Integrated Production Systems Optimization: A mature Niger Delta Field Case Study

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Abstract: ***Integrated production system models are being applied to a lot of global liquid production in the petroleum industry today. The integrated systems are fit for purpose and essentially support decision making in any application they are used. Integrated models are typically combined systems of the reservoir models, well models and surface-network model in a single higher-level model. Production Systems should be designed for optimum performance of every component, which for oil and gas systems range from the reservoir, to the wellbore, up the surface facilities. Nodal Analysis, in conjunction with integrated production models, offer a cost effective means for having this desired performance, hence having more economic systems. This paper demonstrates the use of Nodal Analysis and an integrated production model, to optimize production in a mature Niger Delta field. Continuous declining rates have greatly limited the economics for routine production optimization activities. Therefore, an integrated model was built for the wells, reservoir and flow lines. It takes into account all the connectivity and varying dimensions of all the wells and flow lines in the field. The model, together with a systematic Nodal Analysis of the entire system, was used to identify common optimization challenges such as choke size selection, debottlenecking of flow lines, amidst others, and make good recommendations. Upon application, this approach enabled optimum increase of production rates for the field.***

Keywords: Integrated Production Modeling, Niger Delta, Debottlenecking, Production Optimization

1. Introduction

Oil and Gas Systems, designed to move hydrocarbons from their position at the reservoir to their desired destination at the surface/stock tank, are made up of components which play individual roles to ensure an effective hydrocarbon recovery. In actual field designs, it is easy to lose sight of these components, the common tendency being to design them as separate systems but this work will demonstrates the values of a holistic approach in field management, especially for a mature field.

Today, production systems optimization has become the hub of activities related to complete field and asset management. The various optimization activities such as reservoir pressure maintenance, debottlenecking of flow lines, amidst others, have helped petroleum production engineers and earth scientists understand the interdependence of the various existing system components. Due to continuous decline in efficiency of oil production systems, optimization activities are performed to enhance and ensure effective oil production by improvement in efficiency of the producing system. The improvement may be dramatic in some situations thus enabling development of a field which would otherwise have been considered uneconomical.

Production optimization applies proper well and reservoir management for the following target areas: increase in oil flow rate, decrease in cost (with possible decrease in flow rate), and overall increase in NPV (Net Present Value).

The normal methods used to forecast petroleum production rates do not properly account for the interaction between fluid flow in the reservoir and in other components of the production system. However, when complex gathering systems are present, models to handle surface facilities, wells, and reservoirs as integrated systems are necessary to improve the accuracy of predicting reservoir deliverability. An efficient method for coupling surface facilities to reservoir simulators is an important step for the development of management routines and optimization of system performance.

In existing management routines and in some full-field case studies, the production facilities model is normally treated explicitly and, frequently, operating conditions must be estimated before the simulation run.

Several models for determining well productivities and predicting future reservoir performance have been formulated by different authors over the years, which rely heavily on the well characteristics such as horizontal and vertical permeability, effective well length, formation porosity and compressibility, obtained from transient well testing methods. These models are based on many assumptions, resulting to a wide range of uncertainty in the productivity calculations. At times, well flow rates are simply distributed according to pre-calculated well potentials and pressure drop in the surface facilities may even be ignored. Chokes are also rarely considered in such models. In this work however, they play a vital role as instruments for field analysis and management.

2. Background

For the purpose of this project, a brown Niger Delta Field X was discovered in 1974 by the X-01 exploratory well. However, production never started until later in 1993. There are three major oil-producing reservoirs present (X-C-01, D-02, D-07). Eight wells have been drilled in the field with nine completion intervals (one of the wells being dual completed). Five of these wells are currently producing (X-01D, 02, 04, 05, 08) while three are shut-in (X-01, 03,04D). Long term production has resulted in decline in production rates for this field. It is hereby necessary to identify factors responsible for this decline and thus, initiate an optimization schedule for this field.

