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ANALYSIS OF SMART OIL WELLS INFLOW PERFORMANCE RELATIONSHIP CURVES

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Abstract: **The gradual shift of attention from the conventional well completion to smart well completion has triggered the call for information concerning smart wells operations and methods for evaluating the performance of smart wells. In this paper, an integrated model was reviewed and used to calculate the dimensionless oil flow rate and bottomhole flowing pressures variables. Oil production data from a commingled smart well were simulated on a FASTWELL software and their plotted IPR results analysed to study; the oil inflow rate for a single phase flow, oil inflow rate for a multiple phase flow, Absolute Open flow (AOF), the effect of water and gas on oil inflow rate and the effect of anticipated formation damage. The results obtained show that the actual oil inflow rate is 4,800 bbl/d for 8USIG while the other two commingled reservoirs follow the same trend. The actual oil absolute open flows (AOF) are 4,575.1 bbl/d, 7,670.4 bbl/d and 6,528.6 bbl/d for 7USIG, 8USIG and 9USIG respectively. Comparing these AOF values to the total AOF mostly used for decision in well performance, it is evidence that the total AOF contributes errors to well performance decisions as investigated. The oil inflow rate for smart well is 20,500 bbl/d, while the total inflow rate of producing zones under conventional completion assumption gives 19,000 bbl/d. The three producing reservoirs show a significant increase in the AOF for oil in the absence of gas and water in the oil inflow stream. The approach used here provides a quick insight for early isolation of the errors contributed by gas and water in the analysis of oil inflow performance relationship (IPR) curves.**

Keywords: **Smart Well, Commingled Well, Absolute Open Flow, Inflow Performance Relationship, Operating Point, Integrated reviewed Model and FASTWELL Software.**

1. INTRODUCTION

Smart or intelligent wells are nonconventional well with downhole instrumentation (sensors, valves and inflow control devices) installed on the production tubing. Such wells allow for the continuous in-situ monitoring of fluid flow rates and pressures and the periodic adjustment of downhole valves. Smart well technology provides great flexibility in the operation of multilateral wells, as each branch of the well can be controlled independently. In the case of a monobore well (such as a horizontal or deviated well), the downhole instrumentation essentially transforms the well into a multi-segment well, again with the ability to control each segment independently. The benefits of smart wells have been demonstrated in practical applications, especially for multiple reservoirs where commingled production is the main production strategy [14], [18]. In operation, the control devices are commonly used in on/off mode (that is, the branch is either opened or closed to production), which may not be the optimum way of operating these devices. The applicability of intelligent completions however is not confined to scenarios involving commingled production. The potential benefits for production from a single reservoir have also been demonstrated. Specifically, smart wells can be used to monitor and control flow rate and pressure, these completions can be effective for controlling the coning of water and cusping gas. The genesis of the smart well was marked by the first successful installation of intelligent completions in 1997 in the Norwegian part of the North Sea [10]. Since the first smart was installed at saga's snorre tension leg platform in North Sea in 1997, more than 300 smart well systems have been installed worldwide [7]. Due to its proven capabilities, many companies have heavily implemented this technology during the last decade. In 2004, Saudi Aramco coupled intelligent completions with its multilateral MRC wells to manage and optimize production from different laterals. Field results have shown direct advantage of using inflow control valves (ICVs) over conventional wells in terms of improving overall productivity and sweep, managing water production and minimizing production interruptions [11]. The main driver for this technology is the emergence of horizontal and multi-lateral wells around the world. The trend of increasing hydrocarbon demand is faced with a decrease in new discoveries; the need to enhance productivity from existing fields and improve their ultimate recovery is an imposing challenge for producers. Horizontal drilling and well completion technologies have seen rapid developments in the last decade in addressing this issue. Smart well technology is one of the most significant breakthroughs in modern petroleum production technologies. It allows operators to remotely control production of multilateral wells without intervention, thereby, optimizing production, and maximizing recovery and capital-expenditure efficiency while minimizing operating costs [13]. Some applications of this technology include managing production where there are significant variations among laterals in reservoir pressure, productivity, gas/water fractions, or permeability due to presence of fractures and faults [11].

Another important challenge in this current situation is to maximize recovery at a profitable rate. The positive aspect of this situation is that technology is progressing as those reserves get more challenging to produce. Many petroleum engineering technologies have been developed in order to ease the production of new reservoir. Slanted and horizontal well technology were developed in the early 1920's but was rarely used until the 1980's.

