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Initial Killing Process Improvement for Plug and Abandonment Job at Duri Steam Flood Environment

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Abstract – **Every year, Maliha Minyak Indonesia (MMI) should perform Plug and Abandonment (P&A) in the uneconomic existing wells. One of the wildly unpredictable procedures that take longer duration and budget is the Initial Killing procedure. From 159 well executions, initial killing takes an average of 15 hours, while the target stated in P&A programs is only 4 hours. The research focuses on seeking the best alternatives to improve the initial killing process in the Plug and Abandonment well. It starts to correlate the contributing factors then find the root causes of the prolonged initial killing process. The root cause is analyzed using the Current Reality Tree based on interviews and observation. The data to support the research are from P&A job execution in 2019 - 2020. The best alternative is to perform an offline initial killing process by pumping cement. This solution has been implemented in 3 wells and contributes to rig cost reduction, kill fluid cost elimination, and cycle time acceleration in USD48,031.**

Keywords – **Plug and Abandonment, Initial Killing Process, Kepner Tregoe, Cycle Time**

I. INTRODUCTION

Plug and abandonment mean permanently closed the well by pumping the cement plugs. Plug and abandonment (P&A) is part of MMI's obligation set out in the PSC to restore the site from the drilling activity to its original condition. As of December 2020, the total P&A Wells executed reached 164 wells. This number is lagging five wells from the 169 wells that shall be performed in 2020, as shown in Fig.1. Besides that, there are delays in completing the target in August 2020.

Fig. 1. P&A Job Performance 2020

One of the reasons is due to prolong the initial killing process during the execution phase. The Initial Killing is mandatory to be done before continuing to the next steps. The success parameter of initial killing is zero surface pressure which means the well is safe for execution and the risk to have the Well Control Event reduced. Based on 159 sample data of initial killing duration takes an average of 15 hours with a deviation of 30 hrs. In contrast, the target stated in P&A programs is only 4 hours. In 16 injector wells in 2020, the initial killing duration is 64 hours which most delays occur in this type of well. The total excess cost due to the inability to complete the initial killing in 4 hrs takes at the maximum of USD48,211/per well entangling for a rig and kill fluid cost.

Operational efficiency to accelerate the Initial Killing process is necessary to meet the P&A targets. The research will seek the answer to the following research questions.

1. What is the issue(s) faced by MMI during the initial killing process in the P&A Job?
2. What are the best alternatives to improve the initial killing process in the P&A job?

The research will focus on Initial Killing Job Process in P&A with Steam Injector well type. The baseline data are from Steam Injector Well Type P&A execution in the range execution range 2019 – 2020.

II. LITERATURE REVIEW

A. *Well Control Risk*

The objective to perform the initial killing is to establish a hydrostatic barrier, thus eliminating the risk of a Well Control Event. Refer to Maliha Global Technical Standard, a Well Control Event means any uncontrolled flow of Well fluids to the environment, including subsurface formations or unscheduled or unplanned closure of an element of BOP equipment due to loss of primary Well Control as a result of an influx into the well [5].

From 2016 until 2020, there are 54 Well Control events in MMI Operations. Even though the number of The Well Control events in Level 1A is only 1 in the last five years, the frequent occurrences of Well Control Event in MMI concluded that the risk of The Well Control events is very high. One of the root causes of the single Level 1A Well Control Events was the failure in the Initial Killing Process.

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B. Well Control Barrier

One of the safeguards to mitigate or overcome the Well Control Events is by establishing sufficient barriers in the well. A barrier is an impenetrable material or object that prevents uncontrolled flow. The initial killing is the initial procedure after the rig moves and rigging up to the Well pad to establish the hydrostatic barriers [2]. Without the initial killing process, there are no verified barriers available in the well. The initial killing process sets hydrostatic barriers not only by waters but also kill fluid materials.

C. Operation Rigor

The standard operating procedures of initial killing, as shown in Fig 2, is a mandatory step before continuing the job that has objectives to eliminate or reduce the potential of the Well Control Events. The initial attempt starts with pumping water to the well. An observation for zero shut-in pressure in 30 minutes is required to confirm the availability of hydrostatic barriers. If it fails, then another attempt of pumping water is made. The difference in this step is the limit of water volume pumped to the well. If pumping maximum water volume with maximum rate fails, then the fluid used for initial killing is changed to Kill Fluid, Polymer, CaCO3, or other Loss Circulation Materials. Besides the difference of Well configuration, job purpose, and formation characteristics, the initial killing process shall undergo every step of this SOP.