3. Optimization of Field X With Integrated Well/Reservoir Management

An integrated model was built for the entire Field X network using Petroleum Experts' Integrated Production Modeling

(IPM) toolkit. MBAL was used for the reservoirs, PROSPER's Nodal Analysis for the wells and GAP for the flow lines/surface facilities.

4. Material Balance Analysis (MBAL)

With respect to the reservoirs in field X, accurate fluid and production history matching and simulation was done to predict the fields production capacity. The MBAL platform makes it possible to simulate and predict, to a particular degree of certainty, future reservoir pressures and expected fluid production.

From the reservoir and well models built, it is required to link these with the surface network consisting of chokes, flow lines and the separator. This is necessary to obtain a holistic view of the production system and hence carry out integrated production systems optimization.

Using the General Allocation Package (GAP), a surface production model was built for FIELD X. Fig. 1 shows the GAP outlook for Field X, which is a complete representation of the field's surface development. Based on the field production history and the incorporated models, it can be noticed that over time, some of the chokes and flow lines have bottlenecked (icons in pink from Fig. 2). This is a significant factor responsible for the production system's reduced efficiency. It was hereby established that Field X had factors limiting its efficiency.

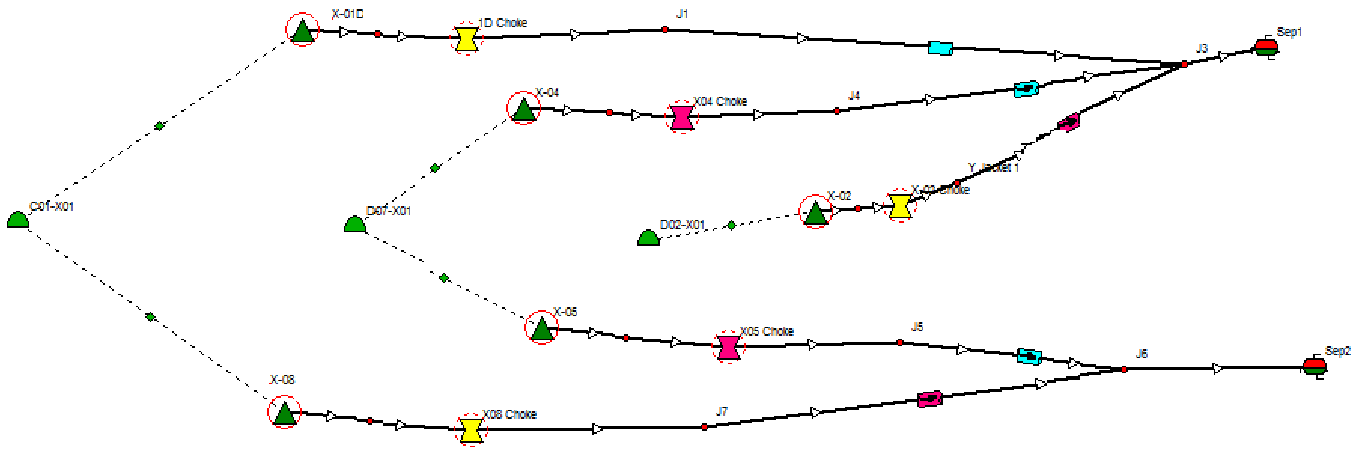
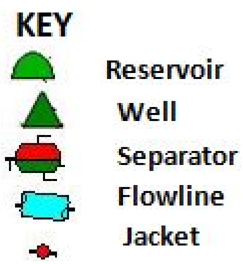


Figure 1: Gap Model for Field X



Thus, debottlenecking and further Nodal Analysis were carried out to optimize the system with the results shown. The various optimization activities include:
1. Nodal Analysis,
2. Choke Optimization,
3. Debottlenecking.

