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## **A cost-effective method to isolate and protect shallow aquifers in south Oman**

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### **ABSTRACT**

Isolation between shallow aquifers in newly drilled wells has remained a challenge for many years in the south of Oman. The success of such isolation depends on effective cementation behind the casing. Total losses encountered while drilling through these weak, high permeable and cavernous formations, which implies a poor cementation. Changing well design by adding extra casing sections and/or multiple cement jobs can be costly and time consuming in addition to the HSE exposure. The protection of aquifers is a crucial matter to comply with the environmental regulations and PDO takes it as one of its top priorities.

There are two aquifer systems with different properties in terms of H<sub>2</sub>S presence, salinity level and the pressure difference which is likely to create cross flow between the two systems if the natural barrier is not reinstated. Thus, the proper isolation between the aquifers is crucial.

In the industry, there are different techniques available to isolate different sections. This paper outlines the trials in three wells in which multi-stage inflatable packer collar (MSIPC) was utilized. The packer collar serves as an effective barrier to mitigate fluid migration and support multiple stage cementing through integrated stage cementing ports in the tool.

Due to the total losses often occurring in these carbonate formations, the conventional way of cementing been found to be mostly ineffective as proven by cement bond logs (CBL/VDL). Installing a stage-cementing tool at a specific point in the casing above the loss zone has managed to create the isolation that complies with integrity criteria. This technique proved to be reliable, easy to use and cost effective in isolating the two shallow aquifers.

The cost of the isolation using the MSIPC compared to adding an extra casing section resulted in about 60% cost saving. This achieved only by the integration of all the

stakeholders starting from the Environmental Authorities to Asset and well engineering team to achieve the ultimate goal, the protection of the natural water resource.

Introducing the MSIPC to the well design and without a change in the cement recipe, an excellent column of cement bond had been achieved, which eliminated the need for adding an extra casing section. Moreover, understanding the loss interval versus non loss is a key point in selecting the depth setting of the MSIPC tool to get the effective zonation. This technique will be replicated across other areas, generating significant savings.

## 1. Introduction

Groundwater in the Sultanate of Oman is considered a national wealth protected by royal decrees. It represents the main water source for domestic, industrial and agricultural use. Oil and gas activities involve drilling through shallow aquifers to access underlying hydrocarbon reservoirs. This might cause a potential contamination of groundwater through various pathways include leaks in well casing, corrosion, drilling fluids, crossflow due to poor cement behind casing, etc. such contaminations are persistent and results in long lasting adverse effects. Moreover, oil and gas industry demand high volumes of water that might cause depletion and pressure difference between existing multi aquifers.

X1 and X2 fields are located in South Oman. There are two groups of aquifers exist in both fields: Group 1 (F & D formations) and Group 2 Upper R (UR) and Middle R (MR). The main aquifer for supporting company activities is (MR). MR aquifer thickness has minimal variation with thickness of about 80m in both X1 and X2 fields. It is characterized with fractured flow with very high permeability. Permeability is expected to be in 10s of Darcy in this layer. There are other aquifers in UR and F-D formations just above MR but are minor compared to MR's aquifer. However, F aquifer in the vicinity of both areas, especially X2 field, hosts a freshwater lens which is used for drinking purpose.

