Paper ID 2004589

Effective Completion Strategy and Problem Diagnosis through Integration of Advanced Production Logging System (FSI) in Highly Deviated and Horizontal Wells

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Abstract

Resolving complex borehole flow profile using production logging tools has always been a challenging task especially in highly deviated and horizontal wells. With the advent of advanced technologies for horizontal drilling and well placements in thin heterogeneous reservoir sections, complexities have further increased. FSI* (FloScan Imager) tool has been recognized as the state of the art advanced production logging tool which is specifically designed to provide solutions for highly deviated and horizontal wells with complex flow regimes and diagnose well problems.

Production profiling across drain holes helps understanding the performance of the layers and compartments. It was observed that well trajectory and undulation has a direct impact on the deliverability of reservoir compartments. A trajectory going down dip reduces the chances of gas cusping, however leads to inactivity or lesser production from the toe area. Possible debris or sand blocking renders sand face of down-hill toe section affected. While on the other hand, trajectories drilled with a consistent path or drilled up-hill provide a better environment for uniform contribution and deliverability. This analysis further led to recommended drilling by optimum length of the wellbore trajectory in order to minimize the drilling cost and improve lateral performance. Segmentation of reservoir sections by advanced horizontal well completions like Sliding sleeves and Inflow control devices was recommended for optimally control fluid inflow especially in high water cut scenarios.

The advanced FSI* hold-up sensors and array of minispinners helped in the wellbore scanning and mapping the complex wellbore flow regimes like recirculation in highly deviated wells whereby layer potential could be assessed and further stimulation and workover planning could be done. Furthermore, effect of dominant layers in multi layered reservoirs was also analyzed and it was concluded that dominant layers tend to subdue the production from depleted reservoirs. Selective completion of depleted layers avoids dominance of other layers and improves the layer productivity.

These reservoir studies were done based on availability of information in few wells completed in similar platforms, completions and reservoirs. Acquiring more database of production profiling in number of wells within same platform would further consolidate the same. This paper illustrates how advanced production logging FSI* service helped in abovementioned analysis with several examples from Mumbai Offshore.

Introduction

Field description

The Mumbai High Field is about 160 km North West off the Mumbai City and is the biggest oilfield in western offshore India (Ref to figure-1), with an aerial extent of 1200 sq km.

The Mumbai High Field is a multi-layered limestone reservoir with large variations in fluid flow properties both vertically and laterally, produces about 250k bopd (~40% of India's oil production). In terms of reservoir heterogeneity The Mumbai high field started producing in 1976 and a pressure maintenance scheme using water injection was started in 1984, since there was unexpected and sharp pressure drop with initial production.

The field is currently in decline phase with problems like increase in water cut and high GOR which are affecting the oil production the average field produces about 220,000 bbls of oil per day. Mumbai High field is separated by a Graben area into Mumbai high north and Mumbai high south.
Mumbai high north is basically the western flank of the anticline trending SE-NW direction dipping gently towards North West. Mumbai high south is western flank of the anticline structural dipping towards the west and south. Several oil and gas zones have been identified in this field, LIII being the most prolific with 90% hydrocarbon accumulations. The reservoir is essentially composed of limestone layers separated by the thin shale sections. The shale section divides the L-III reservoir into no of zones which are termed as A1, A2, B, C, D and E. Several thin shale sections further sub-divide A2 into seven sub layers. Both the fields are supported by partial water drive from western side extending from north to south. In order to maintain peripheral water injection was started. However the benefit accrued on by the peripheral water injection was insignificant. Therefore two rows of water injection were installed in central part of the field.

Advancements in Production Logging Measurements

Production logging has been used for decades to diagnose existing wells and plan better strategy for future wells in India like other parts of world. These activities and needs has not changed with time, however logging environment has become much more challenging. Flow regimes and characteristics in highly deviated and horizontal wells are very different and complicated from those of vertical wells. Accurately understanding the multiphase flow behavior in such conditions was the main concern for oil companies. Various factors like differential depletion, fluid stratification, misting, segregation, recirculation of heavier phase, changes in wellbore trajectory and drain hole length influence and complicate flow regimes. Moreover, these factors directly impact the production performance of the wells both in short and long term.

