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Improvement of Gas Production Using A Multilateral Well in A Field

Nestor Tsamo[1], Kasi Njeudjang[2], Rolande Tsapla Fotsa[1], Finalise Komofor Ngopuh[3*], Serge Gervais Ngueuteu Mbouna[4] and Philippe Njandjock Nouck[5]

[1]*Department of Mechanical Engineering, College of Technology, University of Buea, Cameroon*

[2]*Laboratory of Civil and Mécanique Engineering, Department of Civil Engineering, National Polytechnic School of Yaoundé, University of Yaoundé I, Cameroon*

[3]*Department of Physics, Faculty of Science, University of Bamenda, Cameroon*

[4]*Laboratory of Modelling and Simulation in Engineering, Biomimetics and Prototypes and TWAS research unit, Faculty of Science, University of Yaoundé I, Cameroon*

[5]*Department of Physics, Faculty of Science, University of Yaoundé I, Cameroon*

***Corresponding Author**
Finalise Komofor Ngopuh, Department of Physics, Faculty of Science, University of Bamenda, Cameroon.

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Abstract
This paper aims to improve gas production using a multilateral well and to determine the optimal depth to avoid the presence of the salt dome encountered in a well of the field called X (for confidential reasons). Based on modelling, nodal, sensitivity, and economic analyses carried out with the computer modelling group (CMG) prosper, and excel softwares, this paper presents several improvement scenarios by varying the tubing diameter and wellhead pressure: (1) a reduction in the wellhead pressure from 200 to 50 psi while maintaining a tubing diameter of 3 inches; (2) improvement of the production rate from 44.5899 MMscf/day to 57.5247 MMscf/day; (3) from an economic perspective, a return on investment of 12 years and 8 months, with a net present value (NPV) of $824,636,751.60 per year.

Keywords: Gas Production, Multilateral Well, Wellhead Pressure, Nodal Analysis, Return on Investment, Net Present Value

1. Introduction

Although naturally occurring gas has been known since ancient times, its commercial use is relatively recent [1-3]. Today, natural gas is a vital component of the world's energy supply [4-6]. Natural gas is currently consumed by residential and commercial customers, and about 41% of the energy used by unite state industry comes from it [7-9]. It is one of the cleanest, safest, and most useful sources of energy. Natural gas has brought significant changes to some African countries by providing export revenue in a world where gas demand has risen significantly and is projected to continue rising in the years ahead. This reflects an increasingly global market, a commitment to lower carbon emission fuels [10-13]. Improving gas methods typically refers to maximizing production efficiency or minimizing costs in industrial processes involving gases. Gas production from wells can be improved to maximize reservoir recovery and economic viability by using improved methods such as nodal analysis, hydraulic fracturing, side-track wells, and multilateral wells [14-16]. In the dynamic landscape of petroleum engineering, the optimization of gas production from multilateral wells within a field represents a great advantage. Multilateral wells, with several branches from a single main borehole, can significantly improve reservoir contact and boost production efficiency [17-19]. The advantage of using multilateral wells over drilling many vertical wells is, firstly, that drilling multiple wells can have significant environmental impacts, including groundwater contamination and subsurface fault destabilization, which could potentially lead to subsidence [20-22]. Secondly, drilling many wells demands high costs.

In the case of the X field, a geological obstacle was detected, that is salt domes, which can complicate drilling operations and necessitate deviations to prevent issues like stuck pipes, lost circulation, and difficulties in maintaining the wellbore trajectory. A central question arises from this observation: How to determine the ideal depth (junction point) for deviating the salt dome and enhance production efficiency and reduce risks? The purpose of this paper is to improve gas production using a multilateral well. The three main specific objectives to be achieved are: (1) The modelling of the reservoir of the X field; (2) design and evaluate the performance of the multilateral well, and (3) perform a sensitivity analysis to choose the optimal flow parameters and do an economic analysis. To successfully achieve these set goals, the present paper includes three sections: Section 2 details the data, tools, and methods approaches to improve gas production of the X field; Section 3 presents the results, and this paper ends with a conclusion.

2. Materiel and Methods

This section presents the data, tools and methods used to achieve the goal of the paper. The well of X field used in this paper is a newly drilled well whose location will not be given to keep the client's confidentiality. The drilling data consisted of deviation data, tie point data and junction data, followed by lateral data, which were obtained from mud while drilling and log while drilling. The multilateral data are presented in Tables 1 to 3.

Measured depth	True vertical
0	0
900	900
1068	1062.3
1188	1164.1
1285	1237.3
1360	1288.8
1516	1374.1
1578	1398.4

Table 1: Deviation data

Parameters	Measured depth	True vertical depth
Tie point	1577	1398.4
Junction	1650	1424

Table 2: Tie point and junction data

Parameters	Measured depth	True vertical depth	Azimuth
Tubing	1577	1398.4	0
	1650	1424	230.6
Lateral 1	1650	1424	230.6
	1701	1437	230.6
	1840	1449.3	243
	1940	1450.9	264.9
Lateral 2	1650	1424	230.6
	1710	1430.1	231.6
	1784	1432.7	239.2
	1908	1432.2	257.6
	2024	1438.5	267.1
	2155	1447.9	256.6

	2290	1445.8	248.1
	2395	1449.8	238.8
	2436	1449.8	235
	2493	1449.8	231

Table 3: Lateral data

The complete data was obtained through well testing. It is subdivided into two tools and perforation data, as shown in Tables 4 and 5.

