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Reserve Estimation Using Decline Curve Analysis for Block 74F-S Oil Field

Salem Khalefah Fattouh
Department of Petroleum Engineering, Sabratah, University, Sabratah, Libya
Salem Fattouh@gmail.com

Rasheed Hassan Abo-gofah
Department of Petroleum Engineering, Sabratah, University, Sabratah, Libya

Abdulbasit Ali Mohamed
Department of Environment Engineering, Sabratah, University, Sabratah, Libya
abdulbasit.mohamed@sabu.edu.ly

Naser Molood Abd Aslam
Department of Environment Engineering, Sabratah, University, Sabratah, Libya

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Abstract

This study employs DCA to estimate the remaining reserves of the SABAH oil field within concession 74F-S by using the Oil Field Manager (OFM) software 2019 version; provided by SENSIA-SLB.

Specifically, our estimated reserves using OFM software predicted to be 26.069 (MMbbl) with (ARE %) equal to 0.27%, The obtained results for these wells reported as in following: Well 18/74F-S–remaining reserve estimation=2.274 MMbbl. Well 20/74F-S – remaining reserve estimation=2.171MMbbl. Well 31/74F-S – remaining reserve estimation = 0.270 MMbbl. Well 37/74F-S–remaining reserve estimation=0.074 MMbbl.Also, ARPS recovery factor's correlation resulted a lower (ARE % = 2.23%) among the correlations used to calculate (RF); when compared to the (RF) provided by Zueitina Co. "49.31%".

Keywords:

Decline Curve Analysis (DCA); Remaining Oil Reserves; Oil Field Manager (OFM); ARPS Model; Recovery Factor; Reservoir Performance; SABAH Oil Field

Introduction:

Reserves refer to the estimated quantities of crude oil, condensate, natural gas, natural gas liquids, and associated substances expected to be commercially recoverable and marketable from a given forward, under current economic conditions, using established operating practices, and adhering to current government regulations. These estimates are based on the interpretation of available geologic and/or engineering data at the time of estimation. The prevailing economic conditions encompass prices, costs, and markets at the time of estimation. Different assumptions about future economic conditions may yield varying estimates of recoverable volumes, which are then classified as resources rather than reserves under current economic constraints. Reserves may be assigned to either natural reservoirs or enhanced recovery methods. Enhanced recovery includes all techniques that supplement natural reservoir energy to boost ultimate recovery. Reserves attributed to enhanced recovery methods are generally distinguished from those attributed to primary recovery (2).

Various methods are used to determine oil and gas reserves, with the decline curve analysis (DCA) method being one of the most popular. The decline curve is a fundamental tool for predicting future production rates, estimating oil reserves, and determining remaining productive life. The most common decline curve represents the decline in oil or gas production rate over time (rate-time plot), while another common technique plots production rates against cumulative oil or gas production (rate-cumulative plots) (2).

Sabah Oil Field:

The Sabah Field was discovered in 1964. A major part of the field lies in ZOC's concession 74F and minor part in AGOCO's concession NC131 at the northern flank. A total of 67 wells have been drilled in the field, 49 are producers (one well is shut-in due to high water cut and 5 producer shut-in due to ESP fishing in the hole), 11 are abandoned, 2 are observation wells and 8 wells are water injectors, and they are shut-in as Sabah water tank under repair.

As of last update in September 2021, the Sabah oil field is located in Libya. It is one of the oil fields in the country that contributes to Libya's oil production. The field is managed by the National Oil Corporation (NOC) of Libya.

Since the situation in the oil industry can change rapidly due to various factors such as geopolitical events, market conditions, and government policies, it is important to refer to up-to-date sources for the most accurate and current information regarding the Sabah oil field in Libya.

Figure (1): Show the location of Sabah field.

Study Objectives:

The main objectives of this study are as follows:

1. Enhance our understanding of utilizing OFM Software within the DCA process.
2. Estimate the forecasted ultimate reserve for the SABAH oil field utilizing OFM Software.
3. Forecasting the remaining reserves of four wells in the SABAH field using OFM Software.
4. Compare the results generated by OFM Software with the reserves reported by Zueitina Oil Company (ZOC).
5. Conduct a comparative analysis to estimate the Recovery Factor (RF) using various empirical correlations.