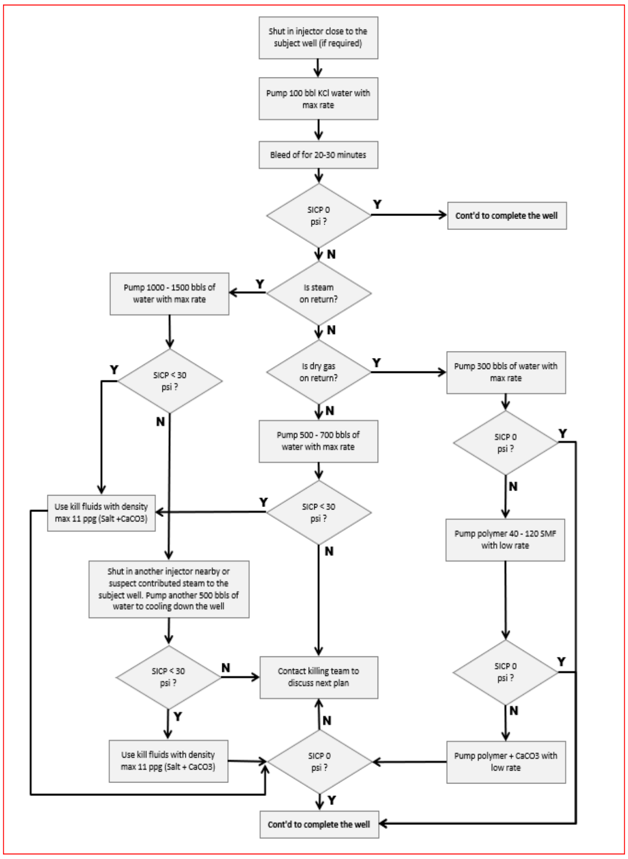

Fig. 2. Initial Killing SOP

D. Well and Formation Characteristics

The Duri Steam Flood Operation in MMI is the largest steam flood generation in the world. The Well formation in the Duri Steam Flood operations is categorized as depleted and loss formation. The depleted zone means the left reservoir pressure does not enough to push hydrocarbons or fluids in the wellbore to the surface by itself. This condition occurs due to lack of pressure and reduction of hydrocarbons volume in the reservoir [8]. The fluid we pumped into loss formation will penetrate, and there is no fluid return to the surface. As a result, the well cannot establish a static hydrostatic column, and the verification test of a hydrostatic barrier fails.

E. Human Capability

The most contributing factor in the initial killing process is the Human. There are various parties from the Rig Crew Personnel, other 3rd party service companies, and MMI Company representatives in the rig operation. The excellent experience and high skills of those following personnel is a critical principle in the success of the initial killing process [4]. They shall comprehend the Well situation, including its well's history, to anticipate and plan the initial killing process.

F. Fluid Material Characteristics

Due to the high loss, the water cannot provide the static column of fluids. Thus, the other alternative if pumping water is not successful is pumping polymers or a combination of polymers, CaCO¬3 and KCl. The 3rd party service company of MMI provides those fluid materials at a higher cost than water. Besides the cost of the material itself, there is a cost for engineers and time spend on mixing the materials. The polymers are a high molecular weight xanthan biopolymer to provide effective viscosity for solid transport and suspension in the water base. In severe loss formation, the utilization of polymers is not enough to cure the loss and combines with CaCO3 as loss circulation materials. The CaCO3 is a high purity ground limestone that increases weight or density and reduces fluid loss in drilling and workover fluids.

III. METHODOLOGY

The research starts by gathering historical data of initial killing performance in Well Injector execution in MMI Operations. Then based on the baseline data, the team initiates a brainstorming session to discuss the contributing factors during the initial killing. Furthermore, based on those contributing factors, the team will find the root causes using the Current Reality Tree.

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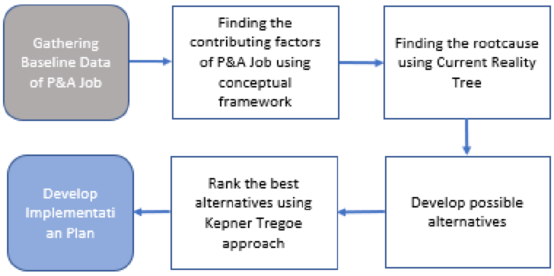

Fig. 3. Methodology Flow Chart

After the team discovers the in-scope root causes, they will conduct Focus Group Discussion to identify the goals. The selection of the best alternatives will use Kepner Tregoe Analysis. The team will discuss the potential solution based on their previous experience and applicability in the MMI operations.

