The Prediction of Future Oil Wells Production from Decline Curve Pattern

Dr. Dhorgham Skban Ibrahim

Department of Petroleum Engineering, College of Engineering, University of Baghdad, Iraq

Abstract

The production decline analysis is a traditional method of identifying wells production pattern and predicting its performance and life based on real production data. The study of the application the production decline curves using one of the empirical models either the exponential, hyperbolic or the harmonic decline curves which occur often in the later life of production units has been done. Decline curve analysis applies oil production versus time plots to extrapolate an estimation of the future production rates for wells. Production data were plotted in different ways to identify a representative decline model. In this study, the historical data were provided from five oil wells of the 4th pay formation reservoir in Zubair field in southern Iraq (Basrah region). These data were used to estimate the total future recovery of petroleum and the end of a productive life to the economic limit. The relationships between production rate, time, and cumulative production for each well were studied. The production data points for each well were analyzed separately to evaluate the effect of the change in the production and reservoir conditions on the remaining reserves. The typical decline curve was applied in each oil well and the estimation of total reserves isn't changing with the time or by the workover action.

Keywords: —Decline curve, production history, remaining reserve, producing life

Introduction

The oil and gas industry depend on the production data to determine the life span of a producing oil/gas facility and to predict the profitability of producing oil/gas facilities. The production from an oil well tends to pass through a number of stages during its producing life. These stages are the build-up stage; later the oil well enters a plateau stage, where the full installed extraction capacity is used, before finally arriving at the onset of decline, which ends in abandonment once the economical limit is reached [1].

Decline curve models are a routinely analysis technique to estimate of the future rates of production for wells. Decline curve analysis was first documented by J. J. Arp (1945). He developed a set of empirical decline curves for predicting oil reservoirs [2]. The decline curve was introduced in the oil industry in the 1970. Further development and generalization has been done by McCray (1975) [3]. Later, it expanded by Fetkovich (1980) who used a type curve approach which applies for changes in pressure or drainage [4]. Blasingame and many others were developed a wide number of decline curve for utilization in different applications [5-7]. Also, it's discussed by Boyun Guo et al, (2007) that presents empirical models and procedure for using the models to perform production decline data analysis and use computer program for model identification and production rate prediction [8].

The advantages of decline curve analysis that the data is easy to obtain, it is easy to plot, it yields results on a time basis, and it is easy to analyze [9]. Decline curve method is not based on physical principles such as a change in production conditions, well damage, and equipment failure. Decline curve analysis can only be used as long as the mechanical conditions (completion, production method, etc.) of the well and the driving forces in the reservoir are unchanged. However, when a workover is taken to improve the oil recovery, such as fluid injection, fracturing, and acidizing, decline curve analysis can be used to estimate the performance of the well or reservoir in the both of cases and compare it to the actual performance with the change [10].

The decline curve method can be applied for final well evaluation when the producing patterns become established. Also, it can be used to estimate the ultimate recovery of oil and the producing life. The most popular decline curve plots is that which represent the oil production rates with time, and the oil production rates versus cumulative oil production.

The estimation methods are commonly made by extrapolating a performance trend. The method of extrapolating a trend, depend upon the assumption that the factors which are caused changes in the past will operate in the same way in the future [11]. As the oil wells are produced, the energy causing oil flows into the wells is depleted, so that production rate gradually decreases and net revenue is reduced so that it merely equal operating expenses. Beyond such a limit, further production is uneconomical, therefore, the final limit of production is generally defined as economic limit, the remaining reserves of oil and the time required to produce it are estimated empirically. Thus, it must be providing production data that will continue into the future. This is can be done graphically by plotting the data and it can be extrapolated into the future to the economic limit. If the oil production rate of a well drops to the economic limit (surface oil rate < 10 bbl/day), the well will be considered to reach the stop production point [10].

The objectives of this study are the prediction of total future petroleum recovery, and the production time pattern for five oil wells in Zubair field in southern Iraq depends on the dynamic wells data.