Parameters	Measured depth	True vertical depth	ID	OD	Grade
Tubing	1650	1424	7 inch	9.625 inch	H40
Lateral 1	1900	1450.26	3.5 inch	6.25 inch	L80
Lateral 2	2483	1449.8	4 inch	7.25 inch	H40

Table 4: Tools data

Table 5: Perforation data

The pressure-volume-temperature (PVT) data were obtained through petrophysical analysis, as shown in Table 6.

Parameters	Values
Gas gravity	0.63
Separator pressure	500
Condensate to gas ratio	0
Condensate gravity	50
Water to gas ratio	2
Water salinity	100000
Mole %H2S	0
Mole %CO2	0.015
Mole %N2	3.6

Table 6: PVT data

The reservoir data were obtained from petrophysical analysis as shown in Table 7.

Parameters	Values
Reservoir pressure	557 psi
Reservoir temperature	65 0F
Reservoir permeability	244
Reservoir thickness	50 ft
Drainage area	800 acre
Reservoir top depth	1400
Vertical permeability	25
Reservoir porosity	0.28
Connate water saturation	0.25

Table 7: Reservoir data

To carry out this work, it required three software: CMG, Microsoft Excel, and Prosper. The goal of this methodology is to obtain the model of the reservoir and design of the multilateral well to improve the production of gas within the X field. This will require a design of the geological structure and a methodological approach linked to the economic evaluation.

3. Results

This section begins with the presentation of the 3D model of the reservoir, the design of the multilateral well, the performance of the well obtained before and after introducing optimal parameters, and lastly the economic evaluation.

3.1. Reservoir modelling

The objective of reservoir modelling was to accurately simulate and understand the behaviour of the reservoir over time. Figure 1 presents the reservoir model, along with the gathered data (permeability, porosity, saturation).

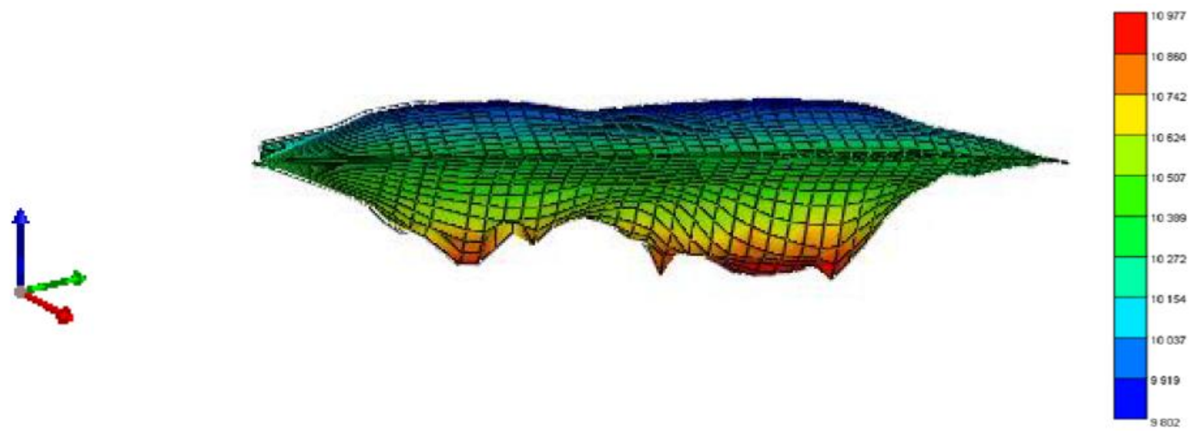


Figure 1: Representation of the 3d Reservoir Model

Through observation, the reservoir model of Figure 1 shows significant challenges due to the presence of a salt dome, which renders the reservoir inaccessible.

3.2. PVT Analysis

It is a crucial part for understanding fluid behaviour in reservoirs, particularly for gas. The gas formation volume factor represents the volume of gas at reservoir conditions per unit volume at standard conditions. The gas formation volume factor versus the pressure is presented in Figure 2.

