Analysing Flowing Bottom Hole Pressure data to estimate zonal contribution from multi-zone completions – a case study from Santhal Field, India

Pranav Kumar Mishra[1], Amit Chauhan
[1]Email: mishra_pranavkumar@ongc.co.in, Oil and Natural Gas Corporation Limited

Abstract

In multi-zone completions, estimation of layer-wise contribution has always been challenging in situations where layers are producing under different drive mechanisms/EOR techniques. In cases where an EOR technique has been applied in one zone, and the remaining zone(s) have been left to produce with their existing mechanism, monitoring of FBHP can prove to be a key in estimating zone-wise oil contribution.

The paper presents one such case from Santhal Field, India, a heavy oil field producing under water drive, wherein thermal EOR (In-situ Combustion) was applied in one zone, and the remaining two zones were left to produce with their existing mechanism. It gave rise to complications in wells with multi-zone completions. It was observed that the non-EOR layers, ie. the two layers where In-situ Combustion was not applied, were sub-optimally producing in presence of an EOR layer, which was due to an increase in mobility and pressures inside the EOR layer, which restricted flow from the non-EOR layers. An effort was made to quantify contribution from non-EOR zones using flowing bottom hole pressure data. The zonal contribution was successfully established, and it helped in devising individual development of the two non-EOR zones.

Background

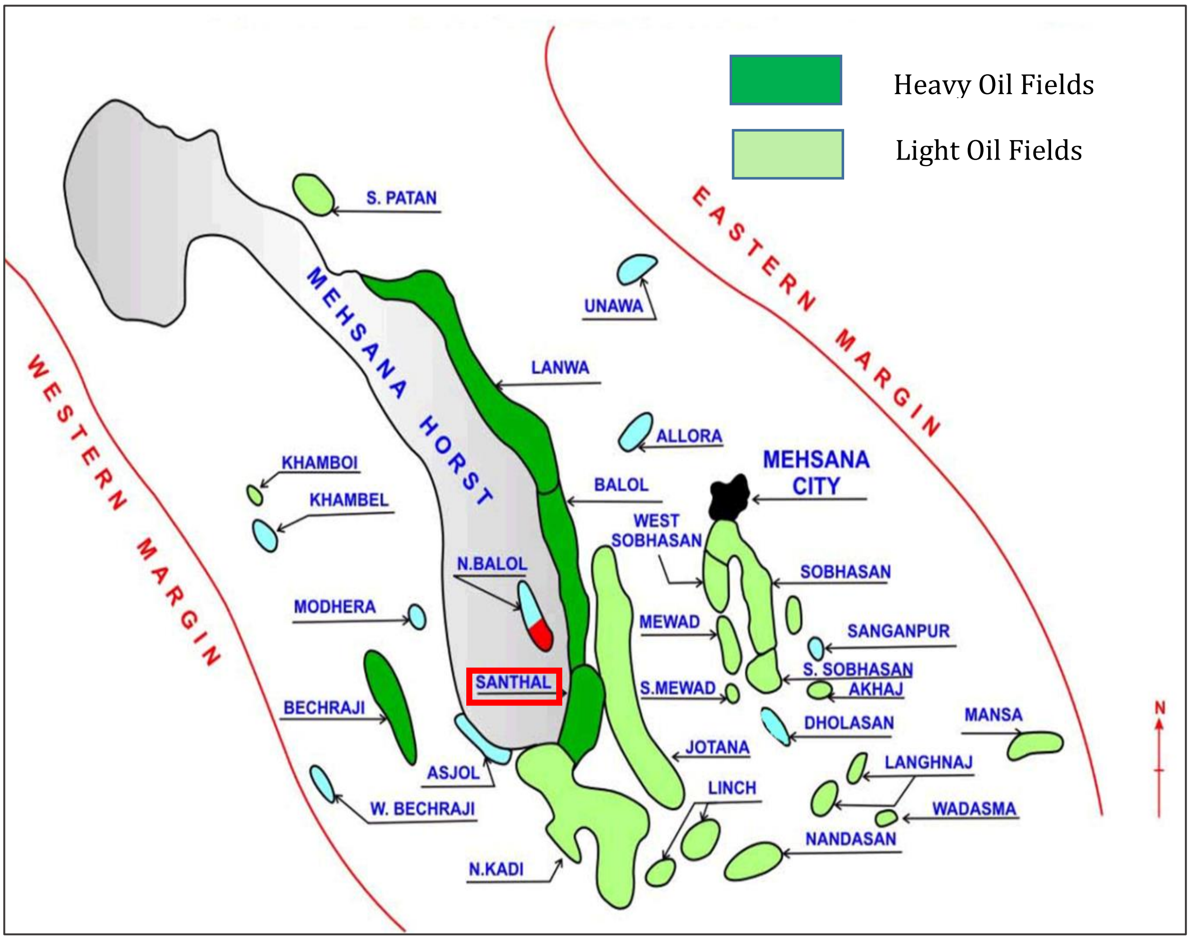
Santhal field, discovered in 1971, has multi-layered sandstone reservoirs namely Upper Suraj Pay (USP), Kalol Sands-I, II, III (KS-I, II, III) and Lower Sand (LS) of Kalol formation of Eocene age, separated from each other by shale of varying thickness. All the pay sands are hydro-dynamically connected and are supported by active edge water drive with common oil water contact (OWC) at -994 m (MSL). The porosity and permeability of the sands range from 25 - 30 % and 5 -15 Darcy respectively, except USP which is tight in nature. Oil is viscous in nature with average viscosity of around 100 cp. KS-I, II & III are the most prolific reservoirs of the field.