To account for the present and the future performance of oil and gas wells, production engineers are often called upon to predict the pressure-production behavior of wells to determine their productive capacity. Having an idea of the pressure-rate behavior enables engineers to evaluate various operating scenarios to ascertain the optimum production scheme and to design and install surface and subsurface production equipment when necessary. Knowledge of the pressure-rate behavior can be quite helpful in designing and evaluating stimulation treatments or any operation that improves flow efficiency, like the estimation of future performance which is required for forecasting and planning purpose [15]. Inflow performance of a reservoir is defined as the functional relationship between the flowing bottom-hole and the resulting flow rate. It is the rate at which fluid will flow towards the wellbore and depends on the viscosity of the fluid, the permeability of the rock, and the driving force. For an oil/gas well to flow there must be a pressure difference from reservoir to the well-bore at the reservoir depth. If the well-bore pressure is equal to the reservoir pressure there can be no inflow. If the well-bore pressure is zero, the inflow would be a maximum possible that is the Absolute Open Flow (AOF).

From inception, petroleum engineers have geared their energy in answering the question of 'how much oil a conventional completed well can produce before it reached the depletion stage?' In view of this, little or no effort has been made on smart oil well which is the newest well completion method currently used in the oil and gas industry. The concept of smart well completion is to prevent the inflow of water and gas into the oil flow stream in the oil producing well. This fluid (water and gas) reduces the flow rate of oil during production which leads to low oil production. To further succeed in this regard, there is need to analyze the IPR of smart oil wells with emphasis on single phase flow, multiple phase flow and the likely anticipated damage of the producing formation. This will equipped the operators of smart with more information and ideas needed for operation, monitoring and optimization of smart wells.

A few authors have previously addressed the optimization of smart wells. [6] Introduced an optimization method for multi-zone or multilateral flow control completions. He used the IPR and valve performance relationship (VPR) information to optimize the valve settings. In the absence of a commercial package to optimize the performance of laterals, he proposed the use of a graphical representation of the performance curves. He concluded his study by stating that the hardware for smart completions has advanced substantially in the last five years, but work on the optimization of the performance of smart wells has not matched hardware advancements. He also claimed that the industry is using trial-and-error approaches for well control. This recent paper clearly challenges academia and the industry to put more effort on this subject. [2] Presented a static optimization method that maximized sweep in a waterflood study. They considered fully penetrating smart horizontal injection and production wells. Their basic algorithm involved shutting in the segments of the well with the highest productivity index and adding the production from these segments to other well segments. By doing that they could balance the production along the well and attain a better sweep efficiency. [4] Introduced a dynamic optimization algorithm that used optimal control theory. Using this approach they demonstrated improved sweep and recovery over their previous method [2]. [3] Investigated the effects of smart completions with different well targets and constraints in a water flooding project using optimal control theory. They found considerable scope for accelerating production and increasing recovery for wells operating with rate targets.

[9] Studied the impact of valve placement, inflow configuration and mode of operation on production performance using a horizontal well on a synthetic bottom water drive model. They envisaged control in reactive and proactive modes. They defined reactive control as the surface production choking or zonal isolation of production through closing valves discretely or continuously. With proactive control they rely on the data which is supplied from the sensors (distributed electrical arrays) installed on the well. With this data, they showed that the proactive control strategy can be used to avoid the displacing phases invading the near-well region. They used simulated annealing and conjugate gradient optimization algorithms to determine the optimum location and control settings of the valves to maximize the cumulative oil production. They did not update the valve settings in time, and assumed that they would be actuated from initial production. They converged to the same optimum with both of the methods.

[12] Performed an intensive production test as a reactive measure to eliminate water production from a trilateral smart well. Although their production test procedure was determined based on their observations in the field, some interesting results and observations that could be considered in a proactive approach have been revealed. Among these observations was the laterals‟ sensitivity to the ICV setting. In one lateral, a low ICV setting completely eliminated water production as the water production was a result of water conning through nearby vertical fracture. On the other hand, a low ICV setting slightly reduced water production in another lateral and shut-in of that lateral was necessary as the source of water in this case was the advanced water injection flood front. [8] Successfully increased the deliverability of a smart gas well drilled in a two-layer system by producing the top layer without downhole restriction and gradually unchoking the bottom layer as the bottomhole pressure declined. [17] Described a gradient-based technique to maximize cumulative oil recovery from smart wells. Their optimization technique was performed over discretized time steps to ensure that earlier ICV settings determined for earlier time steps would not have negative effects at later time. [1] Presented waterflood optimization using smart wells and optimal rate control. Their approach relied on equalizing the streamline time of flight at the producing wells to maximize sweep efficiency. [16] Proposed a general methodology to optimize the type of nonconventional well, trajectory, location, and ICV setting. His method was based on genetic algorithm coupled with hill climbing and artificial neural networks.

