Application of Inflow Control Devices in Horizontal Well in Bottom Water Drive Reservoir using Reservoir Simulation

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Abstract - **Maximizing reserves recovery using horizontal wells requires management of fluid flow through the reservoir. One increasingly popular approach is to use inflow control devices that delay water and gas encroachment and reduce the amount of bypassed reserves.**

Maximum reservoir contact (MRC) is an important parameter which has several benefits such asEfficient Drainage area, Delayed coning or cusping and Increased Sweep Efficiency.

MRC can be achieved using smart wells such as Horizontal wells, Multilateral Wells and Extended Reach Drilling (ERD). With advances in drilling technology over the past 30 years, horizontal and multilateral wells have become a primary design type to develop reservoirs. The need to produce efficiently, economically and environmentally-friendly has promoted the development of extended reach horizontal and multilateral wells which enable greater reservoir contact and lower draw-downs to achieve higher rates than conventional vertical wells.

This paper compares the well productivity of Vertical, Horizontal and Horizontal wells with ICD using numerical simulation techniques in three dimensional grid of Upper Assam Arakan Basin.

Keywords—Horizontal well, Inflow Control Devices,heel-toe effect, Well Placement, Reservoir simulation, Recovery, Maximum Reservoir Contact, MRC

I. INTRODUCTION

Problem Description:Maximum reservoir contact (MRC) is an important parameter which has several benefits such as Efficient Drainage area, Delayed coning or cusping and Increased Sweep Efficiency.MRC can be achieved using smart wells such as Horizontal wells, Multilateral Wells and Extended Reach Drilling (ERD).However this increased wellbore length has led to some problems in producing from such a well. Higher pressure drawdown around the heel section as a result of frictional pressure drop of fluid flow in the wellbore causes non-uniform fluid influx along the length of the wellbore and higher production rates at the heel. This often leads to early break-through of water or gas, which causes a reduction in oil recovery and uneven sweep of the drainage area. With longer contact between reservoirs and wellbore, heterogeneity is more likely encountered, and permeability contrasts along the wellbore can also result in the same phenomena because of unevenly distributed pressure along the wellbore.

A Schematic of Horizontal well bore has been given where Heel-toe effect has been shown in Fig. 1. Pressure losses along a horizontal wellbore in a homogeneous formation cause the flowing tubing pressure to be lower at the well's heel than at the toe. In time, and long before oil (green) from sections near the toe arrives at the wellbore, water (blue) or gas (red) is drawn to the heel (top), resulting in an early end to the well's productive life.

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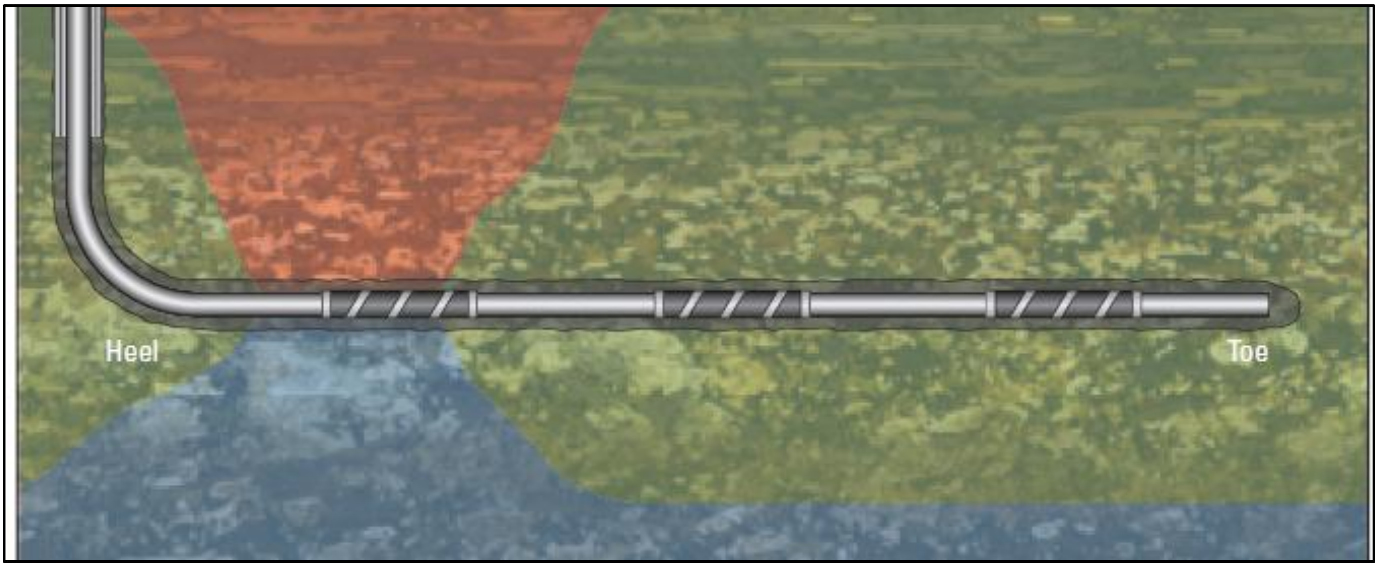

Fig. 1. Schematics of Horizontal well (heel-toe effect) – Oilfield Review Winter 2009/2010: 21, no. 4.

