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Direct Wireline Logging Through Sidetrack Casing Window in Offshore Sisi Nubi, Mahakam Field

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Abstract. As part of operation optimization in offshore Mahakam, a new method to run open hole wireline logging through sidetrack casing window has been introduced. Previously, pipe conveyed logging method was used to run wireline logging in sidetrack well. Despite quite long time is needed to run the wireline logging; this method is considered to be safe as it will prevent damage on wireline cable when passing through sidetrack window. At the moment, Mahakam reserve is getting marginal, simpler operation must be introduced in order to achieve economic limit of the well without sacrificing safety aspect.

A new method to run direct wireline logging in a sidetrack well is considered to be solution to reduce wireline logging duration when drilling sidetrack well. Shifting from pipe conveyed logging to direct logging mode can reduce logging duration up to 3 days of operation time. However, there is an increased risk of wireline cable fails at the sidetrack window in case of overpull during logging stuck in open hole. The risk has to be assessed and proper risk mitigation has to be created in order to ensure readiness of the trial in Sisi Nubi field. A new method to conduct surface e-line cable testing has been prepared, this test can simulate real condition when wireline logging is passing casing window area under high tension force condition. The testing method can generate a quantified risk of e-line cable failure on the window area. The result of the test then will be used as a basis to define limitation for wireline logging job in the sidetrack well. The first trial has been successfully executed at Sisi Nubi field and contribute to reduction of 3 days for wireline logging job which is equivalent to 700,000 USD cost saving. From the post job analysis, there is no indication of significant damage to wireline logging cable for both the armor and the internal part of the wireline logging cable.

Keyword: Direct logging job, Sidetrack well

1 Introduction

Mahakam block is a concession area of oil and gas fields which is operated by Pertamina Hulu Mahakam. This block is located across the Mahakam offshore and delta, East Kalimantan. Mahakam block has been producing oil and gas since more than 50 years ago. Today, this field is categorized as brown field due to its marginal oil and gas reserves.

Significant efforts have been done to increase the efficiency of drilling process in Mahakam so the well can be drilled in economical manner. One of the initiatives which have been successfully implemented in Mahakam offshore is to drill with re-entry method, this method is done by drilling sidetrack from non-producing well. So, cost to build a new platform and production pipeline can be reduced. In the future, re-entry drilling will be solution to reduce drilling cost in Mahakam, especially for marginal wells.

There are two main objectives of drilling, the first one is to create flow path for hydrocarbon transport to surface, the second one is to gather as much information as possible from the reservoir formation.

Generally, formation data acquisition in sidetrack well can be completed by using wireline logging equipment which is conveyed by drill pipe until sidetrack depth, before the logging equipment continue to run to the bottom hole to start logging the formation characteristics. This method is known as pipe conveyed logging method. This method is commonly done in side track well due to its safer practice to prevent damage in wireline cable when passing casing window (sidetrack point). However, based on historical data for wireline logging activities in offshore Mahakam within 2019-2020 (Figure 1), data acquisition process by using pipe conveyed logging requires 4.07 days to complete the job, meanwhile conventional logging only requires 1.19 days to finish the job. Considering this fact. a new method to drill with re-entry well has been introduced, namely direct wireline logging method in sidetrack well.

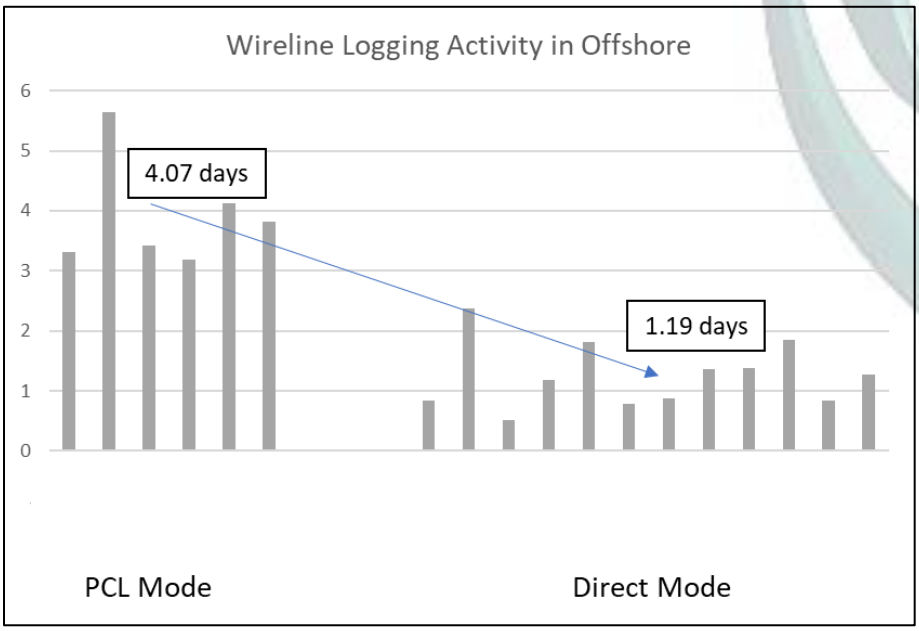

Figure 1. Wireline logging activity in offshore Mahakam, 2019-2020

The utilization of this method can reduce operation time to finish wireline logging job from 4 days to only 1 day. However, increased risk for running direct wireline logging through sidetrack casing point must be assessed and any additional risk should be properly mitigated. The main challenge is there was no available method to test the friction between e-line cable and casing under high tension prior to job execution.

