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Continuous Implementation of Well Integrity Management System Integrated with Online Application Module Bringing High Level Safety of Well Integrity in Pertamina Hulu Mahakam

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Abstract. Mahakam has more than 2500 wells with various type of well architecture and some of mature well has been exist more than 40 years. Well integrity becomes critical aspect to ensure proper containment as per well barriers philosophy. Since 2015, elaborate well integrity management system has been implemented in Mahakam and successfully maintained tremendous safety level of well integrity. The method used is by implementing NORSOK D.010 standard definition of well integrity which will be focusing on technical, operational and organizational approach. Furthermore, the online application system developed internally is also used as well database reference and well integrity classification by colour code. All information related to well barrier are recorded in one portal which are updated regularly. Standard operational procedure as one of the main reference also has been developed since 2015. Dedicated well integrity team, engineering in town and operation team are also established. Detailed monitoring and frequency is also precisely determine as per reference. It is concluded that well integrity management system in Pertamina Hulu Mahakam has significant advantages to maintain high level safety aspect of well integrity without any uncontrolled hydrocarbon leak to environment. The integration between technical, operational, organizational and also online module application is proven as a robust method.

Keyword(s): Well Integrity Management System; Well Barriers; Integrated Application,etc.

1 Introduction

Mahakam oil and gas block of Pertamina Hulu Mahakam (PHM) is located in the East Kalimantan Province, Indonesia. This block consists of 3 fields in swamp environment (Handil, Tambora, Tunu) and 4 fields in offshore platform environment (Bekapai, Peciko, Sisi-Nubi, South Mahakam). These fields are all founded nearby Mahakam river delta where production from the field started in 1970s. Throughout 50 years of operatorship, more than 2000 wells have been drilled in Mahakam Block with various type of wells based on function, architecture, completion type, lifting mechanism and wellhead-tree technology, Rangga Saputra et al (2017).

Well Integrity Management System with online application module in PHM is implemented since 2015 and managed according to following standards to guarantee that the containment and the prevention against escape of fluids (liquid and gases) to any subterranean formations and subsea or surface environment are maintained all times. The implementation successfully tremendous safety level of well integrity in PHM.

2 Methods and Procedures

Well Integrity definition by NORSOK D.010 is application of technical, operational, and organizational method to prevent uncontrolled flow of fluids at the surface or across subsurface formation throughout the lifecycle of the well. The main rule used to asses well integrity is well envelope which contain composed of one or several well envelope elements also called barrier. Well envelope prevents effluent from flowing unintentionally from the formation to the environment or into another formation. Dual independent well barriers, both internal and external shall be in place to isolate reservoir from environment in order to conduct production operation safely.

Internal well envelope is first well envelope directly contact with potential source from reservoir. It consists of Packer, Tubing and Downhole Safety Valve (DHSV). On a non-flowing (non-eruptive well), formation fluid of well acts as internal well envelope and should be validated periodically. In addition, annulus pressure monitoring performed to identify any internal well envelope issue.

External well envelopes is second well envelope that contain pressure in case internal well envelope failed. External well envelope consists of Casing, Cement, Wellhead annulus valve and X-Mass Tree (XMT) master valve. If there is any failure or ineffective of these well envelope, immediate action should be taken to restore the well envelope elements.

2.1 Well Integrity Management System – Organizational

Well ownership is different according to operation performed on the well. In PHM, wells within operation phase are under ownership of Production Operation (PO) Division after handed over by Drilling & Well Intervention (DWI) Division. Several well are remained under ownership of DWI, inclusively for suspended, temporary, and permanently abandoned wells. The well ownership is defined by the handover document and illustrated in Figure 1.