The "heel-toe effect" is the difference in the specific inflow rate between the heel and the toe of the well due to frictional pressure drop along the completion. The effect becomes significant when this frictional pressure drop is comparable with well drawdown. The "heel-toe" effect problem is greatest in reservoirs with Darcy permeability or when a small diameter flow conduit is employed while producing at high flow rates, resulting in significant frictional pressure drop along the length of the conduit. It can be mitigated via an increase in either the wellbore conduit diameter or by the use of shorter laterals, though such solutions are not always affordable or practical.

II. PROPOSED METHODOLOGY

To eliminate this problem Inflow Control Device (ICD) has been increasingly used in producing wells as a part of well completion to control and optimize individual well or overall reservoir performance. The purpose of ICDs is to equalize inflow along the length of the wellbore regardless of location and permeability variation. These ICDs enable the entire length of the wellbore to contribute to the total production and thereby optimize hydrocarbon recovery. ICDs are choking devices that balance inflow by adding an additional pressure drop at the sandface. They are designed to apply a specific differential pressure at a certain flow rate. Schematics of ICD with proposed contact movement has been shown in Fig. 2.

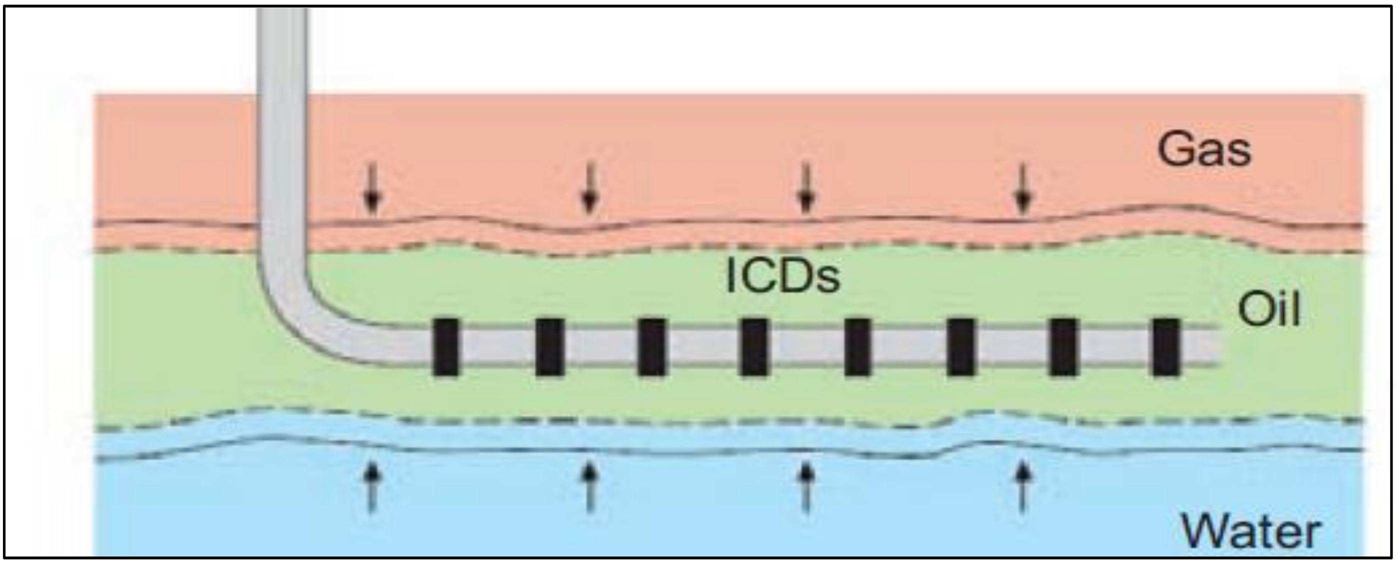

Fig. 2. ICD Completion showing uniformity in contact movement (Ref: JPT-May 2010)

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A. Study Area

Makum-North Hapjan field is one of the most prolific producer of OIL's fields in Upper Assam Basin, contributing around 40% of OIL's total oil production. Makum-North Hapjan structure is a faulted anticline, about 35 sq km in size at the Barail Arenaceous Top level.

The field consists of 72 wells, out of which 50 are vertical and 22 horizontal. The field is currently producing around 25, 000 bbl/d through 57 producing wells (21 horizontal and 36 vertical wells) from Barail sand reservoirs with around 62% contribution from horizontal wells.