2. METHODOLOGY

Integrated reviewed model is an extension of the Vogel’s IPR expression by Standing’s to account for the real case condition encounter during oil production. The review of this model for the analysis of IPR in this research is referred to as integrated model derivation. This model account for the effect of formation damage which is a common problem encountered during oil production. In this research, both the curve and the model expression analysis approach are used to study and analyzed IPR’s of smart oil well. The expressions are reviewed as below;

In applying these equations to this research work, the assumption is that the flowing bottomhole pressure is below the bubble point pressure.

The productivity index (J) of the well is given by Equation (1)

$$J = \frac{q_o}{(P_r + P_b) + \frac{P_b}{1.8} + \left[1.02\left(\frac{P_{wf}}{P_b}\right) - 0.8\left(\frac{P_{wf}}{P_b}\right)^2\right]} \tag{1}$$

To simplify the final IPR, a flow rate (q_{oc}) was introduced as shown in Equation (2).

$$q_{oc} = \frac{q_o}{\left[1.8\left(\frac{P_r}{P_b}\right) - 0.8 - 0.2\left(\frac{P_{wf}}{P_b}\right) - 0.8\left(\frac{P_{wf}}{P_b}\right)^2\right]} \tag{2}$$

The oil flow rate (q_{oh}) at bubble point pressure was determined by Equation (3).

$$q_{ob} = \left[1.8\, q_{oc} \left(\frac{P_r}{P_b}\right) - 1\right] \quad (3)$$

Hence, the maximum oil flow rate q_{omax} at zero bottomhole flowing pressure was determined by Equation (4).

$$q_{omax} = qob + \frac{JP_b}{1.8} \quad (4)$$

Finally, the IPR values were generated by the Vogel model on FASTWELL test software using Equation (5) to obtain the oil flow rate.

$$q_o = q_{ob} + q_{oc}\left[1 - 0.2\left(\frac{P_{wf}}{P_b}\right) - 0.8\left(\frac{P_{wf}}{P_b}\right)^2\right] \quad (5)$$

The study of IPR in term of formation damage was investigated with standing's assumption for flow efficiency. The outcome of his work leads to the model equations reviewd below. The equations were used to generate the results of tables 1and 2. study the effect of formation damage on the obtained well test data IPR curve using an assumed flow efficiency values.

The bottom hole flowing pressure Pwf^1 at damage is determined by equation (6) from Standing's model.

$$\underline{P_{wf}^{1}} = 1 - FE\ (P_r - P_{wf}) \quad (6)$$

Using the smart well test data, the absolute open flow q_{omax} at assumed flow efficiencies are determined by Equation (7).

$$q_{omax} = \frac{q_o}{\left[1 - 02\left(\frac{P_{wf^1}}{P_r}\right) - 0.8\left(\frac{P_{wf^1}}{P_r}\right)^2\right]} \quad (7)$$

By rearrangement of Equation (6), the bottom hole flowing pressure was determined by Equation (8).

$$P_{wf} = \frac{P_{wf}^{1} - 1 - FE\ P_r}{FE} \quad (8)$$

Finally, Equation (9) gives the flow rate q_o at the assumed flow efficiencies used to generate the IPR curve.

$$q_o = q_o \max \left[1 - 0.2\left(\frac{P_{wf^1}}{P_r}\right) - 0.8\left(\frac{P_{wf^1}}{P_r}\right)^2\right] \quad (9)$$

The simulation was done at different pressures staging to check and study the effect of inflow of undesired fluid on oil inflow rate and the anticipated effect of formation damage on inflow rate, which are fundamental for a quick insight on the performance of smart oil wells. The data variables of the reservoir pressures, bottom hole flowing pressures, oil flow rates and water flow rates were inputted into the simulator to obtain the inflow performance relationship curves for the three comingled producing reservoirs using field unit for simulation results consistency.

3. RESULTS AND DISCUSSION

Results:

Results of the calculated dimensionless flow rate and the dimensionless pressures at flow efficiencies of one and zero point seven are presented in tables 1 to 2.

The results of the IPR's for multiple phase flow is presented in Figure 1. Similarly, the results of IPR for single phase flow and the PI determination curve are presented in Figures 2 and 3. The IPR result in term of changes in flow efficiency is presented in Figure 5. Finally, Figure 6 is the results of smart well IPR and the individual producing zones comparison.