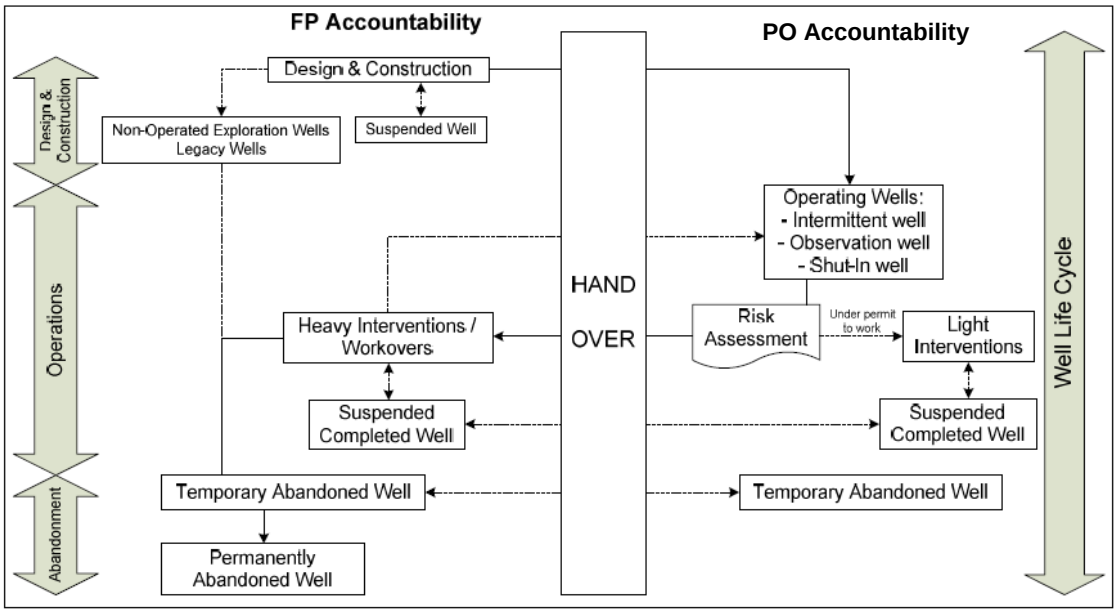

Figure 1. Split of Well Integrity Surveillance Responsibility During a Well Life Cycle (TKI PHM, 2021)

2.2 Well Integrity Management System – Operational

Well integrity is a combination of reliability (as a preventive and restoration action) and traceability data. Preventive and restoration are part of operational directly associated with the wells. Preventive maintenance are XMT valves function test (FT) and leak test (LT), DHSV FT and LT, wellhead annulus valves FT and LT, repair or replace XMT/XMT's valves and annulus valve when required, and well monitoring (well barrier, annulus behavior, corrosion, well elevation, bubbling & leaks)

Well integrity restoration is a means to rectify well integrity status there are investigation, Risk Assessment (RA)/Engineering Evaluation (MIT (Major Integrity Threat)), DGS (Down Grade Situation), and Intervention.

2.3 Smart Well Integrity Module (SWIM)

A systematic approach to well integrity related to data collection is importance to present traceability data called by SWIM developed internally by PHM since 2015. Collaboration between well integrity team with other entity (DWI and PO) is performed for data feed to SWIM based on visit (testing, monitoring, and investigation report) as an alert system when anomaly present and defined color code logic. Figure 2 shows approval system for data entry to SWIM.