A novel method to conduct the friction test on surface has been introduced, the test utilized a set of high tension testing equipment to complete the friction test. The result from the test will become a basis to define maximum limitation for wireline logging movement in sidetrack well.

Additional risk assessment has been made to identify and mitigate potential additional risk coming from direct wireline logging activity. In addition, a decision tree for direct logging go / no-go has been made as a basis for go/ no-go decision judgement.

2 Methodology

Process flow chart for KFDJ diverter implementation in offshore Mahakam is shown in Figure 2. Basically, the process is divided into three main phases: job preparation, job execution, and job evaluation. Job preparation covers the PCL and direct logging time comparison, wireline cable test, until job risk assessment. In the trial execution, actual number of cable movement will be recorded for future reference. Cable condition after job execution will be discussed in post job analysis.

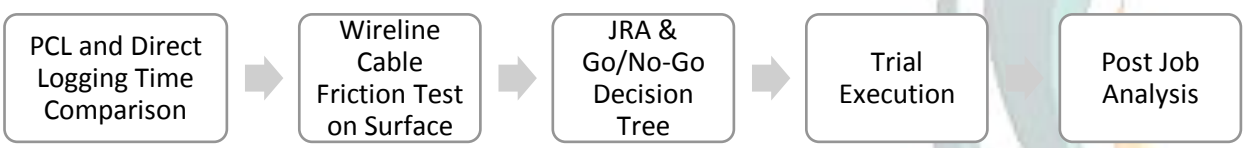

Figure 2. Flowchart for Direct Wireline Logging in Sidetrack Well Implementation

2.1 PCL and Direct Logging Time Comparison

Comparison between PCL and direct logging time in Mahakam offshore has been made. The objective is to see how much is the difference between running logging in PCL mode and in direct mode. As can be seen on Figure 1. Based on historical logging job data between 2019 and 2020, average duration to run wireline logging in PCL mode is around 4.07 days, while for direct logging method, the average duration is around 1.19 days. From the data, three operation days can be saved when shifting from PCL mode to direct logging mode.

2.2 Wireline Cable Friction Test on Surface

A novel method to conduct wireline cable friction on surface has been introduced. The set up for testing equipment can be seen on Figure 3 below.

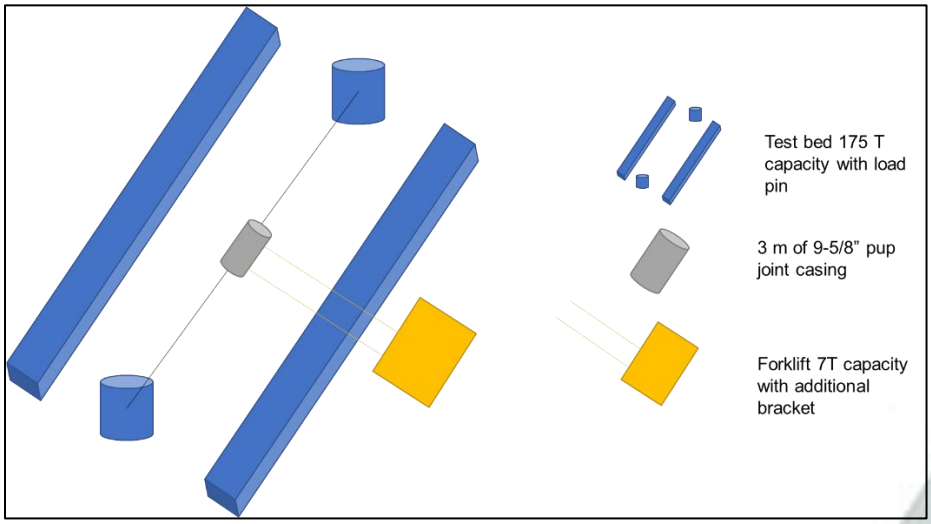

Figure 3. Friction Test Set Up Schematic

The cable is tied to the anchor pile on both side, then the cable is tensioned with up to 13 klbs force to simulate downhole condition when overpull is experienced during running / pulling the logging equipment out of the hole, passing through the sidetrack window.

Pre-made casing window has been created on the warehouse to imitate the shape of sidetrack window. The picture of pre-milled casing window can be seen on Figure 4 below. Two different cutting shapes have been made for the casing window. The first one is oval shape, this is to simulate when the milling process can be done smoothly, the second one is with acute shape, this is to simulate worst condition which might occurred when the milling result is not satisfactory.

Figure 4. Casing Window Cut

During the test, wireline cable will be swiped passing through casing window area under high tension force. The testing itself is completed under several parameters (light condition, medium condition, extreme condition). The testing parameter can be seen on the Table 1 below.
There are 2 test type, the first one is dynamic test and the second one is static test. Dynamic test simulates when wireline tool moves passing through sidetrack window, while static test simulates when wireline logging is taking sample under static tension. Tension force used in the test is 13 klbs for extreme test and moderate test, and 8 klbs for light test. The value is taken based on pre-logging tension simulation result which is provided by subsurface team. For the window profile, there are 2 shapes of casing window profile which can simulate the quality of casing window after milling process.

