing could directly be run in the hole by stands. It shorten the accumulation connection time required for running the tubing. This operation could save the rig time up to 4 hours compared with conventional activity.

2.1.8 Pre-Stab Tubing Hanger with Running Tool and Offline Make-Up Control Line

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Previously, ~~a pre-~~stab tubing hanger with running tool and makeup control line were performed on the rig floor. This activity required a 2 pressure test which was a pressure test between the control line and tubing hanger and a pressure test between the tubing hanger and running tool. To reduce rig duration, this job was done in the workshop. This activity could save the rig time up to 2 hours since at the rig we only connected the tubing hanger pup joint to the tubing below and connected the tubing hanger control line to control line from tubing. Figure-9 shows the pre-stab tubing hanger and control line configuration.

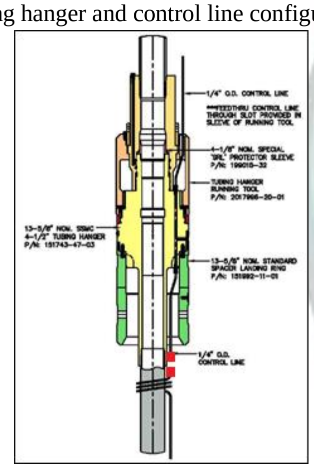

Figure 9. Pre-stab tubing hanger and control line configuration

2.1.9 Offline Tubing Cementing

Similar to offline surface casing cementing, offline tubing cementing was performed directly on the platform instead of the rig floor. Thus, cementing activity was independent of other activities on the rig floor. Since tubingless cementing was performed on the platform, at the same time, activities on the rig floor could be conducted such as:

a) Single well drilling operation → Skid rig and L/D Tubular while preparing for rig move.
b) Batch well drilling operation → Skid rig and M/U BHA for next phase or completion phase on batch well.

To perform offline tubingless completion, BOP has to be N/D after the tubing hanger landed and tested. It will disconnect access from the rig floor to the well. Dedicated cementing spool then installed above the wellhead complete with surface lines for cementing job. Since the tubing hanger was already landed, the return during circulation and cementing are taken from uppermost lateral lines on the CWH (10K lateral valves) connected to choke manifolds through high-pressure hoses. Prior to N/D the BOP, two independent well barriers envelops were established on the well. Figure-10 shows the surface line up of offline Tubingless completion in Swamp operation.

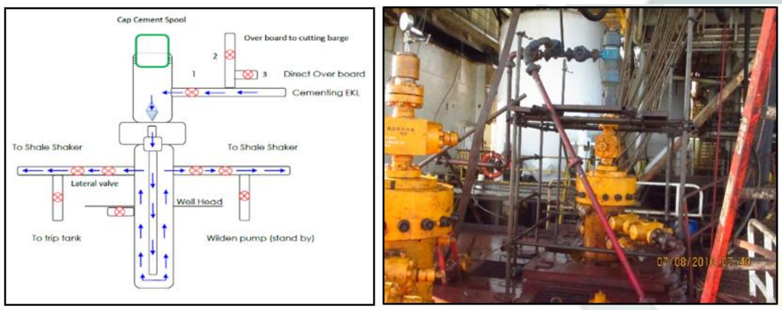

Figure 10. Offline tubingless completion line up configuration

2.1.10 Make-Up Drillpipe while Waiting on Cement

Due to the batch drilling sequence in one platform, makeup drill pipe on the rig floor can be conducted while waiting on cement on another well. This activity could reduce operation time since there was continued operation from one to another well.

2.1.11 Rigless Perforation and Sand Control Operation

Sand Consolidation is a method of stopping sand production by artificially bonding the formation of sand grains into a consolidated mass as shown in Figure-11. This method used epoxy resin mixtures (resin and hardener) to be injected in the near-wellbore sand reservoir. This activity was performed on Rigless operation by intervention barges after well completed and rig move out from the platform. Figure-12 shows Well Intervention Barges performs Sand Consolidation on Swamp well.