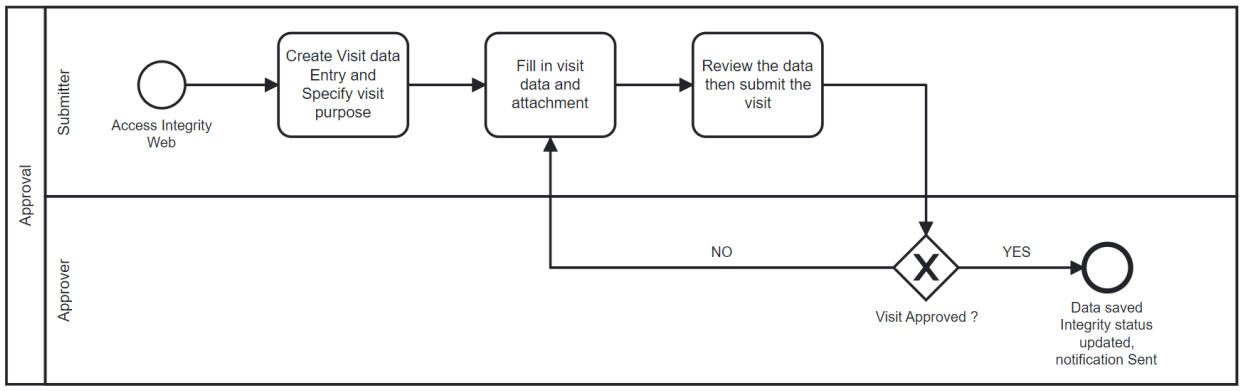

Figure 2. SWIM Approval System

SWIM as integrated application are synchronized with other PHM application to give input and generate output. Input from Subsurface Development & Planning (SDP) application named by iCon-Pro to generate general information such as well name, location, well type, string, etc. And input from PO application named by Direct Viewer to generate general production status and annulus pressure. SWIM output generate well integrity information by color code logic to DWI application to give awareness based on existing risk before performed any operation which required special mitigation.

2.4 Color Code Logic

There are four category system utilizes describe criticality visualization, green/yellow/orange/red and gray for undefined well integrity color code usually for new wells with incomplete data to generate color code logic. Well integrity color code on operational phase classified as follows:

- Green, internal and external well envelopes are working in a good condition and no element failure.
- Yellow, internal and external well envelopes are working in a good condition but there is one or more existed aggravating factors with acceptable risk.

- Orange, one of well envelopes either internal or external failed or not fulfill the acceptance criteria. A single failure of a barrier may lead to leak to the environment.
- Red, both internal and external well envelopes are failed, outside the acceptance criteria and/or when a leak is observed at surface and confirmed.

2.5 RACI Matrix

Well integrity monitoring and testing split responsibility between PO and DWI. Well operator from PO are responsible to performed monitoring and performed function test on surface equipment. While Well Integrity team from DWI are responsible to performed leak test, repair, investigation and release recommendation. Table 1 is RACI matrix for operational well under PO perimeter, showing who will R (Responsible), A (Accountable), C (Consulted), and I (Informed).

Table 1. RACI Matrix Operational Phase Well Monitoring & Task Responsibility (TKI PHM, 2021)

Task	Task Description	Frequency[1]			PO	DWI	Reporting Support
		Base Case	Fully Shut-In[2]	Sensitive[3]			
1	**Data input in SWIM**						
1.1	Registering new well	When required	When required	When required	A	R	SWIM
1.2	Visit data input	When required	When required	When required	AR	AR	SWIM
1.3	Status declaration for fully shut-in or sensitive well	When required	When required	When required	AR	I	SWIM
2	**External envelope checking**						
2.1	Annulus valves and Xmas tree valves function test[4]	Yearly	2-Yearly	2-Yearly	AR	I	SWIM
2.2	Annulus valves and Xmas tree valves leak test[4]	2-Yearly	2-Yearly	2-Yearly	AI	R	SWIM
2.3	Casings and conductor pipe visual check	Yearly	Yearly	Yearly	AR	I	SWIM
2.4	Well equipment visual check (eg. PG, plug, needle valve, fittings, actuator quick exhaust, etc).	Yearly or When required	Yearly or When required	Yearly or When required	AR	I	SWIM
2.5	Cavity checks	2-Yearly	2-Yearly	2-Yearly	AI	R	SWIM
3	**Internal envelope checking**						
3.1	DHSV function test[5]	Yearly	2-Yearly	2-Yearly	AR	I	SWIM
3.2	DHSV leak test[5]	2-Yearly	2-Yearly	2-Yearly	AI	R	SWIM
3.3	Eruptivity test	2-Yearly	2-Yearly	2-Yearly	AI	R	SWIM
4	**Annuli pressure monitoring**						
4.1	Annuli pressure check and record[6]	Bimonthly (max)	Bimonthly (max)	Bimonthly (max)	AR	I	PDMS
4.2	Preliminary diagnosis abnormal annulus pressure	When required	When required	When required	AR	C	SWIM
4.3	Comprehensive diagnosis abnormal annulus pressure	When required	When required	When required	I	AR	SWIM
5	**Maintenance**						
5.1	Xmas tree annulus valves greasing	When required	When required	When required	A	R	SWIM
5.2	Xmas tree valves replacement & annulus valves addition/ replacement	When required	When required	When required	A	R	SWIM
5.3	WR-DHSV regular replacement	2-Yearly	No need (considered as plug)	2-Yearly	A	R	SWIM

2.6 Risk Assessment (RA)

Color code based on barrier envelope philosophy is not absolute but need to be respected regarding an association with risk. As an example, wells with visible leak at surface may have different level of risk based on the Lower Explosion Limit (LEL) value. RA is performed for wells that are categorized as critical, red and orange well. Wells with RA model no longer using SWIM logic. The color code will be manually inputed based on the risk matrix analysis and engineering evaluation to override the SWIM logic. Figure 3 shows well integrity workflow in PHM.