From the well models, the following table was generated:

Table 1: Data from Well Models

WELL	*Oil Flow Rate (STB/day)*	*Flowing Bottomhole Pressure(psig)*	*Choke size (inches)*	*Water cut (%)*
X-1D	77.1	4197.64	12	70
X-04	2201	3686.97	32	10
X-05	1666	3783	38	10
X-08	1171.3	4153	34	25
X-02	205	3270	20	25

From the integrated system for Field X, a component was selected to be optimized. Based on the well test data, the wells with the best options for selection were the X-04 well and X-05 well, being the highest oil producers with the least water production.

5. Choke Optimization Using Nodal Analysis for Well X-04

The existing choke size for X-04 was a 32/64" choke. The choke optimization required selecting a new choke size with optimum performance. The X-04 prosper file hence was used to carry out choke sensitivity.

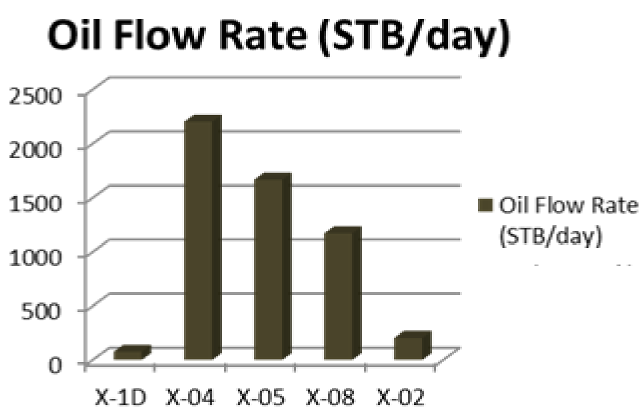


Figure 2: Oil Flow Rate

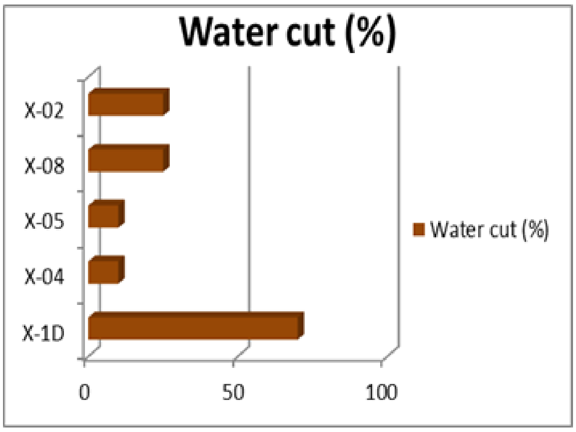


Figure 3: Water Cut

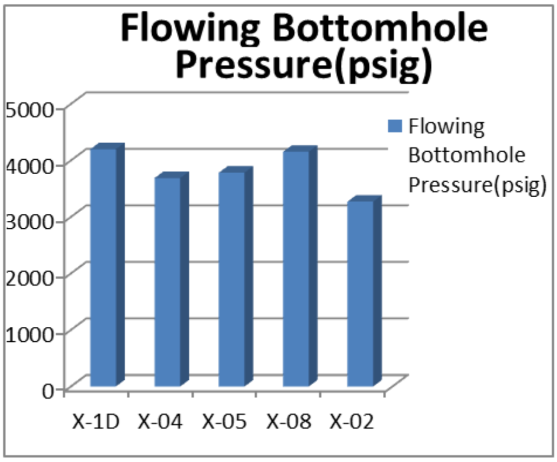


Figure 4: Flowing Bottomhole Pressure

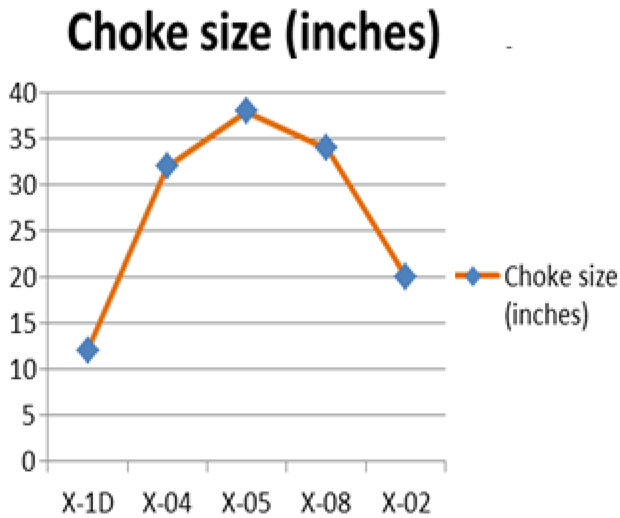


Figure 5: Choke size

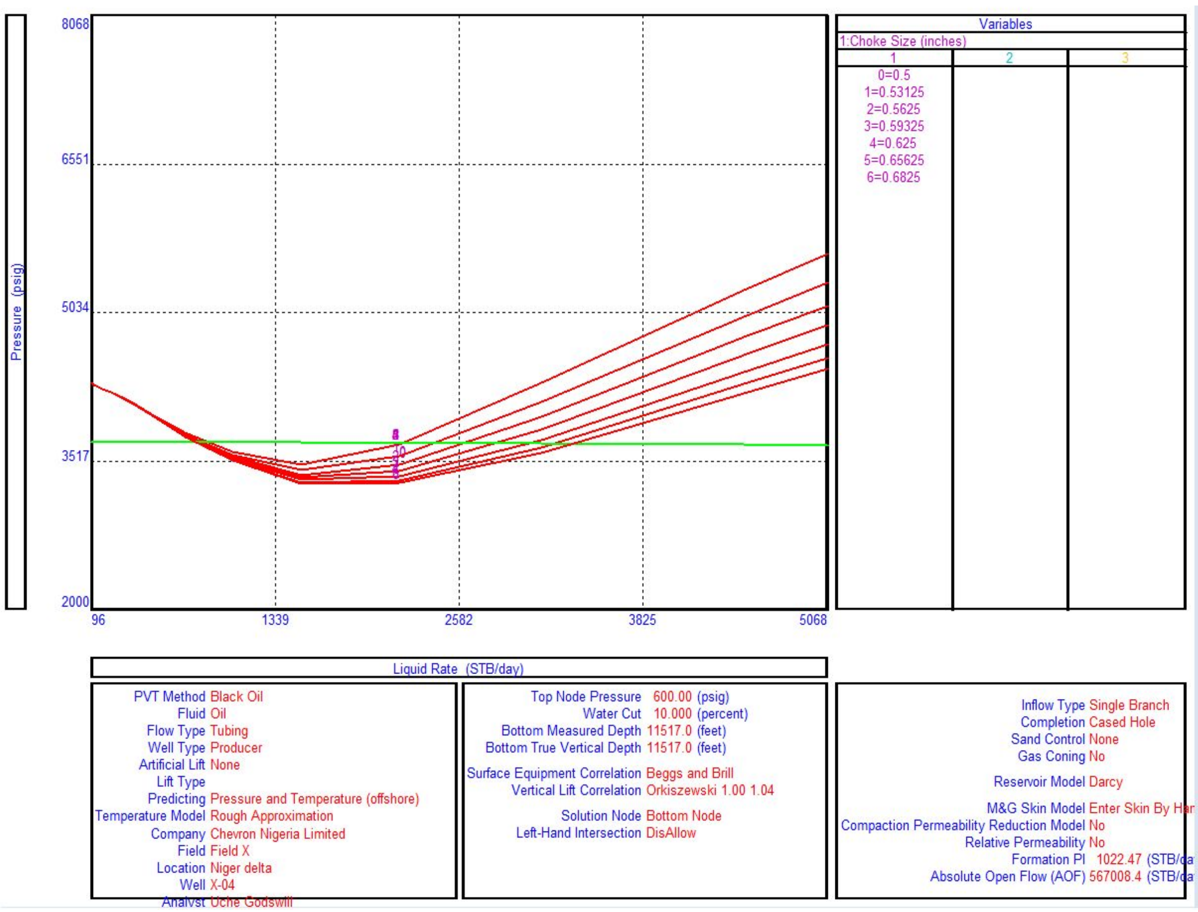


Figure 6: X-04 Choke Optimization Using Nodal Analysis

The figure above illustrates the Nodal Analysis theory. An increase in choke size means a resultant increase in production rate. In Fig. 6 we see that as choke size was increased from form 32/64” (0.5) to 44/64” (0.6875), the VLP plot shifts to the right. Taking the wellhead as a node, the choke hence forms part of the downstream component and hence the resultant shifts in the VLP curve. After performing choke sensitivity, the choke sizes were plotted against their respective flow rates.

