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Successful Application of Through Casing Saturation Technology to Increase Oil Production in an Offshore Mature Well

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Abstract

An oil well incremental production increase of 1534 bopd and water cut decrease from 40% to 26% was the result of collaboration between a new through casing petrophysical technology provider and the reservoir management team. Post-production saturation logging was conducted through casing over an upper unperforated section of sand in a mature Peninsular Malaysia offshore deviated oil producer (Well-X). Well-X initially discovered 16 m of gas and 38 m of oil in a channel sand reservoir. To avoid early gas coning, Well-X was completed as an oil producer in the lower sand below a shale barrier. Simulation studies indicated that oil had been pushed up with water injection from a down dip water injector and that the upper sand should now be oil saturated. The 72 degree wellbore coupled with tubing and casing across the zone of interest added a challenge to cost-effectively confirm the simulation results.

To meet the challenge, the upper sand was logged in real time mode using tractor delivery method with a new through casing petrophysical tool capable of measuring saturation through multiple strings of pipe among other important parameters. Comparing the saturation log with the pre-production saturation log indicated an increase in oil saturation as predicted. Subsequent perforation and flow-back of the upper zone confirmed the simulation studies increased oil saturation. Post perforation test rates indicated an increased oil rate from 2400 bopd to 3934 bopd, and decreased water cut from 40% to 26%, and with no indication of any free gas production.

Background

The H sand oil reservoir is one of many stacked (>250) gas and oil clastic reservoirs located in a Peninsular Malaysia offshore asset. The H sand oil reservoir was discovered by an appraisal / development well (Well X) drilled from one of the field's satellite platforms in 2009. (Figure 1)

Well X was drilled to appraise / develop a primary I sand oil target, with well trajectory optimized to penetrate a secondary H sand gas appraisal (Figure 2). The primary target I sand however turned out to be gas on water, whereas the well discovered a GOC in the H sand (Figure 3).

Well X was completed in the H oil zone below a shale barrier to avoid the gas (Figure 3), and put on an extended well test for 6 mths. Material balance / simulation history match indicated sufficient oil column for subsequent downdip water injection, which was drilled and completed in 2010 and saw the H sand OWC. From 2010 the H sand has been under production with downdip water injection support.

Well-X produced dry oil at about 3600 bopd until early 2013, when water breakthrough occurred (Figure 4). By 2013 Well X had recovered 5 mmstb of an estimated 17 MMstb in place. The observed water breakthrough was predicted by a history-matched Eclipse numerical simulation model of the H sand model.