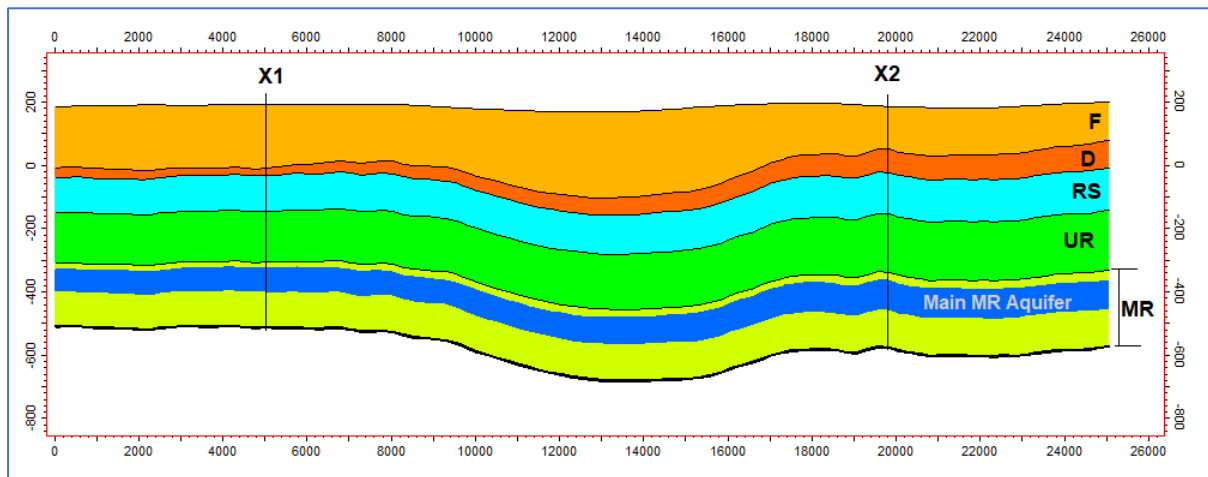


Figure 1: Aquifer Settings in fields X1 and X2

UR and MR aquifers are separated from shallower aquifers by low permeability limestones in the upper part of the UR and anhydrites in RS formation. The natural separation between aquifers is clear from pressure difference between the aquifers. UR & MR aquifers has higher pressure by about 400 KPa compared to the shallower aquifers in F & D formations.

Additionally, water quality is different in term of H<sub>2</sub>S content and other chemical composition. UR&MR aquifers are known to contain some H<sub>2</sub>S and traces of naturally occurring hydrocarbons regionally. Therefore, it is important to separate between the two system of aquifers in order to avoid mixing due to crossflow.

Due to the fact of total losses of mud circulation encountered while drilling through these formations, it is a challenge to get any cement behind the casing with the conventional way of cementing.

## 2. Methodology

This section discusses the proposed technique to avoid cross flow between the two groups of shallow groundwater aquifers and reinstate the natural separation. Several ideas were identified with different procedures and costs. A decision tree was constructed starting with the most economical and easier option to implement and ending with the more operational intensive and less economical option.

There were three solutions listed to overcome this challenge. First option is running MSIPC (multi-stage inflatable packer collar) along with top hole casing (9.5/8" CSG) to perform second stage cementation, using normal cement for the second stage. Cost of this option represent 2% from well cost. Second option is similar to first one but of the normal cement is

replaced with foam cement for the second stage cementation, this will cost 5% from well budget. Third option is adding extra casing string (13 3/8" CSG) with extra which will increase well's cost by about 12%.

It was agreed to start with two trails in one of the fields in South of Oman using option one. The KPI measure decided to consider trail as success, is to get good cement bond across the targeted area minimum 30m as per internal integrity guidelines requirement. This process involved alignment between different parties including drilling, asset & environmental teams, and contractors. The first trail implemented in X1 field in well A with some issues during cementing job operation, cement bond logs has been conducted to evaluate the cement quality behind the casing. Second trail implemented in well B with no operational issues, also cement bond logs has been performed.

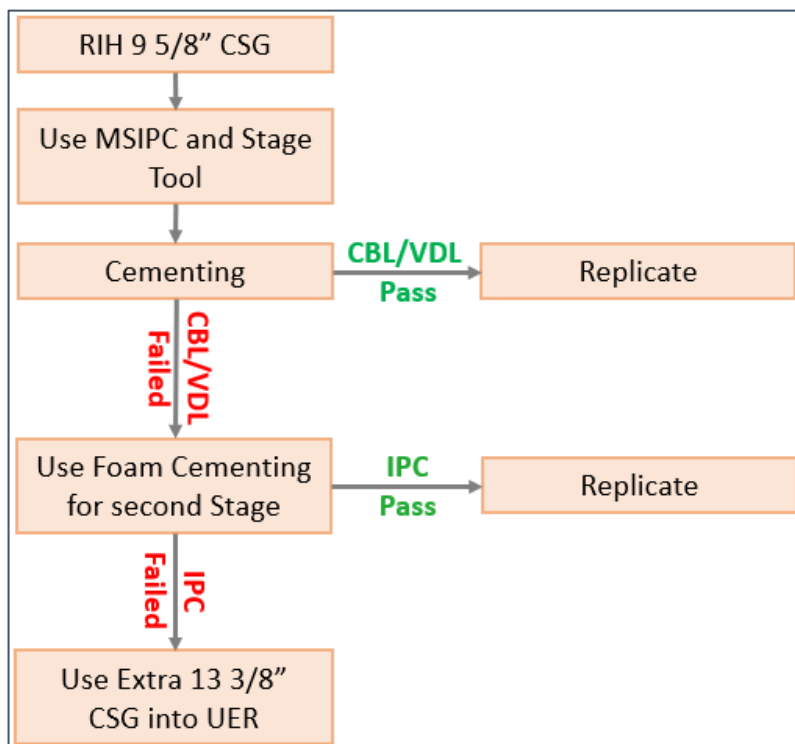


Figure 3: A decision tree approach to try three different suggested ways to overcome this challenge.

