Utilization of Modern Technology Yields Potential Recovery of 936 Million BOE from Mature Fields Portfolio

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Abstract

This paper portrays the methodologies utilized to yield potential “barrier reserves” of 936 million BOE from an Operator’s mature fields’ portfolio.

The paper reviews the whole project in overview and will also go into detail for one particular asset to appraise readers of the pertinent details associated with how each particular methodology yielded the “barrier reserves” it did, including the economic value and risks associated with each mature field.

Introduction

There are many problems associated with mature (or “brown”) oil fields. Among them, oil production becomes expensive if increasing water and gas production has to be taken care of; oil productivity itself is decreasing year-on-year; they are expensive to maintain; expensive to decommission and expensive to remove from the sea-bed. Then there are the costs associated with cutting-up the steel onshore and its disposal thereof, before being scrapped / smelted. (Unless, of course, permission can be obtained from the appropriate government to topple the jacket and possibly the process facilities into the sea to form an artificial reef such as offshore to Brunei for example which has proven extremely successful, particularly from a sports [diving and line fishing] perspective.)

When oil prices drop as they have during the period 2014 – 2015, the value of the oil produced from these mature brown assets decreases to the point where large operators sell them to operators with a leaner infra-base cost structure. For example, in the North Sea, Shell sold many of its aging assets to both Talisman and Taqa and BP sold its Forties Field to Apache.

There comes a point at which decommissioning needs to be stayed through increasing production (by whatever means) if the oil price stays low. (High oil prices artificially keep otherwise expensive projects artificially afloat.)

How can, then, oil production be increased in order to maximise profitability particularly when oil prices are low? This paper shows how one major operator addressed this issue.

Finally, it is worth noting that even though existing mature / brown oil fields may be expensive from a maintenance perspective, nonetheless, since they exist, they have the advantage of not absorbing new CAPEX as would brand new wells or infrastructure. Thus, if existing wells could be side-tracked or worked-over, then the CAPEX cost of a barrel of oil would be much reduced, yielding decent profit – and delaying abandonment.
There is also the advantage that platforms can be tied-into with ever increasingly utilised sub-sea tie-back lines and their process facilities used prior to re-export as opposed to highly expensive sub-sea processing.

Background

Prior to the project, the vast majority of the Operators assets were classified as either “mature” or “very mature” prompting Asset Management and Senior Management to ask the question whether or not it would be possible to increase reserves and increase production (or at least delay the production decline curves).

The possibility of simply increasing reserves was not an easy question to answer; however, the term “barrier reserves” had been mooted for some time and so the term “barrier reserves” became the focus of the study.

In order to answer whether there were sizeable “barrier reserves” which might be produced, a specialised, independent team comprising production, reservoir, completion and drilling experts assembled to spend time with every asset to study the asset’s reservoir, production history, platform design, well design (both drilling and completion), well production profiles and export methodology etc.

The key reasoning for using an outside team was that they might see things which the Asset Team might not. (For example, the drilling expert had previously worked on a similar project in the Fahud Field of Oman for PDO, where the primary task was to increase oil from a near 50 year old field – which had been producing more water than oil for many, many years. The other experts had worked on a number of similar fields worldwide and had seen productivity improvements through the use of both relatively simple and quite complex technologies.) Thus their exposure to technologies which the client was not using was invaluable as was their way of “looking at things”.

There was also an air of creativity about the team; the group not only worked objectively and logically but were also able to work creatively, think laterally and, to use an often used term, “out of the box”, always asking “what if we did this”, “what if we did that” etc. Such creativity can often be highly
productive.

There was also a highly supportive and organised Operator “Support Team” to enable the outside specialist team to acquire all necessary data and information from each Asset’s archives, usually in the form of both hard-copy logs for example, as well as electronically. It was also possible to spend time with all members of the Asset team, including the Asset Manager, to secure highly detailed information, particularly the latest in current and future-time modelled reservoir data.

With the necessary data / information to hand, the analysis phase could then begin.