The field was developed in two major phases.

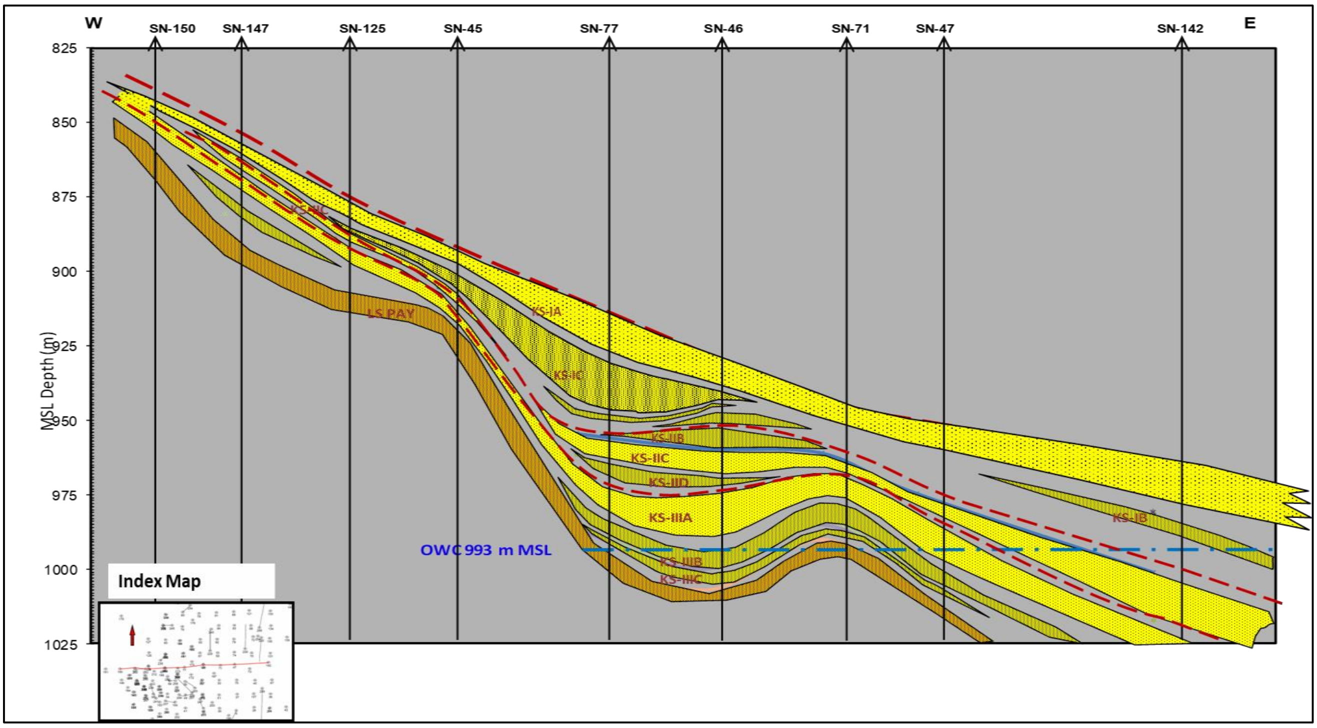
Phase-I (1974-1997): In the first phase, the field was developed with 300m x300m well spacing under primary recovery. With the continued development, the oil production from the field increased from ~400 tpd in 1984 to ~1880 tpd in year 1989. However, due to sharp mobility contrast of oil, the water cut of the field increased sharply to ~70% in 1993 resulting in corresponding decrease in oil production to ~960 tpd. The primary recovery of the field was envisaged low (17%) due to the high mobility contrast. To enhance the recovery from the field, In-situ Combustion (ISC), a thermal EOR technique, was found the most suitable EOR process.