Oval shaped window profile simulates good milling result while acute shaped window profile simulates worst window profile after casing milling process. Acute shaped is used for extreme case test as this will create more friction contact between wireline cable and casing. In medium and light case, wireline cable is lubricated with some OBM to simulate lubrication effect by drilling mud. In the extreme case, wireline cable is left dry to maximize friction force between cable and the casing.

Table 1. Friction Test Parameter

Test No.	Tension Load	Wet/Dry	Window Profile	Window Cut	Test Type	Duration
1.	13 klbs	Dry	Acute shape	Non tapered	Static	30 mins
2.	13 klbs	Dry	Acute shape	Non tapered	Dynamic	1 hour
3.	13 klbs	Wet	Oval	Tapered	Static	30 mins
4.	13 klbs	Wet	Oval	Tapered	Dynamic	1 hour
5.	8 klbs	Wet	Oval	Tapered	Static	30 mins
6.	8 klbs	Wet	Oval	Tapered	Dynamic	1 hour

2.3 JRA & Go/No-Go Decision Tree

As part of risk prevention, a distinctive job risk assessment has been made and discussed with related entities to ensure any additional risk resulted from direct wireline logging in sidetrack well has been clearly identified. Figure 5 below shows some highlights for the JRA which has been made.

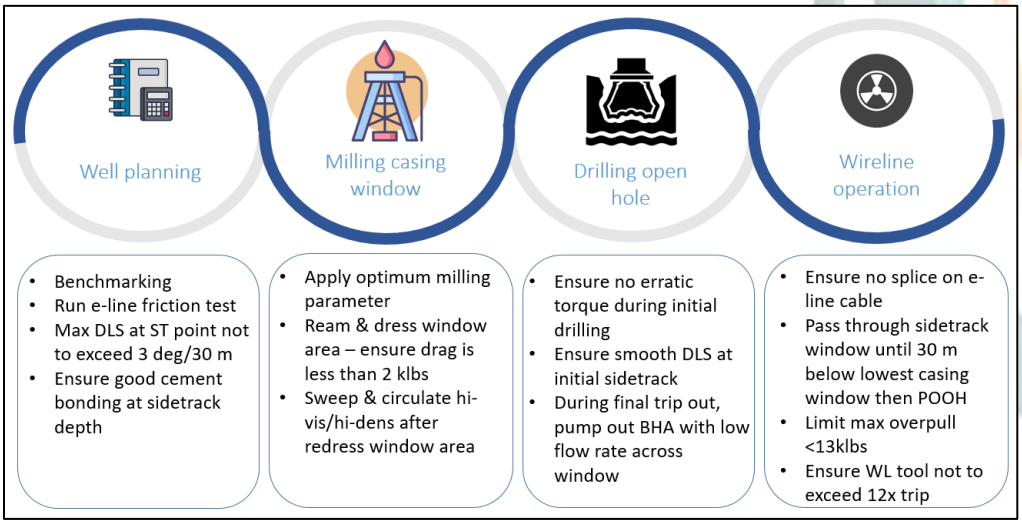

Figure 5. Risk Mitigation Highlight

As can be seen from the figure above, result from friction test on surface becomes maximum limit for wireline logging job in the first trial, this is to ensure that the logging running parameter is still within the testing envelope. Comprehensive JRA can be seen on Attachment A.

Go/No-go decision tree has also been made as a tool to decide whether direct wireline logging in sidetrack could be done or not. The decision tree assessment starts from well design phase until the drilling process. The process diagram can be seen on Figure 6 below.