Methodology

The decline curves analysis technique is characterized by three factors [11]:

• Production rate of particular time

• Curvature of the decline

• Rate of decline

The production decline curve must have been stable over the period being analyzed. The production decline should truly reflect reservoir productivity and not be the result of an external cause. Production decline curve analysis is used in the evaluation of new investments and the economic analysis through the determination of the reserve for a well, or a field. This is an independent method of hydrocarbon reserve estimation, the result of which can be compared to volumetric or material-balance estimation.

Arps (1945) defined three general equations to model the production declines behavior. These models are; exponential, hyperbolic and harmonic [2]. It is difficult to foresee which equation the reservoir will follow. On the other hand, each approach has some disadvantages, for example, the exponential decline curve tends to underestimate reserves and production rates, and the harmonic decline curve tends to over predict the reservoir performance. In some cases production decline data aren't following any model, but cross over the entire set of curves. Each type of decline curve models has a different curvature. The curvature of the decline shows the characteristic shape of each type of decline when the flow rate is plotted versus time or versus cumulative production (N_p) in Cartesian, semi-log, and log-log scales. The main characteristics of these decline curves can be used to select the flow-rate decline model that is appropriate for describing the production rate–time relationship of the hydrocarbon system.

Nearly all the conventional decline-curve analysis is based on empirical relationships of production rate versus time, given as follows [2]:

$$q_t = \frac{q_i}{(1+Dbt)^{1/b}} \qquad (1)$$

Where, q_t= oil flow rate at time t, STB/day, q_i= initial oil flow rate, STB/day, t = time, days, D= decline rate, 1/day, and b = empirical constants or Arps' decline-curve exponent

The decline rate refers to the decrease in the petroleum extraction over time. In many cases the decline rate is calculated on an annual basis, yielding the change in producing volume from one year to another.

The parameters are determined from the classical fit of the historical data, namely the decline rate, D, and the exponent, b; can be used to predict future production. This type of decline-curve analysis can be applied to individual wells or to the entire reservoir. Based on the type of decline rate behavior of hydrocarbon system, the value of parameter b ranges from 0 to 1. When b = 0, degenerates to an exponential decline model, when b = 1, yields a harmonic decline model and when $0 < b < 1$, a hyperbolic decline model.

Discussion of results and diagrams:

The oil production data from five oil wells of the 4th pay formation reservoir in Zubair field in southern Iraq were used to test the decline model. Table 1 shows the historical production decline data for five oil wells and Table 2 is similar to Table 1 with a regular distribution of days in each month which is used in the prediction calculations.

Table (1) Historical production decline data from five oil wells of the 4th pay formation reservoir in Zubair field in southern Iraq (Basrah region) -Raw Data

Year	Month	Well No.				
		ZB-24	ZB-139	ZB-53	ZB-143	ZB-147
		Monthly production (STB/Month)				
2006	JAN. 31	46000	46000	65000	60066	78000
	FEB. 28	51000	51000	77000	77995	77000
	MAR. 31	55000	55000	82000	81700	82000
	APRIL 30	55000	55000	82000	0	82000
	MAY 31	59000	59000	88000	0	88000
	JUNE 30	56000	55162	82000	0	82000
	JULY 31	55000	55365	137000	110000	109000
	AUG. 31	54000	55000	101000	107000	107000
	SEP. 30	52000	52000	78000	78000	52000
	OCT. 31	53000	53000	106000	106000	79000
	NOV. 30	49000	49000	99000	99000	99000
	DEC. 31	51795	53000	106000	106000	147000
2007	JAN. 31	53000	53000	104000	104000	104000
	FEB. 28	74000	50000	100000	75000	100000
	MAR. 31	87000	59000	116000	116000	116000
	APRIL 30	79000	53000	105000	105000	105000
	MAY 31	79000	71000	109000	109000	109000
	JUNE 30	80000	80000	106000	106000	106000
	JULY 31	84000	84000	112000	112000	83000
	AUG. 31	84000	84000	105000	104000	78000
	SEP. 30	79000	79000	106000	106000	79000

	OCT. 31	80000	80000	106000	106000	81000
	NOV. 30	77000	76000	102000	102000	76000
	DEC. 31	80000	80000	107000	107000	80000

