An integrated approach to enhance the production from mature fields of Assam Arakan Basin through advanced cased hole logging and interventions – A case study.

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Abstract:
Most of the oil produced by the E&P companies comes from mature fields, where an annual production decline of 5-7% can be seen globally. Thus, enhancing or maintaining the production from such fields is the major challenge for the operators of these mature fields and Oil India Limited (OIL) is also facing the similar challenge in its mature fields from upper Assam region of India.

To arrest the decline and enhance the production from such fields, it needs induction of new technologies into the existing practices such as advanced cased hole logging, recompletion, stimulation & treatments, surveillance, optimization of artificial lift, in-fill drilling to tap the untapped hydrocarbon established through advanced reservoir simulations, drilling of injectors, polymer flooding, hydro-frac to improve the productivity.

This paper discusses an integrated and systematic approach to study a group of wells from mature field in a cost-effective manner by recording advanced cased hole logs, wherever necessary, then to come up with recommendations for enhanced production considering the limiting factors on case-to-case basis e.g. low reservoir pressure, artificial lift, sand ingression issues etc. The workflow discussed herein includes the process followed while in various stages of the study e.g. initial feasibility study based on available data, selecting the candidate wells, preparing the work program and it's execution, integrated study of these newly acquired well data along with vintage data to come up with the recommendations and then execution of well interventions based on the outcome of the study for enhanced production. It may be worth noting that upon application of the methodology developed, a considerable increase in oil production was achieved in a cost-effective manner.

Introduction:
In absence of major oil field discovery of late, the E&P companies have to largely depend upon the production from their existing fields and importantly from matured fields, for a major fraction of the production. Majority operators are facing many common issues while maintaining the production or arresting the decline from those mature fields and OIL is not an exception to that. Some of such issues are rise in water cut, low reservoir pressure, gas coning, completion integrity issues, sand ingression etc.

In this paper, it has been discussed how production from such matured fields can be optimized with the systematic approach by integration of the existing and newly acquired well data through cased hole logging technologies to better understand the reservoir performance and its remaining potential.

The study was initially carried out with a group of wells from two of the matured producing fields (FLD-1 & FLD-2) from Assam Arakan Basin, which were discovered by OIL more than 3 decades back. As the wells are on regular production for 15-30 years, the declining reservoir pressure and increase in water-cut are the very common factors affecting the optimum production along with other factors. Therefore, it was an effort to revisit the mature fields of the areas for better reservoir management and augmentation of production from these old wells.

The broader objectives of the study through representation this paper are: a) estimation of remaining HC saturation, b) identification of missed / bypassed hydrocarbon zone, c) determination of present fluid contact, d) diagnosing the production related issues and e) to come up with recommendations / remedial actions to be carried out to augment production.

A methodology and workflow have been developed during the study, based on which a considerable increase in oil production was achieved in a cost-effective manner through rig-less operations and interventions. Also, it may be worth mentioning here that this workflow methodology has now been implemented as a campaign for the other mature fields of OIL on large scale.

Methodology and workflow:
To maintain the production from wells placed in matured fields, different workover activities are carried out based on reservoir monitoring through production data, cased hole logs such as updated completion and cement integrity checks along with existing well data etc. It is essential while taking decisions of interventions such as reperforation, extension of perforation or zone transfer based on reservoir performance and remaining potential through detail production analysis using Production Logging (PL), present day saturation estimation along with updated OWC & GOC contacts. Also,

designing of artificial lifts optimization needs to be done time to time based on dynamic nature of the reservoir and well production behavior.

In order to maintain and enhance production from matured fields, the key measurements required to take proper decisions on the sick or non-producing wells are cased-hole saturation analysis, production logging, cement & tubular integrity checking measurements. Slim hole tools may be required to do that in rig-less wells.

Cased hole saturation analysis can be achieved using advanced Pulsed-Neutron reservoir monitoring logging instrument. The High Energy Neutron generator source placed on the tool body emits neutron which go through different types of interactions (i.e. elastic, inelastic, capture) in the formation while it travel through different mediums starting from the source then borehole fluid, casing, cement, formations and finally return back to multiple high efficiency gamma ray detectors placed on the tool. The detector energy spectrums are then recorded using very specific techniques and processed using dynamic response models pre-generated using well parameters. The processed output of 3-Detector Pulse Neutron (PNC-3D) tool finally provides vital information such as present-day oil and gas saturation in cased hole environment which may be useful to identify the updated OWC, GOC with production.