Phase-II (1997 onwards): In the second phase of development, In-situ Combustion (ISC) was implemented in sand KS-I. The implementation of ISC was successful in increasing oil production and restricting water cut. The field produced with a plateau oil rate of ~1200 tpd for almost 4 years (2002-2006) with Water cut of ~60% (with almost constant number of flowing wells during this period) and the present recovery is ~29%.

The field was developed with air injection in KS-I pay sand, whereas most of the producers had commingled completion in KS-I, II & III.



Prospect Map of Mehsana Asset (Santhal field inside red block)



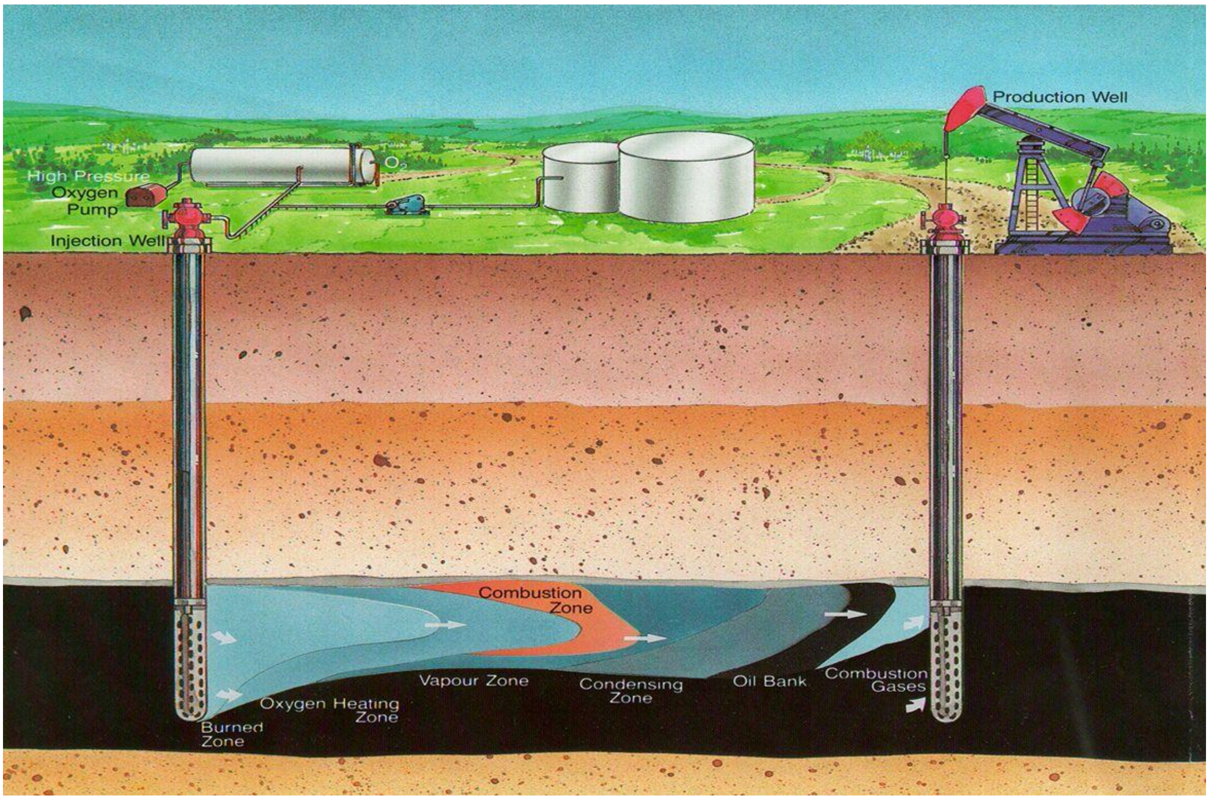
Geological cross-section: Santhal Field

Challenges in exploitation and further Field Development

The ISC process was implemented dedicatedly for KS-I, whereas most of the producers had commingled completion in KS-I, II & III.

The three zones (KS-I, II & III) have the same petro-physical properties, oil properties and drive mechanism. Hence, completing the wells in the three zones together, prior to the ISC, was a prudent decision, which would result in simultaneous exploitation of the reservoirs, with no dedicated development, which would save the overall development cost.