B. Simulation Model

The 50m by 50m gridding of the original model was upscaled to 100m by 100m. The vertical resolution was reduced approximately by a factor of two, increasing average cell height from 0.5m to 1m. The geomodel was resampled into upscaled grid to capture rock types, porosity, and permeability and saturation distribution. The porosity was resampled arithmetically with weighting by pore volume. The resultant upscaled simulation grid has 120x72x86 (743040 cells) having 308326 active cells and upscaled model was migrated into the *Eclipse Simulator.* Further reduction on active blocks was carried out reducing the number of grid blocks in aquifer region and conducting re-dimensions to the pore volume of the aquifer grid cell.

History matching was done satisfactorily on this field for a period of 22 years on oil rate, water rate and pressure. This model was used to perform sensitivity on various completions (vertical Well, Horizontal well and Horizontal well with ICD's) for a period of twelve years.

C. WELL PLACEMENT

Well placement was done based on remaining moveable oil volume. A map showing the moveable oil volume after the end of history match is shown in the Fig. 3. below. The figure depicts the distribution of the large moveable oil volumes together with the existing drilled wells under production. The black grid cells represent oil columns with more than one hundred twenty five thousand (125,000) bbl of moveable oil.

Sensitivity analysis was performed in the area marked in red circle shown in Fig. 3.

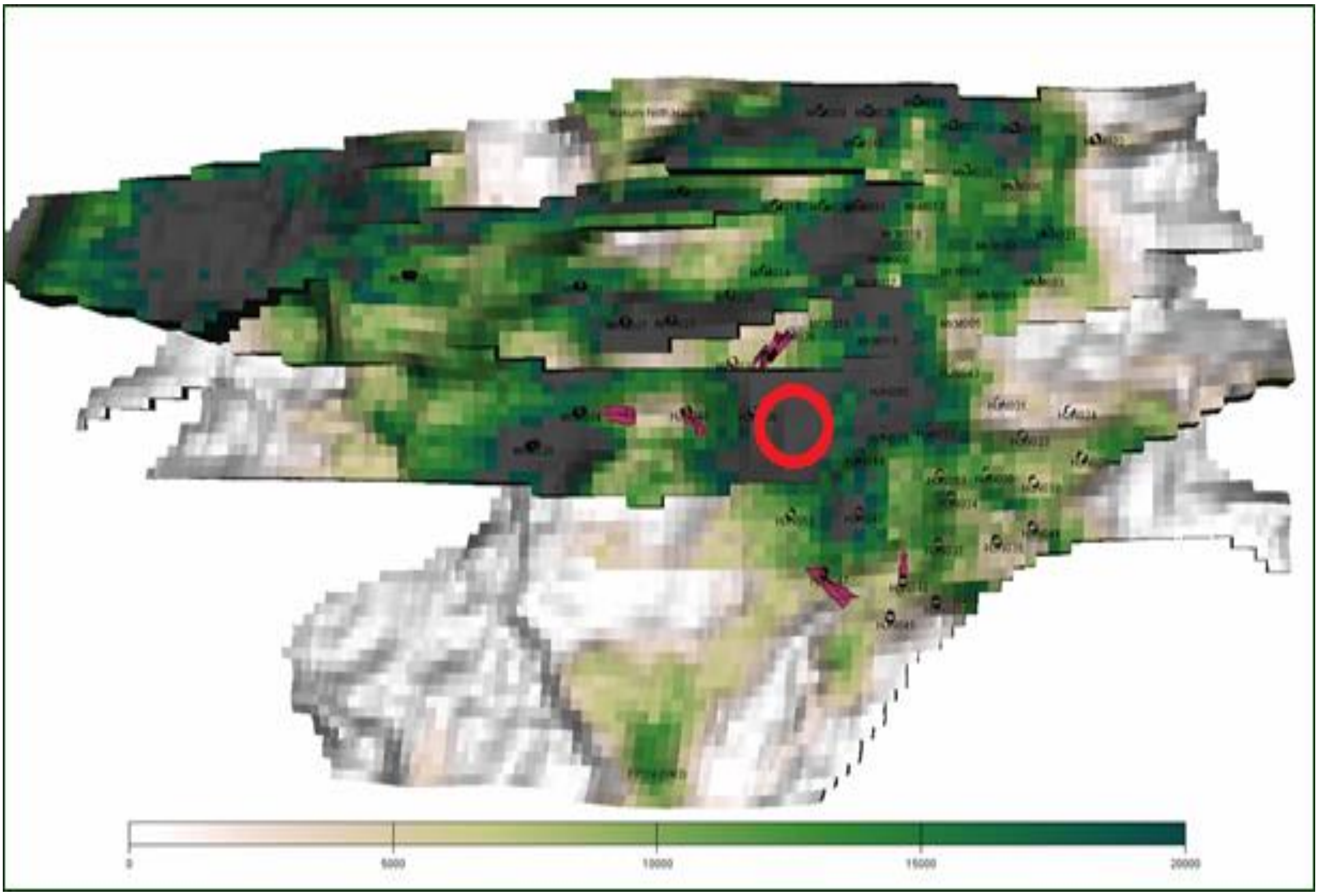

Fig. 3. Moveable Oil Volume Map for at the End of the History Match.