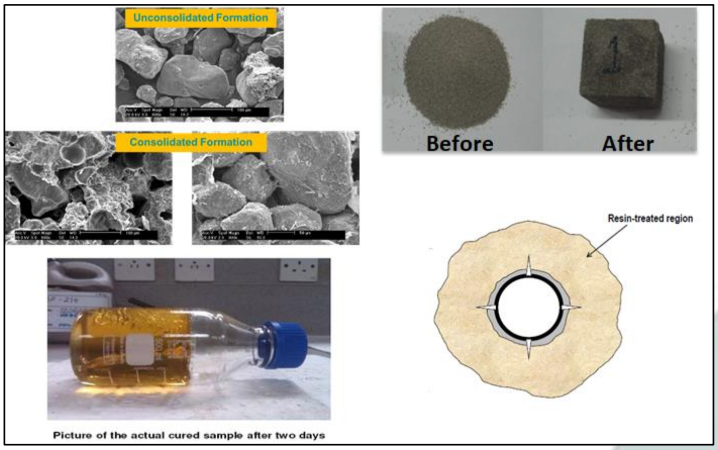

Figure 11. Sand consolidation resin component

Figure 12. SCON activity on Well Intervention Barges

In terms of production, wells completed by SCON delivered a good performance with an average production rate of 3 MMscfd per zone and durability up to 2 years (maximum case). Compare to GP which was better on production rate (6 MMscfd per zone on average) but higher on investment cost, SCON is a more attractive solution as the main sand control mechanism to produce hydrocarbon from matured ~~TSZ~~ shallow zone reservoirs which have a decreasing reserve and have life time less than 2 years.

2.2 Drilling Practices

2.2.1 Shallow Gas Best Practices

The major risk during drilling in the surface section is the shallow gas hazard. Several incidents have been experienced by drillers within a decade ago. To maintain a continuous awareness of shallow gas hazards, the swamp drilling team released shallow gas best practices as shown in Figure-13. These practices have the objective to reinforce competency, knowledge of rules, and procedures regarding shallow gas. By applied the best practice, shallow gas hazard can be safely mitigated while keep good drilling performance in shallow section.