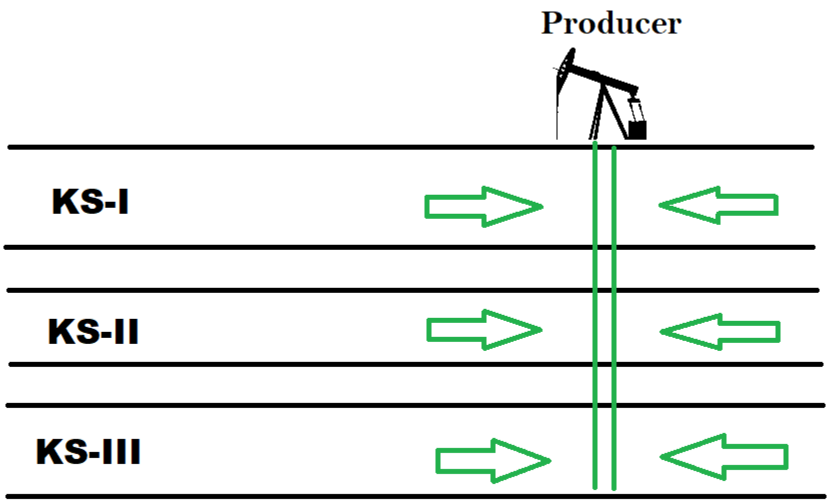
Later, ISC process was implemented in KS-I to improve its recovery. In-situ combustion, with its advancing combustion front, would reduce the viscosity of oil, thus making it more mobile in the reservoir. This would not only improve oil flow within the reservoir and into the wellbore, but would also restrict early water encroachment from the aquifer due to unfavourable oil-water mobility contrast. The In-situ combustion process was expected to improve the recovery from KS-I zone from 17% to 42%.



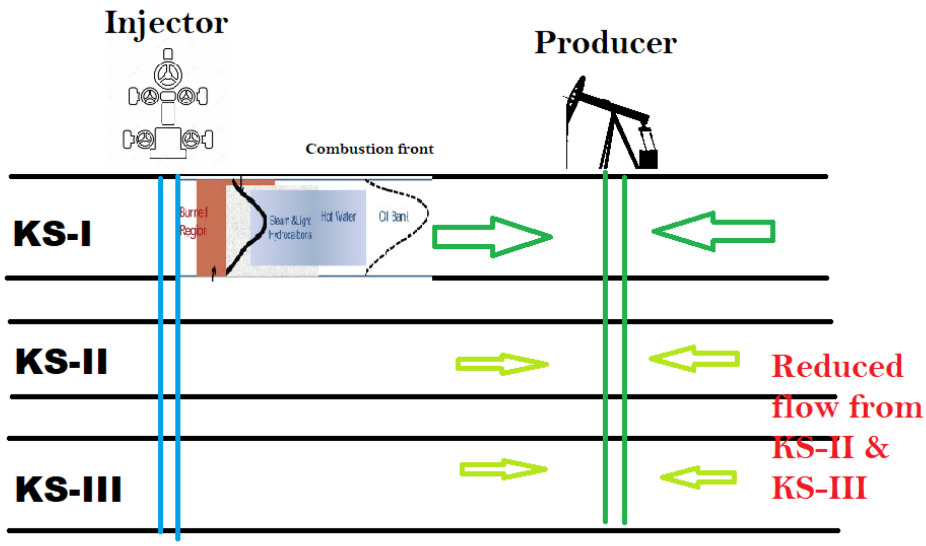
Typical in-situ combustion process (implemented in KS-I in Santhal field) – an air-injector and nearby producer

As years passed, and as in-situ combustion got implemented in the KS-I zone, a need was felt to assess oil exploitation from KS-II and KS-III sands, which were producing without in-situ combustion. Logs obtained from new wells indicated that the zones had not been exploited up to their potential; the resistivities and oil columns had not changed much over the years. It was evident that the zones were not contributing significantly, as the upper zone (KS-I) was producing with the assistance of in-situ combustion EOR, which had made the oil in the zone more mobile (and hence more producible) than the other two layers.

A need for a dedicated development plan for KS-II and KS-III reservoirs was felt, since the zones would remain under-exploited if they were produced with KS-I. As the zones were taken up for a dedicated development plan, an effort was made to quantitatively assess the level of exploitation in the zones. Historical Flowing Bottom Hole Pressure data proved to be instrumental in the study. With the help of the FBHP data, a quantitative estimation of the oil produced from the two zones could be made. It also proved that the two zones were indeed under-exploited, as indicated by the logs of the new wells drilled.



Completion schematic (prior to ISC implementation in KS-I)



Completion schematic (after ISC implementation in KS-I)

Methodology Adopted

Well-wise flowing pressure data since inception of the field was analysed. A marked difference between the data prior to the start of In-situ Combustion in KS-I zone and the data subsequent to the start of In-situ Combustion was observed. An increase in the FBHPs was observed, and they now stood closer to the static bottom hole pressures. It indicated that the wells now needed significantly less drawdown to produce oil, which was because of improved productivity of KS-I sand due to In-Situ combustion process, which had improved the mobility of oil by reducing its viscosity. Pressure in KS-I also increased because of the driving combustion front, which includes burning oil and flue gas.