The Analysis Phase
For all assets, field data was extensively analyzed (the analysis work was all original as such a project had never been carried out before), ranging from revised seismic data and modelling, through to production profiling (and any anomalies), well / completion design and production problems. An expert computer filing system kept track of all potential production up-lift opportunities worthy of further study.

Thereafter, a very wide range of new technologies were studied to see which could benefit production up-lift from each field’s unique well / completion design and reservoir (whether oil, condensate or gas). Once compiled, “planned batch” campaigns were organized in the interests of cost-effectiveness in terms of service provider supply and minimized platform interference / shutdown.

Each expert reviewed his area of expertise in conjunction with his expert peers, particularly with respect to the latest in technology (to see if new technology might create improvement in terms of increasing “barrier reserves” and / or immediate production.

Following the analysis of each agreed topic it was essential to record, with absolute accuracy, how the data / information was collected (i.e. its source), interpolated (how and why), what the results / findings were, how potential improvements might be effected, the estimated cost of the improvements in both “barrier reserves” figures and productivity uplift, the risks associated with the improvements and the resultant nett value (in $) of the improvements.

In order to do this both systematically and accurately, a very comprehensive “intelligent” Excel spreadsheet was constructed to track all the data, all the work and all of the conclusions.

Understanding Reservoir Performance
This phase – i.e. understanding the reservoir – was crucial in understanding not just the reservoir itself but also in understanding the production history of the well – most importantly of course its oil production and any associated gas or water coning.
Examples of reservoir graphics are shown below:

**Example 1: Unswept Sandstone Targets**

![Figure 2: Salt Diaper Flank Reservoir Showing Unswept Sandstone Oil Targets: New Primary Targets (Pink Ellipses); Future Targets (Grey Ellipses) & Potential EOR Targets (Green Ellipses)](image)

The above reservoir schematic relates to a salt diaper flank reservoir whose “S”-shaped wells were difficult to drill, not least because of wellbore stability issues. However, the Asset had the advantage of two reservoirs – limestone and sandstone – one on top of the other – with an astounding 900 metres potential production thickness which translated into plenty of upside potential (despite fractures with the water column) as regards both re-drilling and stimulation.

The schematics below show the unswept limestone areas of the reservoir:

**Example 2: Unswept Limestone Targets**

![Figures 3 & 4: Salt Diaper Flank Reservoir Showing Unswept Limestone Oil Targets: New Primary Targets (Pink Ellipses); Future Targets (Grey Ellipses) & Potential EOR Targets (Green Ellipses)](image)
These unswept areas are prime targets for side-tracking watered-out wells, perhaps by pulling the completion with the well killed, setting a whipstock and milling a window in 9½” casing and drilling to the unswept / unproduced oil prior to running a liner and selectively perforating, for example. Drilling could also commence through a 7” liner with 3½” x 2½” drill-pipe. Alternatively, Shell have written a number of papers on Through Tubing Rotary Drilling, which means that the completion does not have to be pulled, saving a considerable amount of time. The main intent of course is to avoid the water content, which typically always increases over time (as oil pressure declines).

Production Profile
The schematic below, which relates to the above referenced reservoirs, clearly shows that, over an initial four year period, oil production was at a maximum, peaking at 70,000 BOPD particularly during years three and four. However, over the next two year period (years five and six), as depicted on the schematic, there was a 25% - 30% annualized decline in oil production during this time. As can be seen, there is a variety of Gas Lift and Water Injection wells, and frac'ing and re-perforating has been attempted to arrest production decline.

Of note, particularly, is the rapid rise in water cut during this period which is depicted in blue. The water rising (and heading straight for the perforations) due to it being at a higher pressure than the now (relatively) depleted oil column.

The marked drop in oil production in this reservoir coupled with, at the same time, the marked increase in water cut, suggests that remedial downhole works might clearly be beneficial and thus worthy of investigation in order to increase production. One example is portrayed in Figure 6.
Example 3: Oil Rim Remains due to Rising Aquifer

Such analysis was typically the first stage in the analysis phase, which typically led to the next, phase – the conceptual engineering phase.