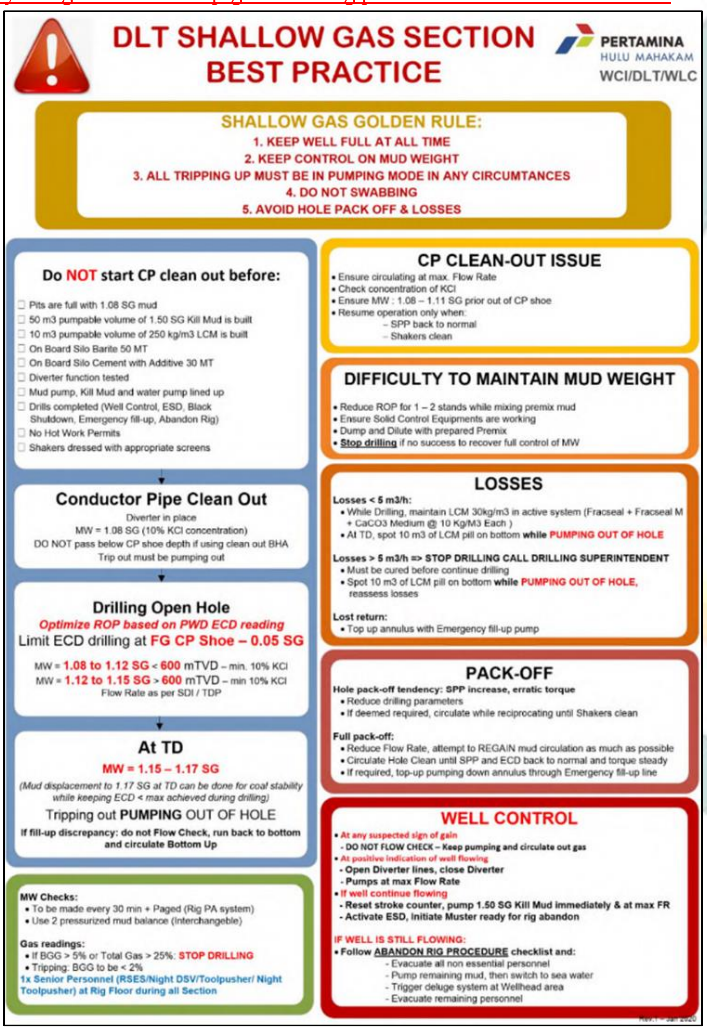

Figure 13. Shallow gas best practices

2.2.2 High Flow Rate

A high flow rate was applied to enhance drilling performance by increasing the bit hydraulic, HSI and jet impact, and also improving hole cleaning. ~~.~~ ~~Measurement While Drilling (MWD) tool capability was considered to optimize the flow rate.~~ In a swamp drilling operation, an enhanced flow rate is applied up to 2900 lpm while initially is only 2400 lpm. A high flow rate could be used in final section when the well was targeted in the main zone where the formation fracture gradient (FG) has been considered strong enough. ECD-FG analysis need to be performed during the planning phase. Upgrade on MWD turbine flow kit is required when using the high flow rate.~~.~~ Figure-14 shows the MWD flow ~~rate~~ kit set up~~configuration~~ between the ~~optimum~~ high flow rate and turbine speed of MWD.

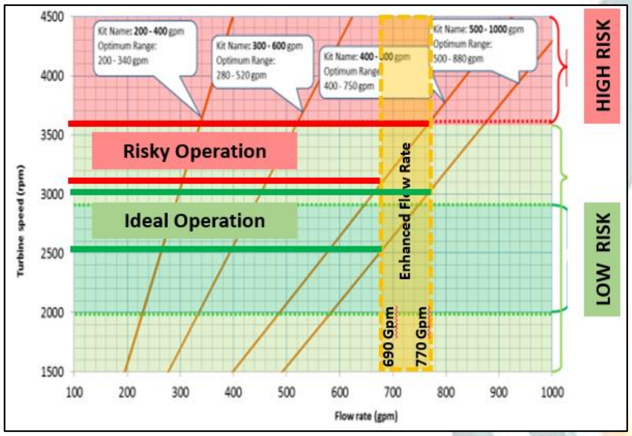

Figure 14. Optimum MWD flowrate configuration

2.2.3 High RPM

With the spirit of drilling enhancement, high string rotation was also considered as the parameter to achieve maximum drilling performance. High string rotation could be expected to give ~~better results such as~~ higher ROP as the bit can cut more formation with the same depth of cut in a period time and also give better hole cleaning. A high RPM in swamp drilling operation used high string rotation up to 23~~2~~0 rpm with the respect of Top Drive System (TDS) tool capability. A high RPM was considered to be used in the main zone well since the shallow gas phase has been passed. TDS ampere set up need to be adjust during high RPM application with take into account the actual generated torque during drilling. Figure-15 shows TDS specifications including RPM, ~~and~~ torque and ampere (A) set up.

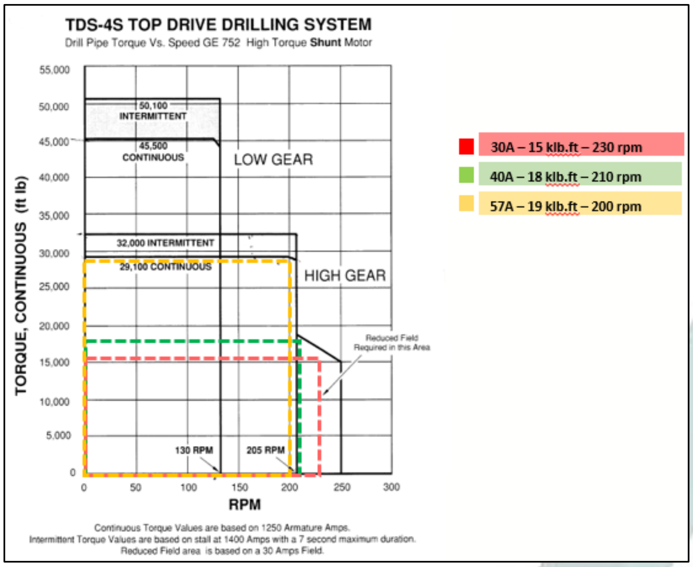

Figure 15. TDS specification

2.2.4 Bit Best Selection

Combined with a high flow rate and high RPM, drill bit design was also considered to complete the enhancement of drilling performance. The drilling team designed the drill bit based on 2 criteria, there are:

a) Total Flow Area (TFA): TFA was designed to give HSI results more than 4.0. HSI is a measure of the energy needed to counteract frictional energy at the bit. HSI is proportional to hydraulic jet impact force to the formation. The higher the HSI ~~result~~and jet impact force,~~,~~ ~~a~~the better bit cleaning~~,~~ and better ROP could be achieved.

b) Aggressiveness and Stable: Depend on the formation hardness, aggressive and stable bit design were the best bit application in swamp area up to 3700 mTVD. ~~t~~To get a more aggressive and stable bit, bit design was programmed with a less double row cutter, lower back rake angle, more than 50% cutter exposure, no depth of cut limiter (DOCL), non-connectingon blade, and high open face volume~~ to improve cutting evacuation~~. Figure-16 shows the drill bit parameter which considers achieving maximum performance.