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III. RESULTS

Sensitivity on Well completion was carried out on history matched three dimensional Model and comparison of various production parameters were done (Oil Rate, Water cut, Pressure, cumulative oil). A graphical representation of the same has been provided in Fig. 4.through Fig. 6.below. Vertical well produces around 0.53 MMbbl of cumulative oil, whereas Horizontal well gives a cumulative oil of 1.26 MMbbl of
Cumulative oil & Horizontal wells with ICD gives 1.7 MMbbl of cumulative oil.

Fig. 7. Clearly depicts the change in water-cut response for the different completion types.

The vertical well gives a sudden rise in watercut which is likely due to increased drawdown and water coning, which results in lower recovery from this well completion. In case of Horizontal well,uniform increase in water-cut compared to vertical well case has been observed which may be de reduced drawdown and increased contact through the reservoir.

However, the water-cut response for the Horizontal well gives a sudden increase in the water-cut during early-time as the water cones into the heel of the well before it reaches the toe, this is practically the case one would expect in a heterogeneous reservoir.The Horizontal well with ICDs - spiral produces with a lower water cut compared to Horizontal well as the drawdown is balanced by the ICD across the length of the borehole.

Comparing water cut profile of various completion in Fig. 7.it can be seen that early water breakthrough has been avoided through change in completion ,and use of ICD in Horizontal well has been successful.

Well completion schematic for Horizontal wells with ICD has been provided along with details of Spiral ICD in Fig. 8.Additional parameters used for Spiral ICD has been presented in Table-1 and Table-2 respectively.

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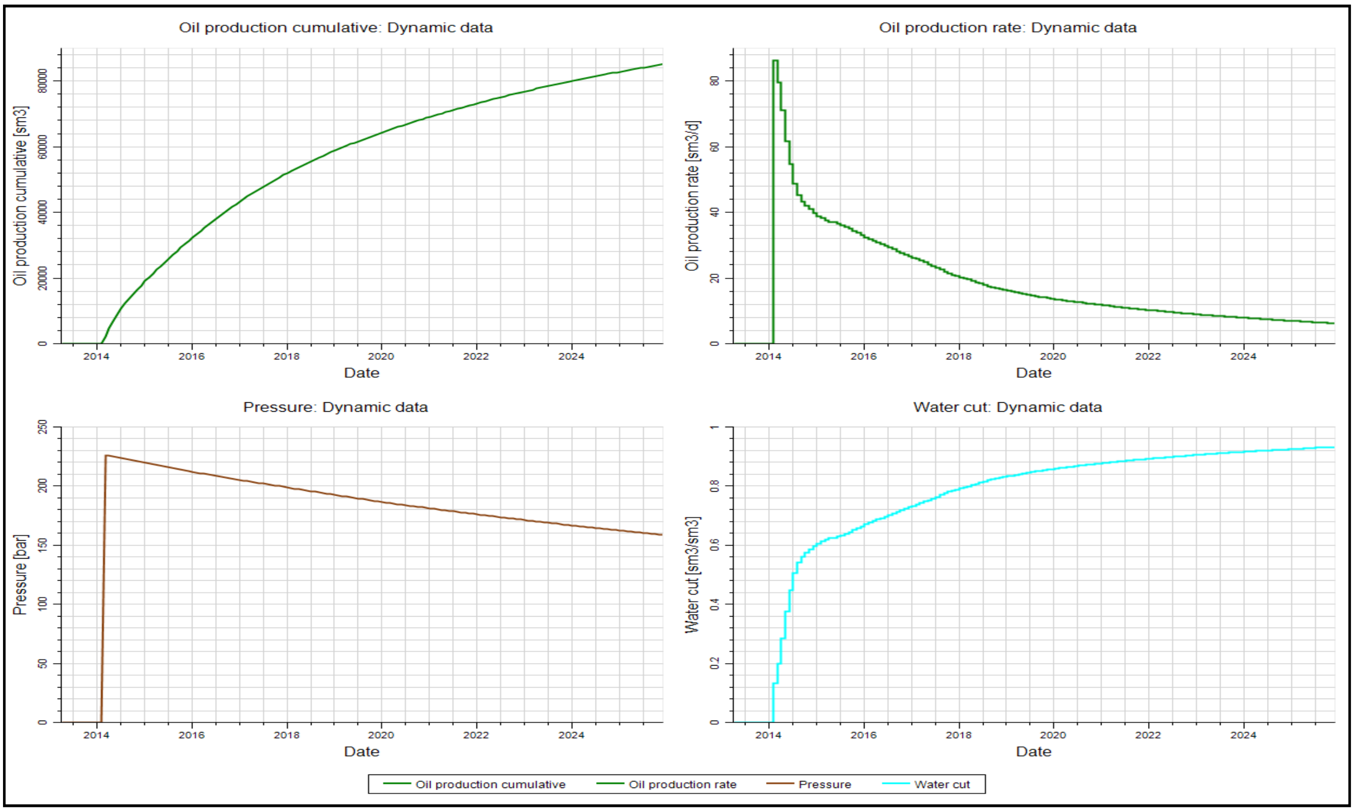