Table (2) Historical production decline data -Average data

Year	Month	Well No.				
		ZB-24	**ZB-139**	**ZB-53**	**ZB-143**	**ZB-147**
		Monthly production (STB/Month)				
2006	JAN.	44516.13	44516.13	62903.23	58128.39	75483.87
	FEB.	54642.86	54642.86	82500	83566.07	82500
	MAR.	53225.81	53225.81	79354.84	79064.52	79354.84
	APRIL	55000	55000	82000	0	82000
	MAY	57096.77	57096.77	85161.29	0	85161.29
	JUNE	56000	55162	82000	0	82000
	JULY	53225.81	53579.03	132580.6	106451.6	105483.9
	AUG.	52258.06	53225.81	97741.94	103548.4	103548.4
	SEP.	52000	52000	78000	78000	52000
	OCT.	51290.32	51290.32	102580.6	102580.6	76451.61
	NOV.	49000	49000	99000	99000	99000
	DEC.	50124.19	51290.32	102580.6	102580.6	142258.1
2007	JAN.	51290.32	51290.32	100645.2	100645.2	100645.2
	FEB.	79285.71	53571.43	107142.9	80357.14	107142.9
	MAR.	84193.55	57096.77	112258.1	112258.1	112258.1
	APRIL	79000	53000	105000	105000	105000
	MAY	76451.61	68709.68	105483.9	105483.9	105483.9
	JUNE	80000	80000	106000	106000	106000

	JULY	81290.32	81290.32	108387.1	108387.1	80322.58
	AUG.	81290.32	81290.32	101612.9	100645.2	75483.87
	SEP.	79000	79000	106000	106000	79000
	OCT.	77419.35	77419.35	102580.6	102580.6	78387.1
	NOV.	77000	76000	102000	102000	76000
	DEC.	77419.35	77419.35	103548.4	103548.4	77419.35

The graphical presentation of the decline curve indicates that a plot of production rate versus cumulative production on Cartesian scale will produce relationships as shown in Figures (1-5).

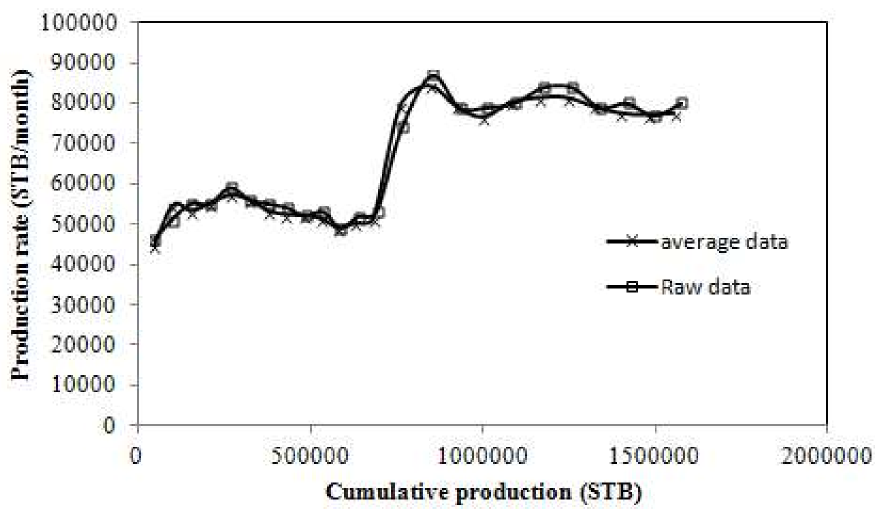

Fig.(1) Relationship between oil production rate and cumulative production of well Zb-24