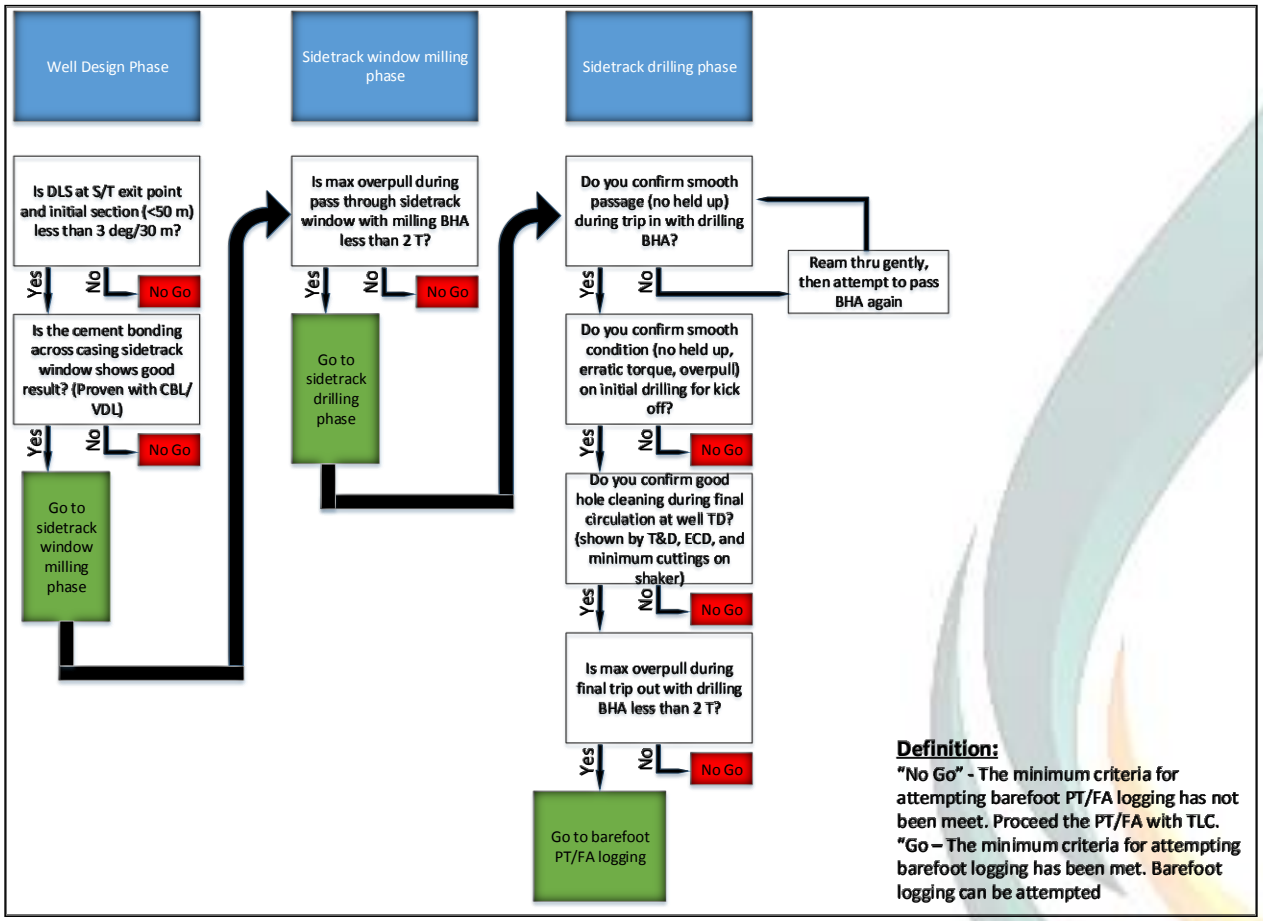

Figure 6. Go/No-go decision tree

Each box on the diagram defines specific criteria which have to be fulfilled to proceed to the next step. Once there is one step fails to meet the criteria, then the wireline logging will be performed in pipe conveyed logging mode.

2.4 Trial Execution

The first direct wireline logging in sidetrack well trial has been successfully implemented in Sisi field, offshore Mahakam. There is no significant overpull obtained during the logging process. This is achievable due to good quality of the borehole. Best practice during drilling and good milling parameter gave positive contribution to the smooth run of the wireline logging equipment.

2.5 Post Job Analysis

A thorough evaluation to the cable condition after wireline logging job in the trial well has been made in the service company's warehouse base. Several parameters such as wireline outer diameter reduction, electrical conductivity, and metal loss were measured.

3 Result and Discussion

From the friction test result, it was obtained that the armor was broken under every testing condition. The summary of the test can be seen on Table 2 below. There are 2 testing output which are monitored during the test. The first is percentage of outer diameter reduction when the armor is broken. The second one is number of cycles before the wireline cable is failed.
From the static test result, there is no changing in outer diameter of the cable. Hence, it is not included in the summary table below.

Table 2. Testing Result Summary

Test No.	Tension load	Condition	Casing Cut	OD reduction when fail	Failed at run#
1	12-13 klbs	Dry	Acute – straight cut	2.8%	22
2	12-13 klbs	Wet	Oval – tapered cut	2.6%	25
3	8-9 klbs	Wet	Oval – tapered cut	1.9%	18

It can be seen that the extreme case (test no.1) gave the largest wireline cable diameter reduction compared to other two tests, while the light case (test no.3) gave the smallest wireline cable diameter reduction. However, there is an anomaly for the number of cycle before wireline cable failed. In light case with 8 klbs tension force, the armor failed at run number 18, while the extreme case with 13 klbs, the armor failed at run number 22. This is most likely because of error during the test. However, 18 cycles will be used as maximum cycle limit when running wireline logging through sidetrack window.
From the trial result, pressure test / fluid analysis wireline logging can be completed in single run, a total of 22 sampling points can be obtained without any issues. The PT/FA logging moving interval can be seen on Figure 7 below. From the graph, it can be seen that maximum up and down movement cycle within same interval is 5 times, this is lower than maximum limit from the friction test result. This result can be achieved due to good borehole quality which is resulted from good milling and drilling practice. There is also improvement from subsurface team to optimize number of sampling and cable movement.
Positive result was obtained from the first trial of direct wireline logging on sidetrack well. Significant amount of time saving was obtained by shifting from pipe conveyed logging to direct wireline logging.

By elimination of running drillpipe, the PT/FA logging job can be completed in just 18 hours, total saving which has been made is USD 700,000 / well. This saving comes from operation time reduction and elimination of pipe conveyed logging additional service.