Criteria for Choke Selection

1. Effect On Oil Rate,
2. Total Pressure drop across skin.

Table 2: X-04 Choke sensitivity results at 10% Water Cut

Choke	*32/64*	*34/64*	*36/64*	*38/64*	*40/64*	*42/64*	*44/64*
Rates (BOPD)	2201	2391.8	2612.	2828.3	3071	3246.	3395.4
Total dP skin (psi)	16.45	17.86	19.53	21.15	22.97	24.29	25.41
% change in dP skin	-	13	11	11	9	9	8

From the sensitivity run, the results were tabulated for a 10% water cut. From, the above stated selection criteria, the choke size selected was 34/64” since there was an increase without intense effects on skin.

6. Choke Optimization Using Nodal Analysis for X-05

Using the sensitivity run in Prosper analysis, it was observed that, just like the X-04 well, an increase in choke size for the X well would reduce the pressure on the succeeding flow line as shown in the GAP model, while increasing flow rate for the well.

A sensitivity study was hence done for the well, with the choke size being the sensitizing factor. The operating choke size from the test data is 38”. Sensitivity was done using choke sizes of 40”, 42” and 44”. For the sensitivity study, the PROSPER well model was used. This is a more efficient method to monitor flow rates and skin effects rather than other manual iterative processes.

A plot was also generated in Excel showing the variation in flow rates with choke sizes. The plot showed an upward trend.

The existing choke size for X-05 was a 38/64” choke. The choke optimization required selecting a new choke size with optimum performance.

An increase in choke size showed a resultant increase in production rate. It was seen that as choke size was increased from form 38/64” (0.59375) to 44/64” (0.6875), the VLP plot shifts to the right.

Taking the wellhead as a node, the choke hence formed part of the downstream components and hence the resultant shifts in the VLP curve.

After performing choke sensitivity, the choke sizes were stated against their respective flow rates.