IV. ANALYSIS OF FINDINGS AND DISCUSSION

A. Root Cause Analysis

The prolonged initial killing contributes to 90% of total potential delay hours during P&A Job Execution. From the Current Reality Tree, there are at least 4 UDEs that contributes to the prolonged initial killing process, including:

a. Failure during the static check as verification for successful initial killing
b. Numerous trials shall be performed as per written SOP
c. Failure to address the Well characteristics
d. The concise duration of the initial killing process.

From the 4 Undesired effects, we generated six root causes as defined in Fig 3. 4 of 6 root causes are the out-of-scope root causes. The two root causes, the fluid pumped breakthrough formation, and the Current SOP, are not designed for the P&A job are the in-scope root causes and utilized to generate the solution.

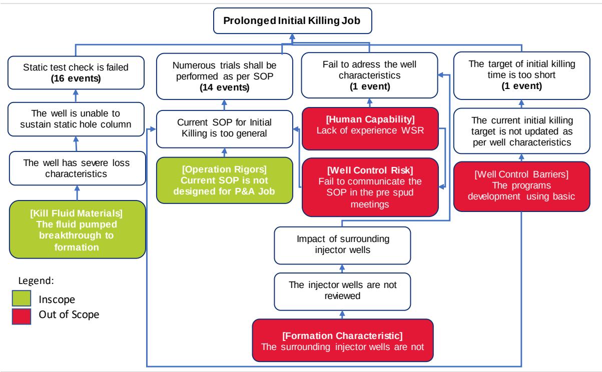

Fig. 4. Current Reality Tree

These two root causes are the main contributors to the business issue. Of 16 P&A Injector Wells stated in Fig 1.10, the 16 events result in static check failure, which contributes to 100% of the total events. At the same time, the 14 events resulted from the repetitive trials as per SOP, which contributes to 87.5%. Thus, by resolving those 2 UDEs, we could solve the prolonged initial killing problem in P&A Well. Besides that, those two major root causes are within Wells Team's control.

B. Business Solution Alternatives

In regards to solve the root cause – the pumped fluid breakthrough to the formation, the alternatives will be generated based on the fluid treatment change during the initial killing as the characteristic of loss formation cannot be changed. There are seven solution alternatives to potentially cope with loss formation characteristics which are:

a. Assign Well Control Team Unit

WCT Unit consists of 1 triplex pump and 2 square tanks. They perform the job before the rig spud-in. The operation of the WCT unit is a combination of bleeding off and pumping the Well operation. The bleed-off operation means that the well is intentionally open from its casing valve or master valve. The objective of the bleed-off process is to release the trapped pressure and observe the type of fluid in the well, i.e., dry gas, oil, water, or steams. The type of fluid to be pumped by the WCT unit is also limited to water. As its objective is to provide initial killing assistance, the completion of this operation is not the zero well pressure. The completion of the WCT unit still has remaining pressure in the well in the amount of 0 until 20 psi.

b. Perform Dynamic Killing

The dynamic killing operation refers to pumping the well continuously with water without shut-in. In each well, there are two casing valves. In the dynamic killing operation, a mud pump connects to one valve for water injection, and the pressure gauge connects to the other valve to monitor the pressure.

However, this alternative is against the MMI barrier standard. As mentioned previously, the hydrostatic barrier shall be established and verified before the commencement of the job. Thus, after pumping any fluid, a static check is performed. The dynamic killing always fails during the barrier verification during the static test. After the water injection stops, the pressure continues to build up in less than 5 minutes.

c. Perform Squeezed Gravel Pack

When the well is gravel packed, the porosity is significantly reduced, and the permeability is changed. A slurry of accurately sized gravel in a carrier is pumped into the annular space between a centralized screen and a perforated casing or open hole [1]. The squeezed pack is the injection of gravel pack in the existing well to fill the voids in the well [3].