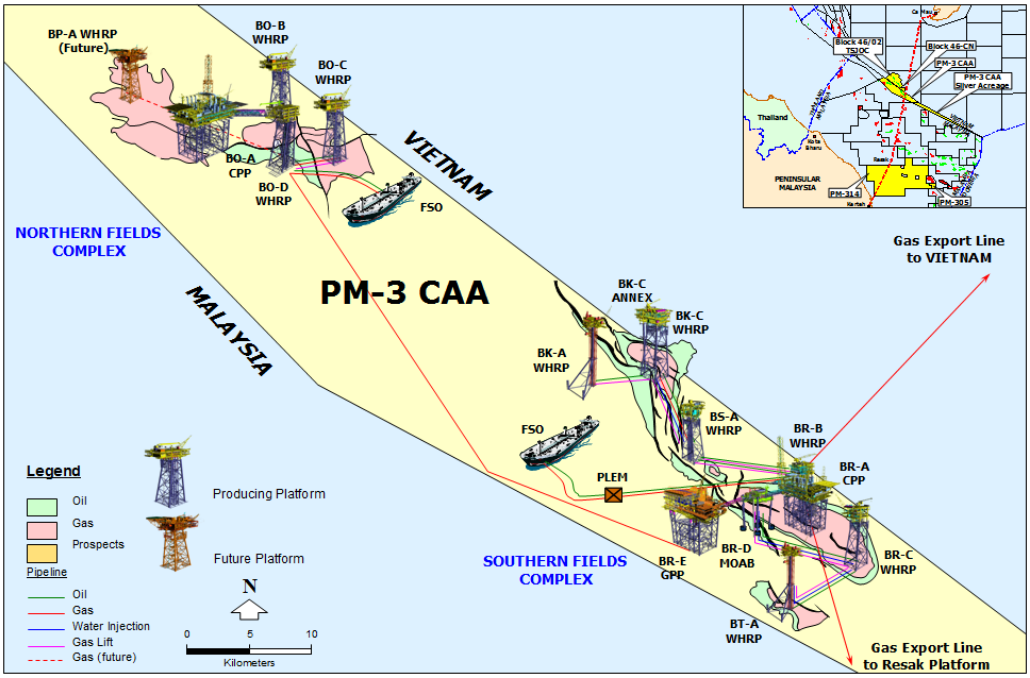

Fig 1. Field Location

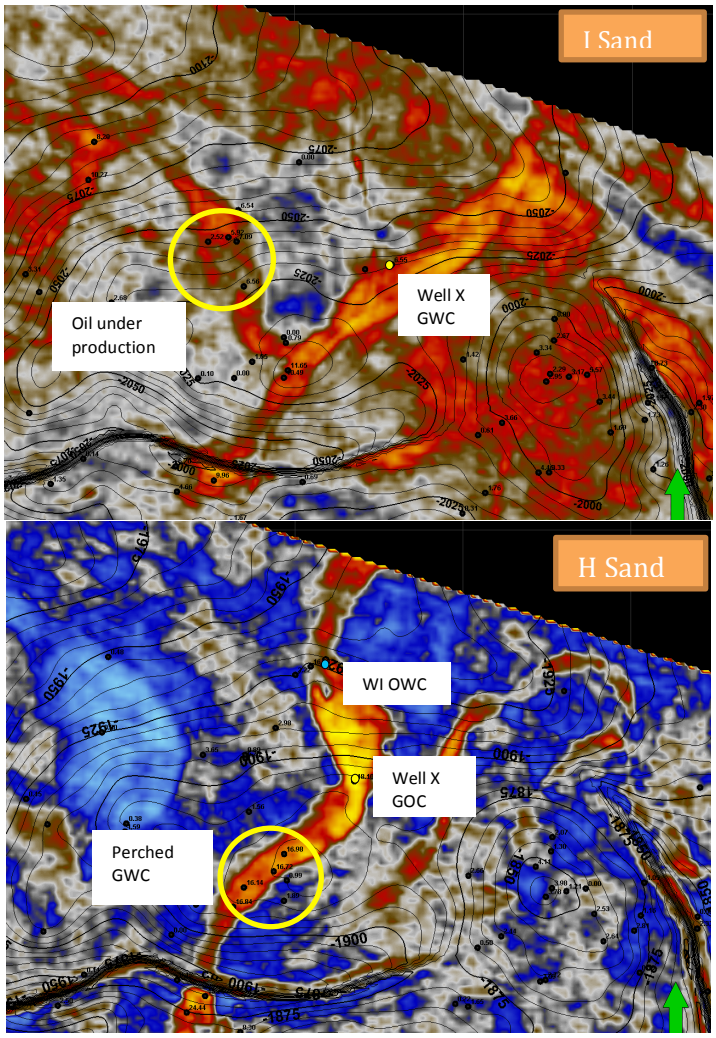

Figure 2. : I sand and H sands seismic amplitude maps showing location of Well X

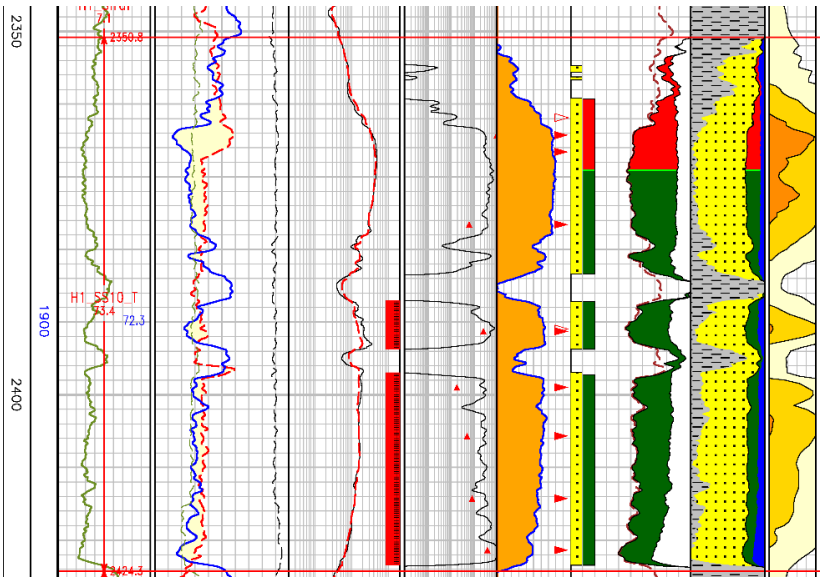

Figure 3. Well X H sand log showing GOC. Well was initially completed in oil below shale barrier (indicated in red).