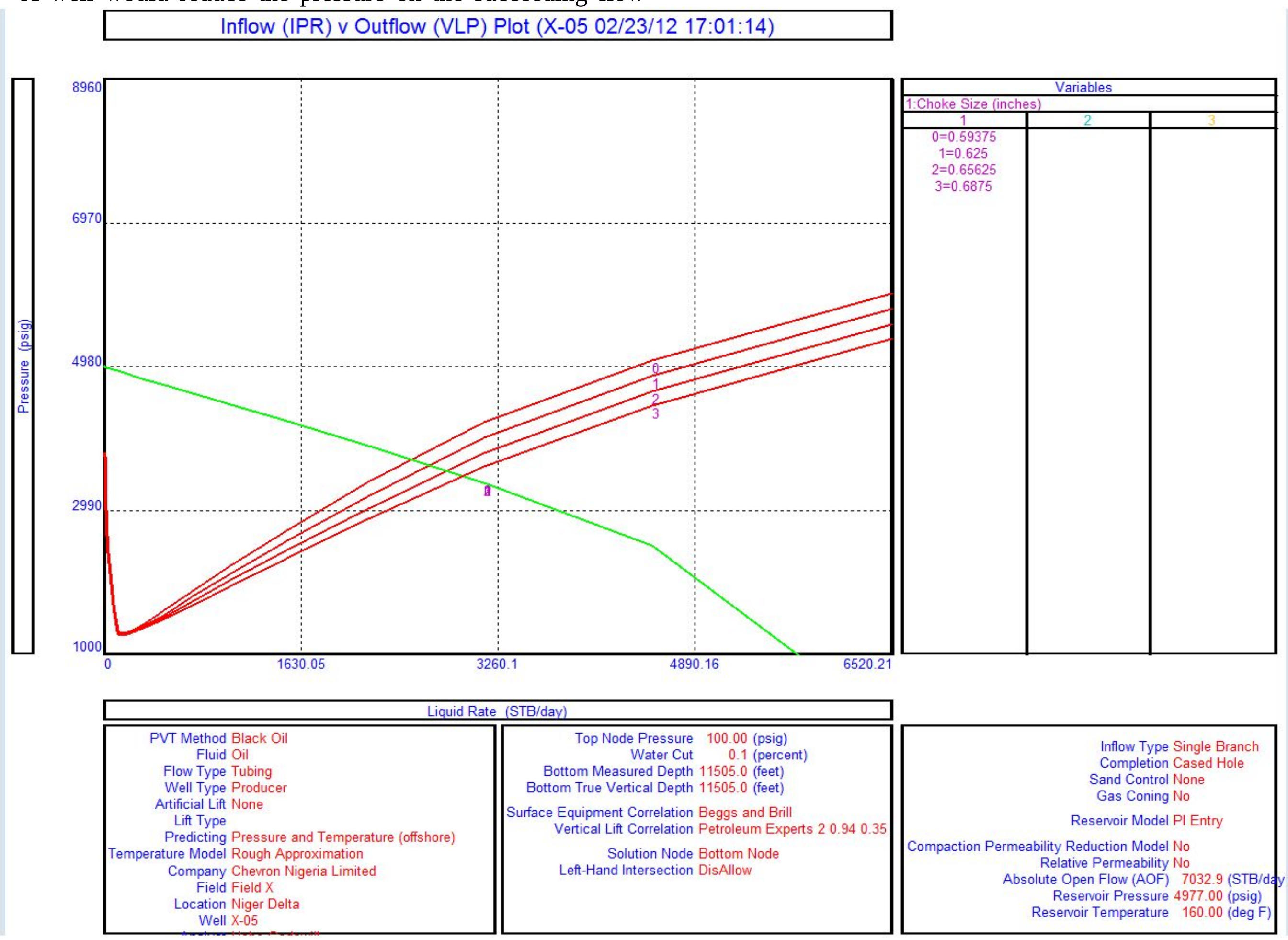


Figure 7: X-05 Choke Optimization Using Nodal Analysis

Table 3: Results from PROSPER Choke Sensitivity

CHOKE SENSITIVITY FOR X-05 at 0.1% water cut				
CHOKE SIZE	38	40	42	44
Oil Rate(STB/Day)	2208.2	2265.7	2357.1	2504.8
Total dP skin	7.5	7.9	8.3	8.74

7. Debottlenecking of Surface Network

From the Nodal Analysis and Choke Optimization done, the entire field network was affected thus:

Table 4: GAP network data before optimization

WELL	*Flowing Wellhead Pressure, FWHP(psig)*	*Oil Flow Rate (STB/day)*	*Pressure Drop Across Choke(psi)*	*Pressure Drop Across Pipe(psi)*
X-1D	100.1	77.1	0.1	0
X-04	751.21	2201	473.24	177.97
X-05	771.04	1666	433	238.04
X-08	1066.35	1171.3	155.77	810.26
X-02	827.52	205	46.66	680.86

Table 5: GAP separator data before optimization

Separator	Pressure(psig)	Oil Flow Rate(STB/day)
Sep-01	100	2494.8
Sep-02	100	3488

Table 6: GAP network data after optimization

WELLS	*Flowing Wellhead Pressure FWHP(psig)*	*Oil Flow Rate (STB/day)*	*Pressure Drop Across Choke(psi)*	*Pressure Drop Across Pipe(psi)*
X-1D	-2.6	0	0	98.15
X-04	270.06	2243.8	0.04	170
X-05	330.47	2208.8	0.06	230.41
X-08	116.57	1280	0.47	14.09
X-02	136.31	251	0	36.31