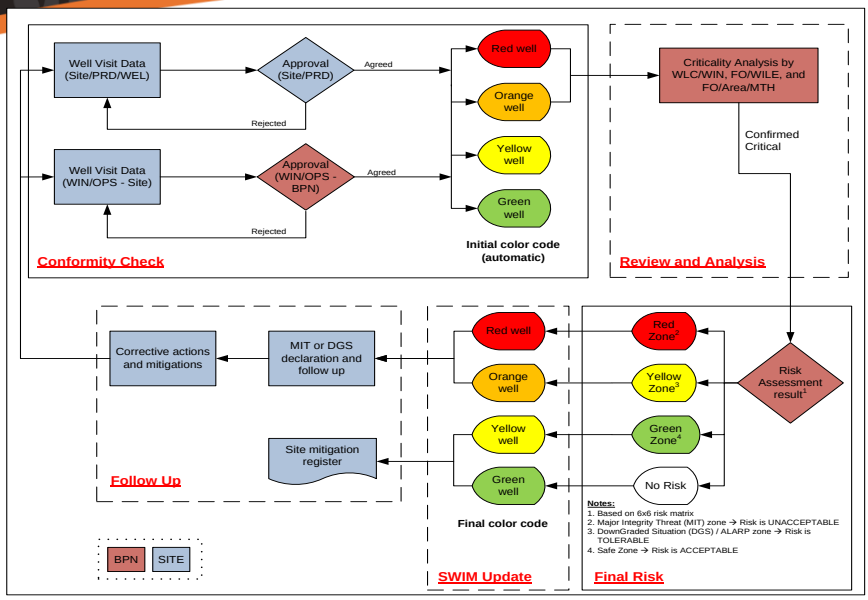

Figure 3. Well Integrity Workflow

3 Results

SWIM development in PHM give benefit for working effective and efficient to identification, prioritization, and problem solving. Digitalization reduce the manual paperwork and personnel can be optimized to focusing on trouble shooting instead of data gathering. As an integrated application any anomaly such as annulus abnormal pressure can be identified early through email notification before any escalation occurs.

Furthermore, Well Integrity Key Performance Indicators (KPI) in PHM are monitored and maintained with monthly basis to give focus for achieve performance and set improvement in the beginning. These are maintained Well Integrity KPI in PHM:

- Number of red and orange well is less than 5% of well population (Figure 4).
- XMT & DHSV leak test backlog for red and orange well is maximum 2% of well population (Figure 5).
- DHSV replacement backlog for red and orange well and shut in well is maximum 10% of non-fully shut-in well with Wireline retrievable DHSV (Figure 6).