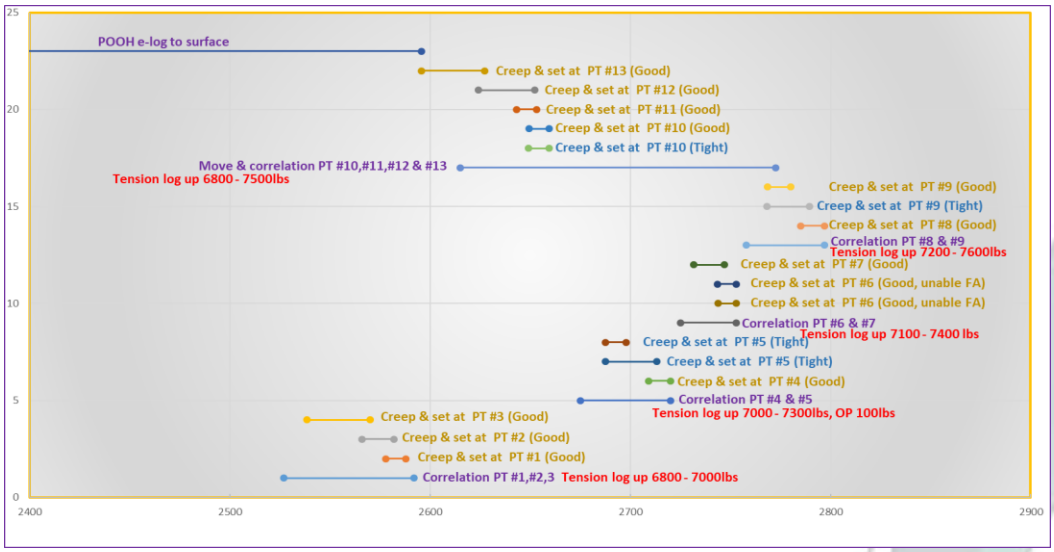

Figure 7. PT/FA Logging Moving Interval

Post job analysis from the first trial has been made. Comparison between actual wireline cable tension and the pre-job tension simulation can be seen on Figure 8 below.

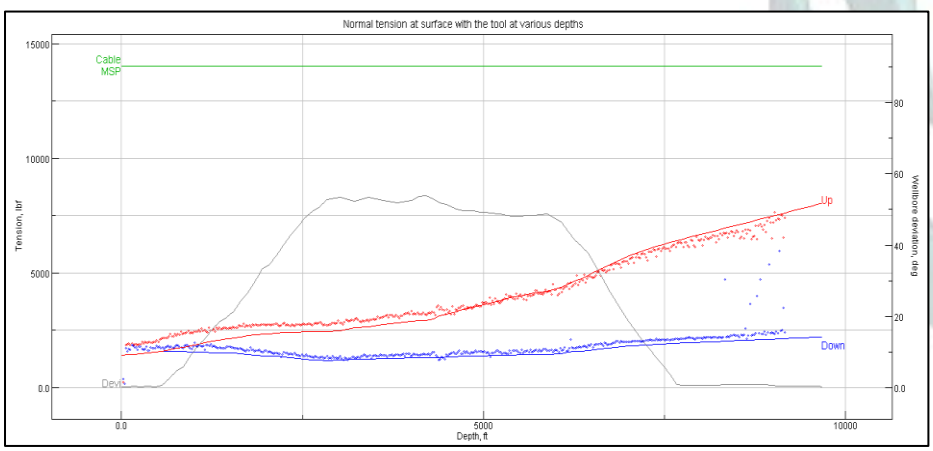

Figure 8. Final Tension Simulation

As can be seen above, the straight line is result of pre-job tension simulation and the dotted line shows actual tension simulation. There is no significant difference between the simulation and the actual result, this is because good borehole quality can be achieved from the open hole drilling process.

Figure 9 below shows cable diameter measurement after job is completed. It can be observed that there is quite significant cable diameter reduction below casing window area. This result proves that sidetrack window contributes to higher friction to wireline cable. However, the cable diameter reduction is still within allowable limit from the current wireline logging service provider's standard.

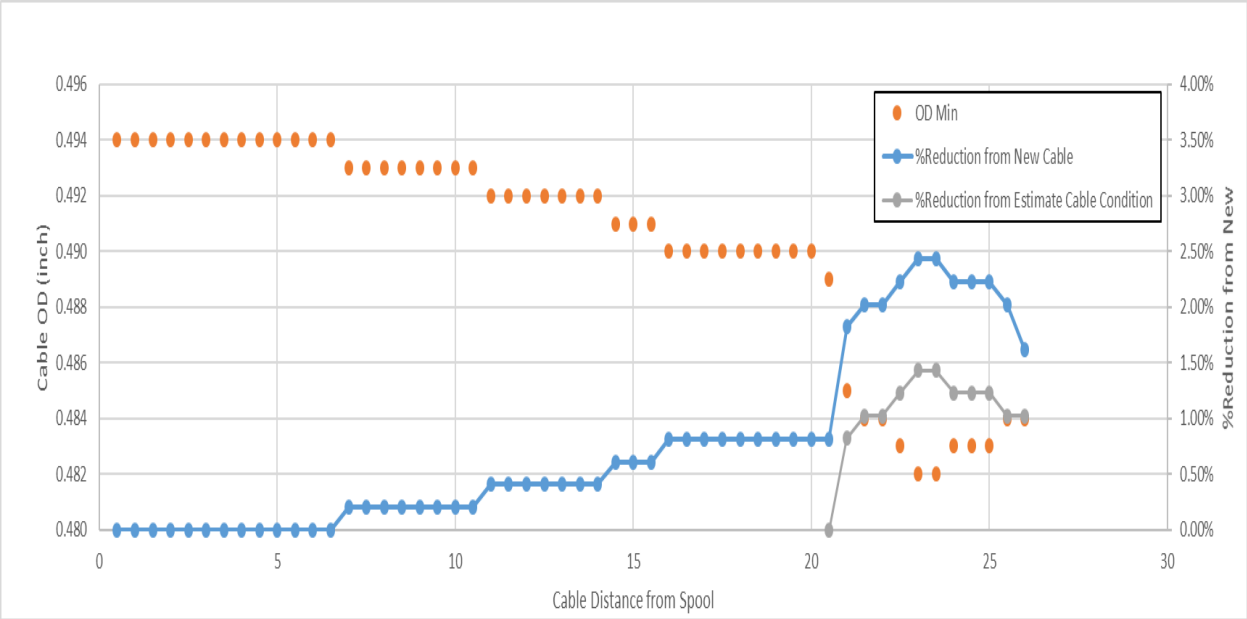

Figure 9. Post Job Cable OD Measurement

Other post job tests were also completed in order to check cable condition after job in the trial well. Those tests are electrical check, metal loss check, and torture test check. It can be confirmed that there is no critical damage to the wireline cable for both the armor and the internal part (electrical line).