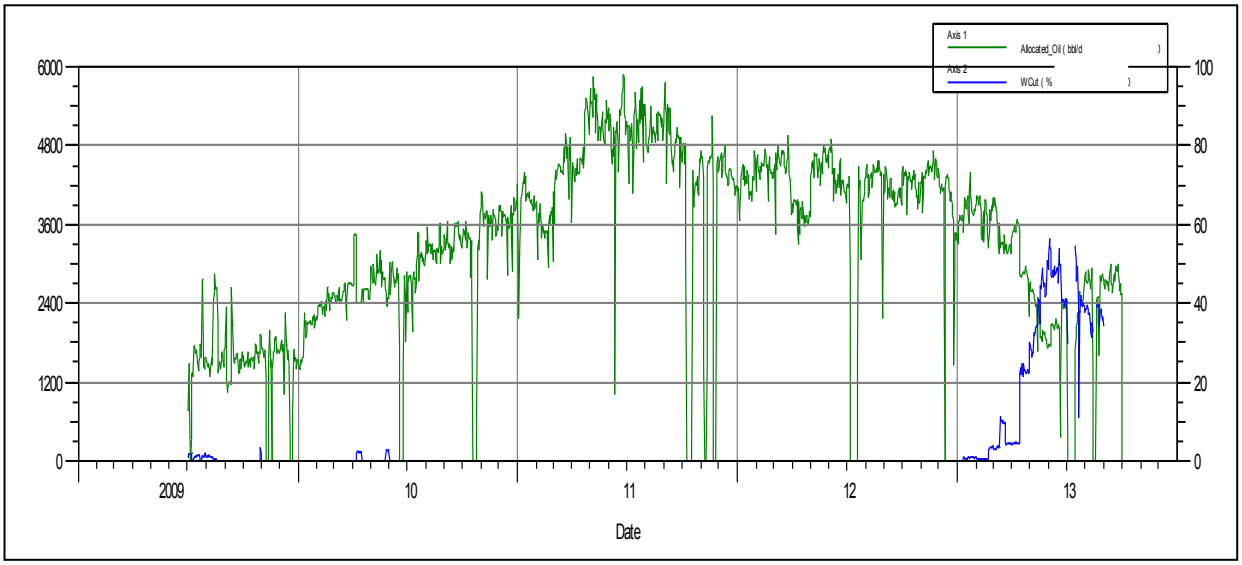

Figure 4. Well X production profile up to water breakthrough in 2013

Simulation studies using this model indicated that oil had been pushed up dip with the water injection, and that in the unperforated upper section of the H sand in Well X, the GOC was predicted to have moved up with full oil to top of sand (figure 5).