Production log analysis on the other hand helps to understand the phase-wise fluid contribution from one or multiple open perforation zones, identification of water source, channeling behind casing, plug leakage, casing leakage, crossflow, analyzing gas lift performance etc. Other important factors to be considered are checking the integrity of casing, tubing, cement behind casing etc. which may be analyzed with conventional or slim-hole tools as per the present completion design.

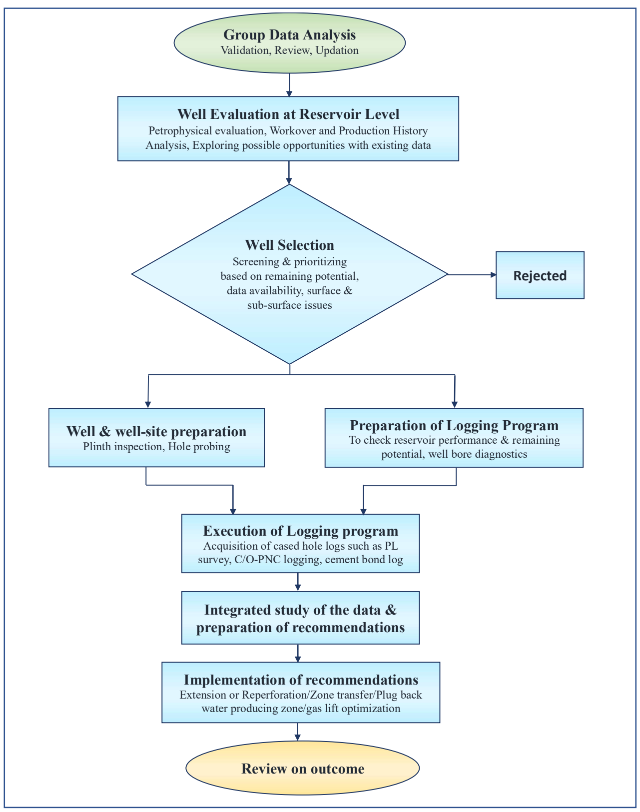


Fig.1: Workflow for Logging enabled production enhancement.

In the initial phase of the study, few sick and old wells from two of the matured fields (FLD-1 & FLD-2) of Upper Assam region were selected with one of the key objectives as production enhancement.

The workflow (Fig.1: Workflow for Logging enabled production enhancement) followed during the execution of this program of production enhancement is as described here along with two case studies where incerase in oil production was achieved.

To begin with, initial feasibility study was carried out through Group Data Analysis. The wells were categorised area-wise and all the available data pertaining to the identified wells were checked and validated together for data quality. The well logs and other data were also improved and updated wherever the author found necessary.

Well-wise evaluation at reservoir level for each of the initially identified wells where available data for each particular well e.g. basic and advanced open hole logs, petrophysical analysis, resevoir data sheet, well commentry, well workover history, production history etc. were analysed.

Based on that, the candidate wells were selected with priority as per expected remaining potential or chance of missed oppurtunity, if any, for further operations. Few wells were also rejected from study, which were identified with no potential left as all the hydrocarbon bearing reservoirs are exploited or further logging or interventions are not possible due to some typical well completion. Refer Fig.2 showcasing a snapshot how a group of initially selected wells from a particular field are being prioritized and analysed through execution of different logging and related jobs as per the work-program.

The process was followed for each group of wells from these fields. As the whole work program was planned to be executed through rig-less operation and interventions, therefore at multiple wells, the complete work-program could not be executed due to various surface and subsurface issues e.g. plinth not accessible, tool got held-up during hole probing or logging, completion related restriction, low pressure profile of well etc. With utmost efforts and attempts, the intended program coulde be executed in few wells where the required well data and logs could be recorded for further analysis of the wells.

Group-1										
Sl. No.	Well	Priority	Plinth Inspection	Hole Probing	Hole clearance (Dummy/GR/CCL)	Production Logging	CH Saturation Estimation	Cement Bond	Other Measurements	Final Report
1	ABM-10	1	✓	✓	✓	✓	✓	✓	-	✓
2	ABM-14	2	✓	✓	NA					
3	ABM-11	3	✓	NA						
4	ABM-03	4	✓	✓	✓	NA				
5	ABM-01	5	NA							
6	ABH-23	6	✓	✓	✓	NA				
7	ABH-29	7	✓	NA						
✓- Job Completed, NA - Not attempted as per work program, due to some surface or surface issues (e.g. plinth not accessible, held-up during hole probing, completion restriction etc.)										