4 Conclusion

Direct wireline logging method has been successfully implemented on offshore Sisi Nubi, Mahakam field. The trial has been successful without any issue. Risk assessment for cable failure in sidetrack window has been mitigated through a proper cable friction test on yard. Risk assessment and go/no-go decision tree has also been made as a justification tool to increase the confidence level to run the initiative.

Through the utilization of direct wireline logging in sidetrack well, Pertamina Hulu Mahakam can reduce 3.3 days of operation time which is equivalent to $ 700,000 cost reduction per well from rig time reduction and elimination of additional PCL service cost. Moreover, faster logging process means safer operation from risk of well control incident because the duration for the well to be left open can be managed to be shorter.

From post job analysis, it is proven that the sidetrack window contributes to the reduction in cable diameter, but there is no significant damage to the wireline cable (for both the armor and the internal cable part) and the reduction of cable armor diameter is still within acceptable standard.

Attachment A

JOB DESCRIPTION

Wireline Operation Through Sidetrack Casing Window at SS-108

No.	Task	Hazard; Risk & Consequence	Initial Risk S	Initial Risk P	Initial Risk R	Risk Reduction Measures	Residual Risk S	Residual Risk P	Residual Risk R	Action Party	Target Date	Last Minute Risk Assessment
1	Picking up/Laying down of WL Tools	**Drop objects as a result of the movement of the tools from/to Rig floor - Main deck**										
		Human Consequence	4	4	16		3	3	9			
		1 Fatality &/or several disabilities due to drop object incident (WL Tool / Dummy Tool)				Prejob safety meeting prior to this activity		x		Service Company & Rig Crew	Prior operation	
						Certification of lifting gear, 6 monthly inspection, lifting color code		x		Service Company & Rig Crew	Prior operation	
						Personnel competency		x		Service Company & Rig Crew	Prior operation	
						Good communication between driller and crews		x		Service Company & Rig Crew	During WL operation	
						Proper crew positioning. No personel below suspended load.	x			Service Company & Rig Crew	During WL operation	
						Maintain housekeeping at workplace	x			Service Company & Rig Crew	During WL operation	
						Supervision of deck crew		x		Service Company & Rig Crew	During WL operation	
						Standard PPE to be used by crew (safety helmet, etc).	x			Service Company & Rig Crew	During WL operation	
		Pinch points										
		Human Consequence	2	4	8		1	3	3			
		Single lost-time injury (LTI) with no disability due to pinch point incident				Implement hands off policy (minimize touch the load) by using push pull stick, finger saver, etc.		x		Service Company & Rig Crew	During WL operation	
						Prejob safety meeting prior to this activity		x		Service Company & Rig Crew	Prior operation	
						Good communication between driller and crews		x		Service Company & Rig Crew	During WL operation	
						Standard PPE to be used by crew (safety gloves, etc).	x			Service Company & Rig Crew	During WL operation	
		Tripping and slipping										
		Human Consequence	2	4	8		1	3	3			
		Single lost-time injury (LTI) with no disability due to tripping & slipping incident				Standard PPE to be used by crew. Min. PPE: safety helmet, safety glasses, coverall, high impact safety gloves, and safety shoes.	x			Service Company & Rig Crew	During WL operation	
						Maintain housekeeping at workplace		x		Service Company & Rig Crew	During WL operation	
						Safety Briefing to new personnel. Implement Green Helmet Policy.		x		Service Company & Rig Crew	Prior operation	
2	Rigging up/down Wireline tools	**Drop objects as a result of the movement of the elevator with sheave wheel and cable, Drop objects as a result of the SLB WL tools movement during connecting and disconnecting toolstring - SLB WL tools and hand tools**										
		Human Consequence	4	4	16		3	3	9			
		1 Fatality &/or several disabilities due to drop object incident				Prejob safety meeting prior to this activity		x		Service Company & Rig Crew	Prior operation	
						Certification of lifting gear, 6 monthly inspection, lifting color code		x		Service Company & Rig Crew	Prior operation	
						Baricade area - careful during elevator movement	x	x		Service Company & Rig Crew	During WL operation	
						Good communication between driller and crews		x		Service Company & Rig Crew	During WL operation	
						Proper crew positioning. No personel below suspended load.	x			Service Company & Rig Crew	During WL operation	
						Maintain housekeeping at workplace	x			Service Company & Rig Crew	During WL operation	
						Supervision of deck crew		x		Service Company & Rig Crew	During WL operation	
						Standard PPE to be used by crew (safety helmet, etc).	x			Service Company & Rig Crew	During WL operation	
		Pinch points - WL Rig up Equipment (incl. Cable Spooling)										
		Human Consequence	2	4	8		1	4	4			
		Single lost-time injury (LTI) with no disability due to pinch point incident				Baricade Area - crossing by cable; no personnel permitted to walk crossing the spooled cable. No other work operation surround the baricade area e.g. clean derrick / mast.		x		Service Company & Rig Crew	During WL operation	
						Implement hands off policy (minimize touch the load) by using push pull stick, finger saver, etc.		x		Service Company & Rig Crew	During WL operation	
						Prejob safety meeting prior to this activity		x		Service Company & Rig Crew	Prior operation	
						Good communication between driller and crews		x		Service Company & Rig Crew	During WL operation	
						Standard PPE to be used by crew (safety gloves, etc).	x			Service Company & Rig Crew	During WL operation	
		Tripping and slipping - SLB WL rig up equipment and cable Tripping and slipping - SLB WL tools connection and rigging up-rigging down - need 1 meter table to elevate the operators for connection										
		Human Consequence	2	4	8		1	4	4			
		Single lost-time injury (LTI) with no disability due to tripping & slipping during R/U				Standard PPE to be used by crew. Min. PPE: safety helmet, safety glasses, coverall, high impact safety gloves, and safety shoes.	x			Service Company & Rig Crew	During WL operation	
						Maintain housekeeping at workplace		x		Service Company & Rig Crew	During WL operation	
						Buddy system during tool connection		x		Service Company & Rig Crew	During WL operation	
						Safety Briefing to new personnel. Implement Green Helmet Policy.	x	x		Service Company & Rig Crew	During WL operation	