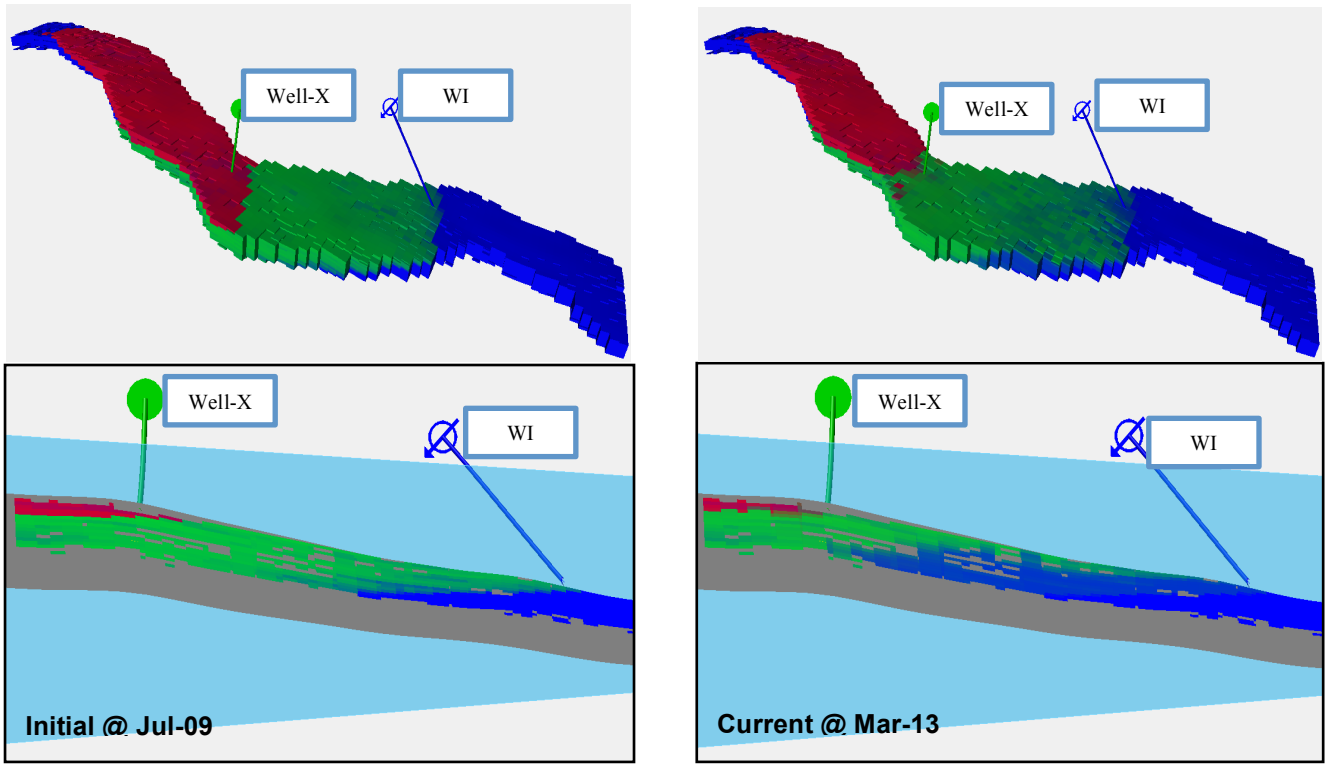

Figure 5. Simulation model showing predicted oil movement and full oil in upper H of Well-X

If the GOC had moved up, the simulation predicted that adding perforation to the upper section of the H sand in Well X would increase oil production by up to 1000 bopd, reduced WC by 10%, and increase EUR by 0.4 MMstb (Figure 6).