There is an uncertainty of gravel sands volume to be squeezed, and the sand will be continuously injected when there is a significant increase of pressure during injection, indicating the sand already fills the void spaces. The squeezed pack could cost \$20,000 - \$40,000 per well due to high sands volume. When the void spaces are filled up with gravel sand, the hydrostatic barrier could be established. Besides its high cost, the operation of the squeezed pack also requires a clean-out process before commencing the cement plug.

d. Pumping Non-Damage Higher LCM

The term of non-damaging means that the fluid will not damage the formation. Besides the CaCO3 and Polymers, there is an alternative to pump Lightweight fluid or Thixotropic Fluid as Non-Damaging LCM. One of the Lightweight fluids is diesel. In MMI operations, the provider of lightweight fluid is not available. Furthermore, the fluid is treated using rig equipment that is not compatible with diesel. The other non-damaging LCM is Thixotropic Fluid (i.e., Crosslinked Gel). The crosslinked Gel could provide higher viscosity material in the amount of 1000 – 1300 cp compared to the current polymer viscosity in 75 – 90 cp. With the higher viscosity, the fluid does not break through to the formation and provides a temporary hydrostatic barrier during the initial killing. The Crosslinked Gel is available in MMI operations. The cost is considerably expensive at \$8,000/100 barrels.

e. Pumping Non-Damage Higher LCM

Different from alternative 4, this alternative will create damage after being pumped into the well. The Well condition could not be regained to its original condition. Example of damaging LCM Materials includes Frac Seal plus sawdust or Nut Plug.

The price of a combination frac seal and sawdust is around USD5,000 per 100 barrels. In comparison, the nut plug is around USD4,000 per 100 barrels. This cost is considerably cheaper than the Non-Damaging LCM. In addition to its damaging drawbacks, the injection of these materials requires additional work after pumping. These LCM could create the pipe stuck and requires washover operations to release the pipe and clean out the well. For the same reason as other non-damaging LCM, the assurance of a clean well without LCM materials is necessary to achieve a good cement barrier in the cementing job.

f. Pumping Cement Slurry during Initial Killing

For active wells, this option is not preferable as it will plug the well. This option is suitable for P&A Jobs as, in the end, the cement slurry will be pumped to plug the well [6]. This operation requires another service company which is a cementing service provider. The cement is mixed and pumps by the cementing truck. During cement pumping, the rig does not provide any services and keeps to be paid at a normal operation rate.

This operation could create a potential problem, such as cement locked up during the pumping operations. However, it could be mitigated by performing initial observation through an injectivity test. The injectivity test measures how much fluid could be injected through the well.

Despite its risk, this method is proven to combat the loss and also support the main cementing job. This operation is considerably cheap for the monetary judgment as to the pumping cement during the initial killing is a part of the first cementing plug. Fig 4. shows the revised SOP for initial killing with cementing.

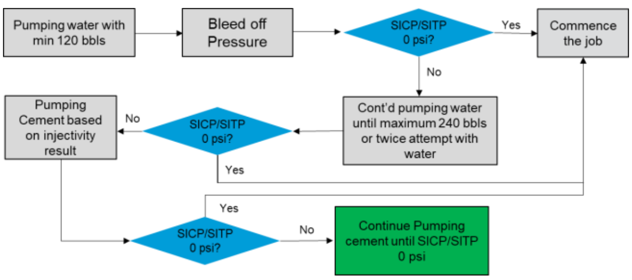

Fig. 5. Revised SOP Initial Killing with Cementing

g. Perform Offline Initial killing by Cementing Pump Truck

This alternative is quite similar to alternative 6, except for the execution flow process. The difference with alternative 6 is the cementing pump pumping the cement before the rig spud into the well. Thus, this alternative eliminates the rig cost during pumping and waiting for the cement. This alternative has cheaper cost than the alternative six. Fig. 5 elaborates the difference between alternative six and seven.

Fig. 6. (a) Alternative 6 and (b) Alternative 7

C. Analysis of Alternatives

To seek the best alternatives for the root cause, the Kepner – Tregoe (KT) decision analysis is used on the seven proposed alternatives. The KT Decision Analysis is a combination process of problem analysis, decision analysis, and potential problem analysis [10]. Before finding the best alternatives, we shall develop musts and wants attributes. Musts are mandatory to be fulfilled for each alternative. If an alternative satisfies all musts attributes, then the alternative could be accepted. However, if an alternative does not satisfy any of the musts attributes, then the alternative cannot be accepted. Wants attributes are desirable but not mandatory. The best solution shall meet all the Musts attributes and have more wants attributes. The development of musts and wants attributes combines qualitative and quantitative parameters during P&A Job [7].

