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The Economic Evaluation of Various Production Scenarios for Zubair Reservoir in the Kifl Field

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ABSTRACT

This work evaluates the economic feasibility of various production scenarios for the Zubair reservoir in the Kifl oil field using cash flow and net present value (NPV) calculations. The Kifl field is an exploratory field that has not yet been developed or assessed economically. The first well was drilled in 1960, and three other wells were later drilled to assess the oil accumulation, so in this research, Different production scenarios were evaluated economically. These scenarios were proposed based on the reservoir model of the Zubair formation in the field. The research methodology used QUE$TOR software to estimate capital expenditures (CapEx) and operating expenditures (OpEx) based on field-level data, production profiles for each scenario, and produced fluid properties. CapEx estimates were mainly based on the number of drilled wells and plateau duration, while OpEx estimates were based on the number of barrels produced from each scenario. Cash flow values were estimated each year in the production interval after subtracting water handling costs, CapEx, and OpEx from the gross revenue of oil produced. The NPV for each scenario was then calculated using a 5% interest rate, and the most economical option was determined by comparing the NPV values of each scenario. Case-3 scenario was identified as the most economical option, with a high NPV value of approximately 612 MM$, an oil production rate of 10 MSTB/d, a Plateau duration of 3 years, a total number of wells of 11, and an Initial water cut of 13 %.

Keywords: Zubair reservoir, Kifl oil field, Economic feasibility, Production scenarios, Cash flow, Net present value (NPV).

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التقييم الاقتصادي لحالات انتاج مختلفة في حقل الكفل

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الخلاصة

تقوم هذه الدراسة بتقييم الجدوى الاقتصادية لمختلف سيناريوهات الإنتاج لمكمن الزبير في حقل النفط الكفل، باستخدام تدفق النقد وحساب القيمة الحالية الصافية (NPV). يعد حقل الكفل حقلًا استكشافيًا لم يتم تطويره أو تقييمه اقتصاديًا بعد. تم حفره لأول مرة في عام 1960، وتم حفر ثلاثة آبار أخرى لتقييم رصيد النفط فيه، ومن هنا تم تقييم مختلف سيناريوهات الإنتاج اقتصاديًا. تم اقتراح هذه السيناريوهات استنادًا إلى نموذج الخزان لتشكيلة زبير في الحقل. تضمنت منهجية البحث استخدام برنامج QUE$TOR لتقدير النفقات الرأسمالية (CapEx) والنفقات التشغيلية (OpEx) استنادًا إلى بيانات المستوى الميداني، وملفات الإنتاج لكل سيناريو، وخصائص السوائل المنتجة. كانت تقديرات CapEx أساسًا على عدد الآبار المحفورة ومدة التلة الصخرية، في حين كانت تقديرات OpEx على أساس عدد براميل المنتجات من كل سيناريو. تم تقدير قيم التدفق النقدي لكل عام في فترة الإنتاج بعد خصم تكاليف معالجة المياه وCapEx وOpEx من الإيرادات الإجمالية للنفط المنتج. تم حساب NPV لكل سيناريو باستخدام معدل فائدة 5%، وتم تحديد الخيار الأكثر جدوى اقتصاديًا عن طريق مقارنة قيم NPV لكل سيناريو. تم تحديد السيناريو Case-3 الأكثر جدوى اقتصاديًا، بقيمة NPVعالية تبلغ حوالي 612 مليون دولار، ومعدل إنتاج للنفط يبلغ 10 برميل يوميا، واستقرارية الانتاج لفترة 3 سنوات، وإجمالي عدد الآبار 11، ونسبة الماء المنتج 13.

الكلمات المفتاحية: مكمن الزبير،حقل الكفل النفطي, الجدوى الاقتصادية, سيناريوهات الانتاج, التدفق النقدي ,صافي القيمة الحالية .

1. INTRODUCTION

The executive committee of the largest oil and gas companies is responsible for making decisions regarding developing new exploration and production projects, and capital restraint is essential to balancing technological, geological, financial, and geopolitical risks. To get the optimum performance of any reservoir in the field, many strategies should be proposed, and vertical and horizontal wells should be involved in addition to different production rates **(Ali et al., 2015; Hamdullah et al., 2020)**.