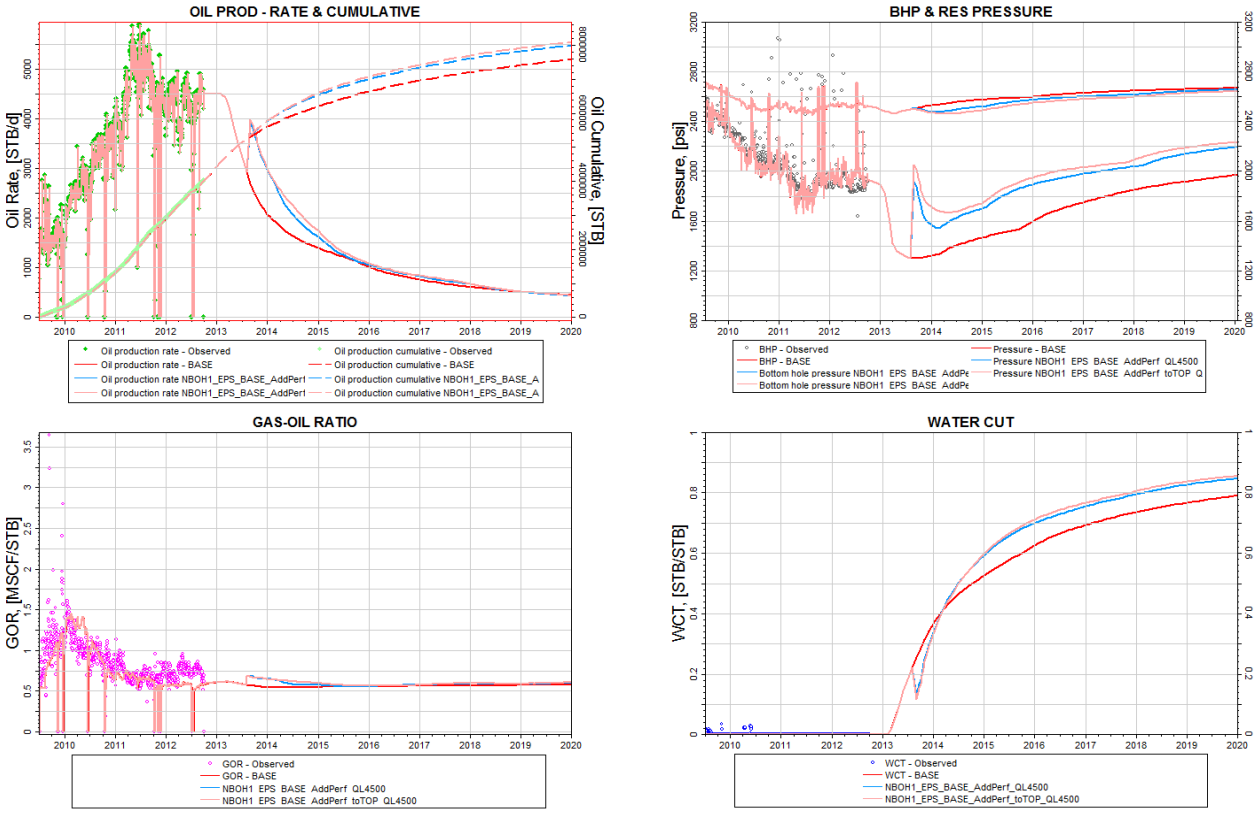

Figure 6. Well-X simulation history match and prediction. Comparing the base vs adding perf to upper H sand.

Process

To confirm if the Oil had moved up as predicted the following logging program was outlined.

1. Run the quad-detector neutron tool via E-line with wireline tractor and log thru tubing and casing
2. Cleanout trip to be performed prior to logging job.
3. Logging job to be completed over the selected interval in 2 passes to ensure repeatability of the data.

The logging job was conducted in August 2013 in a total time of 8.5 hours from rigup to rigdown of the downhole equipment. Due to significant time constraints and perforating equipment standing by on location data analysis was performed and delivered for decision within 2 hours after rigdown. The logging results are shown in figure 7.