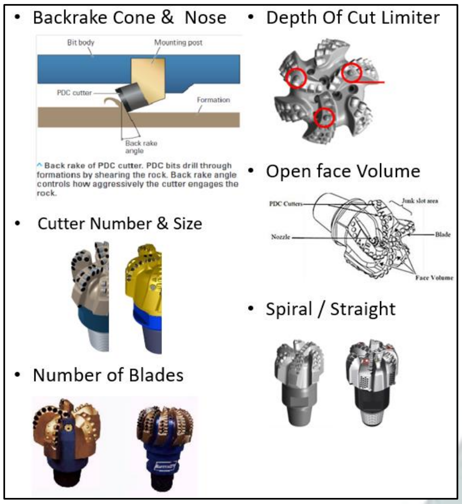

Figure 16. Bit selection parameter

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2.2.5 Fast String Connection

Statistically, connection practice could take more than 35% of drilling time. To shorten~~queeze~~ this duration, the swamp drilling team optimized the connection by reducing pre-connection time and survey time. Pre-connection time practice was updated (0.5-1 single Backream and TnD every 3-5 stands) and survey time only took 30 sec by theoretical sync on MWD-LWD without ~~the~~the wait on Sync and Survey confirmation as ~~below~~ seen in Figure-17 and Figure-18.

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

Figure 17. Evolution of Connection Practice

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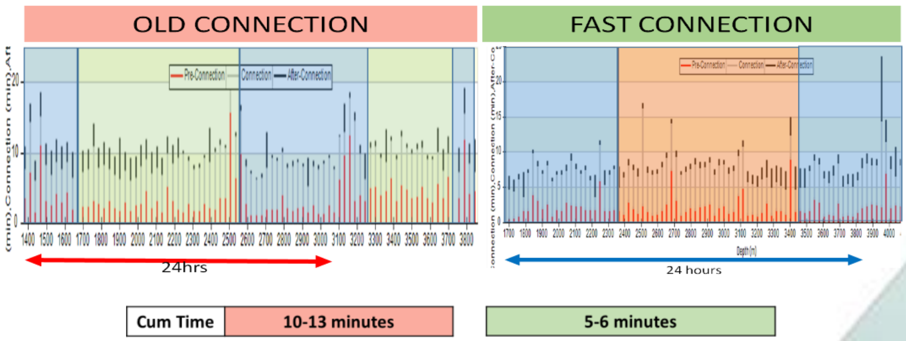


Figure 18. Comparison between old and fast connection method

2.2.6 Team Motivation

To support all initiatives, team motivation should be built all along from down to top. All teams were encouraged to have a sense of belonging to get new achievements every single time. Start from setting up the goal and strategy which involved all team members. ~~until~~ A~~motivating a~~ll team was also motivated by daily call and pre-spud meeting. In addition, ~~Team~~ consolidation in team was strengthen~~also conduct~~ed ~~such as~~by having monthly birthday celebrations for all team members and meet up on-shore. Figure-19 shows several activities to encourage the performance of all team members.

Figure 19. Team consolidation

3 Result and Discussion

Implementation of massive co-activity and best practices have delivered significant time saving of 24% for SLA wells and 27% for ELA wells. As a result, the 2020 average cost of SLA well is 2.6 MUSD while ELA well is 4.1 MUSD. Figure-20 and Figure-21 shows the reduction of well duration and cost year after year. Those practices have also made a new record of fastest well completion in 2.17 days and highest drilling ROP for 141 m/hr with drilling 2303 m in the first 24 hours.