A third trial was conducted in field X2 and again cement bond logs was conducted to evaluate the cement quality.

### 3. Operation:

#### Multi-Stage Inflatable Packer Collar (MSIPC) Rig installation:

##### Definition of inflatable packer:

An inflatable packer is a type of packer that uses an inflatable bladder to expand the packer element against the casing or wellbore so it can isolate sections in a well or borehole to achieve zonal isolation. Mainly the fluids used to inflate the bladder drilling mud, water, or cement.

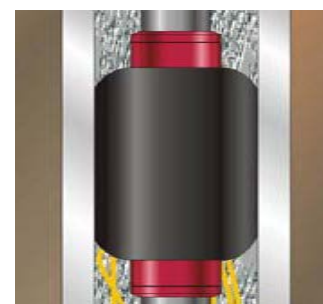


Figure 4: Zonal Isolation with ACP Packer

MSIPC should be ran with 9 5/8" CSG to the target depth. MSIPC assembly is made up to the casing string as per the approved tally. Once at determined setting depth, circulation is established to ensure proper operation of the float equipment and proper cleaning of the well. Rig equipment and cement unit are lined up and tested according to the cement job requirements, then first stage cement is mixed as per recipe and pumped as per the calculated volumes as per program (cement vendor). The Shut Off Plug will be released after pumping the cement volume then displaced with water as per casing volume required to bump the plug.

After the Shut Off Plug lands (bumps), pressure is increased gradually till the ACP packer valve opens (a pressure decline will indicate the functioning of the opening valve). Once observed, stop the pumps, and note the pressure decrease. Pressure will level off when the closing valve has functioned. Increase pressure back up to the opening valve activation or the closing valve setting pressure, whichever is greater pressure and hold for 2-5 minutes as shown below. Release all pressure as quickly as possible to allow for the opening valve to lock. Pressure tests the casing string to verify the valves are locked closed and to confirm casing integrity as per the barrier plan pressure test requirements. Bleed of pressure and monitor the back flow.

Open the plug container (Cement head cup) and drop the Free Fall Opening Cone then preload the Closing Plug in the plug container. Pressure is increased to open the Stage Tool. Mix and pump second stage cement, pump the calculated displacement fluid volume to seat the Closing Plug in the Stage Tool. When the Closing Plug seats, continue pumping until the plug bump and close the stage tool by applying higher pressure as per the tool specifications and hold for 1 to 5 minutes. Release pressure and observe the volume of bleed back to confirm that the Stage Tool has closed. Pressure test the casing as per the barrier diagram and casing integrity requirements.

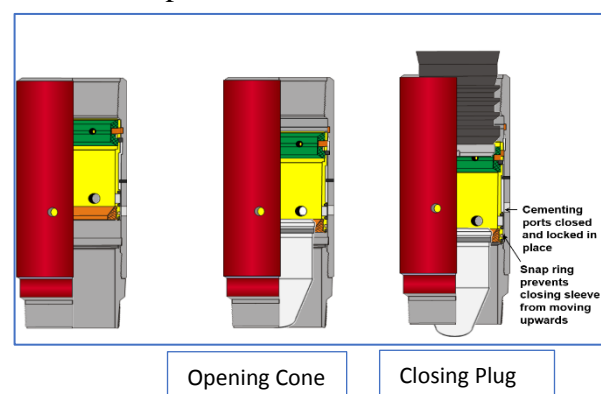


Figure 5: Stage tool activation process

#### 4. Results:

Cement bond logging was executed in 3 wells, namely, A, B and C in field X1 to determine the quality of cement bond behind the casing of the zone of interest and confirm the success

of the trial. Historically, cement logs showed poor cement bond to free pipe (figure 5) since the conventional way of cementing is not working due to the losses encountered across these formations.