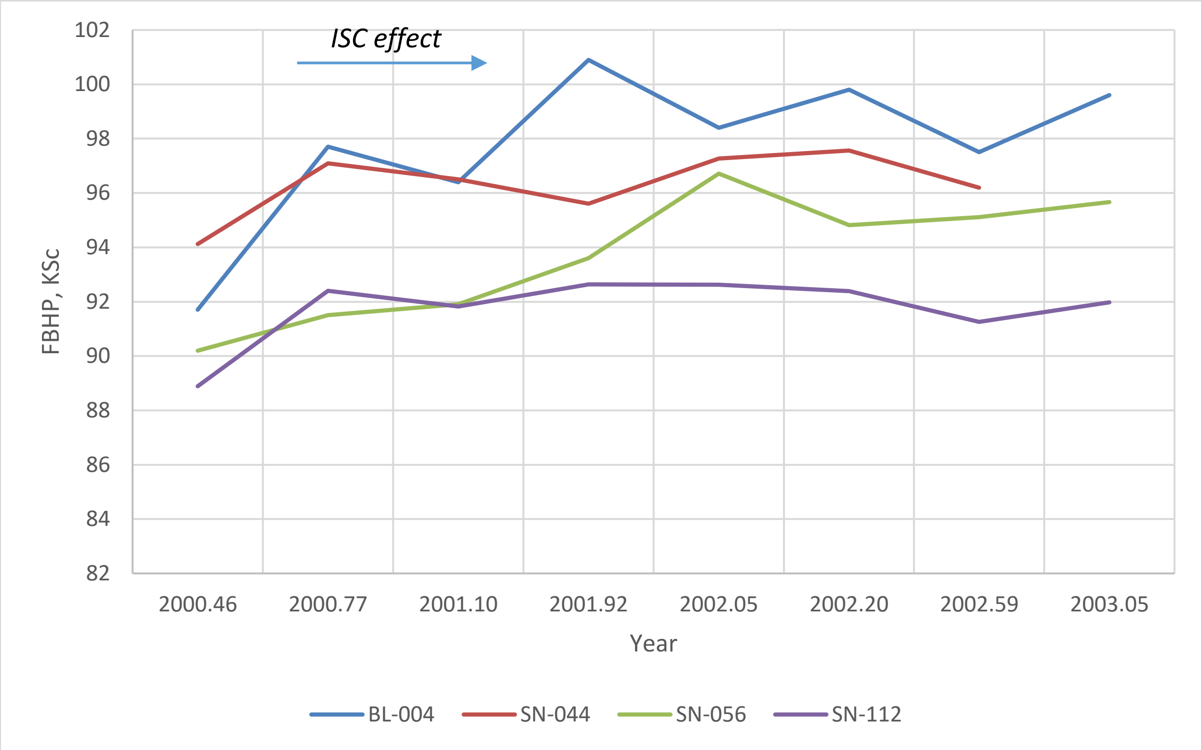


Figure: increased FBHPs in four example wells. The first data indicates pre-ISC FBHP, and the subsequent points represent post-ISC effect FBHP. A marked increase in FBHPs can be observed.

The reduced drawdown, owing to increase in FBHP, would cause reduction in oil production from KS-II and KS-III sands, which were producing without in-situ combustion.

Flow ∝ Drawdown ($\Delta P = Ps - Pf$)