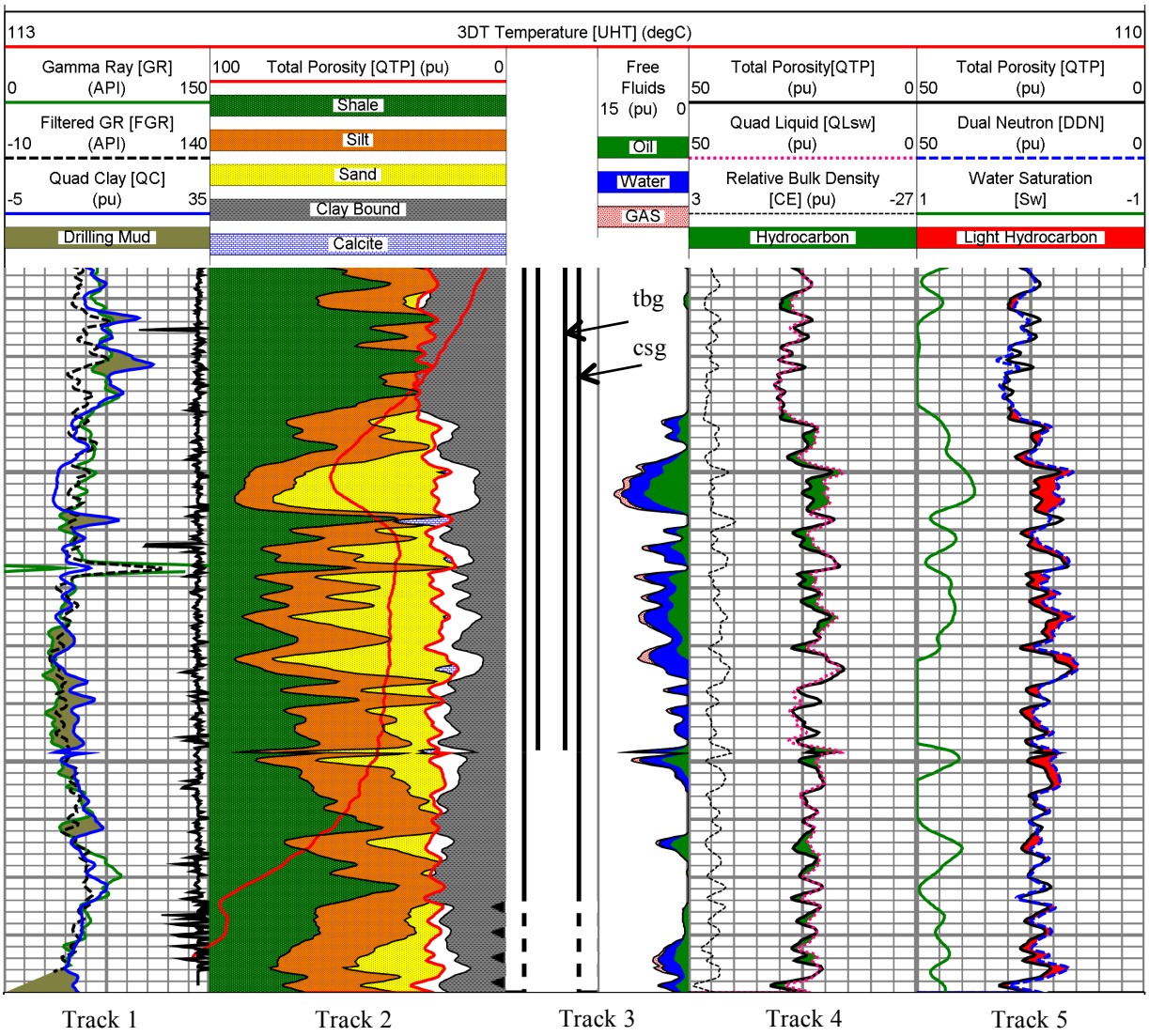

Figure 7. Logging digram over zone of interest in Well-X

Track 3 shows well tubulars on the left and the free fluids interpretation. Water saturation, Sw, is shown in track 5. The highest oil saturation in the logged interval was measured in the upper sand interval (shaded yellow in track 2). The data also indicated that the oil was light oil and that there was no gas cap.