Fig. 4. Vertical well Production Profile

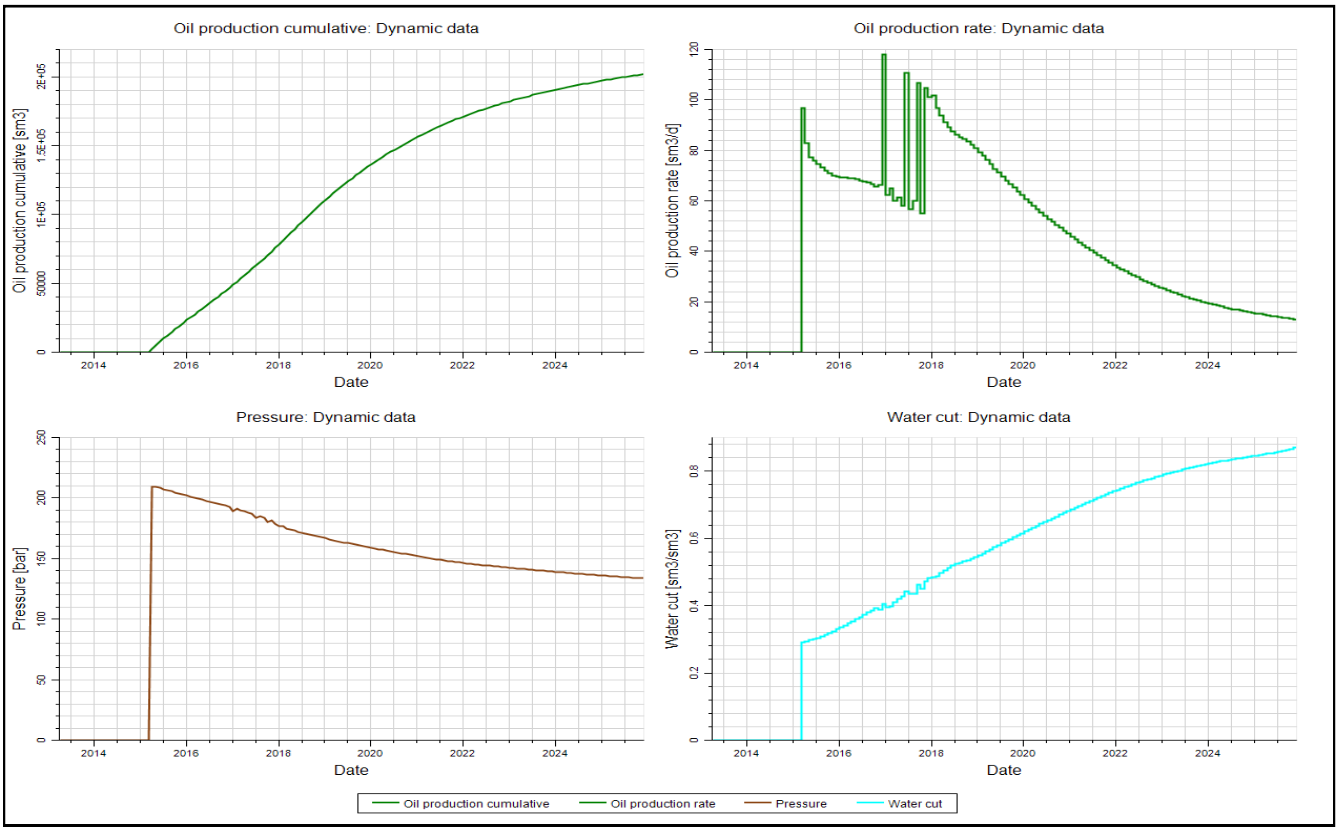

Fig. 5. Horizontal well Production Profile