Decline Curve Analysis:

Decline curve analysis is a method for forecasting future oil or gas well production based on historical production data. It has traditionally been used to identify production issues and predict well performance and lifespan by analyzing measured oil well production. Initially, decline curve analysis was performed manually using semi-log plot paper, but now computer software allows for more sophisticated analysis and economic evaluations [5].

The primary application of DCA in the industry relies on three fundamental equations and curves to model production declines. To accurately fit the hyperbola, three key variables must be determined: the initial rate (qi), the initial decline rate (Di), and the degree of curvature of the line (b) [5].

The origins of DCA date back to the early 20th century when it was first developed to provide a systematic approach for analyzing production decline in oil wells. Traditionally, this analysis was performed manually using semi-logarithmic plot paper, where production data points were plotted to identify trends and patterns. Today, with advances in technology, sophisticated software tools are available to perform DCA with greater accuracy and efficiency [3].

Decline curve analysis (DCA) is a widely used method in reservoir engineering to forecast production rates and estimate reserves based on historical production data. It involves fitting mathematical models, such as exponential, hyperbolic, or harmonic decline equations, to observed production trends to predict future performance. This technique provides insights into reservoir behavior, aiding in decision-making for reservoir management and economic evaluations. While straightforward and cost-effective, its accuracy depends on the quality of data and the assumption that past trends will persist under similar operating conditions [3].

The basic principle of DCA involves plotting production rate data against time and fitting a decline curve to this data. There are three primary types of decline curves used in the analysis:

- **Exponential Decline:** This model assumes that the production rate decreases at a constant percentage over time. It is characterized by a straight line on a semi-log plot and is commonly used for wells with stable reservoir conditions.
- **Hyperbolic Decline:** This model accounts for a varying decline rate and is more flexible in representing different reservoir behaviors. It is characterized by a curved line on a semi-log plot and is often used for unconventional reservoirs or wells with changing production dynamics.
- **Harmonic Decline:** This model assumes that the production rate decreases inversely with time. It is less commonly used but can be applicable for certain reservoir conditions[5].

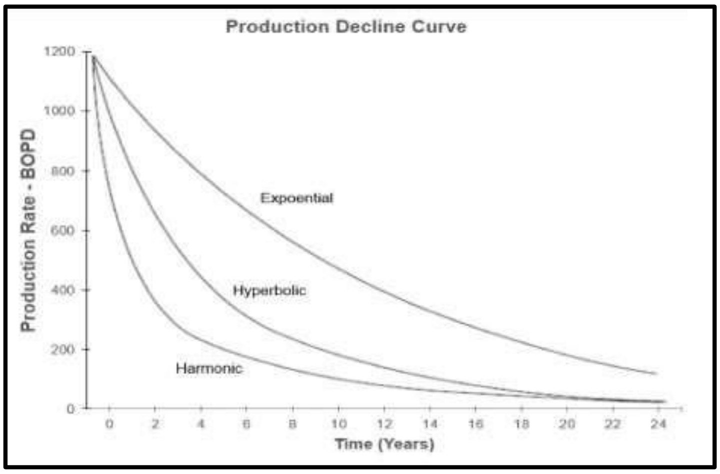


Figure (2): Types of decline curves used in the analysis

To accurately position the decline curve, three key variables must be determined: the initial production rate (qi), the initial decline rate (Di), and the decline exponent (b) for hyperbolic and harmonic models. These parameters help define the shape and trajectory of the decline curve, allowing for more precise forecasting of future production rates. DCA is not only valuable for predicting future production but also for diagnosing production issues and optimizing well performance. By analyzing the decline trends, engineers can identify problems such as mechanical failures, reservoir depletion, or the need for enhanced recovery methods. This insight helps in planning interventions, improving recovery efficiency, and extending the productive life of wells (5). Moreover, DCA plays a critical role in economic evaluations of oil and gas projects. Accurate production forecasts are essential for assessing the profitability of investments, planning budgets, and securing funding. The decline curve analysis provides a reliable basis for estimating the remaining reserves, projecting cash flows, and making informed financial decisions (1). In summary, Decline Curve Analysis is a powerful tool in the petroleum industry, offering a systematic approach to forecasting production, diagnosing issues, and making strategic decisions. Its application has evolved from manual plotting to advanced software-driven analysis, enabling engineers to maximize reservoir performance and optimize economic outcomes (1). Estimating oil reserves is a crucial aspect of a petroleum engineer's work, as solutions to related problems typically depend on comparing estimated costs in terms of barrels of oil. Forecasting future production is a critical component of the economic analysis of exploration and production expenditures. This can often be the weakest part of the analysis, as it may be based on limited actual production performance (6). Estimation of petroleum reserves is conducted for specific purposes, and the purpose largely dictates the method used and the time invested in making the estimate. The estimate is rarely an end in itself but is usually the first step in a series of calculations aimed at gaining insights that will influence current or future decisions [6].