With the limitations of conventional production logging sensors at highly deviated and horizontal wells, FSI*, an advanced production logging system was designed to address the production logging problems in these difficult logging environments. Multiple sensors (5 mini-spinners, 6 E-probes and 6 O-probes) in FSI* and their position along the wellbore vertical diameter proved to be working very well in such conditions. It measures the velocity variation across the wellbore cross section occurring due to slippage of fluid phases and undulations in wellbore trajectories which was not possible with single spinner. It also gives direct measurement of Gas velocity and detects water recirculation, thus a complete velocity profiling. Together, E-probes and O-probes measurement provides full three-phase hold-up profile across the entire cross section.

Once the downhole flow dynamics have been accurately interpreted, to understand the reservoir performance and make better decisions not only for existing wells but also for future wells becomes the next target. To pursue this interest of oil companies, integration of other measurements like MDT data and petrophysical evaluations etc. with FSI results becomes inevitable. Forthcoming section illustrates various case studies where an integrated approach was adopted to understand the key parameters for production and completion optimization in highly deviated and horizontal wells.

Case Study-1: Identification of Root Cause of Layer Dominance and Proposed Completion Strategy Based on FSI* and MDT Integration

RS platforms were commissioned as part of ONGC initiative to increase production from Mumbai Offshore. Several highly deviated and horizontal wells were drilled and put on production from these layers. Wells of RS platforms are mainly completed in A2-VII and B layers. On the platform RS15, FSI* survey was carried out in three highly deviated wells: RS15-9, RS15-11 and RS15-4H (Figure-2). RS15-9 and RS15-11 are completed in A2-VII and B layers and RS15-4H is completed in B, C, and D layers. On analyzing the FSI* data, it was revealed that B layer was not contributing to the well production in wells RS15-9 and RS15-11 (Figure-3), whereas B layer had a good contribution to the production of RS15-4H well (Figure-4)

Further investigation was done with the help of MDT pressure measurements and a significant pressure difference (more than 200 psi) and mobility contrast between A2-VII and B layers was observed. It was concluded that higher pressure and higher mobility of A2-VII layer dominating over B-layer and thus not allowing it to produce. (Figure-5)

In well RS15-4H where Layer A2-VII is not perforated, Layer-B is completed with C and D; Results revealed that B was producing to its potential in this well.

Following conclusions were drawn of this study:

1. Dominating layer (A2-VII) subdued the production from other layers.
2. Commingled production of two layers, A2-VII and B was not a good decision especially after years of production and observed differential depletion.
3. Instead of commingling two layers, lower pressure layer (Layer B) could be opened first. Once depleted, layer at higher pressure (Layer A2-VII) could be opened for production.
4. Dual completion was proposed to be a solution for simultaneous production from both layers.

Case Study-2: Wellbore Diagnosis and Multi-well Analysis for Enhancing Well Production by Minimizing Recirculation Effect

A multi-well production logging campaign with advanced FSI* tool was done for wells in RS-12 and RS-16 platform namely; RS-12-10, RS-12-11, RS-16-5z and RS-16-1. High water cut (~80%) was observed to be one of the common production problems in all these wells with high deviation. Most of the wells were completed with 7" liners across reservoir zones except well RS-16-5z where 5" liner was used. The wells were completed for commingled production in multiple sub layers of L-III reservoir. Multi-spinner response of FSI* showed water recirculation at heavier extent across producing zones in all the wells resulting to productivity reduction. Production profile of one of the wells RS-12-10 is shown in (Figure-6).

A comparative analysis was carried out between all four wells in terms of completion size, well deviation, production rates, static pressures at each layer and cumulative productivity indices (PI) as illustrated in Table-1. It was observed that the effect of recirculation on overall PI of well RS-16-5z however deviated but with smaller completion size (5" liner) was minimal as compared to rest of the wells. The PI for RS-16-5z was observed to be around 2.2 bbl/d/psi as opposed to ~0.5 for RS-16-1, ~1.4 bbl/d/psi for RS-12-11 and ~1.1 bbl/d/psi for RS-12-10. One of the noticeable observations was lower permeability and lower static pressure for layer A2-VI in which well RS-16-5z was completed as compared to other layers but still leading to a higher productivity from the well (Table-1).

Following conclusions were drawn with this study:

1. Three major factors which cause recirculation to occur:
    a. Low flow rate
    b. High deviation
    c. Completion size
2. Depleting reservoirs require smaller size completions in order to optimize productivity and reduce down chances of recirculation.
3. As seen in the well RS-16-5Z with 5" liner, productivity was much better than other wells with 7" liner since minimal recirculation is observed in this well.
4. Completion strategy based on reservoir performance analysis and gas lift optimization is essential to minimize effect of recirculation in the brown field development scenario.

