

## Uncertainty Reduction through Planning and Technology Integration:

### Optimizing field development by utilizing new technologies and real-time data to deal with field uncertainty

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## INNOVATION FEATURE

### Background

The Nong Yao field is geographically located in the southern part of the Gulf of Thailand in approximately 75 m of water. The field is operated by Mubadala Petroleum on behalf of the G11/48 block concessionaires, which include KrisEnergy and Palang Sophon Limited. Nong Yao recently commenced production following a successful development campaign, which included the drilling of some very challenging wells.

Subsurface wise, the Nong Yao field is made up of multilateral and multistory fluvial-tidal channel reservoirs with multiple separate pools; thin oil columns, many of them gas on oil on water. The structures are low relief structures and the reservoirs are shallow.

### Subsurface Development Challenges

At project sanction, the development team was still faced with a number of subsurface uncertainties associated with the Nong Yao field development, which had to be addressed prior to, or as part of the development. These uncertainties included but were not limited to the following

#### Subsurface:

- Shallow reservoirs with a high level of structural uncertainty particular due to shallow gas
- Sand development uncertainty both in distribution and connectivity.
- Fluid contacts and type – thin oil on water sands with unpenetrated Gas Water Contact (GWC) / Oil Water Contact (OWC).
- Pressure support uncertainty – size and strength of the aquifers were unknown.

#### Drilling:

- Well placement / landing which is critical for horizontal well placement.
- High deviations and dog legs which makes data gathering and running completions challenging.

### Subsurface Development Method

Conventional further appraisal drilling would have been required to reduce the range of subsurface uncertainties. However, due to the cost and the potential negative impact on project economics, the subsurface team adopted two key innovative methods;

1. Sequencing of wells and optimization of targets such that every well drilled is used to de-risk other wells in the campaign, and fine tuning targets on the fly.
2. Deployment of key new technologies to ensure the data required to support optimizations and decision making are acquired. Technologies deployed include:
  - i. “PeriScope Distance to Boundary LWD”, and “StethoScope Formation Pressure While Drilling” tool,
  - ii. “PowerDrive Archer High Build Rate RSS” tool, and
  - iii. GeoSphere with “EcoScope LWD Near Bit Triple Combo”.

## IMPACT AND VALUES

From a broader point of view, with the recent drop in oil prices just prior to execution of the subsurface development / wells program, it became even more imperative that a novel approach be adopted in resolving / reducing the subsurface uncertainties, and hence reducing overall project cost while increasing value not just to Mubadala Petroleum and its partners, but to Thailand as a whole.

The methodology mentioned above and application of the new technologies helped in achieving the following benefits;

- i. Appraise while drilling both in the static and dynamic sense helped in optimizing well

locations and led to the cancellation of multiple water injection wells, which were not required, leading to substantial savings in well costs and enabling the drilling of additional production wells.

- ii. Use of PeriScope Distance-to-Boundary LWD technology helped in geo-steering the well to ensure wells stayed in the reservoir sands, but additionally was also used to map the top and extent of structures, and in many cases leading to extension of horizontal sections; more developed volume and improved drainage area. (Figure 1)

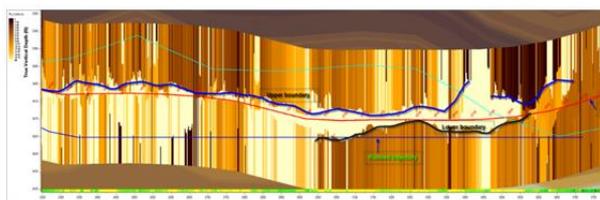


Figure 1: PeriScope Distance-to-Boundary LWD Technology used to Geosteer & Reduce Structural Uncertainty

- iii. Another key challenge was to land and steer horizontal wells with very challenging well profiles, in order to remain high in the sand, away from OWC. Mubadala Petroleum deployed the PowerDrive Archer High Build Rate RSS tool, delivering complex 3D well profiles while maintaining high ROP and wellbore quality. This fully rotating system builds high angles from any deviation in one run without requiring a trip out of the hole, increasing hydrocarbon production potential and reducing risk. (Figure 2)

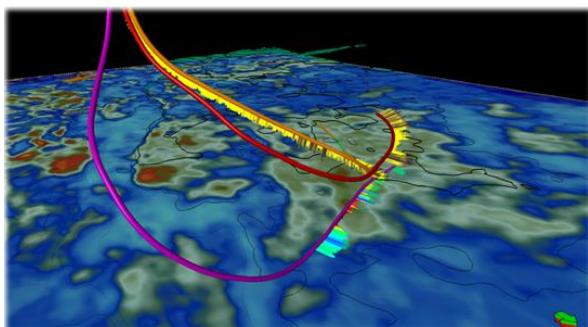


Figure 2: Complex 3D Well Trajectories, Targeting 3 Different Sand Bodies, drilled with PowerDrive Archer RSS

- iv. Application of GeoSphere with EcoScope LWD Near-Bit Triple Combo, the first use of this technology in Thailand and the region, gave greater than 40ft depth of investigation and helped in mapping the reservoir prior to entering it, supporting wells landing and placements. (Figure 3)

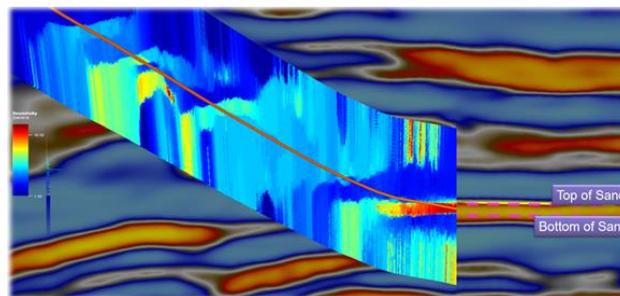


Figure 3: GeoSphere & EcoScope utilized for Well Landing, GeoSphere Inversion overlaid on Seismic

- v. The StethoScope tool was used in obtaining formation pressure while drilling for wells where wireline logging was not possible due to well inclination and doglegs. This was not only used to determine formation pressure and mobilities, but also to reduce uncertainty on fluid contacts, which greatly improved the planning and placement for later horizontal wells.

The clear value of these innovations was to lower the overall development cost and optimize well placement. With lower development costs, more reservoirs in the Gulf of Thailand can become viable to develop, which has a significant impact to Thailand's oil and gas Industry. The techniques that have been developed and employed can be extended to other developments in the Gulf of Thailand, which could unlock significant potential for additional local production, and reduce Thailand's dependence on oil imports.

*Note - the use of the tools provides better accuracy and optimizes the well while the impact is that more marginal oil pools can be developed with confidence.*

## WHY PROJECT SHOULD WIN THE AWARD

The Gulf of Thailand is a challenging development environment, with relatively short well life, complex seismic and compartmentalized reservoirs with thinner sands, meaning that development costs must be kept as low as possible to make more fields economically viable.

The Nong Yao development methodology provides a model strategy for how a development can be approached in order to reduce overall costs, in turn making more reservoirs viable to develop. In following this development philosophy, Mubadala Petroleum was able to successfully complete the Nong Yao subsurface well development campaign at ca. 25% lower cost and reach the expected peak rate

of 10,000 BOPD with overall less wells, while developing additional resources.

The value and impact to Thailand's oil and gas industry is significant, as it has the potential to unlock more reservoirs in the Gulf of Thailand for development in the current cost pressure and oil price environment.