Reserves Types:

Oil reserves are categorized based on their extraction feasibility and certainty [2]:

Proven Reserves: These are quantities of oil that can be extracted with a high degree of certainty using current technology and under existing economic conditions. They are based on geological and engineering data.

Probable Reserves: These reserves are less certain than proven reserves but are likely to be recoverable. They are estimated based on geological data and are often associated with additional development risk.

Possible Reserves: These are the least certain reserves, with a lower likelihood of being extracted economically. They require more exploration and development.

Unconventional Reserves: This category includes sources like oil sands, shale oil, and tight oil, which require advanced extraction techniques, such as fracking or thermal recovery.

Contingent Resources: While not classified as reserves, these are quantities of oil that may become recoverable in the future but are not currently economically viable or require further development.

Proven Reserves:

Proven reserves (1P) are quantities of oil that geological and engineering data demonstrate can be extracted with a high degree of certainty, typically at least 90% probability.

These reserves are already discovered and are currently being produced or can be produced economically using existing technology. They are subject to regular audits and are often reported in financial statements of oil companies, for example: Conventional oil fields where extraction techniques are well established, such as offshore oil platforms [2].

field general data information:

Production Formation	Beda"C", concession: 74F-S
Depth (ft)	5500
Total wells completed	67
Total Production wells	49
Total Injection wells	8
Total Observation wells	3
Total abandonment wells	7
Avg. Net Pay (ft)	35.5
Pressure Datum (ft-SS)	4600
Temprature (Deg.^{o} F.)	178
Initial Pressure (Psia)	2256
Present Pressure (Psia)	1023
Average Porosity (%)	27.2
Average Permeability (md)	0.373
Initial Average S.W (%)	28.2
Rock Compressibility (1/Psi}	$2.85*10^{-6}$
Initial Oil In Place (MMbbl)	504.4
Initial Gas In Place (BScf)	103.4
Initial Oil Reserves (MMbbl)	248.7
Initial Gas Reserves (BScf)	71.761
Remaining Oil Reserves (MMbbl)	26.141
Recovery Factor (%)	49.31
Recovery Mechanisim	Water Drive
Start Production	1978
Cumulative Oil Production (MMbbl)	217.4
Avg. Oil Rate (bbl/d)	0
Cumulative Water Production (MMbbl)	806.309

Avg. Water Rate (bbl/d)	0
Cumulative Gas Production (BScf)	71.761
Avg. Gas Rate (MMScf/d)	0
Cumulative Water Injection Vol. (MMbbl)	30.59
Saturation Pressure (Psia)	442
Solution GOR (SCF/STB)	205
FVF @ P. Initial (bbl/STB)	1.17
Oil Gravity (^{o} API)	41.3
Oil Viscosity @ P. Initial (cp)	0.723
Oil Compressibility (1/Psi)	$1.019*10^{-5}$
Water Viscosity (cp)	0.385

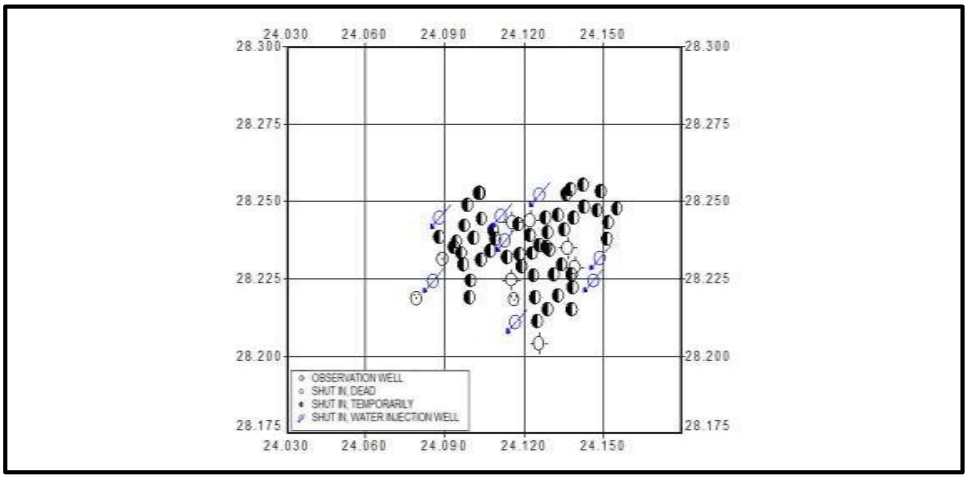
Table (1): A general well Reservoir data information