Since oil production is a very uncertain process, capital decision-making is crucial. Oil businesses can create a revenue model for the duration of the field by using cost estimates, oil and gas price assumptions, and fiscal and contractual terms **(Gupta and Pahwa, 2013)**.

The ultimate function is to determine the net present value of each scenario, which is a cash flow application. The cash flow is determined by various parameters that must be considered when evaluating the field's economic development plan. The optimization task involves considering a particular combination of decision parameter values, and the cash flow analysis provides the value (i.e., future income) for that combination **(Al-mudhafar and Al-Jawad, 2015; Andriana and Anggono, 2023)**.

The net present value was used as an objective function of the optimization in the oil fields where the main parameter was cumulative oil production presented by **(Al-Mudhafar and**

Al-Jawad, 2010), a relationship between net present value and future production time to estimate the abandonment time presented by **(Al-Mudhafar et al., 2010)**.
The concept of the present value of money involves comparing the worth of a particular sum at present with its worth at a future point while also accounting for factors like inflation and returns. The net present value is computed by determining the difference between the present value of cash inflows and outflows. The cash flow, the surplus cash generated from operations after deducting the amount invested, can be a useful indicator for the cash-based portion of profits **(Guizani, 2017; Yemets, 2021)**. A comparison between the Real Option method, NPV, and IRR was conducted to evaluate the investment of energy based on a high degree of uncertainty and the time to invest **(Santos et al., 2014)**.
An organization utilizes the net present value as a tool for evaluating the profitability of an investment or project and making decisions related to capital budgeting. This approach considers future cash inflows expected from the investment **(Nwaozo, 2006)**.In addition to the costs associated with drilling, completion, and surface facilities, the present research considers operational expenses, water handling costs, and revenue from oil sales **(Badru et al., 2003)**. Risk analysis is used to evaluate and forecast the net cash flow (NCF) of petroleum exploration and Improved Oil Recovery (IOR) projects covered by **(Belhaj et al., 2010)**. The results showed that the Break-Down Method is proven to work efficiently in reducing the error associated with predicting NCF of petroleum projects, and while only STOIIP was targeted in this phase of the study, more risk factor analyses will improve the model capabilities inspired by the success gained in this phase. Geological model results such as STOIIP and oil-water contact level play an important role in the economic evaluation of fields and the number of wells drilled **(Alher et al., 2018)** also Faults and fracture components are essential factors affecting production performance (fluid flow pattern) **(Al-Jawad and Kareem, 2016)**. Drilling horizontal and multi-lateral wells enhances Production rate and recovery efficiency even if the cost of drilling increases **(AL-Jawad et al., 2014).** Scenarios for different field sizes at various oil prices discussed by **(Ocran et al., 2019)** showed the relationship between NPV and oil prices per barrel where the income increases steadily with the oil price for all field sizes. The Economic analysis presented by **(Karimi Vajargah et al., 2013)** showed a good opportunity to develop a field after suggesting different scenarios including various production rates, horizontal and vertical wells, constant Capex for the wells, and 4 $/bbl operating cost.
The main objective of this research is the economic evaluation of the five production scenarios proposed for the Zubair reservoir model in the Kifl field. The economic evaluation of the Kifl oil field was carried out based on the daily production rate, which was 3166, 5000, 10000, 15000, and 20000 STB/d.

1.1 Problem Statement

According to **(Wiggins and Libecap, 1985),** the pursuit of competitiveness in production results in an overabundance of wells and surface storage, causing higher costs for oil extraction due to the ineffective depletion of subsurface pressures and ultimately leading to a decrease in overall oil recovery. In the case of the Kifl field, there was no production from the field and no surface facility, so the economic evaluation was performed based on suggesting a production scenario by using the reservoir model and the number of wells in each scenario. Making comparisons of different production plans and indicating the differences in the NPV between all different production scenarios will contribute to finding the most economical production scenario.