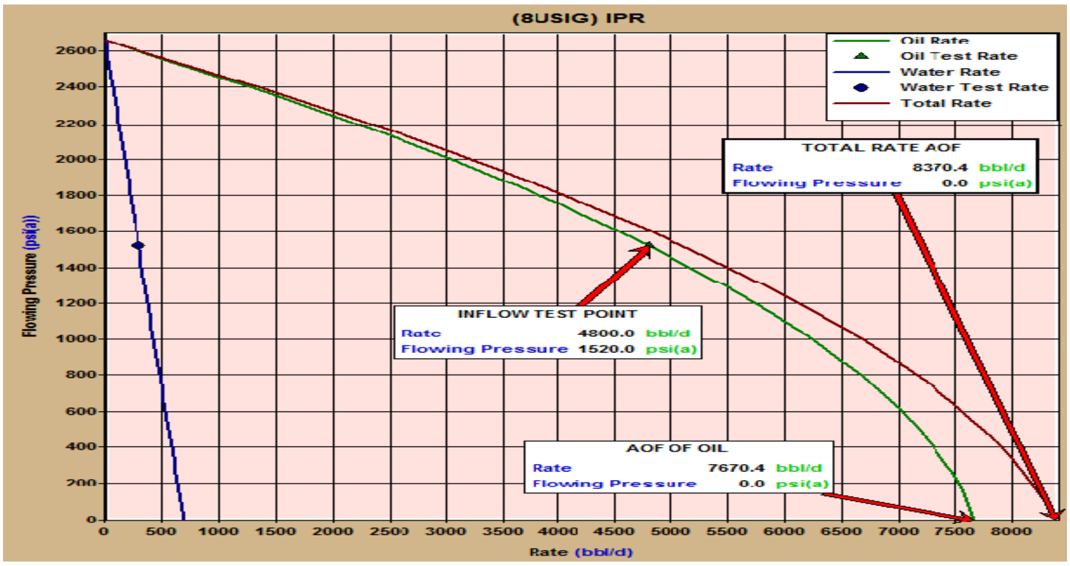

Fig.1: 8USIG Inflow Performance Relationship Curve For Multiple Phase Flow.

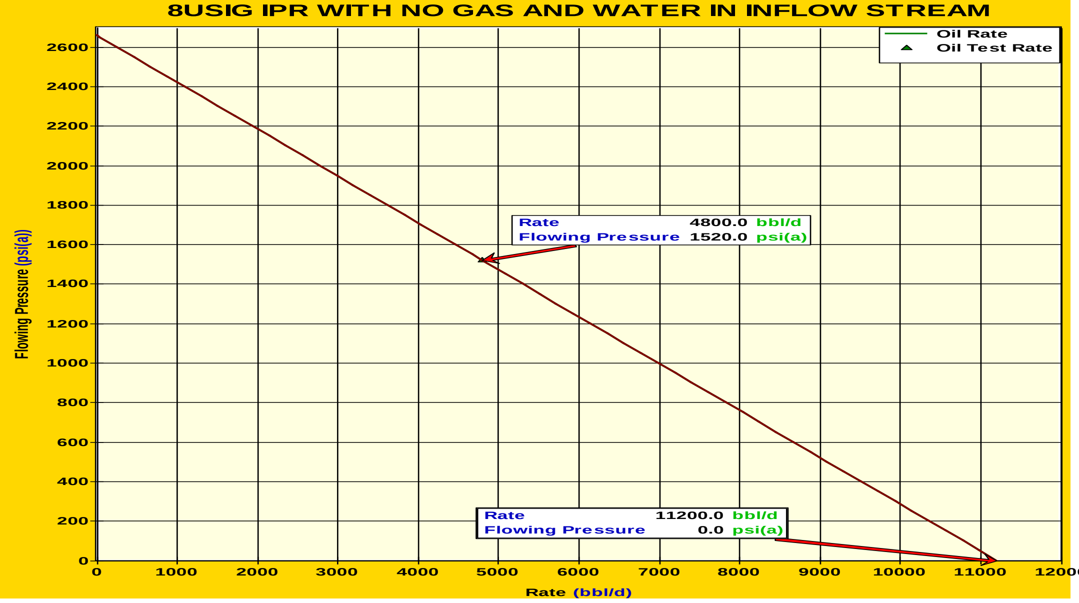

Fig.3: 8USIG IPR Curve for Single Phase Oil in the Inflow Stream.