Analysis Methodology:

Collecting data + **Data checking** + **Sorting Data in Excel sheet** + **Analysis in OFM Software** = **Results Comparison**

SABAH oil field: case study procedures:

Procedure -1-: After we collected the required data and exported to OFM Software, the software plotted the base map of Sabah oil field illustrating the geographic location of the field's



wells in respect to the latitudes & longitudes as shown in figure (3).

Figure (3): SABAH oil field base map, generated by OFM Software

Generated two important plots, which are the grid map “as in figure (4.6)” and bubble map “as in figure (4)”.

As we can see from grid map, the cumulative oil production started since October 1978, and the oil cumulative increased progressively due to the new wells drilling in later years after 1978, and the production stay continues until shut-downs in March 2011 because of the force majeure that was implemented in that time, then the **Zueitina Oil Company (ZOC)** restarted the production in SABAH filed in end of 2011 until August 2013 when reaching to the final Shut-in.

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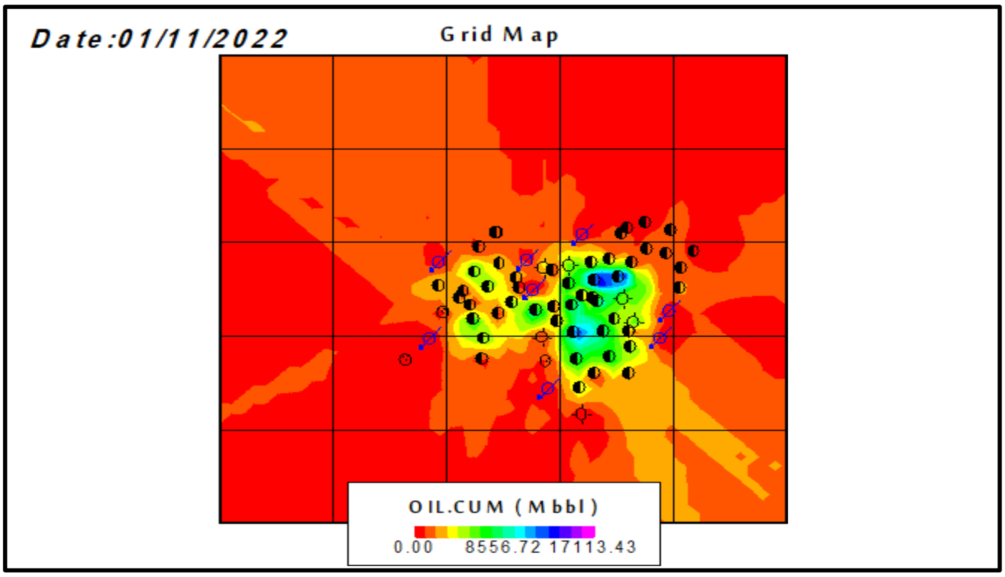
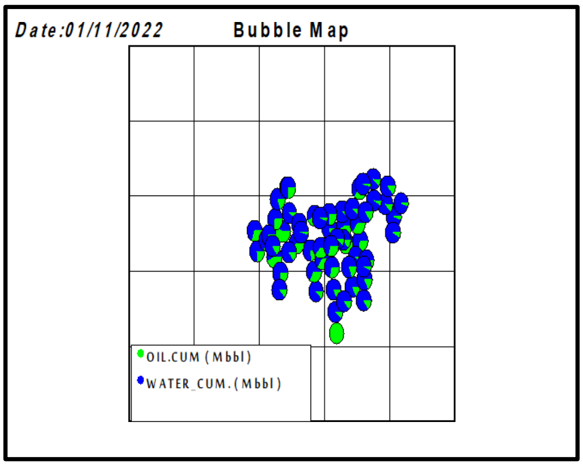


Figure (4): SABAH oil field grid map, generated by OFM Software

In other hand, as we can observe from the bubble map in figure (5); the water breakthrough into production wells started from the early field life in most of the wells, and amount of water cut keep increasing until final shut-in as shown in figure (6).