The must attributes include as follow:

a. Comply with Verified Hydrostatic Barrier

This attribute means that the fluid shall meet the hydrostatic barrier verification. The verification is based on the static check which the well shall have zero pressure after pumping the fluids.

b. Availability

This attribute means that the fluid or services to pumping the fluid is available under MMI or provided by the current available third party provider.

c. Safe to be Executed

This attribute means that the execution of the proposed alternatives does not create potential incidents such as fire, injury, and days away from work.

d. Applicability

This attribute means that the fluid or services can be executed in the P&A wells. It includes the connection to the well and compatibility to rig equipment.

The want attributes include as follow:

a. Cheaper Cost

The proposed alternative will be compared to the existing standard procedure. The cheaper alternatives will have a higher score. The cost includes the cost of materials, engineers, and services. The weight score is 5.

b. Well Control Risk

This attribute means the alternative generates any Well Control risks after being executed or during the completion of the P&A Job. The least the Well Control risk will have, the higher score. The weight score is 5.

c. Additional Work Performed

This attribute means any additional work generated after pumping the fluid or the execution. The additional work generated will impact the P&A job process. The additional work includes additional fishing programs such as washover, clean out, or gel breaking. The minor additional work generated will have a higher score. The weight score is 5.

d. Execution Duration

This attribute means the execution duration that contributes to the main job programs. The main job programs are started after the rig moved in. If the execution of the alternatives is prior rig being moved in, then the execution duration is zero. The least execution duration is the higher score. The weight score is 5.

e. Offline Activity

This attribute measures whether the activity could be done in offline activity or not. The offline activity means that the alternative could be performed before the rig spud in. Thus, there will be no rig cost paid for offline activity. The offline activity contributes to the higher score for the wants matrix. The weight score is 4.

f. Rig Personnel Familiarity

This attribute measures how familiar the rig crew personnel are to handle the post job execution of alternatives. The more familiar the rig crew possesses, the higher score. The weight score is 3.

g. Contribution to P&A Job Objectives

This attribute measures whether the alternative has any contribution to the P&A Job. The P&A job objective is to establish the cement barrier. If the proposed alternative has a more significant contribution to the cement barrier establishment, it will attain a higher score. The weight score is 3.

After developing all attributes, each alternative will be measured on every attribute. The seven alternatives shall meet the must attributes and have a higher score in want attributes. Table 1 depicts the KT Matrix result.

From Table 1, we could conclude that the offline cementing job for initial killing is the best alternatives as it meets all the must attributes and attain the highest score for want attributes. The offline cementing job has a cheaper and most significant contribution to P&A Job due to the pumping cement during initial killing could be a part of cementing job. The cementing job in a loss formation could be repetitive. The first attempt of the cementing plug is to cure the loss and then the next attempt to establish the cement barrier. As on alternative seven, it pumped the cement during the initial killing. Thus, the cure loss cementing part could be completed offline. Furthermore, when the rig spuds in, it just continues to establish the cement barrier.

The execution duration and offline activity also acquire the highest score due to this activity are performed prior rig moved in. Thus, the execution duration could be excluded from the main P&A Job Duration. This alternative also acquires a higher score in additional work due to no clean-out or additional fishing operation requirements. The pumping cementing does not possess the Well Control risk due to this activity establishing verified barrier and no removal of cement activity during the P&A Job Execution.

TABLE I. KT MATRIX RESULTS

MUSTS		Alternative #1 - Assign WCT Unit		Alternative #2 - Perform Dynamic Killing		Alternative #3 - Perform Squeezed Pack		Alternative #4 - Pumping Non Damaging Higher LCM	
Comply with Verified Hyrdostatic Barrier		NO		NO		YES		YES	
Availability		YES		YES		YES		NO	
Safe to be executed		YES		YES		YES		NO	
Applicability		YES		YES		YES		YES	
WANTS	**Weight**	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Cheaper Cost	5	No Go Alternatives as not meet all the must attributes		No Go Alternatives as not meet all the must attributes		2	10	No Go Alternatives as not meet all the must attributes	
Well Control Risk	5					2	10		
Additional Work Performed	5					2	10		
Execution Duration	5					8	40		
Offline Activity	4					4	16		
Rig Personnel Familiarity	3					8	24		
Contribution to P&A Job	3					4	12		
TOTAL SCORE	30	0		0		122		0	