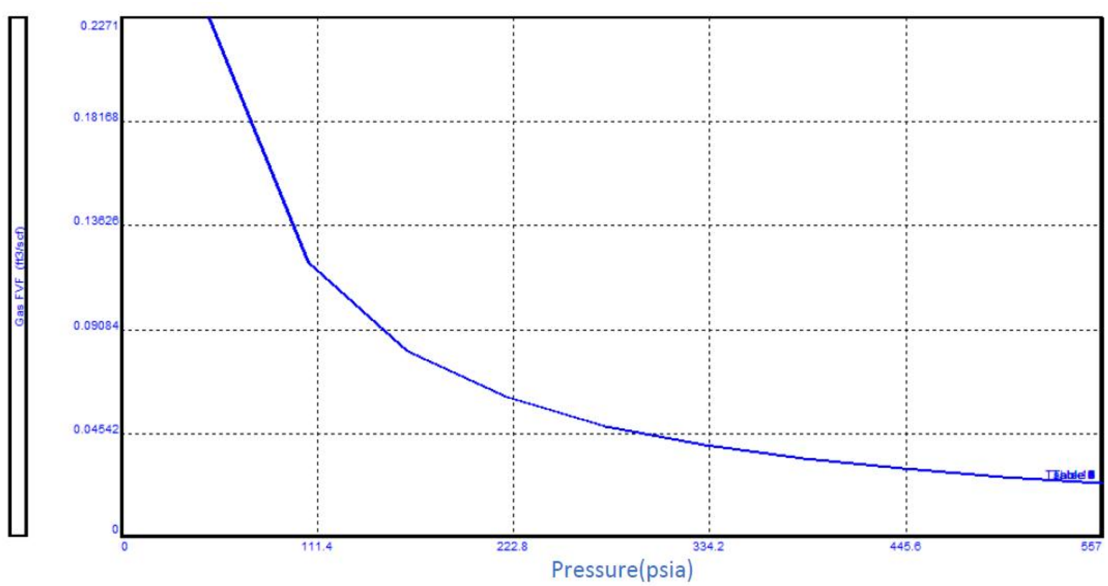


Figure 2: Gas Formation Volume Factor as A Function of Pressure

Figure 2 shows a decrease in pressure, which causes the gas formation volume factor to increase due to gas expansion, which is essential for estimating reserves and understanding gas behaviour during its transition from the reservoir to the surface. The compressibility factor versus the pressure is depicted in Figure 3.

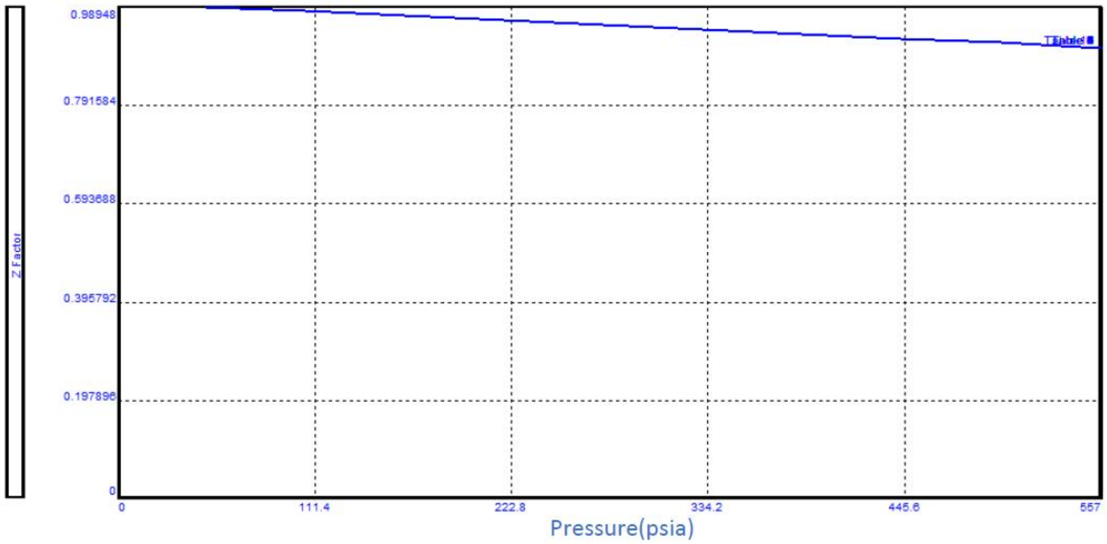


Figure 3: Compressibility Factor as A Function of Pressure

Figure 3 shows a pressure decrease, and the compressibility factor approaches 1, reflecting ideal behavior that is a decrease in compressibility. This is crucial for accurate calculations of gas volumes and phase behaviour during production. The complexity of extracting gas from a reservoir containing a salt dome impacts the project's economic viability and prompts the use of multilateral wells.

3.3. Multilateral Well Design and Performance

The objective of designing the multilateral well is to determine the optimal depth for the junction point to deviate the salt dome. By strategically positioning tie points and junctions, it maximizes access to productive reservoirs while managing geological risks, production efficiency, and economic factors. Figure 4 presents a schematic design of the multilateral well targeting the reservoir.