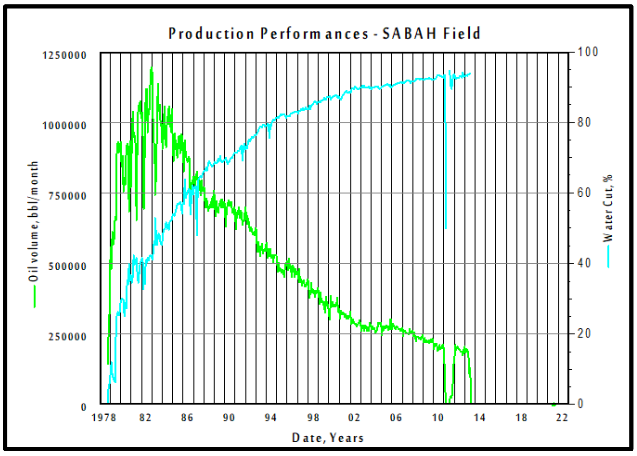


Figure (5): SABAH oil field bubble map, **Figure (6):** SABAH oil field W.C% Vs. Oil production, OFM Software

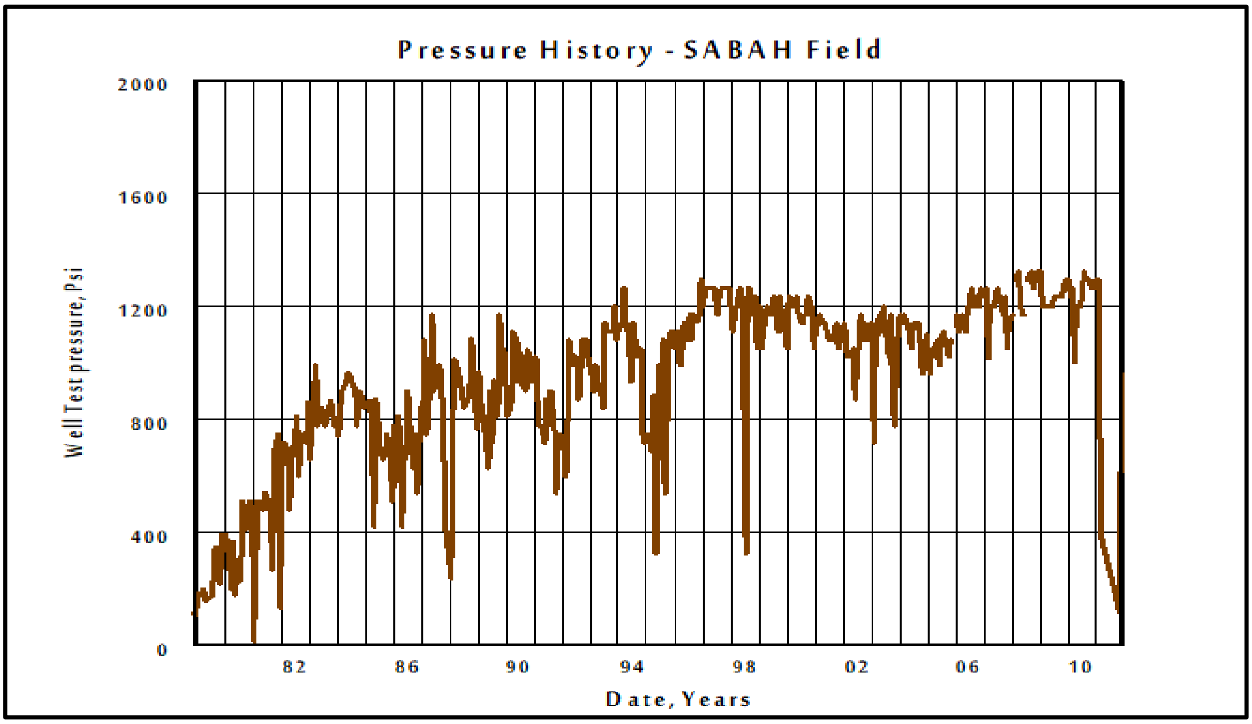


Figure (7) shows pressure performance history in SABAH field from 1978 until 2012.