Conceptual Engineering Phase
This phase of the study was, perhaps, the most challenging and yet the most interesting phase of the study.

It was challenging because the team had to be both logical and objective whilst at the same time being highly creative. It was also important for all of the team to understand the full suite of existing technology available to them for solutions provision as well as both existing and emerging modern technologies – and how, of course the technologies could solve the problems of dwindling production.

Various challenges to ideas were common, which is healthy given so many possible options, in order that the right solution be effected. Once the concept was agreed upon, the detailed engineering work could then begin.

Detailed Engineering Phase
The detailed engineering work required a very wide understanding of the existing wells (particularly the completions – both upper and lower), what required to be done to increase production and, where modern technology was utilized, a full understanding of that technology.

Calculations were carried out in detail, meetings were carried out in finer still detail and the appropriate, relevant expertise sought for advice and cross checks.

Once a particular solution had been determined, work began to see if it was possible to carry out the work in batches, the save time and money on rig-up costs, installation costs, platform shutdown costs, rig-down costs and contractual costs. There were many such derived “batch” projects.

From the Detailed Engineering Phase work, a number of campaigns were derived.
Looking at Risk
When carrying out any form of engineering, it is vitally important to always consider risk. In the first phase of this work, risk was looked at on a relatively high level – green, amber, yellow, red, as can be seen in Figure 7.

Once the opportunity passed into the next phase (i.e. Detailed Engineering) the risk would be studied in greater detail too.

Campaign Themes
The campaign themes which developed as a result of the detailed engineering phase are shown in the figure below. As can be seen, there are themes relating to water shut-off, through tubing rotary drilling, coiled tubing drilling, improvements in surface / process / production facilities, slimhole side-tracks, rig work-over, hydraulic work over, new wells, side-tracks, under- balanced drilling on land (safety case permitting), coiled tubing scale clean-out, re-perforating, fraccing and acidizing.

The expertise for these campaign themes comes largely from the major service contractors / suppliers of the industry; rarely does the expertise reside in-house. Thus, as soon as a campaign was identified, the appropriate experts became involved as to both feasibility and conceptual planning.
As can be seen from the campaign chart, above, the vast bulk of the work could be carried out within 5 years. Efficiency gains will be noted as each batch of equipment goes from platform to platform due to the crews becoming familiar not just with the equipment itself but also with the programs, methodologies, procedures and processes. There are also cost gains from major service companies when campaigns are carried out.

**Quick Wins**

One of the surprises which came out of this lengthy study (which took 6 months to complete) was the number of “Quick Wins” which began to emerge early on. (“Quick Wins” were defined as those workscopes which could produce extra oil quite quickly from certain wells. Their execution was not expensive, circa $25 per bbl extra oil produced. Whilst this may not seem much at todays prices of $55 - $60 per barrel, nonetheless a 100% profit margin at the wellhead is acceptable particularly since both the process and export equipment is readily available.)

The “Quick Wins” comprised 54.6 million boe from a total of 67 opportunities from the following operations:-

- Water shut-off (conventional)
- Gas shut-off, water shut-off through the use of coiled tubing
- Fraccing / acidizing through the use of coiled tubing
- Re-perforating through the use of coiled tubing
- Scale clean-out of production tubing through the use of coiled tubing
- New wells
- Side-tracking of existing wells with rig
- Work-over / Side-track with Hydraulic Workover Unit
- Through Tubing Rotary Drilling
- Improvements in Surface / Process / Production Equipment
One of the advantages of “Quick Wins” is that positive cash flow is generated quickly and without major capital investment such as is sometimes required by major campaigns. There are also the advantages of single jobs being able to be used as training for more complex campaigns.

**Overall Results**

Following the six-month long study several results emerged which took the study team, Asset Management and Senior Management a little by surprise. Perhaps the greatest surprise of all was the amount of oil still left in place (as determined by the latest reservoir modelling).