Overall conclusion, as per the primary logging objective – No gas present, Oil moved up dip. Aside from measuring saturation, the quad-detector neutron technology also provided additional reservoir information, including permeability indicator, clay volume and relative bulk density. The permeability indicator is driven from two separate gamma ray readings, shown in track 1. Permeability is better when the two gamma rays are closer together and vice versa. Overlaid with the gamma ray curves is a Quad Clay curve. In clastics, this curve is sensitive to Aluminum volume and is a good indicator of Aluminosilicates found in clay minerals, hence the association with clay volume. In formations where gamma ray measurements are representative of shale volume, the overlay of the Quad Clay curve with gamma ray can identify areas of drilling mud invasion. In well X, minor amounts of drilling mud invasion were identified. In addition to mud invasion, the

overlay has application in identifying NORM (naturally occurring radioactive material) contamination. In well X there are indications of NORM occurring in the upper sand identified with the highest oil saturation (Quad Clay significantly lower than gamma ray). Support for NORM deposits comes from the temperature anomaly in the same sand unit. The temperature anomaly indicates fluid movement in the sand which can lead to NORM deposits on tubulars.

The relative bulk density curve is presented in track 4 in porosity units. Increasing relative porosity corresponds to decreasing bulk density and decreasing relative porosity corresponds to increasing bulk density. The measurement has good correlation to bulk density from open hole tools and has the benefit of being able to be done through multiple strings of pipe.

Results

The saturation log confirmed the simulation model's prediction, with clear indication of an increase in oil saturation to the top of the sand compared to original log above GOC (Figure 8)