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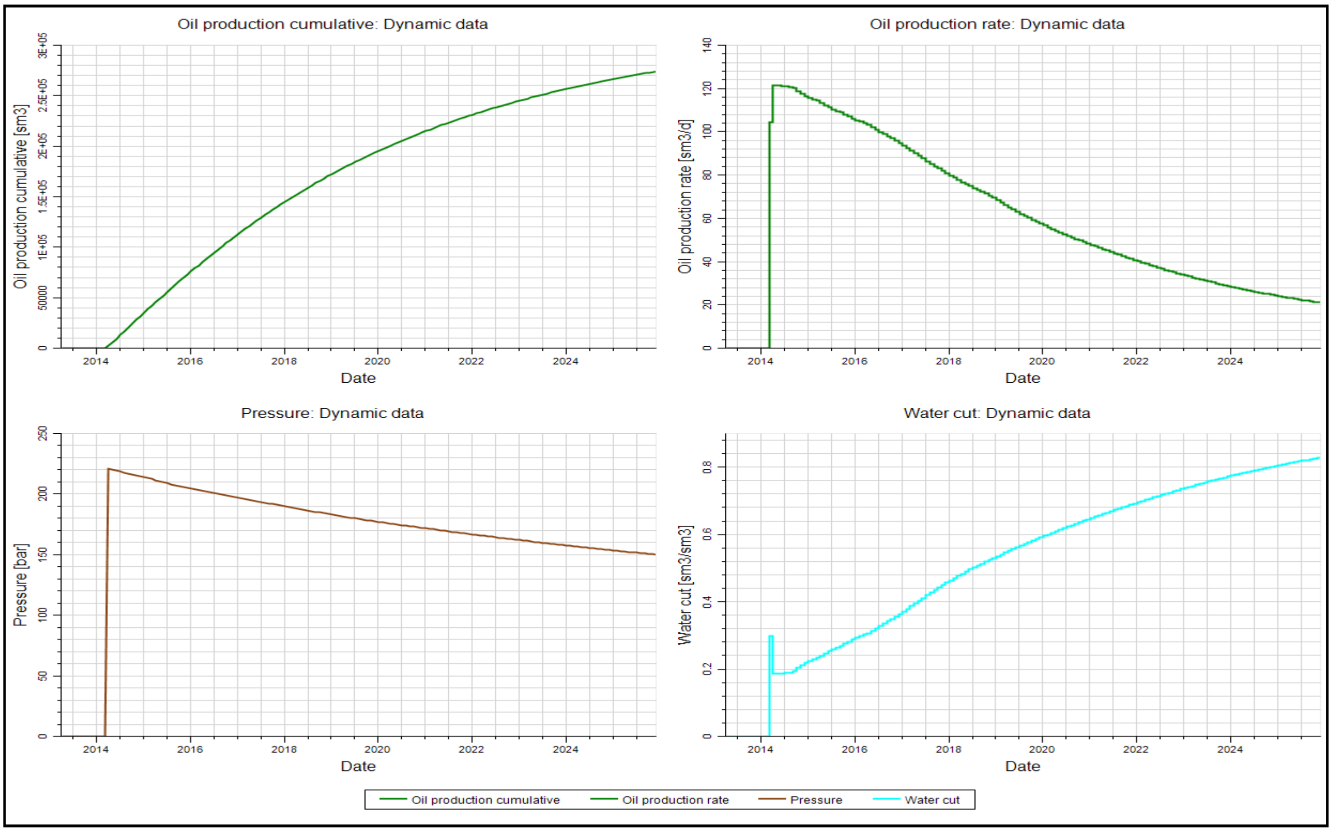