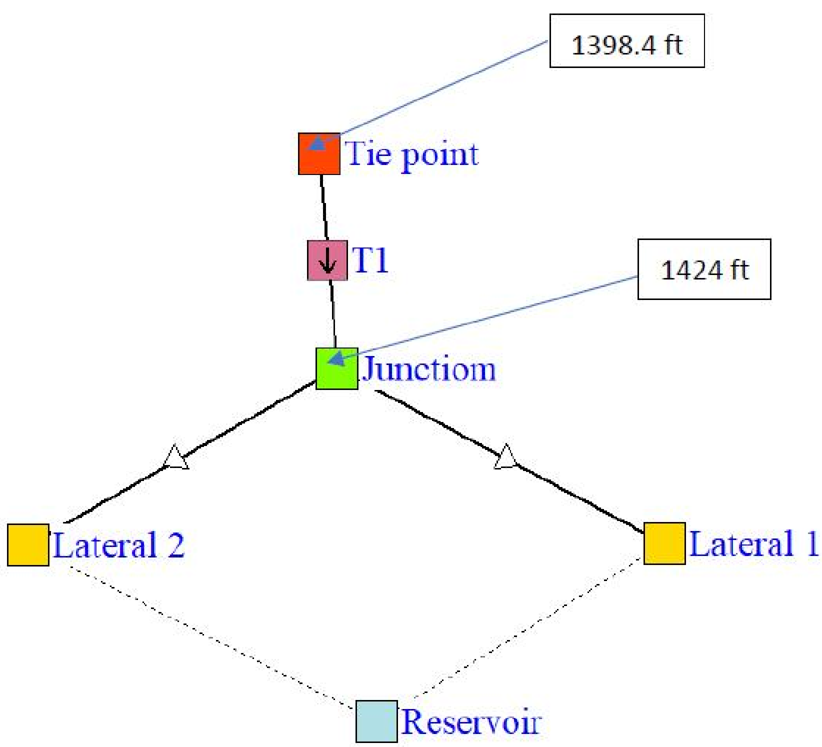
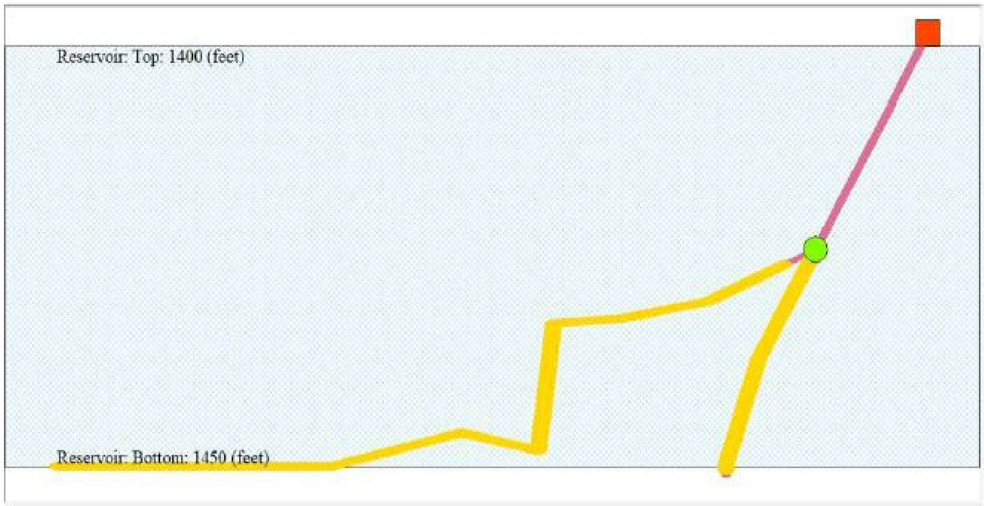
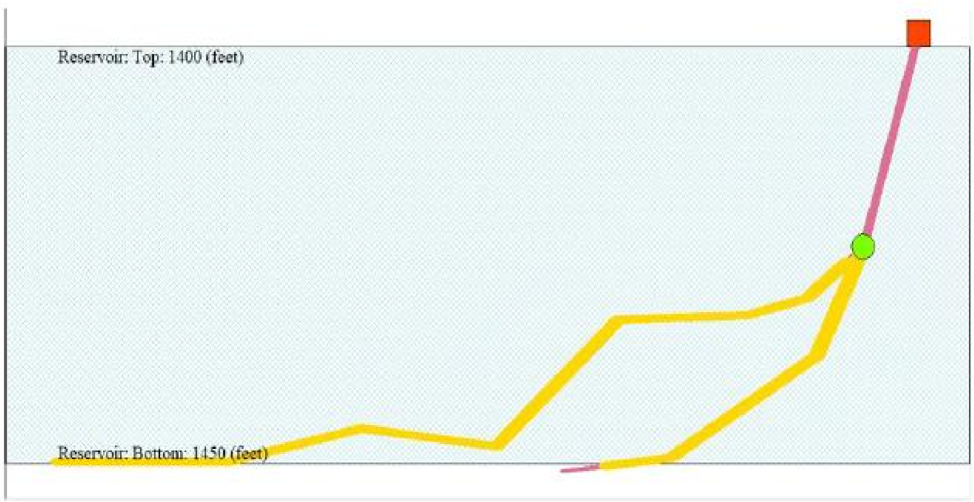


Figure 4: Schematic Design of The Multilateral Well

Figure 5 presents various extended views, providing a comprehensive understanding of the subject.



(a)



(b)

(c)

Figure 5: (a) Front view extent, (b) side view extent and (c) top view extent

Each view of Figure 5 highlights distinct aspects and enhances data clarity. The performance relationship (IPR) curve is depicted in Figure 6.