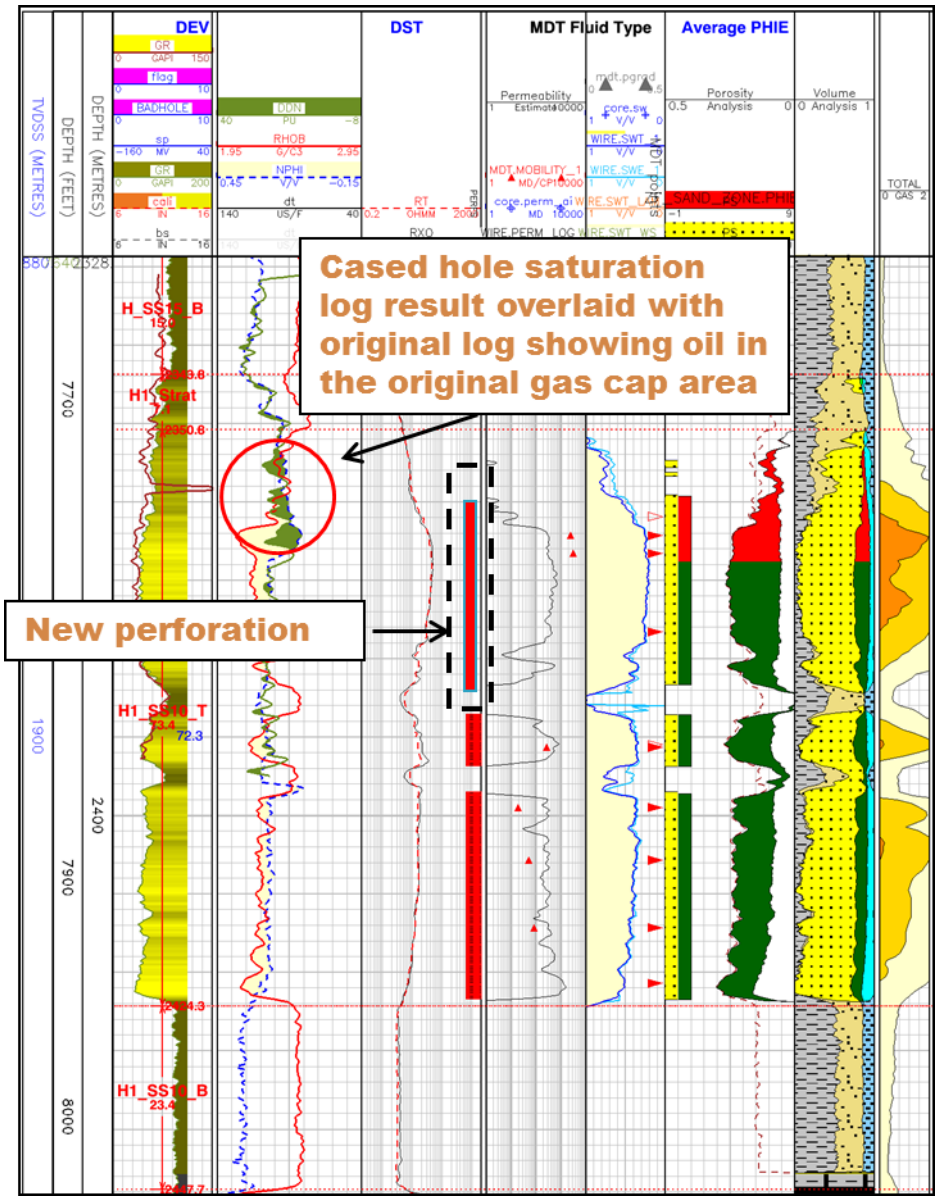

Figure 8. Well-X simulation saturation log result comparison and new perforation

The perforating job was conducted same day using wireline deployed perforating guns though the entire upper sand interval. Post-perforation the well was successfully tested at 3934 bopd (+1534 bopd incremental) and water cut was observed from shake-outs to drop from 40% to 26% (Figure 9). After a few weeks the oil rate dropped off to 3500 bopd and WC increased to 35%. No increase in GOR was observed and well productivity doubled.

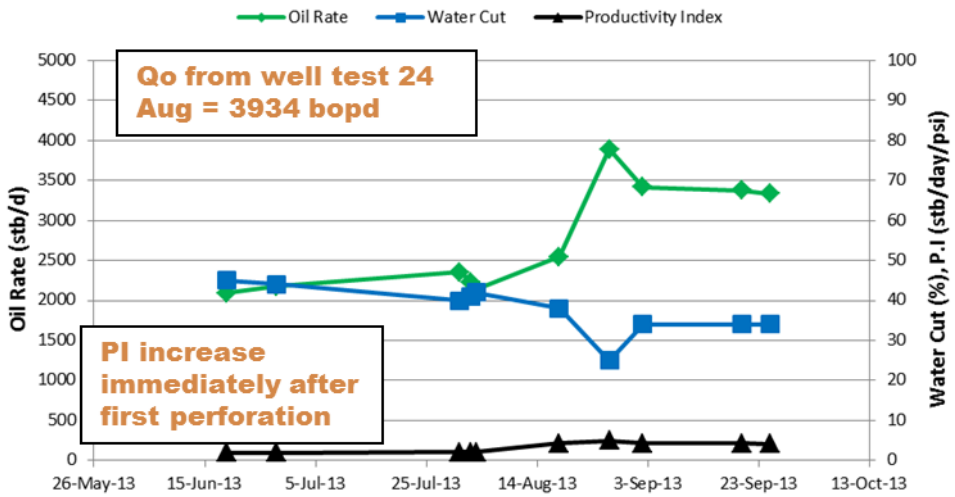

Figure 9. Pre and Post perforation of upper H sand Well-X well test results

Conclusions

The quad detector neutron technology matched reservoir simulation models and both were verified through perforating and production testing. The saturation measurement was successfully performed thru two strings of tubulars in a high angle well bore in a cost effective, efficient manner. In addition to this case study, the quad detector neutron technology was run on five other mature oil and gas wells for the same operator with successful identification of fluids behind pipe, validated by subsequent perforations and production. This case study supports the industries message that application of technology is the key to increasing oil production cost effectively.