Fig.2: Snapshot depicting a group well prioritization and execution of work-program.

Well-wise report was prepared with reccommendations for possible actions to be taken for production enhancement and optimization based on outcome of the integrated analysis. Significant enhancement of oil production was achieved upon excution of those actions. Two of those successful cases are discusssed here to understand the integrated process of analysis of those wells.

CASE-I : Well no. XYZ-83

The well XYZ-83 was drilled in 1982 in FLD-2 field to develop the potential of the reservoir block. During initial testing, the well-produced clean oil sluggishly at the rate of 20 m³/day through perforations in the range XX92-XX98 m. Historically the well has shown poor inflow in-spite of various workover operation carried out to enhance the production. Recently, the well was producing 16 m³/day oil with 3 m³/day water from existing perforations XX86-XX91m, XX89-XX95m & XX92-XX98m of Barail reservoir. The well was then revisited to acquire the Production log, cased hole saturation log and through-tubing cement bond logs in rig-less manner.

The recorded logs were processed & interpreted to understand the production behavior of the well and estimate the remaining hydrocarbon potential of the reservoirs. Combining the outcomes of these interpretation results, an integrated study was carried out to identify the actions to be taken for production optimization. A few of the key observations are as discussed below.

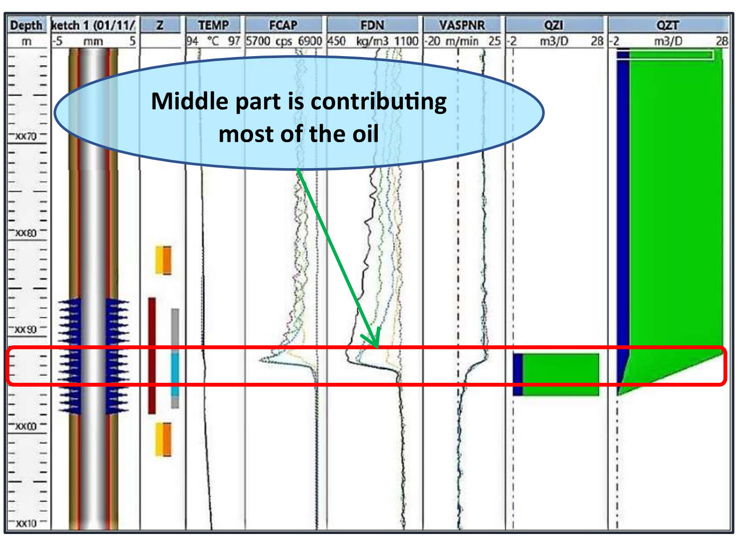


Fig.3: Production Log analysis of well XYZ-83

Production Log Analysis

- Based on spinner data it seems that the active zone is XX91-XX97m, however the main inflow is around XX92m.
- Significant drop in capacitance & density at this depth (XX92m) confirms hydrocarbon (oil) presence in the inflow fluid.
- No additional fluid contribution into the wellbore above XX90m that may be due to the blockage of the perforation tunnels.
- No free gas observed at downhole production.

Cased hole saturation analysis using C/O log

Average oil saturation is estimated about 25%.

Some oil saturation has been computed below the perforated zone that may be residual Oil present there which is still left in the reservoir due it's shalliness and lower vertical permeability at the bottom.
No significant free gas observed as per gas saturation estimation using three detector PNC logging in this zone.

Note : The effective porosity used for saturation analysis was estimated using the newly recorded porosity data measured by PNC-3D tool, which was corrected using an alorithm of normalization and shale correction.