1.2 Kifl Field Description

Kifl Field, approximately 125 km southwest of Baghdad, 20 km west of Kifl, and 40 km south of Karbala **(Al-Khafaji, 2010; AL-Baldawi, 2022)** is characterized by complex anticline structure extending in NW-SE trend with major and minor normal faults **(Al-Ridha et al., 2017; Al-Farhan et al., 2019)**. Zubair Formation is the most significant sandstone reservoir in Iraq and has the most Oil accumulation in the Kifl Field **(Al-Zaidy, 2019)**. The first exploration well drilled in 1960 in the Kifl oil field showed oil in several geological formations, including the Nahr Umr and Zubair formations, with an estimated production flow rate of around 5600 barrels per day then wells KF-2, KF-3, and KF-4 drilled later to assess oil accumulation in the field **(Oil Exploration Company (OEC), 2009)**.

1.3. Description Of the Production Scenarios

In the petroleum industry, predicting the amount of oil production is an important task. Numerous techniques, such as decline curve analysis **(Zhou et al., 2018; Annan Boah et al., 2018)** and well-test analysis (**Levitan et al., 2006; Liu and Homea, 2013)**, have been developed to accurately and quickly estimate production rates. A strategy was employed to predict depletion and water drive using five different production rates in our case. The water thickness in the Kifl oil field was much greater than the oil column, so the aquifer enhanced oil recovery in all proposed cases. However, the strategy was constrained by the maximum allowable bottom hole pressure of 1322 psi and the field production rate. **Table 1.** displays the five scenarios along with their corresponding oil production rates, number of wells, and cumulative oil production after four years of production. Each of the five proposed scenarios contains several wells necessary to achieve the proposed daily production rate. These wells were drilled in places that contain high oil accumulations.

Case-1 scenario includes the vertical wells in the field, which are KF-1, KF-3, and KF-4, with a field production rate of about 3166 STB/d. In the Case-2 scenario, five vertical wells were drilled with a production capacity of 5,000 STB/d. In Case-3 and Case-4 scenarios, 6 horizontal wells were drilled with an open-hole horizontal section ranging between 700 m and 1,000 m and 5 vertical wells with a reservoir production rate of 15,000 STB/d. As for the Case-5 scenario, 4 wells were added to the 11 wells in the previous scenario, with an open hole horizontal section ranging between 700 m and 1000 m and a reservoir production rate of 20,000 STB/d.

Table 1. Oil production rates, number of wells, and cumulative oil production for each case.

Cases of prediction strategy	Number of wells	Field production rate (STB/d)	Cumulative Field production (MMSTB)
Case-1	3	3166	1.6
Case-2	5	5000	3.73
Case-3	11	10000	12.5
Case-4	11	15000	14
Case-5	15	20000	14.3

2. METHODOLOGY

The economic assessment of the Kifl field involved analyzing five cases with varying cumulative oil production over four years. The suggested five cases to monitor the reservoir behavior in the future under some conditions regarding the depletion of pressure, production plateau, recovery factor, and water cut **(Baker and Awad, 2017)**. To determine the operational and capital expenses of the Kifl oil field, QUE$TOR software was used. The cash flow and net present value were calculated using theoretical equations based on barrel pricing, incorporating an interest rate for each year.

2.1. The Capital and Operating Expenditures Estimation

The operational expenditures ($) include operational personal costs, inspection maintenance costs, logistic and consumables costs, well costs, insurance costs, and field/project costs. In contrast, the capital expenditures ($)involve the drilling, completion, cementing, perforation, acidizing services, and rig movement between well locations, wellhead, casing and casing accessories, pipelines, cement and completion material, and equipment, bit, mud material, perforating material charges.
All these costs were calculated using a simulator with the main data required, including the reservoir and production profiles data, as shown in **Tables 2** and **3**.

Table 2. The required production data for each scenario in the Zubair reservoir model.

Development Strategy	Number of wells	Cumulative oil production (MMSTB)	Peak flow (MSTB/day)	Initial water cut %	Plateau duration (year)
Case-1	3	1.6	3	50	0.25
Case-2	5	3.73	5	36	0.5
Case-3	11	13.6	10	13	3
Case-4	11	14	15	16	2
Case-5	15	14.3	20	17	1

Table 3. The required field data for CapEx and OpEx calculations.