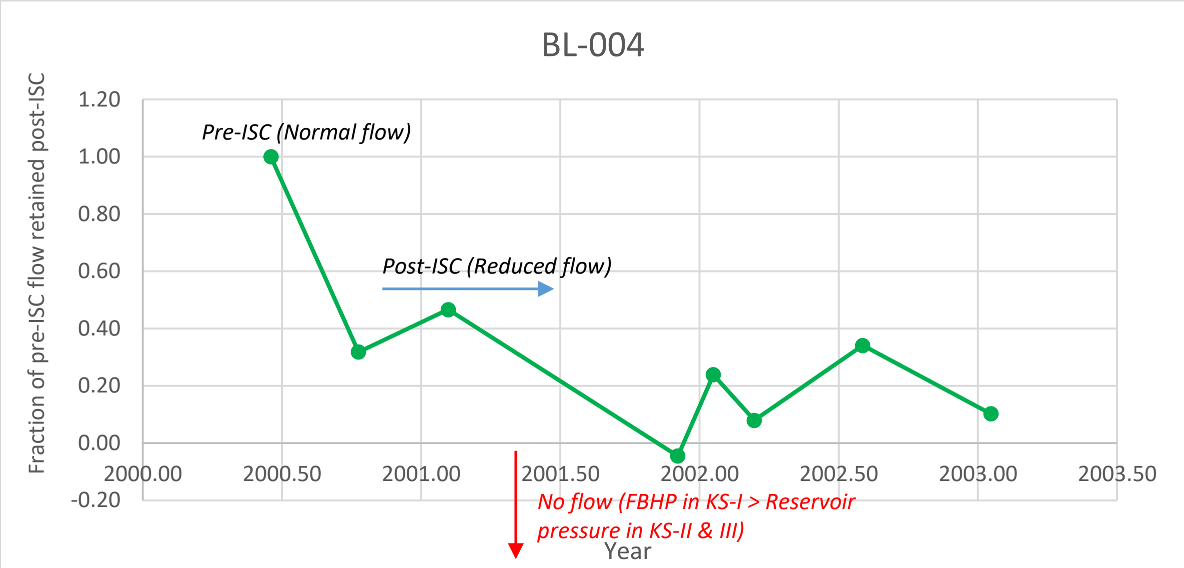
Drawdowns were calculated for all the FBHP points. The drawdowns subsequent to the start of in-situ combustion process in KS-I were compared to the drawdowns of the earlier period, when there was no in-situ combustion in KS-I, and the three zones were producing under similar conditions, flowing in a uniform manner.

Fraction of pre-ISC flow retained post-USC (in KS-II & III)

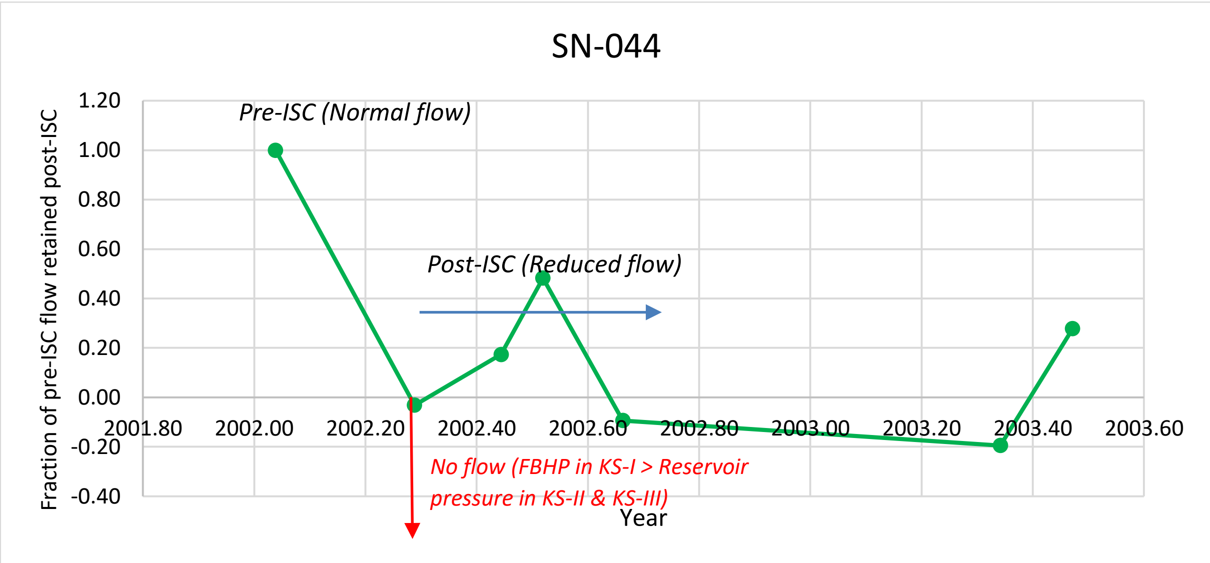
= (drawdown after ISC started in KS-I) / (drawdown prior to ISC)

The above was applied for all the wells for different times, and it gave an idea of the actual flow from the zones KS-II and KS-III over a period of time. Well-wise contribution from KS-II and KS-III was estimated. The effect of improved KS-I flow and increase in reservoir pressure (due to ISC) on the flow from the lower zones could be easily visualized.