JOB DESCRIPTION

Wireline Operation Through Sidetrack Casing Window at SS-108

No.	Task	Hazard; Risk & Consequence	Initial Risk S	Initial Risk P	Initial Risk R	Risk Reduction Measures	Residual Risk S	Residual Risk P	Residual Risk R	Action Party	Target Date	Last Minute Risk Assessment
3	a. RIH PT/FA tool to bottom, b. Take pressure tests and fluid samples on the sample points c. POOH PT/FA tool to surface **The critical task during wireline logging:** Passing wireline logging tool through sidetrack window without TLC mode (running / pulling)	**Unexpected/uncontrolled e-line logging cable cut due to logging tool stuck in open hole**										
		Human Consequence	3	4	12		3	3	9			
		Single lost-time injury (LTI) with disability or multiple lost-time injuries due to tension during e-line free up attempt				Prejob safety meeting prior to this activity		x		Company Man	Prior operation	
						Restricted area surround rig floor prior high tension applied		x		Service Company & Rig Crew	During WL operation	
						Ensure no touching the cable - especially moving cable		x		Company Man	During WL operation	
						Standard PPE to be used by crew (safety helmet, etc).	x			Service Company	During WL operation	
						Good communication between driller and crews	x	x		Service Company & Rig Crew	During WL operation	
						Close supervision during wireline operation		x		Company Man, WSG	During WL operation	
						Proper crew positioning. No personel below suspended load.	x			Service Company & Rig Crew	During WL operation	
						Maintain housekeeping at workplace	x			Rig Supt.	During WL operation	
						Ensure crew competency for running the job		x		Company Man	During WL operation	
						Public announcement prior to Wireline release operation		x		Company Man	During WL operation	
		Material Loss	4	4	16		2	3	6			
		Loss of wireline logging tool leading to: -Material losses ≥ 200K € -Section loss > 2 M €				Follow all risk reduction measures for human consequences section	x	x		All	During WL operation	
						Run friction and tension cable test on e-line warehouse to simulate real logging overpull situation on surface		x		DE	Prior operation	
						Benchmarking with other Pertamina affiliates related to experience with barefoot wirelne thru S/T window		x		DE	Prior operation	
						Ensure maximum DLS at sidetrack exit point during well design phase is less than 3 deg / 30 m		x		DE	Prior operation	
						Apply optimum milling parameter during milling casing window		x		Company Man	During milling operation	
						Pump Hi-vis after milling operation to ensure good hole cleaning from metal and cement --> Ensure good hole cleaning during milling operation by frequently pumping cleaning pills (could be h-ivis or hi-dens combined with supersweep fibers where applicable) to aid recovery of metals and cement. Monitor quantity of metal cutting at surface.	x			Company Man / F&C Supv	During milling operation	
						Ream and dress window area by running milling assembly through window without pump and rotation - ensure no erratic torque and drag is less than 2 T		x		Company Man	During milling operation	
						Sweep and circulate Hi-vis/Hi-dens with super sweep to surface after redress window area		x		Company Man / F&C Supv	During milling operation	
						During first trip in and initial drilling, ensure smooth hole is seen. If reaming is required to pass BHA at initial trip in, ream through gently	x			Company Man	During drilling	
						Use low drilling parameter (minimum flowrate & 10-40 rpm) at initial drilling until top LWD tools & string stabilizer at 10 m below bottom of ST window.	x			Company Man	During drilling	
						Ensure smooth DLS at initial sidetrack during drilling	x			Company Man	During drilling	
						During final trip out, pump out BHA with low flow rate across casing window	x			Company Man	During drilling	
						Ensure no splice on e-line cable (only use one full integrated length of cable)	x			Service Company	Prior operation	
						Pass through sidetrack window until 30 m below lowest casing window (all WL tool in open hole) then POOH until all WL tool inside casing, check for any tension anomalies		x		Service Company, Company Man, WSG	During WL operation	
						Ensure WL tool not to exceed maximum 15x trip (up & down) per sampling point		x		Service Company, Company Man, WSG	During WL operation	
						Set alarms for winch movement - minimum tension allowed during RIH and maximum tension allowed during POOH		x		Service Company	During WL operation	
						Reduce running speed to max 3000 fph when reaching sidetrack window	x			Service Company, Company Man, WSG	During WL operation	
						Stop logging and POOH e-line when significant overpull is detected (limit max overpull not to exceed 13 klbs)	x			Company Man, WSG	During WL operation	
						Fully inspect cable condition before & after logging job is completed		x		Service Company	Before & After WL operation	
4	WL Tool got stuck in open hole -Cut the cable at surface -Dropped cable -Continue run fishing assembly	**High Cable tension - cut the cable at surface and dropped the cable**										
		Human Consequence	3	4	12		2	3	6			
		Single lost-time injury (LTI) with disability or multiple lost-time injuries due to tension during e-line free up attempt				Restricted area surround rig floor prior high tension applied		x		Service Company & Rig Crew	During WL operation	
						Ensure no touching the cable		x		Service Company	During WL operation	
						Standard PPE to be used by crew (safety helmet, etc).	x			Service Company	During WL operation	
						Put the cable clamp prior cutting the cable using hydraulic cable cutter	x			Service Company	During WL operation	
						Public announcement prior to Wireline release operation		x		Service Company & Rig Crew	During WL operation	
		Dropped object - RIH fishing assy										
		Human Consequence	2	5	10		1	4	4			
		Single LTI with no disability				Standard PPE to be used by crew. Min. PPE: safety helmet, safety glasses, coverall, high impact safety gloves, and safety shoes.	x			Service Company & Rig Crew	During WL operation	
						Maintain housekeeping at workplace		x		Service Company & Rig Crew	During WL operation	
						Safety Briefing to new personnel. Implement Green Helmet Policy.		x		Service Company & Rig Crew	During WL operation	