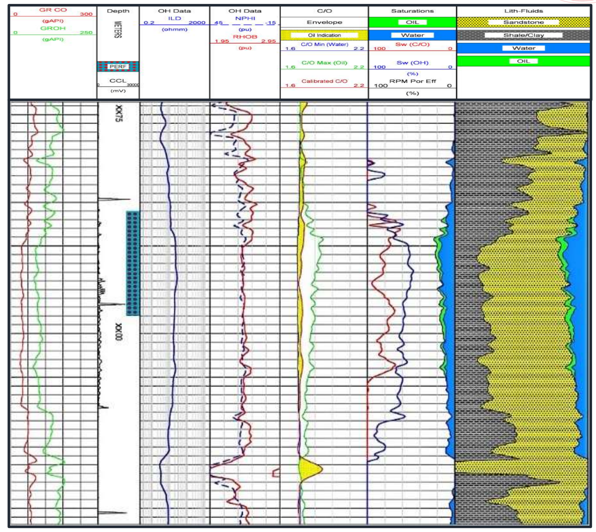


Fig.4: Cased hole oil saturation analysis using C/O log

Based on the detailed study, it was observed that only an interval of less than 2m of the existing perforations (i.e. at around XX91- XX92m) was actually contributing to the overall well production. No additional fluid contribution into the wellbore was noticed above XX90.0m which may be due to blockage of the perforation tunnels as present hydrocarbon saturation shows that oil is still present at top part of the sand. Therefore, it was recommended to re-perforate the existing non-producing top part of the sand interval i.e. XX86- XX90m using multiphase perforation system as it was also found that cement bond behind the casing is also very good as per the presently acquired through-tubing CBL-VDL log. Accordingly, the well was perforated using spiral gun in the recommended range. After perforation, fluid production from the well got enhanced to 25 m³/day oil with 3 m³/day water i.e. 56% increased oil production was achieved without any increase in water production. Also, few supplementary valuable information was also noted such as two additional thin sand layers was evaluated to be hydrocarbon bearing which might be a potential missed opportunity and one sand of 6m thickness which was initially interpreted as gas bearing, was evaluated to be oil bearing using this updated reservoir saturation log interpretation. These sands were appraised to be tested in a later phase of the well.

CASE-II : Well no. ABC-10

The well ABC-10 was drilled in the year 2002 in FLD-1 field as a development well and it was producing 60-70 m³/day clean oil during initial testing through perforations in the range XX05- XX10 m (Perf-A) & XX16.5- XX21.5 m (Perf-B). With gradual increase in water cut and declining tubing head pressure (THP) several activities were carried out, recompleted with Gas Lift Valves (GLVs). The well was producing 24 m³/day oil with 46 m³/day water with continuous gas lift when it was taken up for the study with primary objective to identify the water source and optimize production. Accordingly, production log (PL), cased hole saturation log and through tubing cement bond logs were acquired in a rig-less manner for production profiling and to know the present-day hydrocarbon saturation etc.

An integrated study was carried out using the processed and interpreted results of the acquired log data and few key observations were made, as mentioned below, which were quite helpful to understand the production behavior of the well and to prepare the recommendations for optimized production.

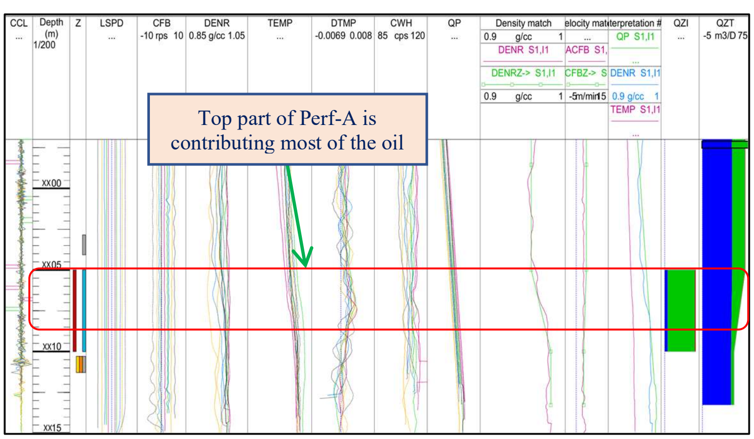


Fig.5: Production Log analysis of well ABC-10

It can be inferred from density and capacitance data that the top part of the perforation (Perf-A) is contributing most of the oil and bottom part is contributing mostly water. Another perforation at bottom (Perf-B) which could not be accessed due to hole restriction, is contributing most of the water as per the Production Log (PL) interpretation.
Due to low pressure regime of the reservoir and production using continuous gas injection through GLVs, the spinner deflection is not depicting the actual production within a particular period during logging.