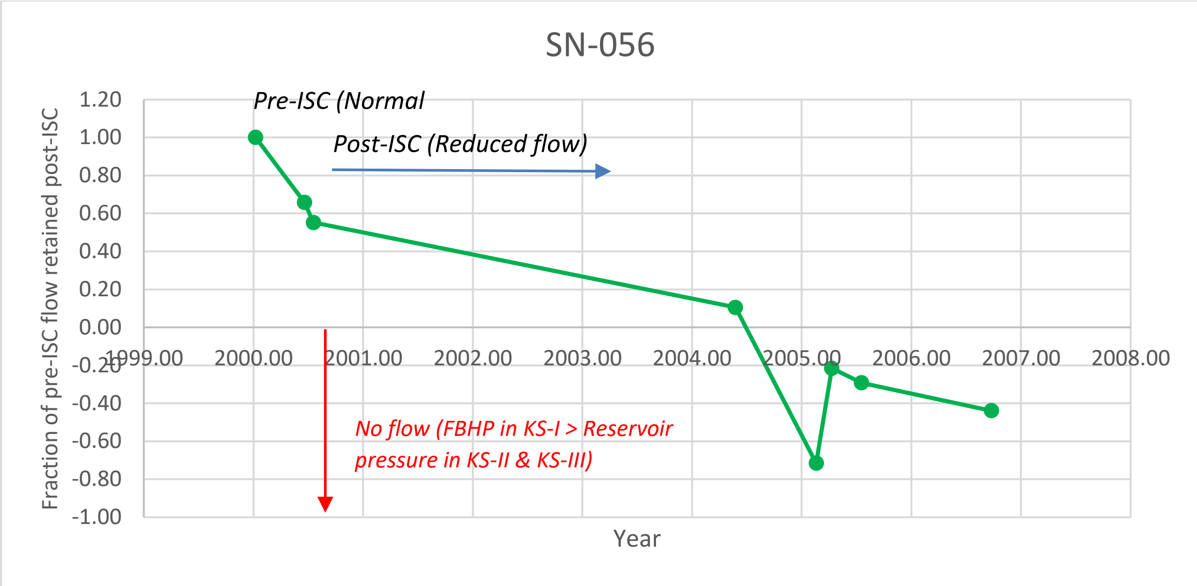
Below graphs show reduction in flow from KS-II & KS-III post ISC-effect realization in KS-I. The fraction of pre-ISC flow retained is shown (in KS-II & KS-III), which is the ratio of drawdown available post-ISC, and drawdown prior to ISC. Negative values indicate negative drawdown for KS-II & KS-III, as the FBHP in KS-I has reached higher than reservoir pressure in KS-II & KS-III, resulting in no flow from the zones. There are significant periods during which the zones KS-II & KS-III didn't contribute at all.



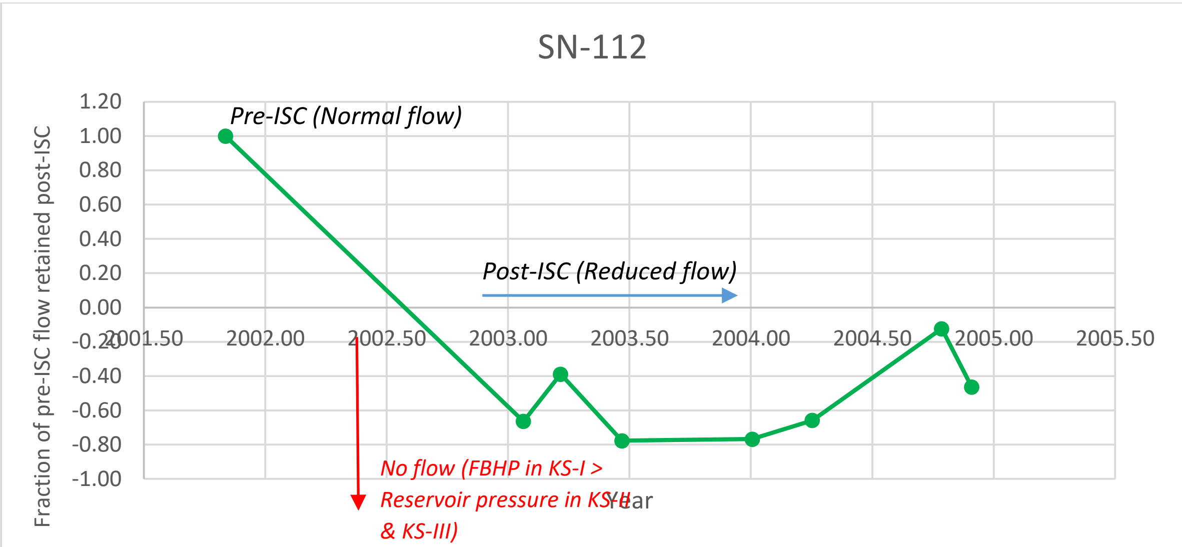
Well Balol-004 (Reduction in flow from KS-II & KS-III post KS-I ISC)



Well Santhal-044 (Reduction in flow from KS-II & KS-III post KS-I ISC)