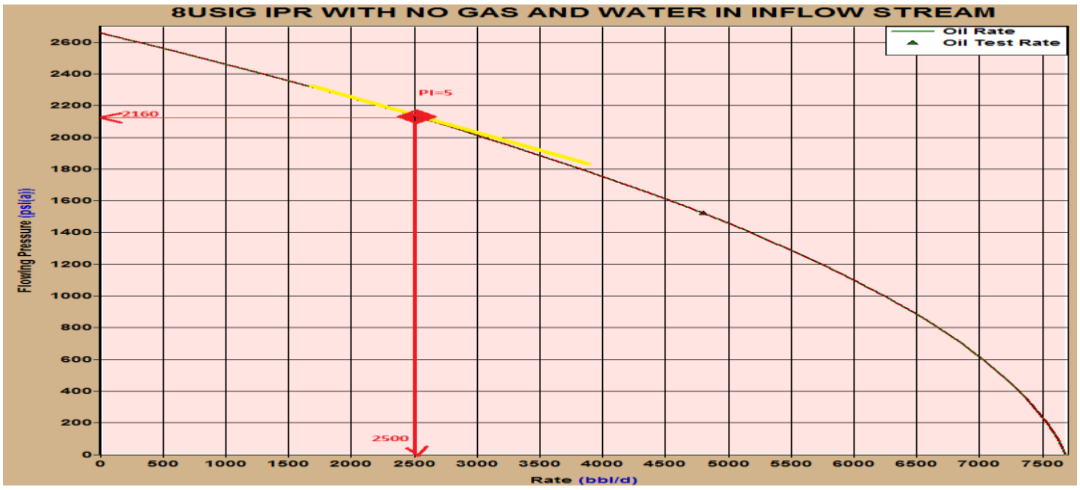

Fig.3: 8USIG PI Determination Curve

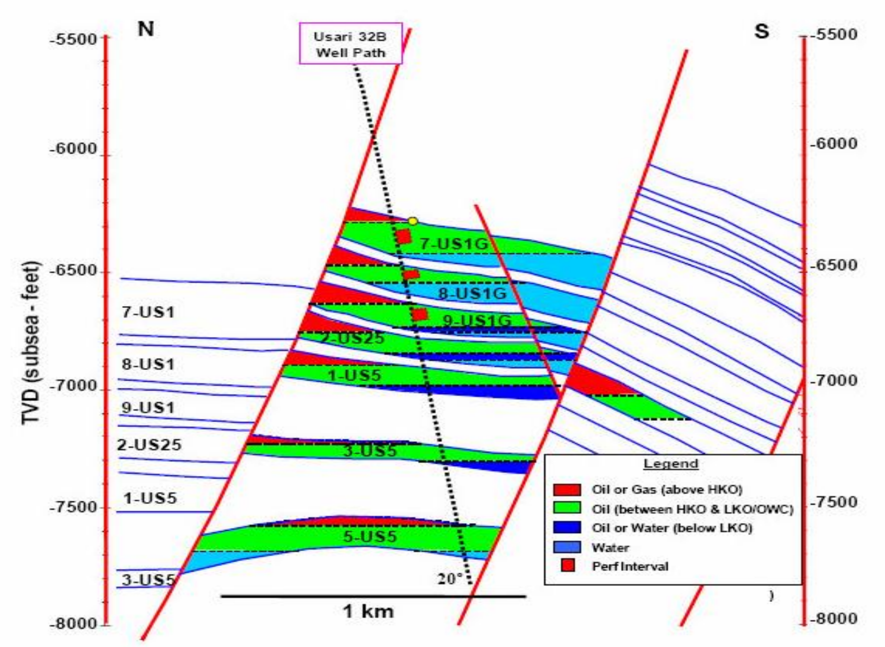

Fig.4: Producing Zones Reservoir Subsurface Map

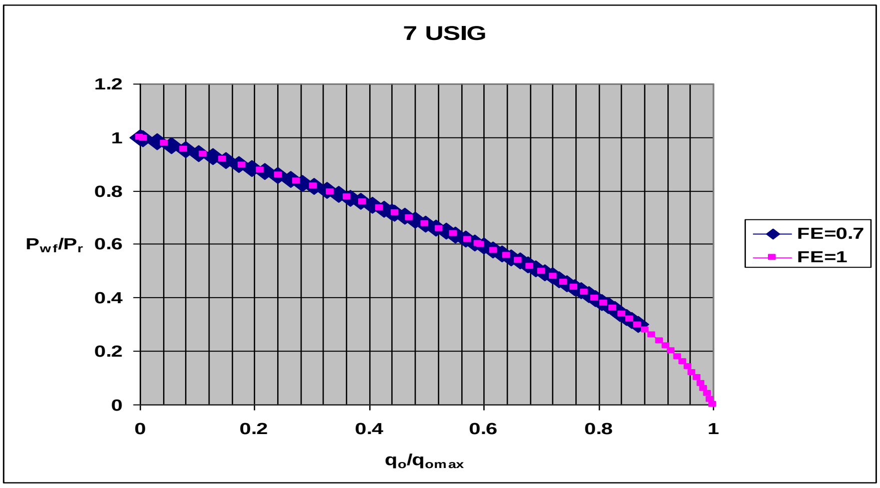

Fig. 5: 7USIG IPR in Terms of Changes in Flow Efficiency.