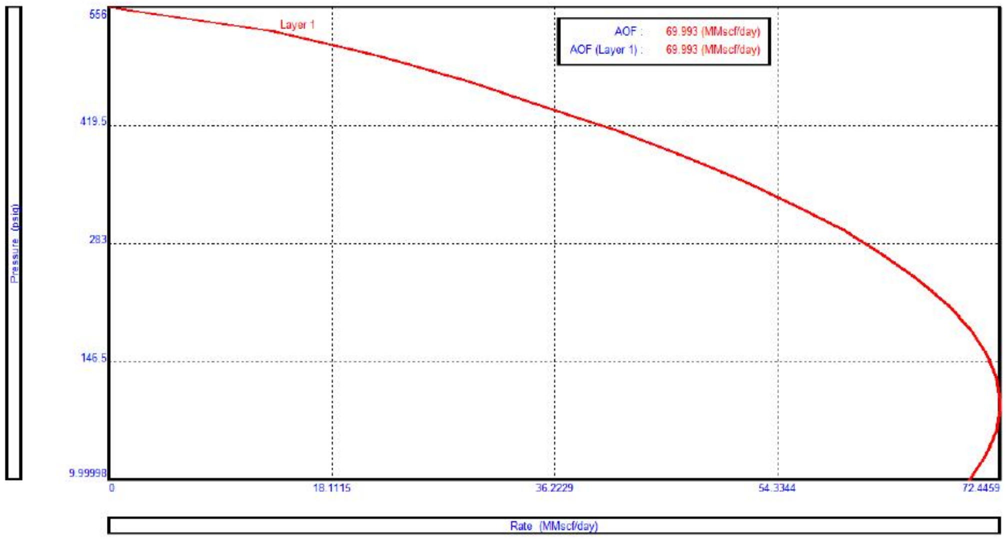


Figure 6: IPR Curve

Figure 6 shows an increase in reservoir pressure leading to an increase in the production rate.

The shape of the IPR curve of Figure 6 is influenced by reservoir properties like permeability and fluid characteristics. The absolute open flow (AOF) is 69.993 MMscf/day, and AOF represents the maximum flow rate that can be produced from a well under ideal conditions, without any restrictions. Factors such as permeability, porosity, and saturation levels of the reservoir rock can significantly influence the absolute open flow. The vertical lift performance (VLP) curve is depicted in Figure 7.

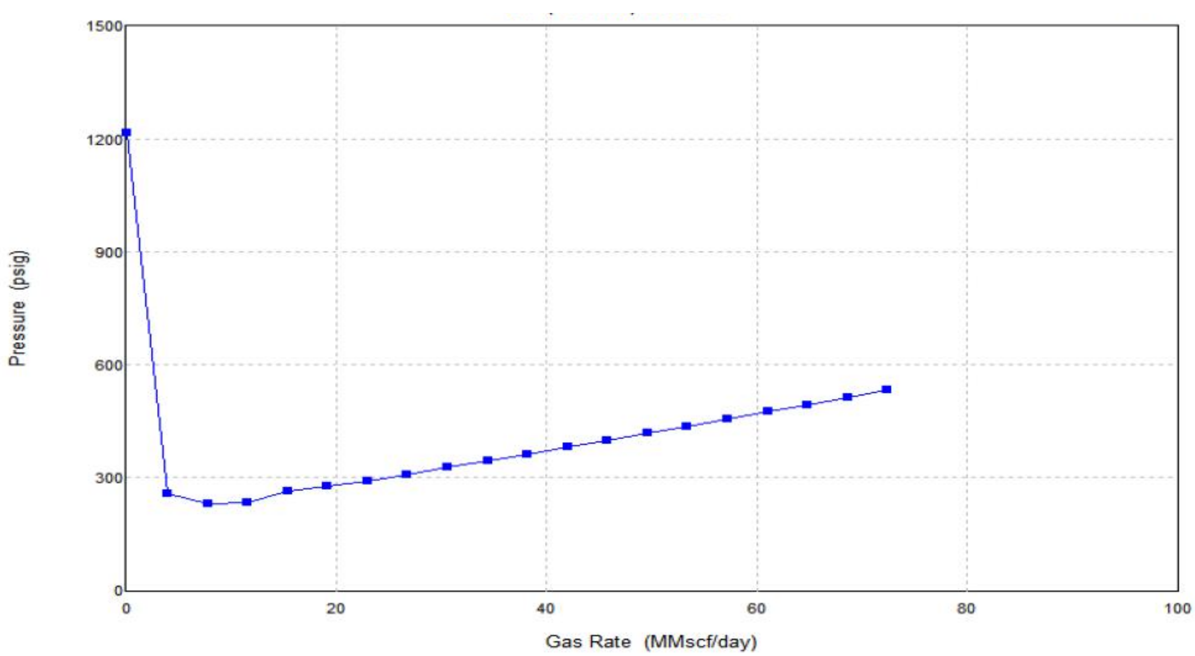


Figure 7: VLP curve

Figure 7 shows an increase in gas flow rate and a decrease in pressure due to the movement of the gas all the way. Figure 7 reveals that improvements in pumping efficiency, fluid properties, or equipment can enhance the well's ability to deliver more fluid to the surface. The nodal analysis conducted on the production well in X field is presented in Figure 8 by combining the IPR and VLP curves.