Fig. 6. Horizontal well with Spiral ICD Production Profile

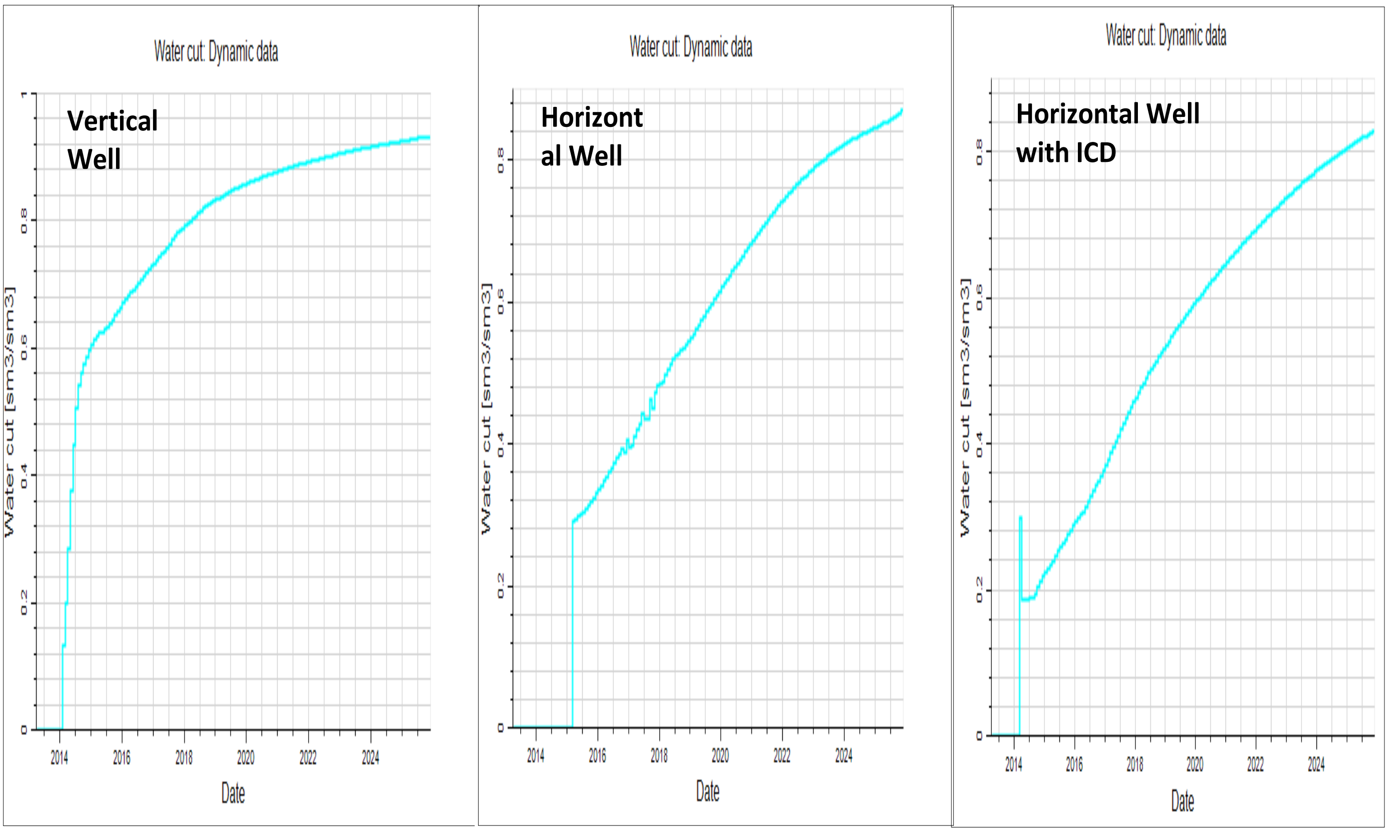

Fig.7. Watercut comparison of vertical well, Horizontal Well & Horizontal well with ICD

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Table. 1. Completion Equipments in Horizontal well with Spiral ICD

Grouping and sorting | Drag a column header here to group by that column.

Well name	Category	Type	Name	Start date	Top from	Top off. (m)	Bottom from	Bottom off. (m)
HWT-H-								
HWT-H-ICD-	Borehole	Borehole	Borehole	2015/03/01 00:00:	Start	0.00	End	0.00
HWT-H-ICD-	Casing	Casing string	Casing 1	2015/03/01 00:	Start	0.00	KB	2300.00
HWT-H-ICD-	Casing	Casing part	Casing 1:1	2015/03/01 00:00:	Start	0.00	KB	2300.00
HWT-H-ICD-	Tubing	Tubing string	Tubing 1	2015/03/01 00:	Start	0.00	KB	3090.09
HWT-H-ICD-	Tubing	Tubing part	Tubing 1:1	2015/03/01 00:00:	Start	0.00	KB	3090.09
HWT-H-ICD-	Devices	Packer	Packer 1	2015/03/01 00:00:	KB	2299.70	KB	2300.00
HWT-H-ICD-	Devices	Packer	Packer 2	2015/03/01 00:00:	KB	3089.78	KB	3090.09
HWT-H-ICD-	Devices	Spiral ICD	Spiral ICD 1	2015/03/01 00:00:	KB	2300.00	KB	2312.00
HWT-H-ICD-	Devices	Spiral ICD	Spiral ICD 2	2015/03/01 00:00:	KB	2497.45	KB	2509.45
HWT-H-ICD-	Devices	Spiral ICD	Spiral ICD 3	2015/03/01 00:00:	KB	2694.89	KB	2706.89
HWT-H-ICD-	Devices	Spiral ICD	Spiral ICD 4	2015/03/01 00:00:	KB	2892.34	KB	2904.34
HWT-H-ICD-	Devices	Packer	Packer 3	2015/03/01 00:00:	KB	2397.20	KB	2411.25
HWT-H-ICD-	Devices	Packer	Packer 4	2015/03/01 00:00:	KB	2571.81	KB	2592.49
HWT-H-ICD-	Devices	Packer	Packer 5	2015/03/01 00:00:	KB	2791.72	KB	2807.98
HWT-H-ICD-	Devices	Packer	Packer 6	2015/03/01 00:00:	KB	3042.57	KB	3058.83
HWT-H-ICD-	Workovers	Open-hole	Open-hole 1	2015/03/01 00:	KB	2305.48	KB	3039.26