Table 7: GAP separator data after optimization

Separator	Pressure(psig)	Oil Flow Rate(STB/day)
Sep-01	100	2495
Sep-02	100	3488

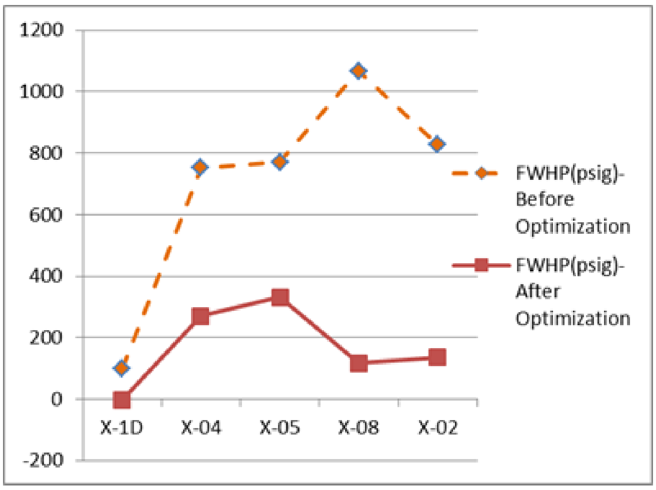


Figure 8: Flowing wellhead pressure before and after optimization

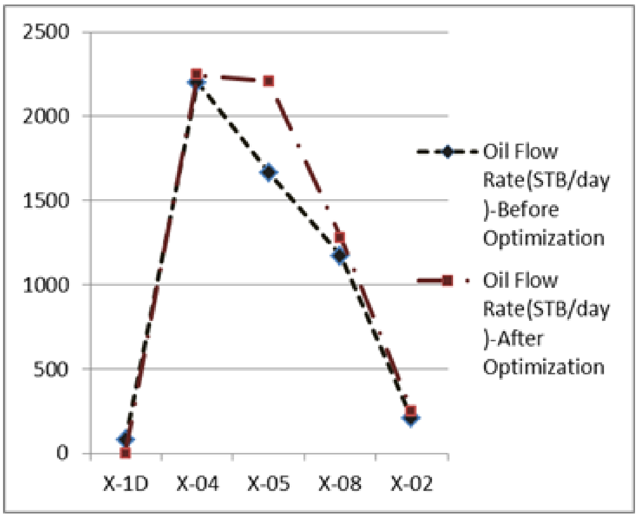


Figure 9: Oil Flow Rate Before and After Optimization

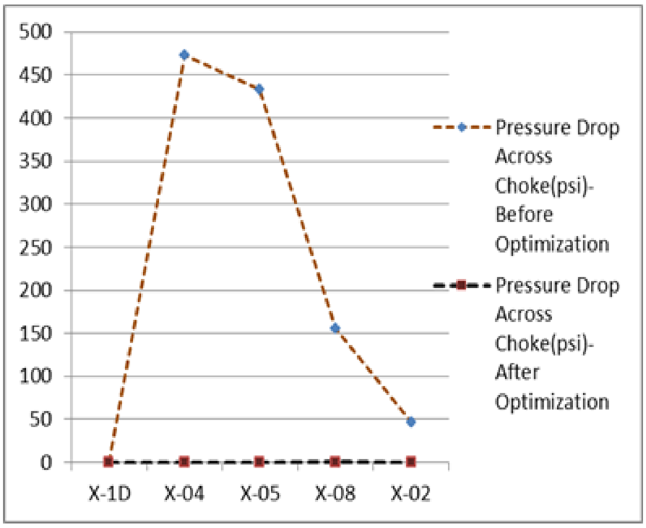


Figure 10: Pressure drop across choke before and after optimization

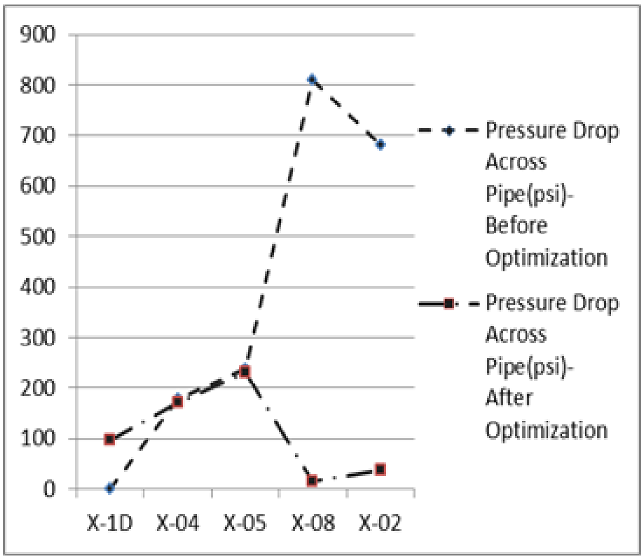


Figure 11: Pressure drop across pipes before and after optimization

From all analysis done above, carrying out the optimization activities undoubtedly resulted in an optimized system with increased efficiency, evident in increased flow rate and better fluid passage through pipes and conduits. An optimized GAP Field Network for Field X is shown in Fig. 12.

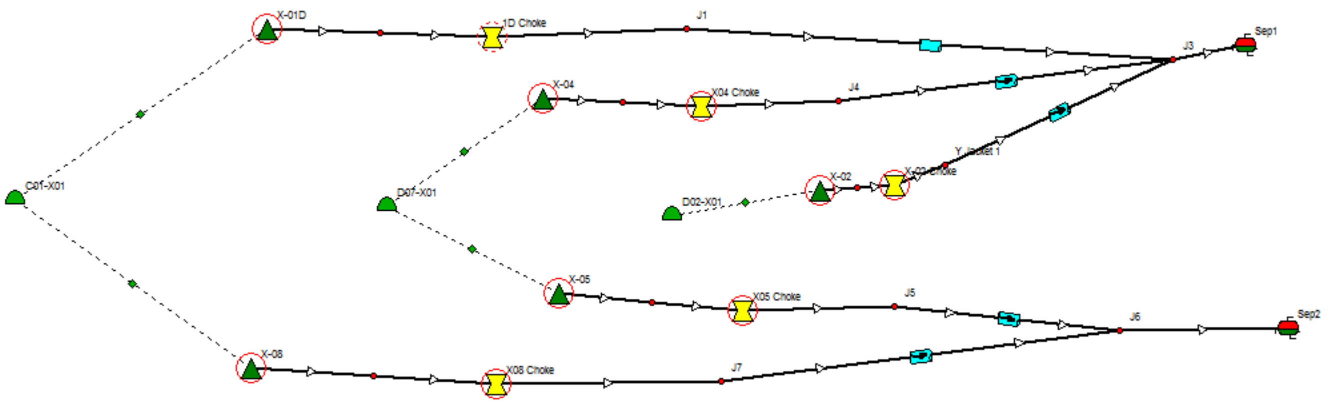


Figure 12: Final Optimized GAP Network for Field X

8. Conclusion

Reliable estimation of productivity of an oil and gas system is essential in order to better evaluate its performance. Today, production optimization is widely applied in different OMLs and generally in the industry. However, it is well recognized that integrated production systems optimization is subject to many uncertainties and interpretation of different sets of data to obtain component characteristics.

This study was able to address issues relating to identifying indicators for optimization and further determine the best method for productivity estimation. Six wells and three reservoirs were considered for the study and the results were presented to demonstrate our evaluations, which would be useful for future estimation of production systems performance. The major conclusions from the study are summarized below:

Chokes used in production systems are important indicators of productivity. Production rate changes with choke size. From the analysis above, the integrated model for Field X and the results obtained from carrying out the choke optimization for well X-04 and well X-05 respectively, were applied and used to achieve the following:

1. Proper well management.
2. Production Optimization.

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