Case Study-3: Horizontal Well Productivity Analysis and Trajectory/Drain Hole Length Optimization

As part of production logging campaign in Mumbai Offshore, a number of horizontal and near horizontal wells were picked up to understand performance of the laterals in terms of well placement, productivity and drain hole length optimization purposes. The study was extended both in the North and South areas of Mumbai High field and was focused specifically on wellbore behavior as number of wells under study and available information were limited with well locations spread at random places in the field.

Horizontal wells are generally drilled in order to reduce water and gas coning because of reduced drawdown in the reservoir for a given production rate, thereby reducing the remedial work required in the future and hence increase production rate because of the greater wellbore length exposed to the pay zone. Generally, highest drawdown is observed at heal part of the well as compared to toe due to lowest flowing pressure in the horizontal section and hence greater production (Figure-7). Although, well placement is generally done with very high precision and accuracy across the pay zones but changes in the bit direction and minor undulations developed in wellbore cannot be ruled out. A direct relation between changing trajectory, undulations in the wellbore flow structure and performance was observed in horizontal wells completed either in open drain hole, slotted liners or tubing with sliding sleeves.

Production logging by FSI* in five wells namely; N-20-5H, N-14-7ZH, N18-2H, RS17-6H and WI6-I1-ZH was carried out in order to scan the horizontal well bore section and determine phase wise compartmental contributions across the drain hole length (Table-2). All the wells were drilled with WMB. Well N-20-5H was completed in LIIB-a,b layer with slotted liner and N-14-7ZH was completed in A2-V, LIII layer with blind and perforated tubing sections. Both wells were horizontal (~90-91 deg) down dipping and total drain hole length was around ~500m. As shown in Figure-8, production from various compartments were determined with the help of FSI* multi spinner measurement which revealed that the amount of fluid entering from toe sections of both the wells was much lower or almost insignificant as compared to heal or shallower part.

Remaining three wells i.e. N18-2H, WI6-I1-ZH and RS17-6H were drilled in the same reservoir zone A1-LIII and deviation around 90 deg. The trajectory profile of these wells was observed to be much more consistent except N18-2H which was updipping towards toe side. FSI* data analysis revealed that all compartments in these wells contributed uniform production as opposed to previous case (Figure-9). The most probable reason for such kind of response was minimal change in wellbore pressure in a consistent horizontal trajectory or minor increase in pressure in updipping well while moving from toe to heal resulting to a consistent or uniform drawdown and hence uniform production profile. Occasional undulations caused water to settle down at saggy areas of the well which did not have any major implications on the production or flow behavior.

Following points were drawn with this study:

1. Well trajectory when down dip reduces the chances of gas cusping, however this leads to inactivity of lesser production from toe area of well (N-14-7ZH, N-20-5H).
2. In such cases with longer drain holes, part of the length does not contribute to effective production. Hence, minimizing the length can keep up with optimized production with reduction of associated drilling and completion costs.
3. Up dip or consistent horizontal trajectory generally leads to uniform contribution across drain hole (WI6-I1-ZH, N-18-2H, RS17-6H).
4. Segmentation by sliding sleeves/ICDs for optimally control the flow from compartmentalized reservoir sections.

Conclusions

- Key to brown field development lies in the proper reservoir and production analysis based on well wise log measurements and field wide production/injection practices.
- Understanding differential depletion in a commingled multi reservoir system provides a better picture of future completion strategy so that production conformance could be achieved from all the reservoirs.
- Water recirculation is one of the most common and complex problems in wells of Mumbai Offshore where productivity is low due to high water cut and suboptimal reservoir pressure. Smaller completions with effective gas lift installations have proved to be improving productivity of the well.
- Optimization of drain hole length and trajectory is the key for effective reservoir drainage. Minimizing the lengths at wells of deviation around 89-90 deg avoids additional drilling costs for the sections which apparently do not contribute to the overall production.
- Most of the analysis was carried out in wells drilled with Water Based Mud as per available data, hence effect of Oil Based Mud on drain hole performance could not be done.
- It was advise to complete campaign wise production logging with FSI* in atleast four horizontal wells within same platform, same layer and spread across different azimuths which could consolidate the horizontal well study.