Procedure -2-: in this step, we start to conduct a decline curve analysis using OFM software, and the model estimated the decline curve production history and continued extend a forecast curve based in real data and based on the shape of decline curve best fit resulted, and we performed the DCA for both (field and some selected wells); to estimate the remaining reserve and EUR (Expected Ultimate Reserve).

a) Decline curve analysis – field case:

As initial action was performed to understand remaining reserve estimation using decline curve by OFM software, there are some steps were done in order to get best accurate results from the software:

1. We use Rate-Time decline analysis with forecast tool in OFM software, as shown in figure (8), with select Arps' empirical equations.
2. The software plots the rate-time decline curve by default settings as in figure (9), but we need to perform some techniques on forecasting's settings as following:

- We exclude some production points, because they weren't smooth with the normal decline curve.
- Flow model: we select oil phase, oil cumulative calculated variable, and oil rate in bbl/day.
- Forecast: we select start time as a **Last historical date**, start rate as a **Last fit rate,** end time in **01/01/2035,** and end rate **1300 bbl/day** as was provided by the **(ZOC)** for SABAH field, which is the average economic limit with production operation for project revenue.
- Calculated: keep it as it is, because the oil phase is not calculated from other phases.

After set up the above settings; we let OFM software performs automatic decline curve analysis by selecting the best fit and show the analysis results in small box on the graph itself.

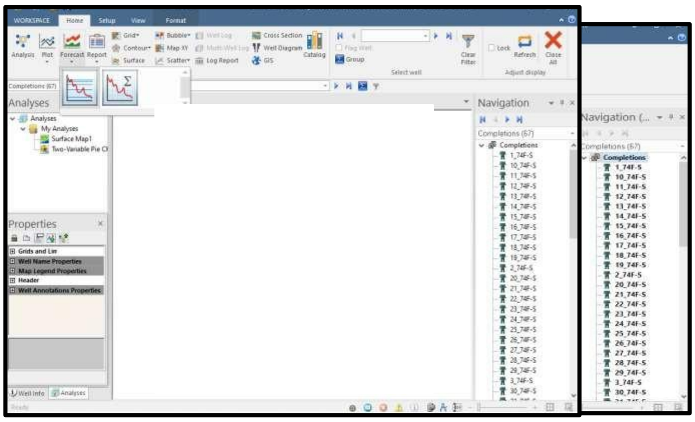


Figure (8): Rate-Time decline analysis with forecast tool **Figure (9):** Rate-Time decline analysis with default in OFM software settings in OFM software

Figure (10) shows the resulted DCA after update the setting, the OFM software select the exponential decline model to forecast the production decline of the field (b = 0). The exponential decline model assumes that the production rate decreases exponentially over time and the forecast will end by Time which was sat up in the setting after 20 years of production, the Remaining Reserve-Predicted by OFM equal to 26069.632 Mbbl with Absolute Relative Error (ARE %) equal to 0.27%, when compared it to the Reserve- Predicted by ZOC which is equal to 26141 Mbbl.

The figure (11) shows the summary of DCA using auto-history match's results by OFM software, and we summarized all results in table (2).

To confirm the mentioned results, we decide to perform manual decline curve analysis by selecting the last historical production decline period in rate-time decline "Arps' assumptions" with keeping all the setting as same as the first analysis except changing the method of history match to be "Manual.