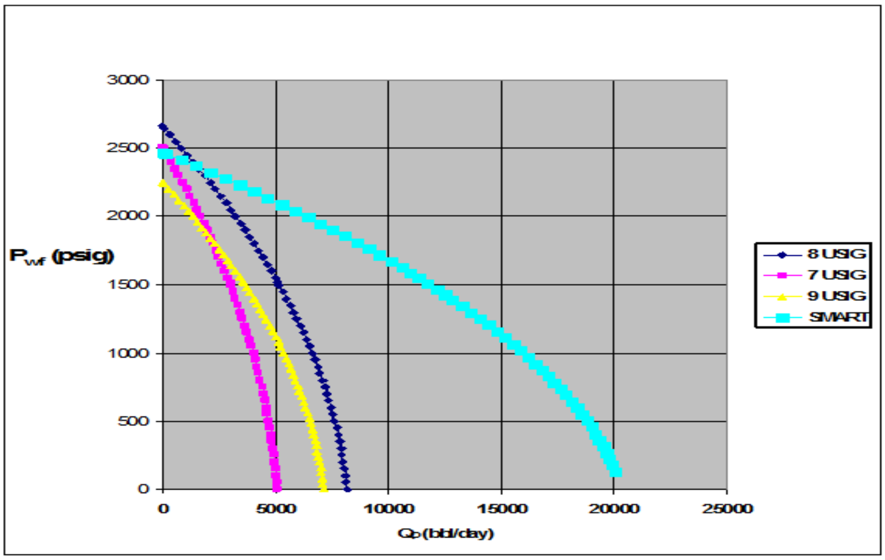

Fig.6: Producing Zones and Smart Well IPR Comparison

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Table 1: Calculated Dimensionless Flow rates and Dimensionless Pressures at FE=1

Q_0/Qo_{max} @ FE =1			P_{wf}/P_r @ FE=1		
8 USIG	**7 USIG**	**9 USIG**	**8 USIG**	**7 USIG**	**9 USIG**
0	0	0	1	1	1
0.006756	0.007159	0.007984	0.996241	0.996016	0.995556
0.040194	0.042571	0.039605	0.977444	0.976096	0.977778
0.073068	0.077348	0.07072	0.958647	0.956175	0.96
0.105376	0.11149	0.101329	0.93985	0.936255	0.942222
0.137119	0.144998	0.131433	0.921053	0.916335	0.924444
0.168297	0.17787	0.161031	0.902256	0.896414	0.906667
0.198909	0.210108	0.190123	0.883459	0.876494	0.888889
0.228956	0.24171	0.21871	0.864662	0.856574	0.871111
0.258437	0.272678	0.246791	0.845865	0.836653	0.853333
0.287354	0.303011	0.274366	0.827068	0.816733	0.835556
0.315705	0.332709	0.301436	0.808271	0.796813	0.817778
0.34349	0.361772	0.328	0.789474	0.776892	0.8
0.370711	0.3902	0.354058	0.770677	0.756972	0.782222
0.397366	0.417993	0.379611	0.75188	0.737052	0.764444
0.423455	0.445152	0.404658	0.733083	0.717131	0.746667
0.44898	0.471675	0.429199	0.714286	0.697211	0.728889
0.473939	0.497564	0.453235	0.695489	0.677291	0.711111
0.498332	0.522817	0.476764	0.676692	0.657371	0.693333
0.522161	0.547436	0.499789	0.657895	0.63745	0.675556
0.545424	0.57142	0.505466	0.639098	0.61753	0.671111
0.568121	0.590149	0.522307	0.620301	0.601594	0.657778
0.590254	0.594768	0.54432	0.601504	0.59761	0.64
0.611821	0.617482	0.565827	0.582707	0.577689	0.622222
0.62449	0.639561	0.586829	0.571429	0.557769	0.604444
0.632823	0.661005	0.607324	0.56391	0.537849	0.586667
0.653259	0.681815	0.627315	0.545113	0.517928	0.568889
0.67313	0.701989	0.646799	0.526316	0.526316	0.551111

Table 2: Calculated Dimensionless Flow rates and Dimensionless Pressures at FE=0.7

P_{wf}^1/P_r			Q_0/Q_{Omax} @ FE=0.7		
8 USIG	**7 USIG**	**9 USIG**	**8 USIG**	**7 USIG**	**9 USIG**
1	1	1	0	0	0
0.997368	0.997211	0.996889	0.800526	0.800558	0.800622
0.984211	0.983267	0.984444	0.803158	0.803347	0.803111
0.971053	0.969323	0.972	0.805789	0.806135	0.8056
0.957895	0.955378	0.959556	0.808421	0.808924	0.808089