Table. 2. Spiral ICD Details

Device		
Flow scaling method	Use 'Flow sc	
ICD strength	0.00021	bar/(rm3/d)2
Fluid density	1000.3	kg/m3
Flow scale factor	1	
Physical valves equivalen	1	
Fluid viscosity	1.45	cP
Critical water fraction	0.5	
Transition region width	0.05	
Max viscosity ratio	5	
VFP table	Undef	
Diameters		
Drift diameter		in
Coupling outer diameter		in
Outer diameter	5.00000	in
Inner diameter	4.56000	in
General		
Completion length	12	m
End date		
Start date	2015/03/01 00:	
Length	12.00	m
Type	Spiral ICD	
Equipment ID	SICD_EQ1	
Category	Devices	
Well folder	Wells/Proposed	
Well name	HWT-H-ICD-Spi	
Name	Spiral ICD 1	
Material		
Inner roughness	0.000600	in
Outer roughness	0.000600	in

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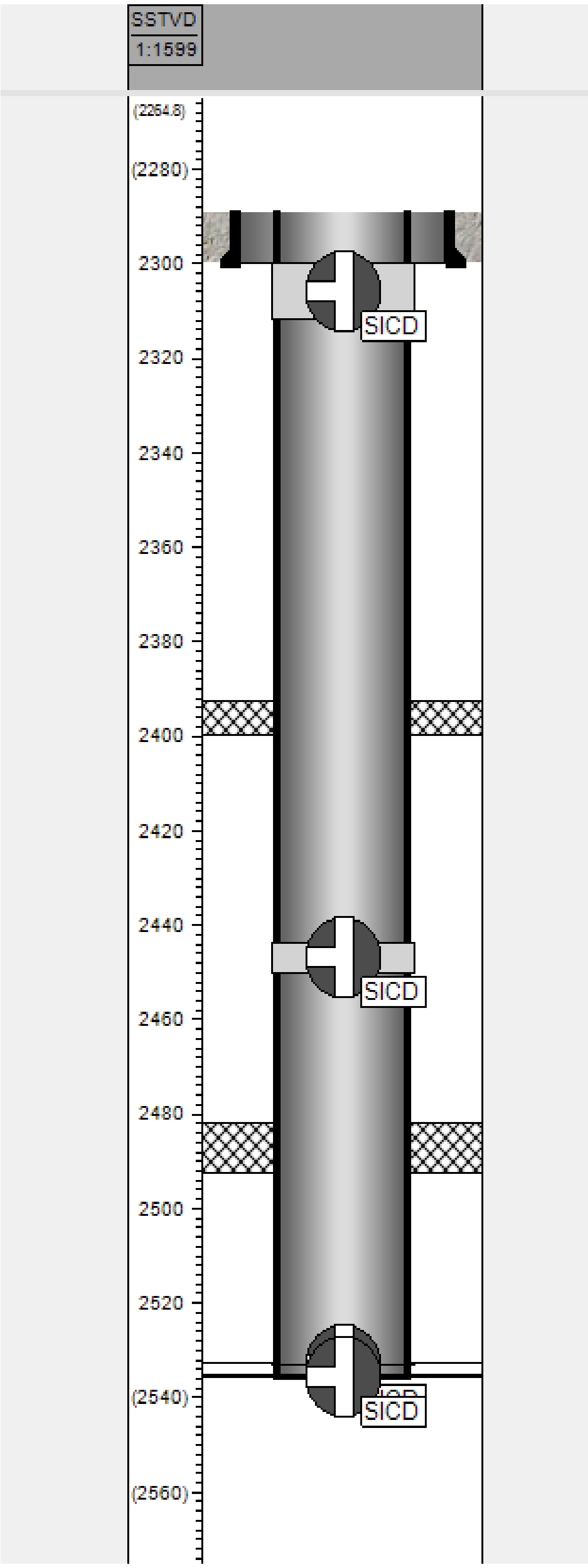

Fig. 8. Well schematic of Horizontal well with Spiral ICD

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IV. CONCLUSION

- Well completion design has been shown to reduce the impact of geostatistical uncertainty on the production forecast using the uncertainty quantification methodology as applied in reservoir engineering. The study of the Oligocene reservoir found that a well completion designed based on ICDs increased the mean recovery with a limited decrease in risk.
- The equation that quantifies the heel-toe effect reduction achieved by Inflow Control Devices installed in horizontal wells have been illustrated using Field data of Upper Assam Arakan Basin.
- ICD design parameters reduce the heel-toe effect to the required level.

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