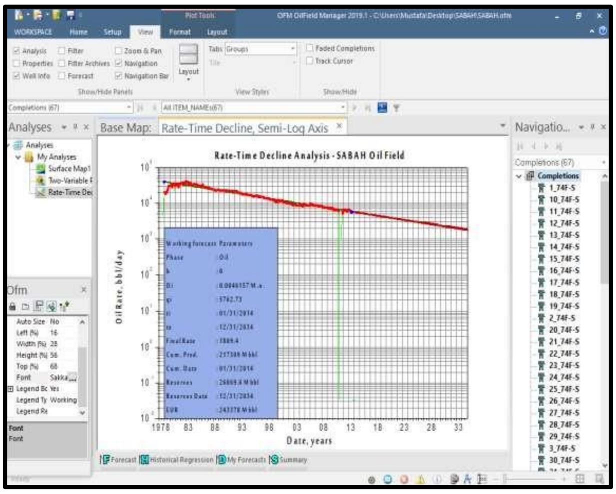


Figure (10): Rate-Time decline analysis: auto-history match

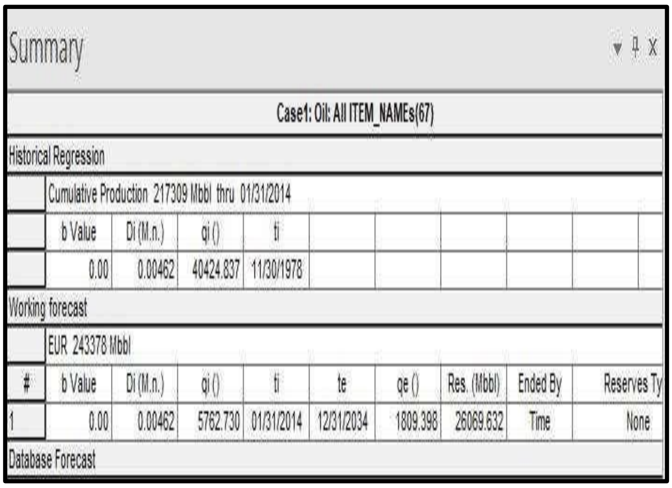
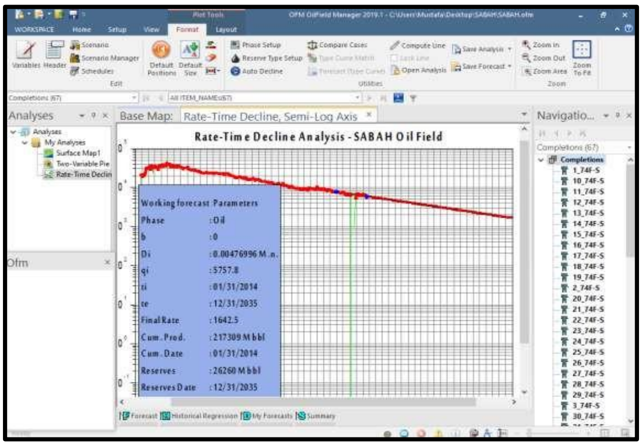
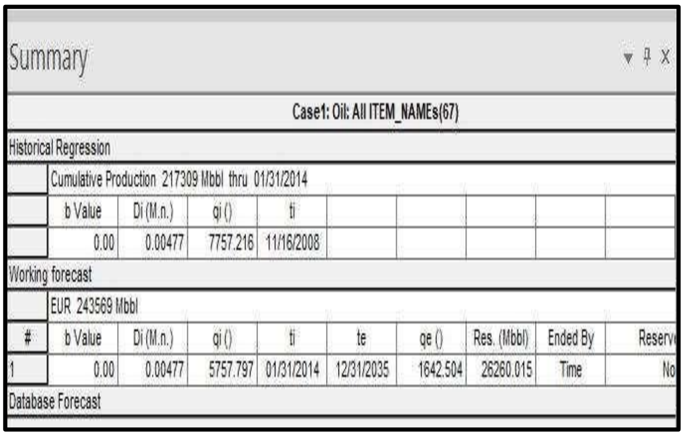


Figure (11): Rate-Time decline analysis: summary of results, auto DCA

Table (2): Rate-Time decline auto analysis: summary of results

Decline Curve Exponent (b)	0
Initial Decline Rate (Di), Month	0.0046
Initial Rate (qi), bbl/day	5762.73
The initial time (ti)	31-01-2014
Economic limit time (te)	31-12-2034
Estimated final rate (qe), bbl/day	1809.39
Estimated Remaining Reserve, MMbbl	26.069
Cumulative Production @ 31/01/2014, MMbbl	217.309
Expected Ultimate Reserve (EUR), MMbbl	243.378





Summary

Case1: Oil: All ITEM_NAMEs(67)

Historical Regression

Cumulative Production 217309 Mbbl thru 01/31/2014

	b Value	Di (M.n.)	qi ()	ti
	0.00	0.00477	7757.216	11/16/2008

Working forecast

EUR 243569 Mbbl

#	b Value	Di (M.n.)	qi ()	ti	te	qe ()	Res. (Mbbl)	Ended By	Reserv
1	0.00	0.00477	5757.797	01/31/2014	12/31/2035	1642.504	26260.015	Time	No

Database Forecast

Figure (12): Rate-Time decline analysis: manual-history match **Figure (13):** Rate-Time decline analysis: summary of results, manual DCA

As we can observe from figure (12) that shows the summary of DCA using manual- history match's results; the Reserve-Predicted by OFM equal to 26260.015 Mbbl with Absolute Relative Error (ARE %) equal to 0.46%, when compared it to the Reserve-Predicted by ZOC which is equal to 26141 Mbbl, and the model of decline was exponential decline to forecast the production decline of the field (b = 0).