References

SPE 36560, Stratified Flow Model and Interpretation in Horizontal Wells, B.E. Theron and T. Unwin, Schlumberger Cambridge Research

SPE 36193, Characterization of a Complex Carbonate Reservoir: A Case Study from a Western Offshore Field of India, Suryanaravana K. and Lahiri G.-Schlumberger Wireline Research Center, New Delhi, India

SPE 64461, Development Strategy and Reservoir Management of a Multilayered Giant Offshore Carbonate Field, R D Tewari, SPE, VAMSR Mohan Rao, SPE and A V Raju, SPE, ONGC, India

Prakash .S, Agrawal .V, Govil .A, Bhide .M, Prakash .R, Kumar .R, Mohanta .S "Operational and Interpretation challenged in Horizontal well Production Logging: Examples from Panna Field, Western Offshore, India", Petrophysics, Vol 49, NO.3(June 2008) p. 271-284; 9 figures.

Figures

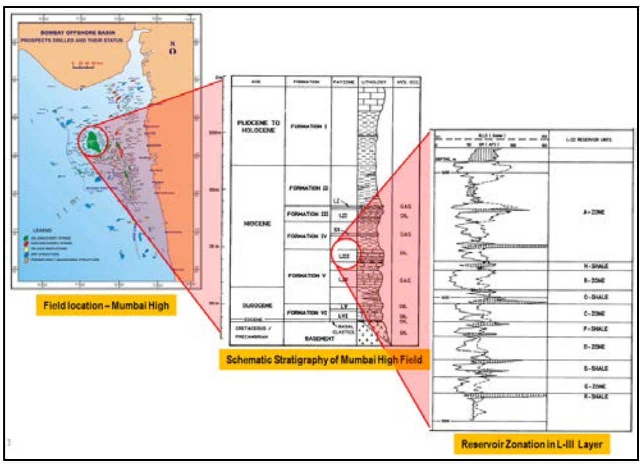

Figure 1: Western Offshore India, Mumbai High Field and Stratigraphy

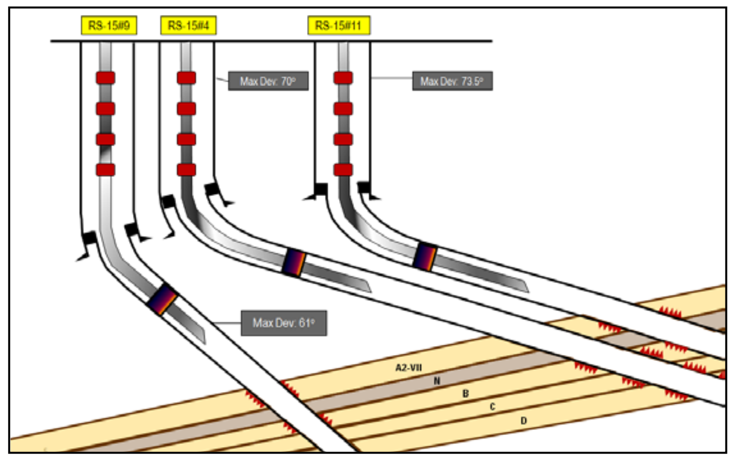

Figure 2: Completion Sketch of Wells in RS-15 Platform

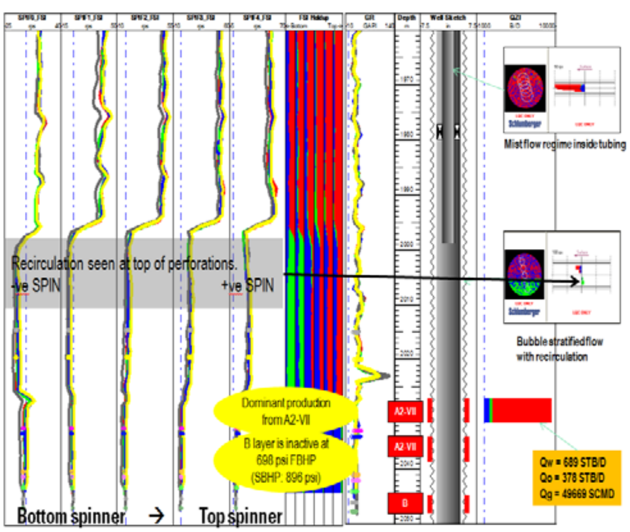

Figure 3: FSI* Production Log Profile of RS-15#9 Showing the Dominance of Layer A2-VII and Inactivity of Layer B