Field data	Value
Reservoir Pressure (psi)	3076
Reservoir Depth (m)	2000
Field length (km)	10
Field width (km)	10
Field elevation (m)	30
Gas oil ratio (SCF/STB)	345

The type and quantity of the surface facility equipment depended mainly on the characteristics of the produced oil. In all scenarios, the CO_2 content of the produced fluid was 1%, H2S was 20700 ppm, and API was 26.6 **(SOC, 1985)**. Because the main objective was to compare 5 development production strategy costs, the equipment cost of all scenarios was set as a default, where the simulator chose the equipment cost depending on the field region.

The surface temperature and pressure affect the cost of the wellhead, Pipelines, well pad group, production facility, and storage of products. In the case of the Kifl field, there was no surface facility and no data available about the wellhead temperature and wellhead pressure, so these values were assumed based on the wellhead pressure and temperature in the other Iraqi fields, which equal to 450 psi as wellhead pressure and 65 °F as surface temperature.

2.2. Cash Flow and Net Present Value

The net future value is defined as the revenues from produced oil and gas sales after excluding the costs of capital expenditures (CAPEX), operational expenditures (OPEX), and costs of produced water handling. The cash flow for 4 years of each case is calculated by Eq.(1), then the net present value (NPV) is estimated using Eq.(2). The proposed prices of oil and water handling and rate of interest are taken from the prices of barrel crude oil in Iraq, and other research covers the economic analysis of oil fields **(Mohanty and Nandha, 2011) (Ponomarenko et al., 2022; Oilprice, 2023)**.
The equation of the Net Cash Flow Eq. (1) was applied for each year in the production plan and the water handling cost was 1 $/bbl as well as the CAPEX and OPEX taken for one year. It should be noted that the value of the capex has been distributed over the four productive years and was not taken as a single payment in the first year, while the value of the operating cost has been accustomed to the productive capacity of the reservoir as a whole.

Net Cash Flow (t) = Cumulative Oil Production (t) ×Oil Price -Cumulative Water production (t) ×Water Handling Cost- -OPEX-CAPEX (1)

where:
Oil price: ($ per STB)
Water handling cost: ($ per STB).
OPEX is the costs of capital expenditures ($)
CAPEX is the operational expenditures cost ($)
The Net Present Value Equation (NPV) was utilized to determine the most economically favourable scenario, which is based on achieving the highest NPV value by the end of the four years. It was assumed that the prices of oil and water handling, as well as the interest rate, would remain constant throughout the project's duration, and these assumptions are summarized in **Table 4. (Ozdogan and Horne, 2006)**.

$$NPV=\sum \frac{NCF(t)}{(1+i)^t} \quad (2)$$

where:
NCF is the cash flow over specified time in our work per one year ($).
i is the rate of interest %
t is future time at which NPV is calculated.

Table 4. The proposed prices of oil and water handling and rate of interest.

Parameter	Value	Unit
Oil price	70	$/STB
water handling price	1	$/STB
rate of interest	5	%

3. RESULTS AND DISCUSSION

3.1 Cash Flow Results

The value of cash flow for each year during the four proposed productive years of the Kifl oil field was calculated using the Net cash Flow equation after assuming the price of the oil barrel and estimation of cumulative water produced at each year in all the proposed scenarios as were characterized by a large amount of water production, which affects the calculation of the value of cash flow, where the cost of water handling, OpEx, and CapEx subtracted from the gross revenue of the oil.
The results of the cash flow calculation over time for each case, shown in **Fig. 1,** indicated that the Case-2 and Case-1 maximum value of cash flow in the fourth year is equal to 0.236 and 27.413MM $, respectively.