We summarized the results of this case in table (3) as in following:

Table (3): Rate-Time decline manual analysis: summary of results

Decline Curve Exponent (b)	0
Initial Decline Rate (Di), Month	0.0047
Initial Rate (qi), bbl/day	5757.79
The initial time (ti)	31-01-2014
Economic limit time (te)	31-12-2034
Estimated final rate (qe), bbl/day	1642.50
Estimated Remaining Reserve, MMbbl	26.260
Cumulative Production @ 31/01/2014, MMbbl	217.309
Expected Ultimate Reserve (EUR), MMbbl	243.569

Table (4): Summary of Recovery Factor Correlations results

Correlations	Recovery Factor	Error%
Zueitina Oil Company	49.31%	-
ARPS	48.21%	2.23
Zekri and Nasr	41.90%	15.02
Craze & Buckley	43.18%	12.44

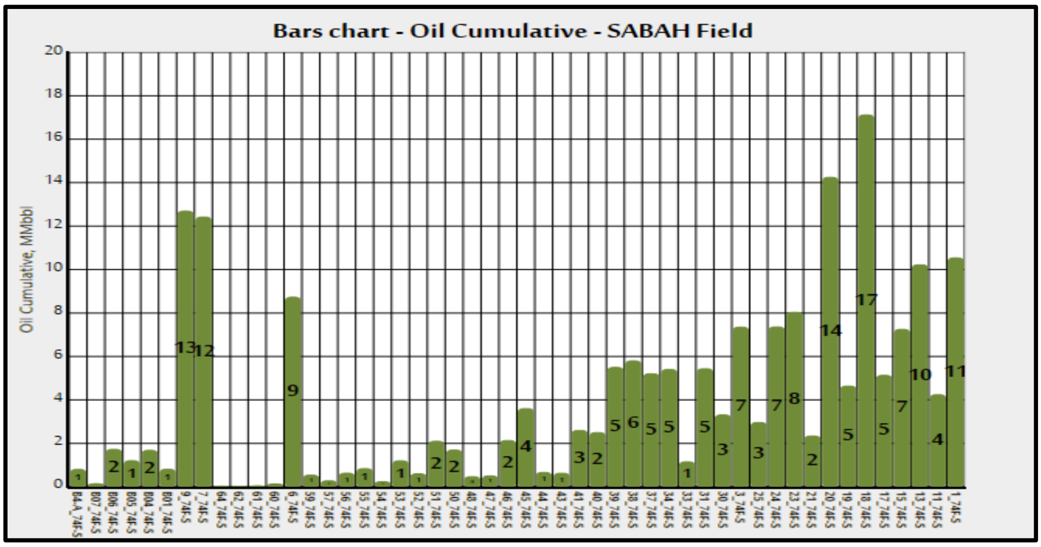


Figure (14): Oil cumulative bars' chart, SABAH field

Conclusions

The followings are the main conclusions that can be summarized from this study:

1. The analysis performed using OFM software revealed a substantial reduction in time requirements when compared to conventional manual analysis methods.
2. The Decline Curve Analysis (DCA) utilizing the Forecast tool within OFM software yielded an Arps decline exponent (b) of 0, indicating that the decline of the SABAH oil field follows an exponential trend, which aligns with the observed decline characteristics.
3. The rate-time decline analysis for the SABAH oil field, conducted using automated history matching, projected reserves to be 26.069 million barrels by December 31,

2034, with an Absolute Relative Error (ARE) of 0.27% in comparison to the remaining reserves predicted by the (ZOC). In contrast, when employing manual history matching by selecting the last decline period, the predicted reserves were estimated at 26.260 million barrels, resulting in an ARE of 0.46%.

Recommendations

The followings are the main recommendations that can be summarized from this study:

4. We recommend that (ZOC) conduct a comprehensive Decline Curve Analysis to assess the effect of long period shut-in on the remaining reserves of the field.
5. We recommend conducting this study using another commercial software and comparing the results with the parameters obtained from OFM Software.
6. It is recommended to install sensors on the wells to accurately record production parameters, in order to avoid human errors. This would provide more reliable data for analysis and decision-making.References:

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