Well Santhal-056 (Reduction in flow from KS-II & KS-III post KS-I ISC)



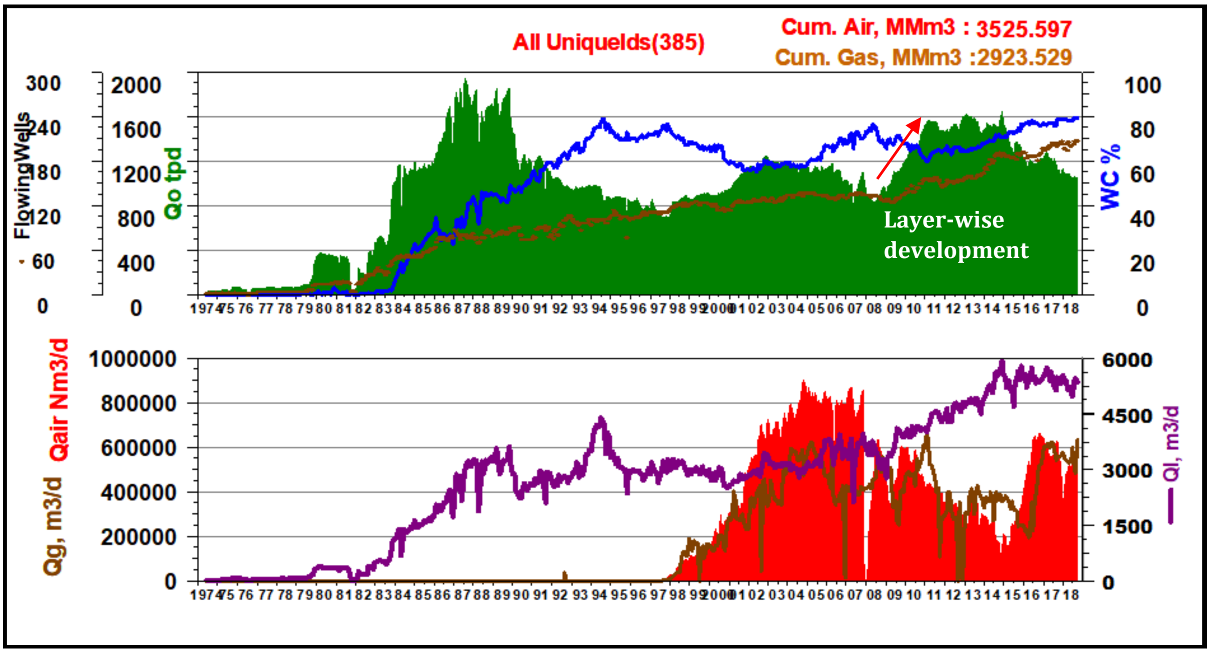
Well Santhal-112 (Reduction in flow from KS-II & KS-III post KS-I ISC)

By combining the flow of KS-II and KS-III in all the wells, an estimation of exploitation from KS-II and KS-III sands could be made. The actual exploitation was found to be significantly lower than hitherto assumed.

Individual Development of KS-II & KS-III

In 2009, the layer-wise exploitation strategy was adopted, and several infill producers were completed to target the lower pay sands viz. KS-II, KS-III and LS (most of the producers in KS-III), along with dedicated infill oil producers for KS-I as well, to capture the EOR displaced oil. The implementation of the layer-wise exploitation strategy resulted in increase in oil production of the field from ~900 tpd in 2009 to ~1500 tpd in 2011. The field produced at a plateau rate of above 1500 tpd for almost 4 years till 2014, with the water cut remaining steady ~62%-66%.

The performance of the field during this period was majorly contributed by the high oil productivity of KS-III wells (KS-III Qo/well: ~20tpd, Field average Qo/well: ~ 10 tpd) at low water cut of ~40%.



Performance of Santhal Field

Conclusions:

Historical Flowing Bottom Hole (FBHP) Data proved to be a significant instrument in estimating zone-wise contribution in Santhal field, where an EOR-layer was being exploited with non-EOR layers in many wells. By observing the changes in FBHPs, it could be inferred (and quantitatively estimated) that the non-EOR layers were not producing significantly in the presence of an EOR layer. The findings strengthened the need to devise dedicated development schemes for the two non-EOR layers. The scheme was approved, and upon implementation, yielded significant improvement in production.

Acknowledgments:

Authors are grateful to Dr. Ravi Misra, Chief E&D Directorate for his encouragement, support and valuable feedback. They are also thankful to Shri Santanu Mukherjee, CGM (Geol.) and Shri Rothindra Nath Goswami, GM (Geol.) for their constant motivation and guidance.