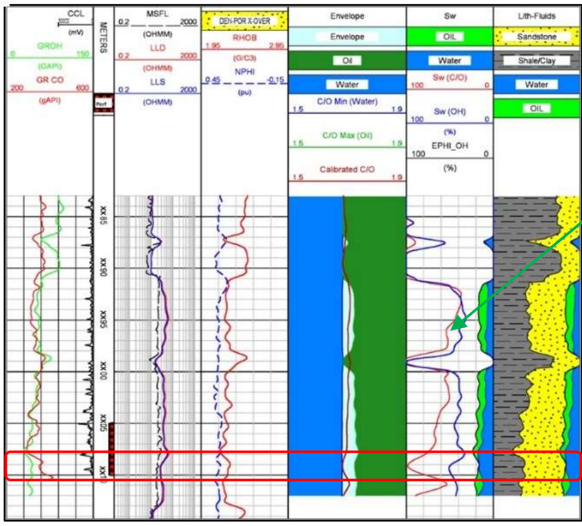
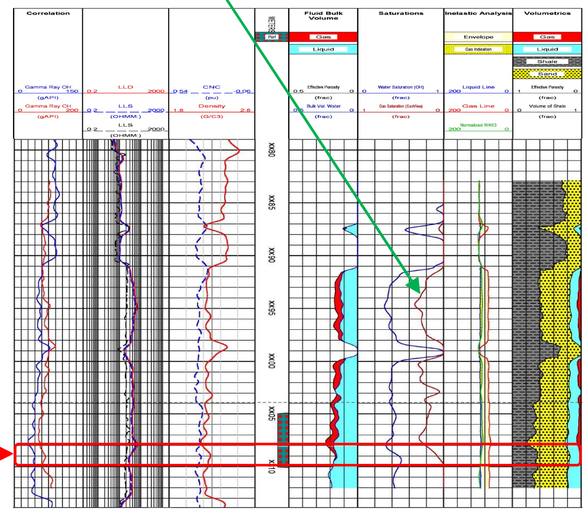


Fig.6: Cased hole oil saturation analysis using C/O log

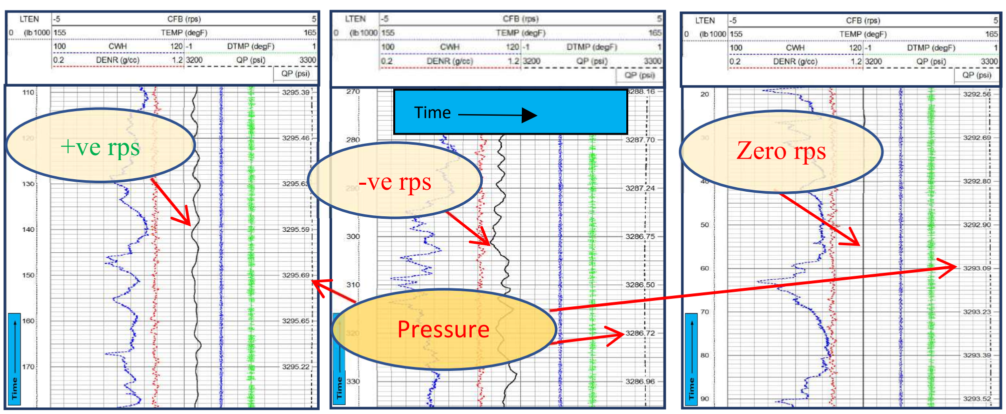
The section of reservoir above the perfoarted zone is still having intact hydrocarbon saturation w.r.t. initial saturation.



Combined oil and gas saturation suggests that the highlighted bottom part of the perforated zone i.e. XX08-XX10m is mostly watered out, whereas top part of the perforated zone is still saturated with 50-60% hydrocarbon.

Fig.7: Cased hole Gas saturation analysis using PNC-3D

Therefore, both the PL interpretation and saturation analysis compliments each other that the bottom part of the sand is watered out and the top part is having producible hydrocarbon and thus producing most of the oil with associated gas. On the other hand, despite the presence of hydrocarbon at the top part of the reservoir including the unperforated zone, the performance of the reservoir is limited by the present reservoir pressure which can be observed below Ref. Fig.-8.



Due to low reservoir pressure and prduction through gas lift these change in flow direction is also observed at some times in the **station passes** recorded at XX16m at different times, which is also supported by measured pressure data, which is effecting the production at surface

Fig.8: Varying RPS & Pressure data depicting low pressure profile of the well

In addition to that, it was also observed that the top-most GLV (at depth of around X50m) was operating as per all the passes recorded on multiple days while logging with PL (ref. Fig.9), whereas as per GLV design and well pressure profile second valve i.e. at around X70m should have operated. So, that is also causing inefficient lifting of the fluid from reservoir operating at such low pressure.