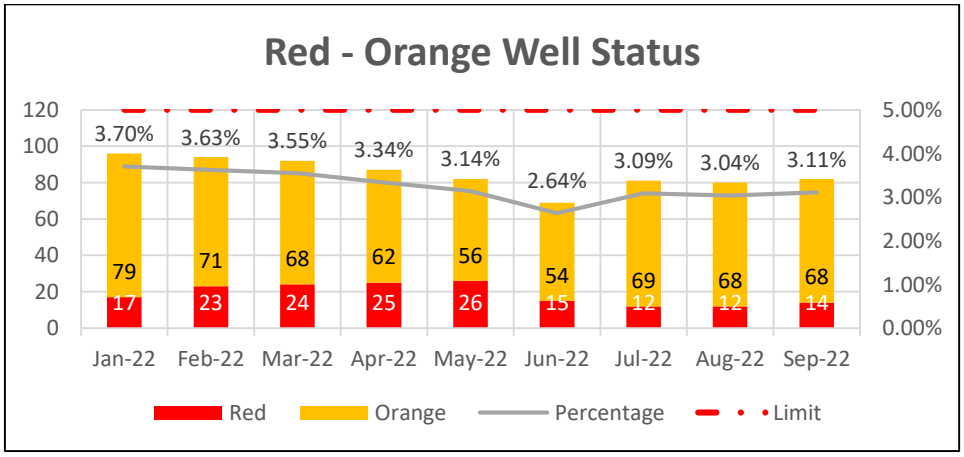

Figure 4. Red – Orange Well Percentage

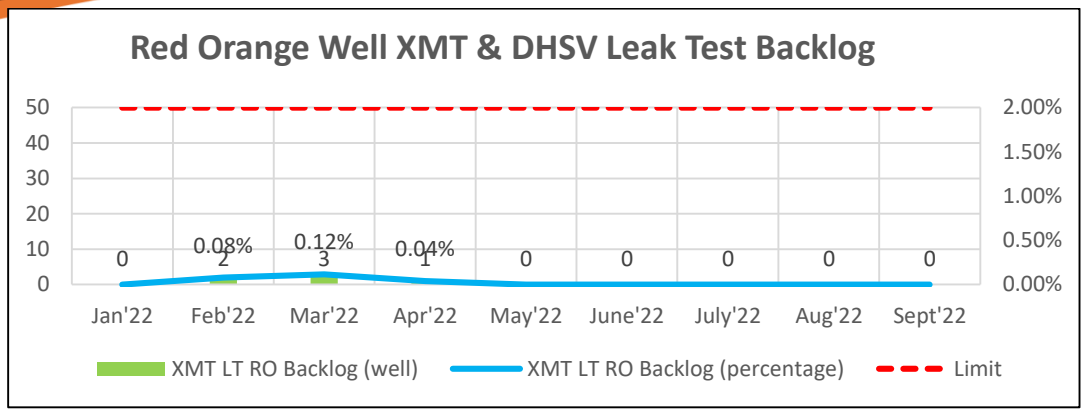

Figure 5. Red-Orange Well XMT & DHSV Leak Test Backlog Percentage

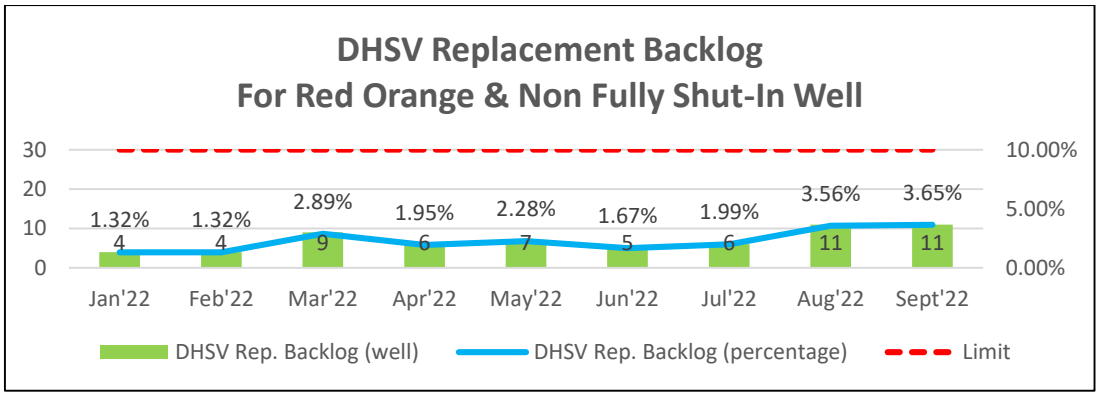

Figure 6. Red-Orange & Non-Fully Shut in Well DHSV Replacement Backlog Percentage

PHM successfully implemented well integrity management system with online application module and it has been mostly adopted as main standard reference for vast upstream Pertamina affiliate.

4 Conclusion

It is concluded that well integrity management system with integrated application in PHM has significant advantages to maintain high level safety aspect of well integrity without any uncontrolled hydrocarbon leak to the environment during 7 years. The integration between technical, operational, organizational and also module application is proven as a robust method. Currently, integrated digital daily report to SWIM is being developed to generated backlog percentage evolution to get KPI update in daily basis. Furthermore, development of SWIM application to be enhanced by implementing machine learning method based on actual visit database in order to obtain automatic recommendation of barrier validity and prediction of barrier failure.

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