There was also distinct demarcations between costs of certain operations which meant that a number of “Quick Wins” could be targeted, thereby increasing oil production quite quickly.

The Operator was conservative as regards certain risks (e.g. associated with work-overs etc) and this conservatism had to be overcome before being able to add these figures to the overall figures.

At the “Results” stage the Operator wanted to know what percentage of opportunities were “Low Cost” as opposed to “Standard Cost’ and “High Cost”. This is portrayed in Figure 9 below which shows an abundance of opportunities available up to the $20 - $25 cost per BOE mark. Although this figure might seem quite high per other oilfields around the world, nevertheless, even at the current $50 - $55 oil price mark, there’s still a relatively healthy profit to be had. (Noting that there are also many opportunities available at $10 or less.)
Of the 936 million BOE potential assets determined by the study team from 336 opportunities from 24 assets, the Operator realized that, as typical drillers and producers, they needed to gain expertise in the Low Cost Reservoir Access Technologies such as those listed below (they being fully experienced in the non-LCRA technologies such as drilling):

- Coiled Tubing Drilling / Fracturing / Acidisation. In many respects the degree of success is closely correlated with the amount of input planning time and how far up the learning curve the Operator is. Generally, “Risk & Reward” appears to work well with the Service Providers.
- Coiled Tubing Underbalanced Drilling. This LCRA technology is relatively unproven offshore (except on the occasional jack-up) due to Safety Case constraints. However, it is very successful on land and so could be used on the Operator’s land wells.
- Through Tubing Rotary Drilling. This is complex and requires a great deal of engineering and operational planning.
- Hydraulic work-over drilling (e.g. Side-tracks). HWO Units are typically utilized whenever a rig is not available. Success requires careful planning and close co-ordination with the HWO Unit Contractor in advance of operations.
- Slimhole Side-tracks. This area of LCRA technology requires a very high degree of planning and operational co-ordination and expertise.

In general, LCRA success is achieved if planning is first and foremost (from both an engineering and operational perspective) and advice (and expertise) is sought from the service suppliers. If these things are carried out there is no reason why LCRA technology cannot be successful.
Conclusions

This project was a great success for the following reasons:

- 936 million BOE “barrier” reserves were uncovered, and it is believed that even more would be uncovered if the seismic data pertaining to older fields could be replaced with new data.
- The 936 million BOE “barrier” reserves are derived from 336 opportunities relating to 24 assets; in other words, each asset contained within the company’s portfolio had yield to give to the 936 million boe figure.
- The “Quick Wins” were not necessarily expected at the start of the project; however they were a welcome flip to the project since they could be carried out both quickly and cheaply.
- The “LCRA Low Cost Reservoir Access” results were also not expected (at least in such quantity) since more “traditional” solutions were thought to be the answer to reserves increases such as drilling (albeit complex drilling such as using whipstocks for side-tracking out of existing wells, horizontal drilling, multilateral drilling and slimhole drilling out of 7” liners using 2⅜” x 3½” PAC drill-pipe with 4¾” thrusters, motors and MWD for example). Simply, the relatively low number of drilling solutions can as something of a surprise.
- Given, then, that many of the required technologies were from areas not typically used by the Operator, investment would have to be made in training both office and offshore personnel in these areas. This proved good investment.
- In certain cases, i.e. for certain assets, the increase in “barrier reserves” associated with the assets meant a corresponding increase in value of the assets. Some were subsequently sold to other Operators who had, perhaps more expertise of LCRA Low Cost Reservoir Access technologies.
- Even though many of the technology areas were not immediately familiar to the Operators’ onshore and offshore teams, success was achieved through the positive inter-facing and training given by the service companies involved and through the spirit of openness by the Operator.
- Splitting the work up into campaigns proved both succesful and economic.

Nomenclature

- BOE: Barrels of Oil Equivalent
- LCRA: Low Cost Reservoir Access
- Barrier reserves: Those reserves which are not readily produced by conventional technology.