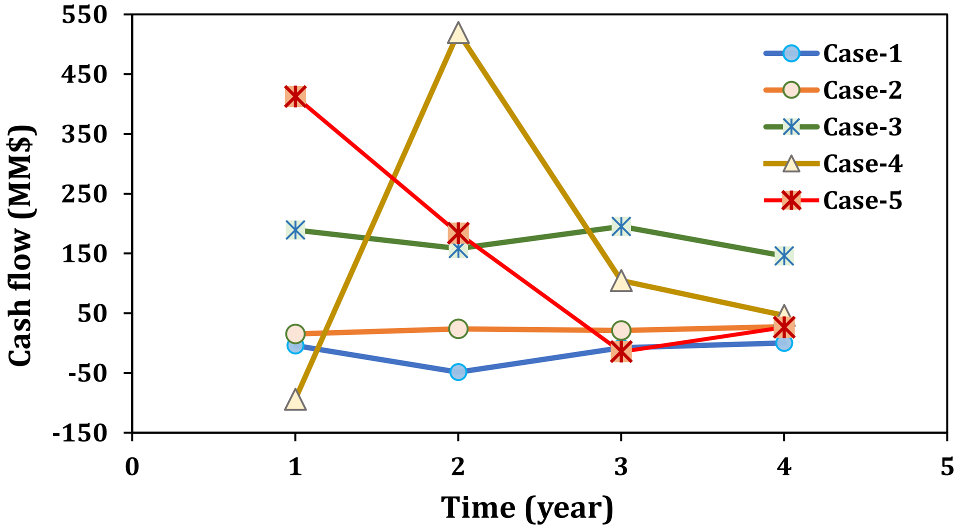

Figure 1. Cash flow curves versus time for each case.

The Cash flow of Case-3 ranged between 145.749 and195.172 MM $ as seen the green curve, where the maximum value of the cash flow195.172 MM $ obtained at the end of the plateau duration in contrast a sudden cash flow increase occurred for the Case-4 yellow curve to reach 519.818 MM $ at the end of the first year Then it declines rapidly and continues to decline until the end of the fourth year to reach 46.103 MM $.The Case-5 curve (red curve) explains the behaviour of a cash flow starts at 412.741 MM $ and decreases gradually until it reaches -14.502 MM $ at the end of the third year, then increases smoothly to gain 26.658 MM $ of a cash flow during the fourth year.

3.2. Net Present Value Results

After calculating net cash flow at the end of each year, the net present value (NPV) was calculated where the interest rate was 5% and assumed constant over the field life. Plot the relationship between the proposed cases versus the NPV of each case as shown in **Fig. 2.** Then the optimal case with the higher net present value is Case-3 which is equal to 612.029 MM$.

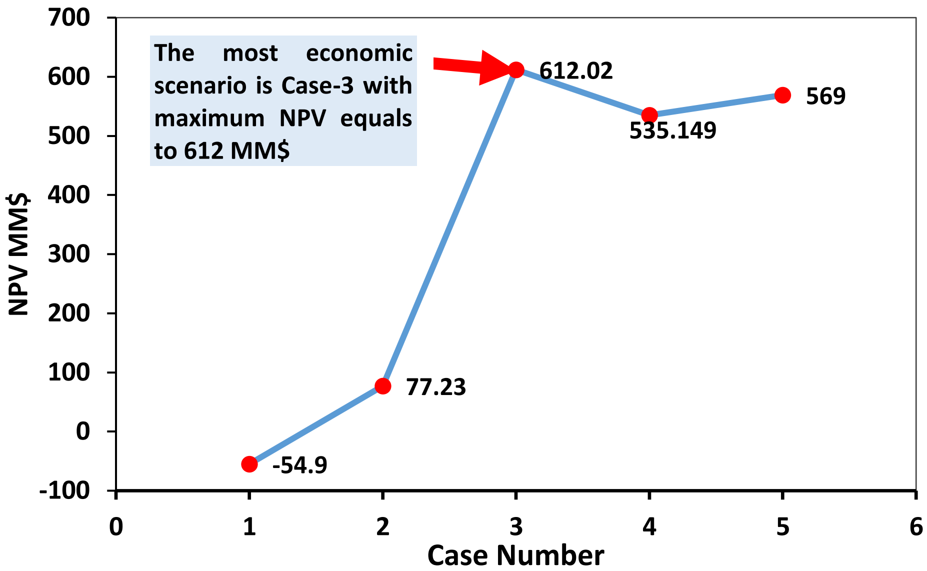

Figure 2. NPV versus Cases.

The economic evaluation of the Kifl oil field is summarized as given in **Tables 5.** and **6.** In these tables, gross revenue in the second column and water handling cost in the third column are calculated at the end of each year, where oil price, water handling cost per barrel, and rate of interest are assumed to be constant during the field life.