0.944737	0.941434	0.947111	0.811053	0.811713	0.810578
0.931579	0.92749	0.934667	0.813684	0.814502	0.813067
0.918421	0.913546	0.922222	0.816316	0.817291	0.815556
0.905263	0.899602	0.909778	0.818947	0.82008	0.818044
0.892105	0.885657	0.897333	0.821579	0.822869	0.820533
0.878947	0.871713	0.884889	0.824211	0.825657	0.823022
0.865789	0.857769	0.872444	0.826842	0.828446	0.825511
0.852632	0.843825	0.86	0.829474	0.831235	0.828
0.839474	0.82988	0.847556	0.832105	0.834024	0.830489
0.826316	0.815936	0.835111	0.834737	0.836813	0.832978
0.813158	0.801992	0.822667	0.837368	0.839602	0.835467
0.8	0.788048	0.810222	0.84	0.84239	0.837956
0.786842	0.774104	0.797778	0.842632	0.845179	0.840444
0.773684	0.760159	0.785333	0.845263	0.847968	0.842933
0.760526	0.746215	0.772889	0.847895	0.850757	0.845422
0.747368	0.732271	0.769778	0.850526	0.853546	0.846044
0.734211	0.721116	0.760444	0.853158	0.855777	0.847911
0.721053	0.718327	0.748	0.855789	0.856335	0.8504
0.707895	0.704382	0.735556	0.858421	0.859124	0.852889
0.7	0.690438	0.723111	0.86	0.861912	0.855378
0.694737	0.676494	0.710667	0.861053	0.864701	0.857867
0.681579	0.66255	0.698222	0.863684	0.86749	0.860356
0.668421	0.648606	0.685778	0.866316	0.870279	0.862844

4. DISCUSSION

The analysis considers the current performance of the well with reference to; the oil flow rate at test point, the oil flow rate at absolute open flow, the water flow rate at test point, the total flow rate for both oil and water and the effect of the likely anticipated formation damage smart wells oil inflow rate.

The inflow rate at test point was studied to determine the current production performance of the smart well. This study was verified with the used of Equation 5 and figure 1 shows that 8 USIG produced 4,800 bbl/day of oil at the tested flowing bottomhole pressure of 1,520 psia, thus, the IPR's of 8USIG contributed the highest oil production in the smart well for the period covered by the data used in this work. This indicates that the reservoir pressure of 8USIG is well managed, with the difference in pressure with other zones being 10psia. The sustenance of production from 8 USIG could be maintained for a longer period before depletion. This is also proven by the high aquifer connected to the three production zones as shown in reservoir subsurface map Figure 4. From this results, it is seen that 9USIG and 7USIG has the highest reserves, but with low oil production rate. For 9USIG and 7USIG, higher inflow rate could be archived if their inflow potential is modeled to accommodate multiple phase flow.

The absolute open flow is the well inflow capacity at zero bottomhole pressure. Although this condition does not exist during production, it a useful theoretical decision point that defines well ability to produce oil. The simulated results show that 7USIG has 4,575.1 bbl/day, 8USIG has 7,670.4 bbl/day and 9USIG has 6,528.6 bbl/day absolute open flow at zero flowing bottomhole pressures. These results were verified with equation 4 as displayed in Figure 1 with the 8USIG having the highest absolute open flow, seconded by 9USIG while 7USIG has the least in the same trend. Again these results present that the three zones have the flow capacities to produce beyond the 59% flow rate which is recorded of the highest production zone. This could be achieve through the reduction of the current high flowing bottom hole pressures which are attribute to gas compressibility that gives rise to the convex sharp of the IPR's curves. Thus, efficient sizing and regulation of the downhole control valves for gas and water inflow limitation could lead to a higher absolute open flow as observed in Figure 2 for 8USIG producing zone IPR curves simulated without water and gas in the flow stream.

The effect of water on the inflow stream was studied to determine its impact on oil inflow rate. The entrained water obtained from the first stage separator was accounted for by the simulator. The results present positive responses from the three zones as shown in Figure 2 for 8USIG having 8,370.4 bbl/day AOF instead of 7,670.4 bbl/day. In the same trend, 7USIG has 5,328.1 bbl/day AOF instead of 4,575.1 bbl/day AOF, AOF and 9USIG has 7,440.8 bb/day AOF instead of 6,528.6 bbl/day. The present of water in the inflow stream contribute to error in the determination of actual oil inflow rate as spotted out in the simulated results. A review of the present operating condition and monitoring of the inflow control devices could stabilize flow to the near flow assurance as shown in Figure 5 with an increased in AOF as a result of absent of water and gas in the oil inflow stream.