MUSTS		Alternative #5 - Pumping Damaging LCM		Alternative #6 - Pumping Cement Slurry		Alternative #7 - Offline Cementing Job	
Comply with Verified Hyrdostatic Barrier		YES		YES		YES	
Availability		YES		YES		YES	
Safe to be executed		YES		YES		YES	
Applicability		YES		YES		YES	
WANTS	**Weight**	Rating	Score	Rating	Score	Rating	Score
Cheaper Cost	5	6	30	8	40	8	40
Well Control Risk	5	4	20	8	40	8	40
Additional Work Performed	5	2	10	10	50	10	50
Execution Duration	5	6	30	4	20	10	50
Offline Activity	4	4	16	2	8	10	40
Rig Personnel Familiarity	3	6	18	8	24	8	24
Contribution to P&A Job	3	4	12	10	30	10	30
TOTAL SCORE	30	136		212		274	

V. RESULTS

A. *Implementation Plan*

The implementation plan started in the early year of 2021. Fig. 6. depicts the implementation plan from execution preparation, meeting coordination, and monitoring process.

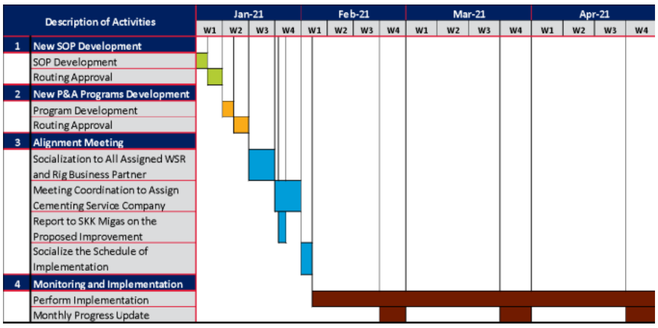

Fig. 7. The Gantt Chart of Implementation Plan

B. *Implementation* Results

The improvement has been performed in three dual injector wells in MMI operations. Table 2. depicts the implementation results in 3 wells. The baseline is the initial killing duration and the Kill Fluid utilization. In the new improvement, cementing is not considered an additional cost during initial killing due to it being a part of the main cementing job. As explained previously, the cementing job during the initial killing accomplishes the 1st plug cementing job, which is to cure the loss. Thus, the overall cementing job cost will be the same.

TABLE 2. IMPLEMENTATION RESULTS

	Baseline			Improvement				
Well Names	Average Duration for Initial Killing per Job (hr)	Average Kill Fluid Utilization	Rig Unit Rate (USD/day)	Total Duration for Initial Killing (hr)	Kill Fluid Cost (USD)	Initial Killing Duration Baseline Data - Actual	Rig Time Reduction (USD)	Eliminate Kill Fluid (USD)
	(A)	(B)	(C)	(D)	(E)	[F = AxC - D]	[G = F/24 * C]	[H = B - E]
PAInj#1	65	6,045	3,837	4	0	61	9,752	6,045
PAInj#2	65	6,045	3,837	1.5	0	63.5	10,152	6,045
PAInj#3	65	6,045	3,837	2.5	0	62.5	9,992	6,045
TOTAL AFB (USD)							48,031	

VI. CONCLUSION

The implementation of this improvement continues in MMI Operations. Below are several highlights for the conclusion:

- During the initial killing process in the P&A Job, the issue faced by MMI is the incompatibility of the current SOP with the P&A job objectives and the formation characteristics.
- The best alternatives to improve the initial killing process in the P&A Job is the initial killing by offline cementing. This alternative offers a short cycle time, cheaper cost, and is congruent with the P&A job objectives.
- The proposed improvement has gained benefits to MMI operation on the three implemented wells. Total Accrued Financial Benefits is USD48,031. The pumping of cement has achieved not only the initial killing process but also partial main cementing job.
- Parallelize the Process. In this case, instead of performing initial killing as a series process. The scope of initial killing is out of the rig scope. Thus, the rig could perform their job in other wells without waiting accomplishment of the initial killing
- Maximize utilizing fit-for-purpose units for each activity. Instead of using a rig with many pieces of equipment and requires a long moving duration, the cementing unit consists of cementing truck, water tank, and banana truck that fit the initial killing and cementing job. While not all the rig set equipment was utilized for initial killing, such as BOP, Accumulator Unit, and PortaCamps.

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