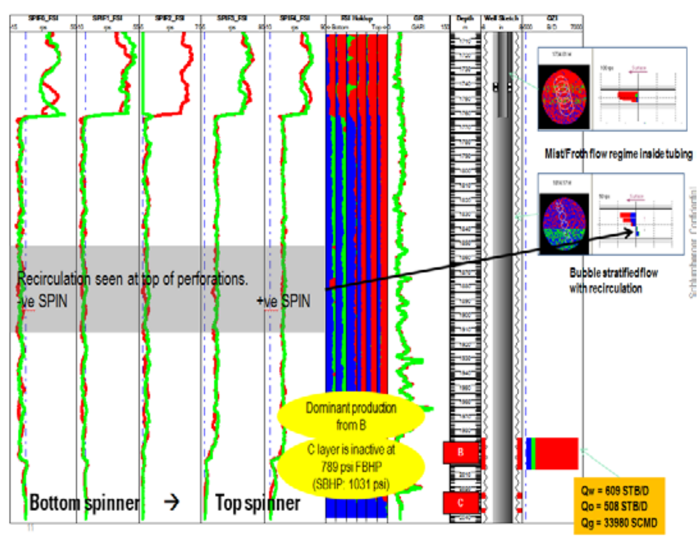

Figure 4: FSI* Production Log Profile of RS-15#4H Showing the Dominance of Layer B in Absence of Layer A2-VII

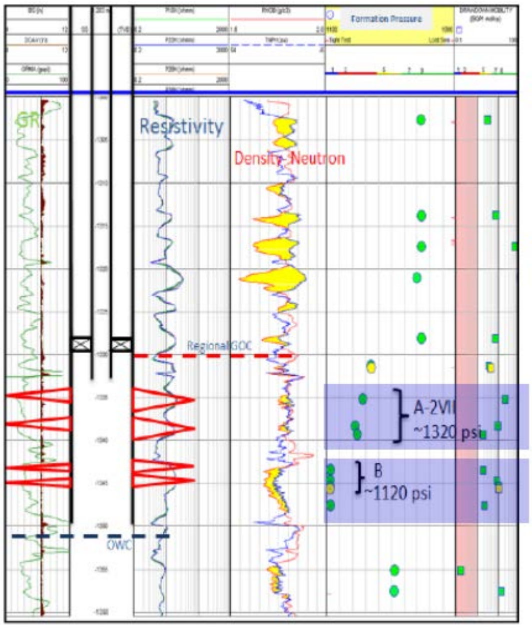

Figure 5: Differential Pressure Observed between A2-VII and B suggesting the reason for dominance of Layer A2-VII over B

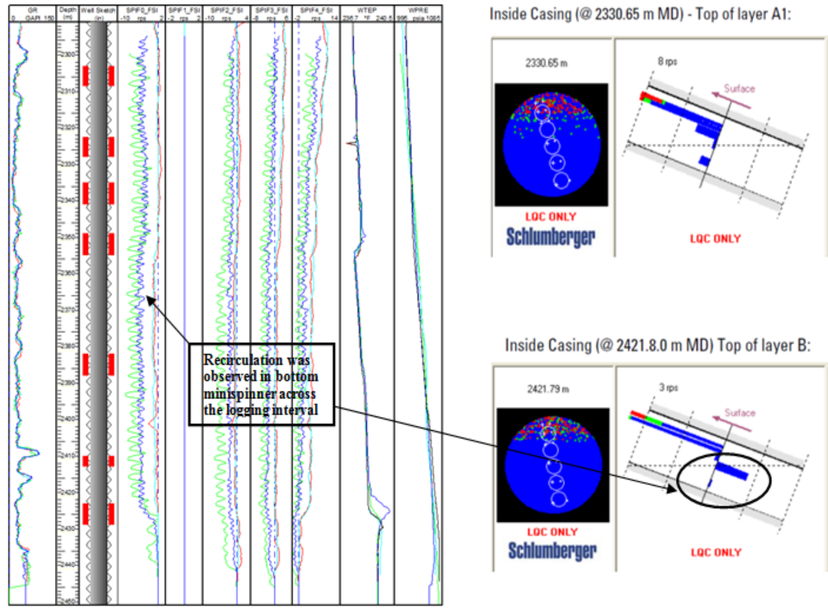

Figure 6: FSI* Spinner response and Monitor Box Suggested Heavy Recirculation of Water in Well RS-12-10