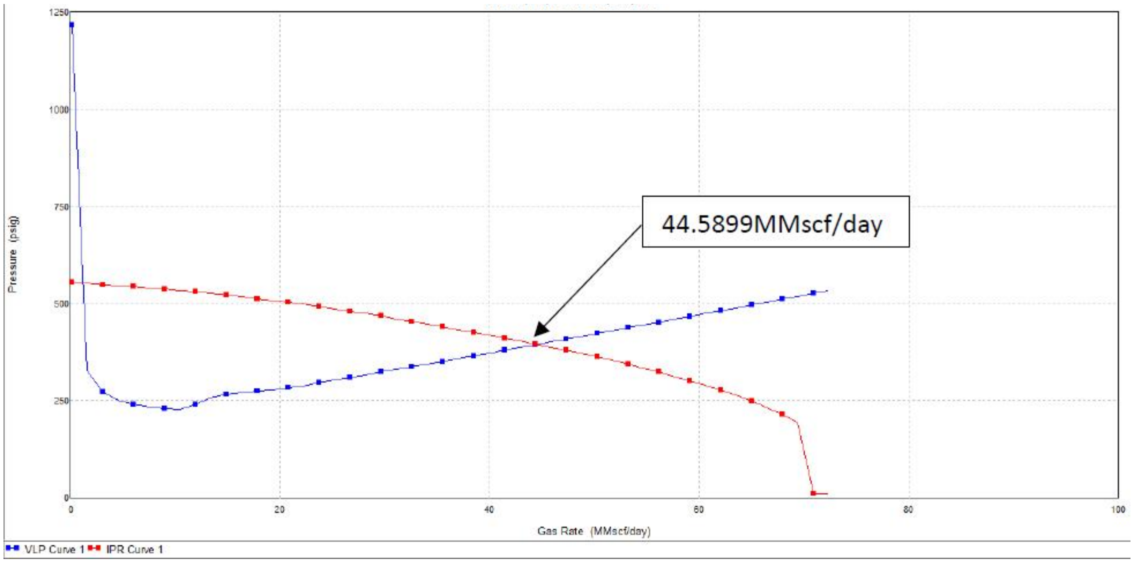


Figure 8: Nodal Analysis of the well in X Field

Figure 8 shows the point of intersection between these two curves, indicating a gas flow rate of 44.5899MMscf/day.

In order to know the influence of the tubing diameter on the production and to justify its choice, a sensitivity analysis is made on the tubing diameter. Figure 9 and Table 9 show the influence of the different diameters used.

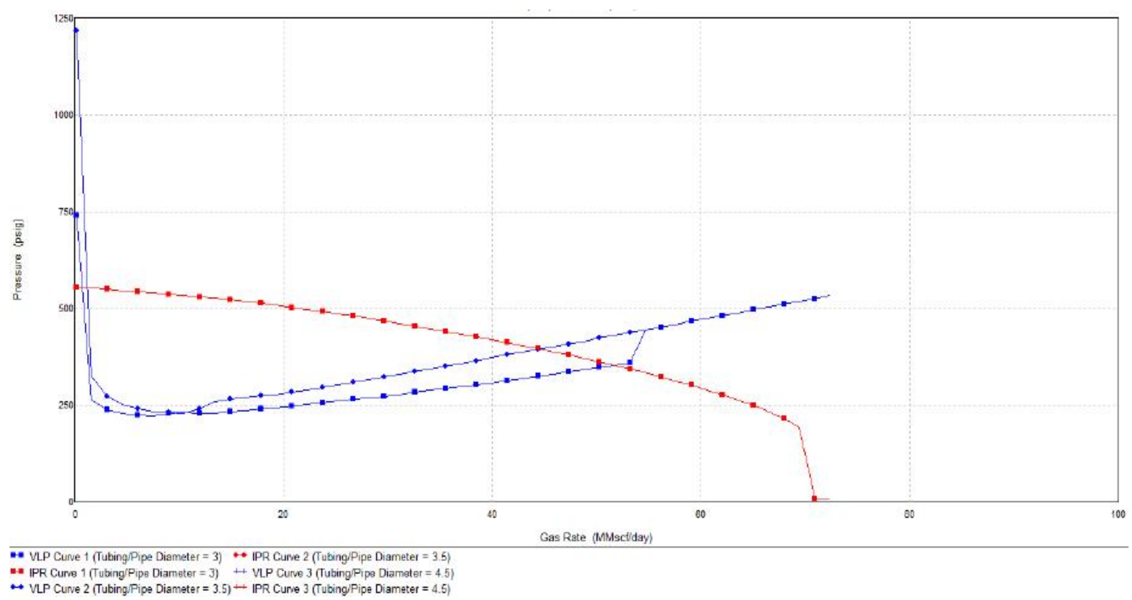


Figure 9: Sensitivity curve of Tubing Diameter on the well in X Field

Table 8 shows the results on the tubing sensitivity.