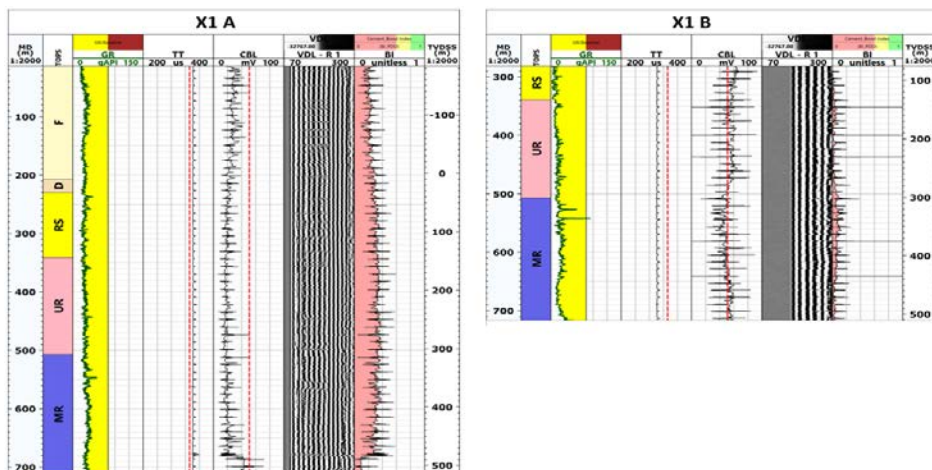


Figure 5: Examples of Poor Cement bond across shallow aquifers in X1 field.

After implementing the idea of MSIPC, the evaluation of cement logs (figure 6) in well A showed 80 m of moderate to good cement above MSIPC depth despite the cement under-displacement issue faced during the cementing job operation. Well B cement logs interpretation showed well bonded pipe of about 150m between the two aquifers. Another cement displacement failure during operation occurred in well C, however 50m of good bond observed based on the cement logs.

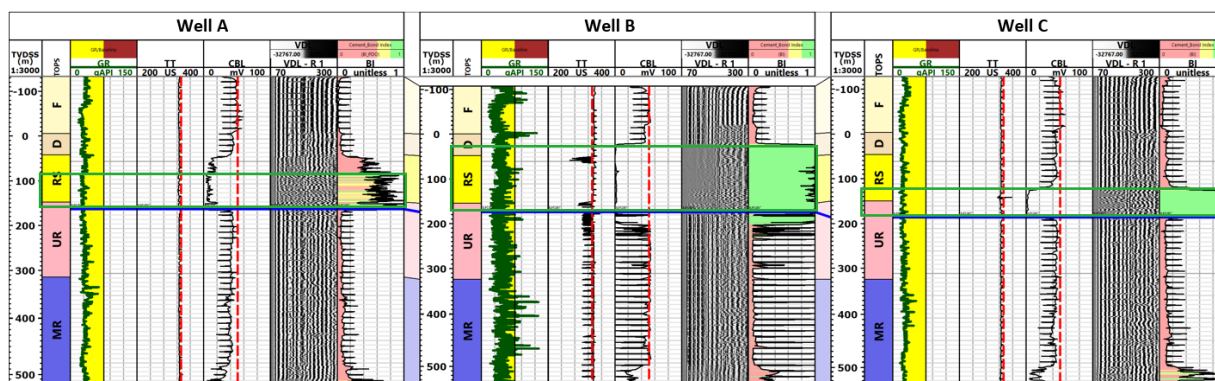


Figure 6: Cement log evaluation in well A, B & C. MSIPC installation depth marked by the blue lines.

As per the internal integrity guidelines, 30m of good cement between the two aquifers is sufficient to isolate them and meet the integrity criteria. Thus, the success of the trial was



approved and MSIPC implementation has been processed in other fields to secure shallow aquifers.

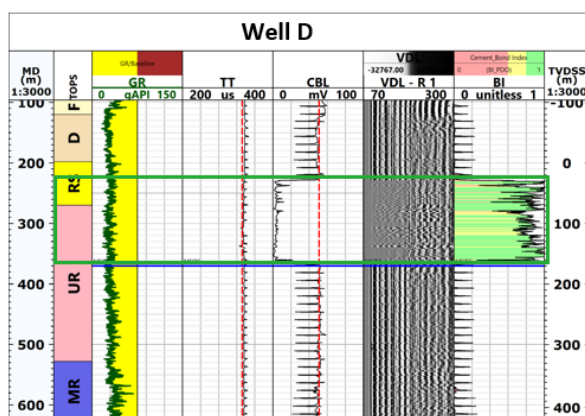


Figure 7: Cement log evaluation in well D from X2 field. More than 130 m of good cement isolation above MSIPC marked by blue lines.

## 5. Conclusion

Based on the demonstrated results, the use of MSIPC has been proven to be an effective way to establish aquifers isolation both operationally and economically. It is a solution that safeguards the exploitable groundwater aquifers across all fields while ensuring the adherence to company integrity standards and environmental policies. Establishing and maintaining well integrity throughout the well lifecycle prevents the occurrence of HSE incidents, loss of containment, production loss and costly remedial activities, safeguarding the long-term Integrity of wells. Therefore, this simple yet innovative solution has been rolled out across the other fields within the area as an integral part of the well design. In the meantime, the company keep on exploring options to further improve on all aspects especially optimizing cements jobs.

## References

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