Table 5. Economic evaluation summary for Case-1, Case-2, and Case-3.

Case No.	Year of production	Gross revenue	Water handling	CapEx	OpEx	Cash flow	NPV
		MM$	MM$	MM$	MM$	MM$	MM$
Case-1	year 1	47.6	1.52	32.87	17.54	-4.33	-4.12
	year 2	23.8	1.86	52.84	17.74	-48.6	-44.11
	year 3	21	1.5	10	17.39	-7.9	-6.824317
	year 4	19.6	1.32	0	18.04	0.236	0.19
	Net						-54.9
Case-2		MM$	MM$	MM$	MM$	MM$	MM$
	year 1	72.1	1.8	37.16	17.49	15.27	14.54952
	year 2	102.9	2	60.12	17.32	23.93	21.70794
	year 3	57.4	1.8	17.19	17.11	21.32	18.4222
	year 4	47.6	1.5	0	18.67	27.41	22.55274
	Net						77.2324
Case-3		MM$	MM$	MM$	MM$	MM$	MM$
	year 1	252	0.95	44.7	17.33	189.1	180.0
	year 2	252	1.45	75.01	17.33	158.2	143.5
	year 3	252	1.4	38.1	17.33	195.2	168.59
	year 4	168	1.4	0	20.85	145.8	119.9
	Net						612.02

For the Case-1 scenario, which has a Cumulative oil production of 1.6 MMSTB, the value of flow and NPV is negative for the first three years and does not give any profit, while in the fourth year, it becomes positive with 0.236 and 0.194158 MM$ for cash flow and NPV respectively, which are considered very low.
Case-2, Case-4, and Case-5, which have a Cumulative Field oil production during field life of 3.73, 14, and 14.3 MMSTB respectively are characterized by a low Cash Flow and NPV compared to the theCase-3, which showed the highest values and was chosen as the most economical scenario for oil production from the Zubair reservoir in the Kifl field at a rate of 10 STB/d and 13 % initial water cut.

Table 6. Economic evaluation summary for Case-4 and Case-5.

	Year of production	Gross revenue	Water handling	CapEx	OpEx	Cash flow	NPV
Case-4		MM$	MM$	MM$	MM$	MM$	MM$
	year 1	98	1.65	155.773	34.88	-94.299	-91.5
	year 2	630	2.2	73.106	34.88	519.818	489.97
	year 3	168	1.4	27.848	34.12	104.635	95.75
	year 4	84	0.8	0	37.1	46.103	40.96
	Net						535
Case-5	Year of production	Gross revenue	Water handling	CapEx	OpEx	Cash flow	NPV
		MM$	MM$	MM$	MM$	MM$	MM$
	year 1	504	2.23	61.378	27.65	412.741	393.08
	year 2	301	4.5	85.686	26.95	183.864	166.77
	year 3	119	5.65	101.711	26.14	-14.502	-12.52
	year 4	77	6.4	13.168	30.77	26.658	21.93
	Net						569

4. CONCLUSIONS AND RECOMMENDATIONS

According to the results obtained from the economic evaluation, several important points were concluded that contributed to the decision-making in the best economic production scenario according to the production constraints, such as the bottom hole pressure at 1322 psi as follows.

1-It was concluded that drilling additional wells in the Kifl oil field to increase oil production may not benefit the field as it leads to production instability, and the cash flow value quickly falls to its lowest levels during the specified production period.

2-The stability of oil production at 10,000 STB/d for three years contributes to maintaining the cash flow values from falling and thus will give the highest NPV in the Case-3 scenario.

3-Case-4 and Case-5 gave net present values of 535 and 569 MM$, which are close to the NPV of Case-3, but the plateau duration is less than two years.

4-The recommendations include proposing other production scenarios and economic evaluations with an increase in the production period for more than four years.

NOMENCLATURE

Symbol	Description	Symbol	Description
API gravity	American Petroleum Institute gravity.	NPV	Net present value.
CapEx	Capital expenditures.	OpEx	Operating expense.
GOR	Gas/oil ratio.	STB/d	Stock tank barrel per day.
MM$	Million Dollars.	STB	Stock tank barrel
NCF	Net Cash Flow		

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