Inner diameter of production tubing (inch)	Gas flow rate (SCF/D)	Bottom pressure (psi)
3	51.7279	353.848
3.5	44.5899	395.199
4.5	44.5899	395.199

Table 8: Results of the sensitivity curve on tubing diameter

The different diameters used in Figure 9 are 3 inch, 3.5 inch and 4.5 inch. The cost of a production tubing is considerable, and given this variation has a small effect on the production rate. So, it is wise to continue with the tubing of diameter 3 inch. A sensitivity analysis is also done on wellhead pressure to determine its influence on production to justify its choice. Figure 10 shows the influence of the different pressures used.

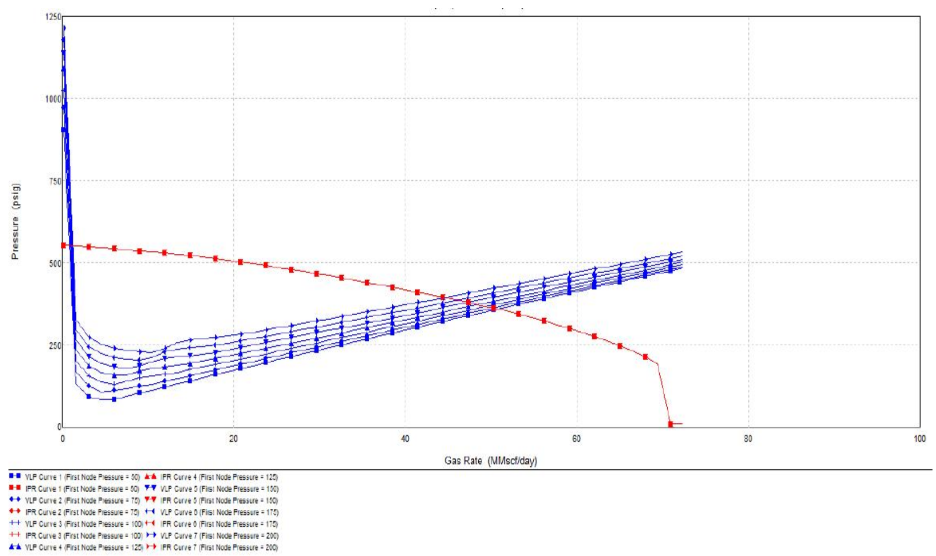


Figure 10: Sensitivity curve on the wellhead pressure

The various values of wellhead pressure utilized in Figure 10 are 50 psi, 75 psi, 100 psi, 125 psi, 150 psi, 175 psi and 200 psi. Based on the sensitivity analysis, it can be concluded that lowering the wellhead pressure enhances the production rate. The improvement parameters obtained after sensitivity analysis are presented in Figure 11 and Table 9.

Parameters	Values
Tubing diameter	3 inch
Wellhead pressure	50 psi

Table 9: Improvement parameters

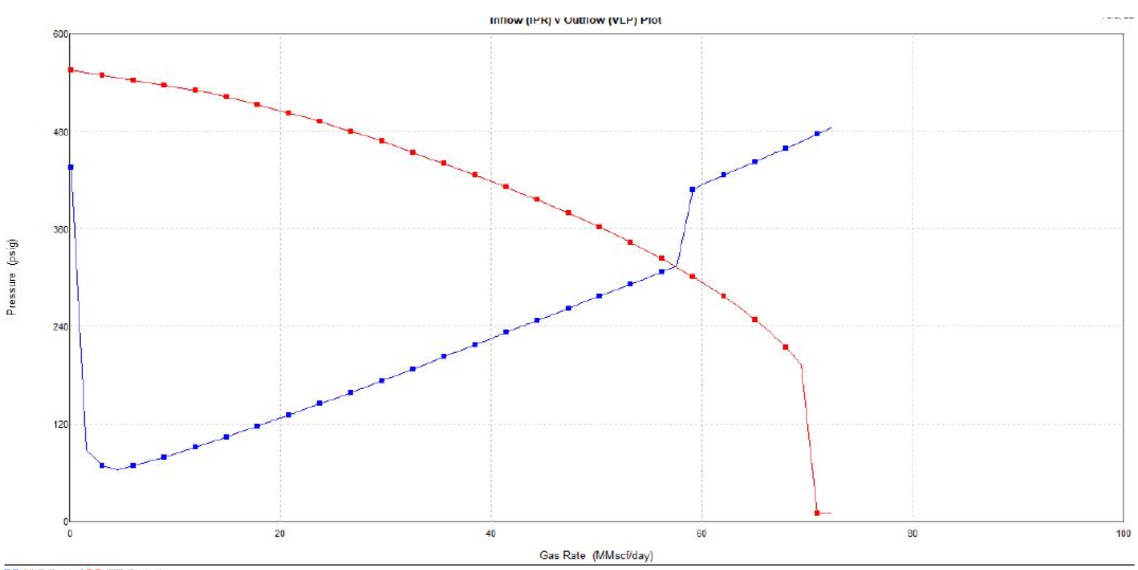


Figure 11: IPR and VLP of the well of X field after the use of improvement values

From Figure 11, the sensitivity curves reveal the key parameters we can adjust to obtain the desired flow rate target flow rate of 57.5247MMscf/day. Table 9 presents these parameters along with their optimal values for consideration.