True productivity index is the focus of the analysis in this work. The term "true" is because it is determine from only oil inflow curves as shown in Figure 3. Equation (1) was used to confirm the results of the deduced values from 7USIG, 8USIG and 9USIG IPR curves. The results are 3.1 bbl/day/psia for 7USIG, 5 bbl/day/psia for 8USIG and 4.2 bbl/day/psia for 9USIG. The high PI of 8USIG confirms that the pressures of the drive mechanisms are high enough to produce the reservoir which is also shown in the subsurface map, but the reverse is the case for 7USIG and 9USIG. This reverse called for a review of the inflow potential of 7USIG and 9USIG. This is because the three reservoirs are located in the same geological region within a uniform reservoir properties of which reduction in the productivity index may have been as a result of improper performance of the downhole inflow control devices and liquid loading from excessive gas evolution and the effect of fluid interactions in the downhole.

Assumed values of flow efficiency were used to study anticipated factors for future performance of the smart well. The flow efficiencies of 1 and 0.7 were deployed in the determination of dimensionless flow rates and the dimensionless pressures, tables 1 and 2 shows the results of the calculated dimensionless flow rates and dimensionless pressures values from the oil production data on the assumed flow efficiencies. Figure 5 shows the plot of the result of tables 1 and 2 for 7USIG. From this plot, a change in the flow efficiency below 1 affected oil flow rates and the absolute open flow. The absolute open flow rates shifted from 1 to 0.88 for the flow efficiency of 0.7. The response of the flow rate to these changes clearly shows what likely is to be the outcome of future performance of the smart if the well is damage for any reasons. With this fact, production engineers can plan for a better production schedule to delay water production which is found to be a likely threat that could lead to sand and clay migration that could result in flow channels plugging.

Inflow performance relationship comparison was also studied to determine how the different producing zones will perform if they were to be completed independently in separate tubing. Figure 6 shows a simulated absolute open flow of commingled smart well at 20,500 bbl/day, while the sum total of the three producing zones has 19,000 bbl/day as the absolute open flow. These results indicate that smart well has the tendency of improving the recovery of oil over none smart wells. But, the implementation of smart well must be based on economic reserves justification due to the high cost that accomplished the designs and deployment.

5. CONCLUSION

Wells equipped with smart completion hardware's are unconventional complex multilateral wells that require accurate production performance evaluation. In this work, the followings are the conclusion;

1. The actual oil inflow rate for smart wells can be well evaluated using a quick IPR approach adopted in this work.
2. The actual oil inflow rates of 2,700 bbl/day, 4,800 bbl/day and 3,300 bbl/day are evaluated for 7USIG, 8USIG and 9USIG respectfully from the simulated IPR curves.
3. The PI of 3.1 bbl/d/psia, 5 bbl/d/psia and 4.2 bbl/d/psia are gotten for 7USIG, 8USIG and 9USIG from the PI simulated curve evaluation.
4. Early formation damage will have a significant effect on the inflow rate as shown in the decrease in the ratio of the flow rate and maximum flow rate from 1 to 0.88 when FE equal to 0.7 (Figure 5).
5. In commingling the three zones in smart completion, the absolute open flow is 20,500 bbl/day, without commingling, the three producing zone gives 19,000 bbl/day (Figure 6).
6. The approach used here provides a quick insight for early isolation of the errors contributed by gas and water in the analysis of oil inflow performance relationship (IPR) curves.
7. Integrated approaches are more representative of total systems constraints and should be built for analysis of smart wells whenever possible.

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APPENDIX - A

NOMENCLATURE:

AOF	-	Absolute open flow
Stb/d	-	Stock tank barrel/day
Psi	-	Pound square inch
ICVs	-	Inflow control values
IPR	-	Inflow performance relationship
VPR	-	Value performance relationship
q_{omax}	-	Maximum oil flow rate
q_o	-	Oil flow rate
P_d	-	Dimensionless pressure
P_b	-	Bubble pressure
TPC	-	Tubing performance curve
STOIIP	-	Stock tank oil initial in place
P_r	-	Reservoir pressure
P_{wf}	-	Flowing bottomhole pressure
FE	-	Flow efficiency
P_{wf}^1	-	Flowing bottomhole pressure at formation damage
bbl/day	-	Barrel per day
J	-	Oil productivity index
7USIG	-	The upper producing zone of the case studied well
8USIG	-	The middle producing zone of the case studied well
9USIG	-	The lower producing zone of the case studied well