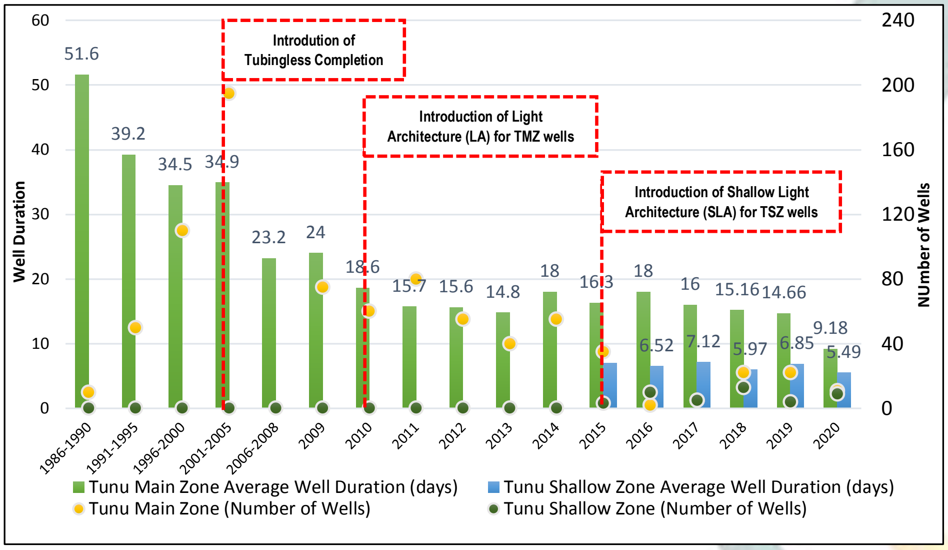
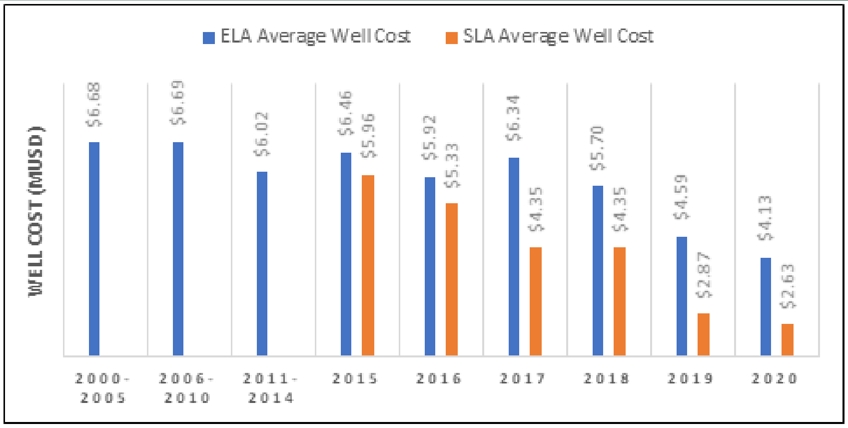


Figure 20. Well duration evolution in Tunu field for TMZ and TSZ



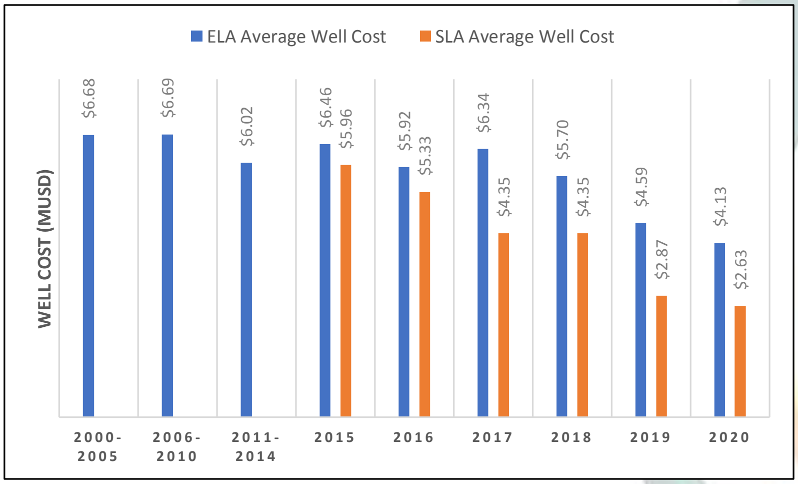


Figure 21. Well cost in Swamp operation

4 Conclusion

Massive co-activity operations and mastering drilling practices have been successfully implemented since 2019 without any safety incident and related NPT. The co-activity operation will give more significant savings in the batch drilling in which more than one well being drilled in the platform. This achievement shows ~~a~~ positive results, opening more well candidates for future development in Mahakam.

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