3.4. Economic Evaluation

To determine the profitability of the project, the production duration must first be established. This duration is provided by the exponential decline curve model, which indicates the point at which production is no longer economically viable or profitable. Figure 12 shows a production forecast/prediction curve.

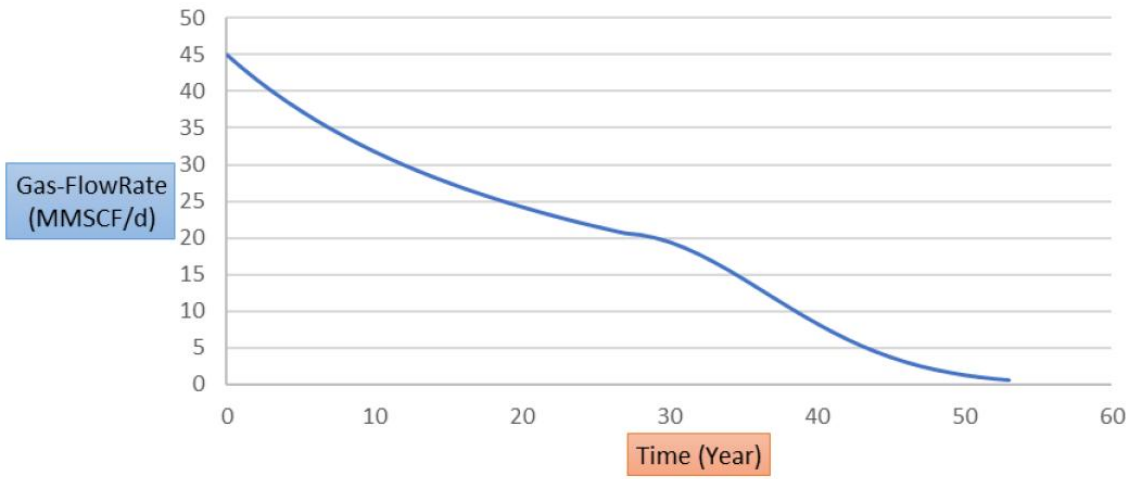


Figure 12: Production forecast/prediction curve of well of X field

The minimum flow rate at which the well is no longer economically profitable is 1.0287 MMSCF/day. Therefore, the production operations will be done within 52 years, as shown in Figure 12. Consequently, the economic balance sheet is prepared for a period of 52 years. To assess profitability, the following parameters are necessary:

a. Expenses (capex & opex)

The costs are entirely based on equipment purchases, drilling costs, completion operations, salaries, and maintenance expenses. The water injection will be done once in the 27th year at $10,000. The hydrate management will be done every 5 years from the start until the 27th year, and then every 3 years thereafter at $25,000. The Clean-up will be performed every 5 years at $20,000. The matrix acidification will be performed every 10 years at $50,000. The cost to produce one SCF of gas is $2/SCF, and Taxes are 25%.

b. Revenue, Net present value (NPV) and Return on investment/ Payback period (ROI)

This is obtained by selling the gas, which is calculated by multiplying the volume produced each year by the price per barrel, which is $2. This gives the total value over the 52 years. It allows for a thorough validation of the project's profitability. For this well, over the 52 years of production, and an NPV of 824636751,6 $. Since NPV > 0, the project is profitable. This is the year in which the company recovers the invested capital. For this project, the ROI is equal to 12 years and 8 months.

<table>
<tr><th colspan="3">Expenses (CAPEX & OPEX)</th><th>Revenue</th><th>NPV</th><th>ROI</th></tr>
<tr><td>Capex ($)</td><td colspan="2"><b>Opex ($)</td><td rowspan="9">1,9697 Billion $</td><td rowspan="9">824636751 $</td><td rowspan="9">12 years and 8 months</td></tr>
<tr><td rowspan="8">375000 $</td><td>Completion cost</td><td>30000</td></tr>
<tr><td>Drilling cost</td><td>850000</td></tr>
<tr><td>Water injection</td><td>250000</td></tr>
<tr><td>Hydrate</td><td>350000</td></tr>
<tr><td>Clean-up</td><td>200000</td></tr>
<tr><td>Matrix acidification</td><td>250000</td></tr>
<tr><td>Gas cost</td><td>787 Billion $</td></tr>
<tr><td>Salaries</td><td>3120000</td></tr>
</table>

Table 10: Different expenses and revenue

4. Conclusion

The present paper aimed to improve the gas production rate using a multilateral well in the X field and determine the ideal depth to deviate the salt dome in order to enhance production efficiency and reduce risks by applying the nodal analysis technique to achieve the desired flow rate. This analysis was performed using Prosper software. It is initially conducted to start production or during production to assess the well's performance. A simulation of the data and their analysis using the software enabled the determination of the exact flow rate, its functional pressure, and other essential parameters. The analysis revealed that the exact flow rate of the well is 57.5247 MMscf/day, with a payback period of 12 years and 8 months, and a net present value of $824,636,751.60.

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