			Production Shortfall	< 2K boe	≥ 2K boe	≥ 20K boe	≥ 200K boe	≥ 1M boe	≥10M boe
			Media Reaction	Local rumour or no media consequence	Local rumour / regional press	Regional press + regional TV national rumour	National press + national TV	International press + international TV	International press + international TV for prolonged period
			Material Loss	< 20K €	≥ 20K €	≥ 200K €	≥ 2M €	≥10M €	≥100M €
			Environment Impact	Minor spill with no environmental impact	Minor pollution with a very limited environmental impact	Moderate pollution with limited environmental consequences	Pollution having significant environmental consequences	Large-scale pollution of ecosystems having a recognized ecological value	Pollution having massive and durable consequences for vast ecosystems having a high ecological value
			Personnel Safety	First aid or medical treatment or restricted work days	Single lost-time injury (LTI) with no disability	Single lost-time injury (LTI) with disability or multiple lost-time injuries	Internal: 1 Fatality &/or several disabilities Public: Disabilities	Internal: >1 Fatalities Public: 1 Fatalities	Internal: >5 fatalities Public: >2 Fatalities
Production Shortfall (or Gain)	**Personnel Safety, Environment Impact, Material Loss & Media Reaction**				**Severity of Consequence**					
					Minor	**Moderate**	**Serious**	**Very Serious**	**Catastrophic**	**Disastrous**
					1	2	3	4	5	6
Incident almost inevitable under current conditions (or for gain) Certain fully successful modification outcome	Expected to occur several times during plant lifetime	**Very Likely** $> 10^{-1}$	**Probability / Likelihood of Occurrence**	6	6	12	18	24	30	36
Incident probable with additional factors (or for gain) High likelihood of fully successful modification outcome	Could occur several times during over plant lifetime	**Likely** 10^{-1} - 10^{-2}		5	5	10	15	20	25	30
Incident possible with additional factors (or for gain) Some uncertainty of successful modification outcome	Could occur once for every 10 to 20 similar plants over 20 to 30 years of plant lifetime	**Unlikely** 10^{-2} - 10^{-3}		4	4	8	12	16	20	24
Combination of rare factors required to cause an incident (or for gain) High uncertainty of successful modification outcome	One time per year for at least 1000 units. One time for every 100 to 200 similar plants in the world over 20 to 30 years of plant lifetime. Has already occurred in the company but corrective action has been taken	**Very Unlikely** 10^{-3} - 10^{-4}		3	3	6	9	12	15	18
Freak combination of factors required to cause an incident	Has already occurred in the industry but corrective action has been taken	**Extremely Unlikely** 10^{-4} - 10^{-5}		2	2	4	6	8	10	12
No similar incident in industry	Event physically possible but has never or seldom occurred over a period of 20 à 30 years for a large amount of sites (> few thousands, ex: wagons, process drums,…)	**Remote** $< 10^{-5}$		1	1	2	3	4	5	6

Risk Level 1

Risk Level 2

Risk Level 3

for more detail definitions, refer MHK-COMP-RUL-EPHSE -0102 HSE Event Definitions Reporting & Recording

Risk Level 1 *First priority, risk level to be obligatory reduce to level 2 or 3*

Risk Level 2 *Tolerable risk level if demonstrated to be ALARP*

Risk Level 3 *Broadly acceptable risk level*

Major Consequence

Severe Consequence