Well	Layers	Completion Type	Deviation	Liquid Rate (WC%)	Pressure	Pwf	PI (bbl/d/psi)	Effect of Recirculation
RS-16-5Z	A2-VI, A2-VII and B	5" Casing Liner	72°	1126 bbl/d (79%)	**A2-VI:** 1250psi	813psi	~2.22	Minimal
RS-16-1	A2-VII and B	7" Casing liner	76°	903 bbl/d (82%)	**A2-VII:** 1785psi	723psi	~0.50	Heavy
RS-12-11	A1, A2-III, A2-VI and A2-VII	7" Casing liner	74.4°	1265 bbl/d (83%)	**A1:** 1930psi **A2-III:** 1920psi **A2-VII:** 1620psi	**A1:** 937psi **A2-III:** 956psi **A2-VII:** 975psi	**A1:** ~0.49 **A2-III:** ~0.44 **A2-VII:** ~0.49	Heavy
RS-12-10	A1, A2-I, A2-II, A2-III, A2-VI, N and B	7" Casing liner	69°	2102 bbl/d (86%)	**A2-III:** 1780psi **B:** 1740psi	**A2-III:** 1036psi **B:** 1069psi	**A2-III:** ~1.03 **B:** ~0.11	Heavy

Table 1: Comparative analysis of RS wells in terms of effect of water recirculation on PI of each well

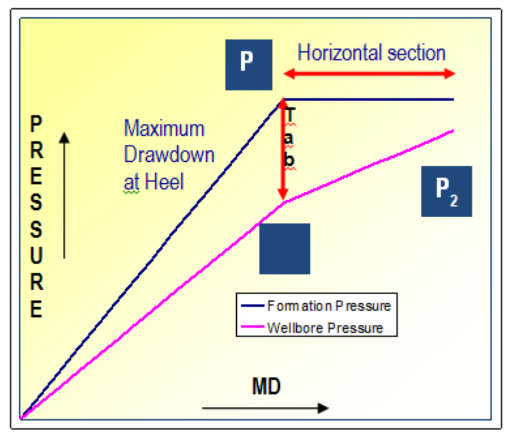

Figure 7: Pressure changes across a horizontal drain-hole suggesting maximum drawdown at heal

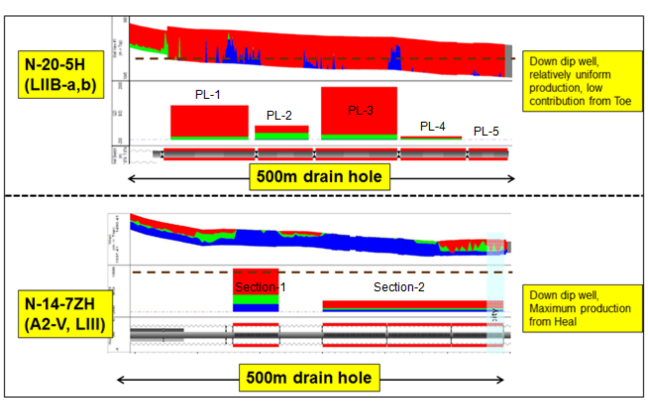

Figure 8: Drain hole flow profile of two wells showing major production from shallow/heal part of the well

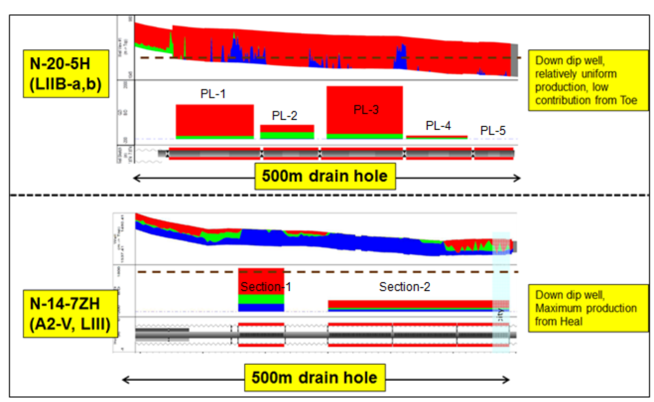

Figure 9: Uniform production contribution from all the compartments in all the wells completed within same layer due to consistent or slightly updipping trajectory