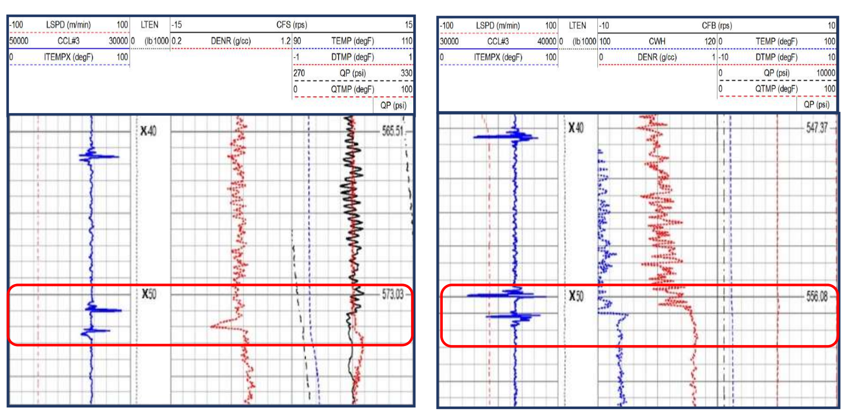


Fig.9: Top-most valve at around X50m was found to be operating in all the passes

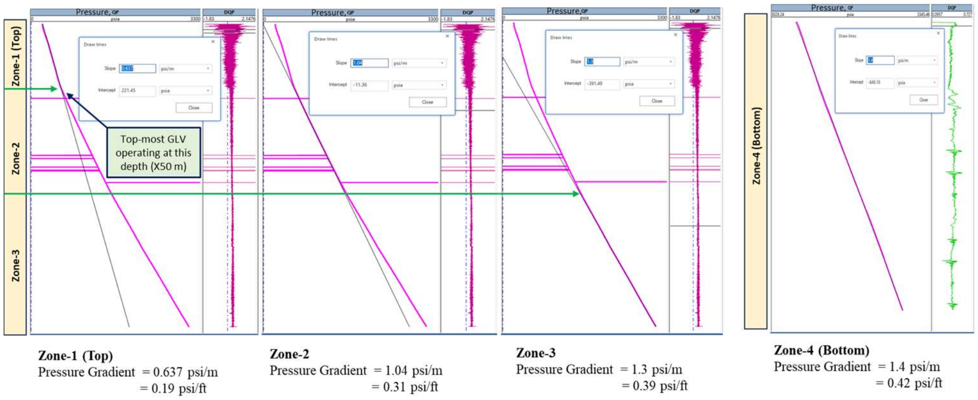


Fig.10: Suspected standing water column

Based on the estimated pressure gradient at different zones of the well, it was also suspected that there is a significant presence of standing water column (ref. Fig.10) which is again reducing the lifting efficiency due to low bottom hole pressure.

Therefore, integrating all the observations from these PL survey, cased hole saturation analysis and through tubing CBL-VDL measurements, it was found that despite the reservoir is having significant hydrocarbon potential left to be produced, the low-pressure profile of the reservoir and lifting related issues are causing subsided production. It was then recommended to optimize the Gas lift on priority basis to enhance the production along with other suggestions such as to plug-back the bottom zone, which is producing most of the water, extend the perforation etc. So, as per recommendations gas lift was optimized considering the sand ingression issue (which is another important factor for this region of the field) with increased volume of continuous gas injection through GLV to reduce the standing water column and increase the drawdown pressure which resulted into enhanced production of 38 m³/day oil with 67 m³/day water. Therefore, a gain of 58% incremental oil was achieved with some additional water production.

Conclusions:

Production logging has been instrumental to understand the well performance for multi-decade now, whereas the time-lapse cased hole saturation analysis is also in use for more than a decade. But to optimize and enhance the production from matured fields, an integrated study is much-needed to make effective decisions through advanced cased hole logging and interventions in a rig-less manner and a data driven cost-effective approach.

These case studies have been useful to showcase the importance of integrated logging and interpretation for a matured field. Multi-facets output from PL data analysis establishes the importance of regular PL logging to understand the capacity and limitations of the reservoir, source of produced water, section of potential non-producing but prospective zones, performance of the gas lift system, behind casing activity, integrity of the bottom plug, identification of standing water column etc. Time-lapse/cased hole saturation analysis is necessary to understand the remaining potential and while taking decisions e.g. re-perforation of the same zone, extension of the zone, zone transfer etc.

Execution of logging and well intervention work through concurrent operation using MAST unit was essential to reduce the overall operational cost of the Production Enhancement campaign thus making the campaign economically viable.

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