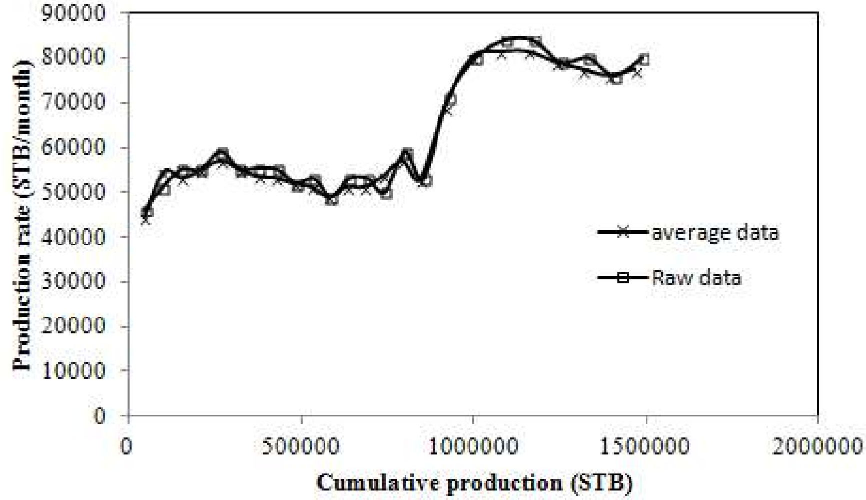

Fig.(2)Relationship between oil production rate and cumulative production of well Zb-139

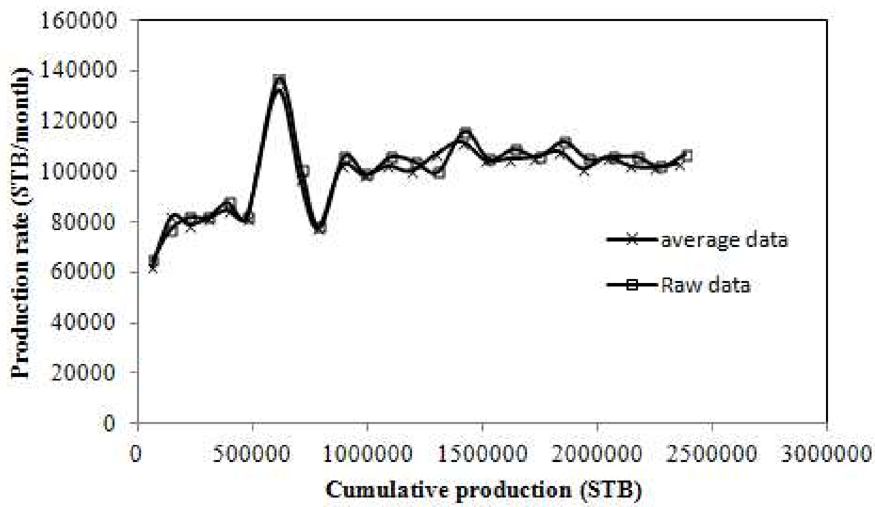

Fig.(3)Relationship between oil production rate and cumulative production of well Zb-53

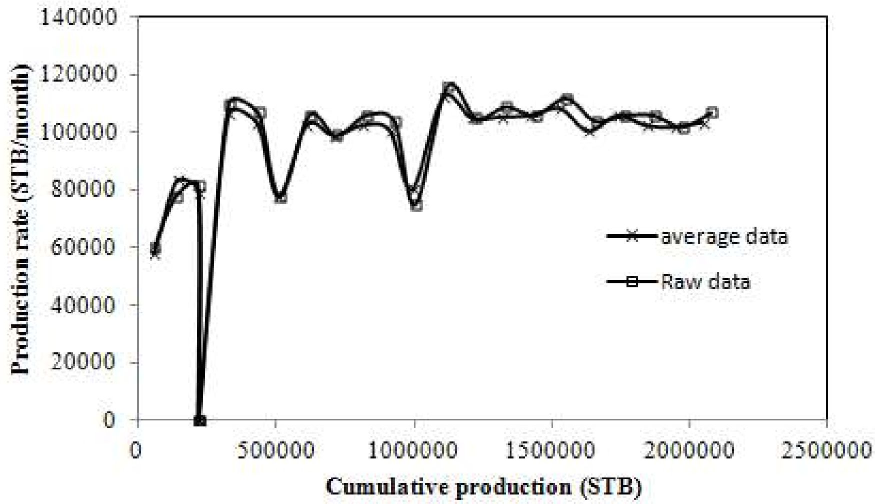

Fig.(4) Relationship between oil production rate and cumulative production of well Zb-143

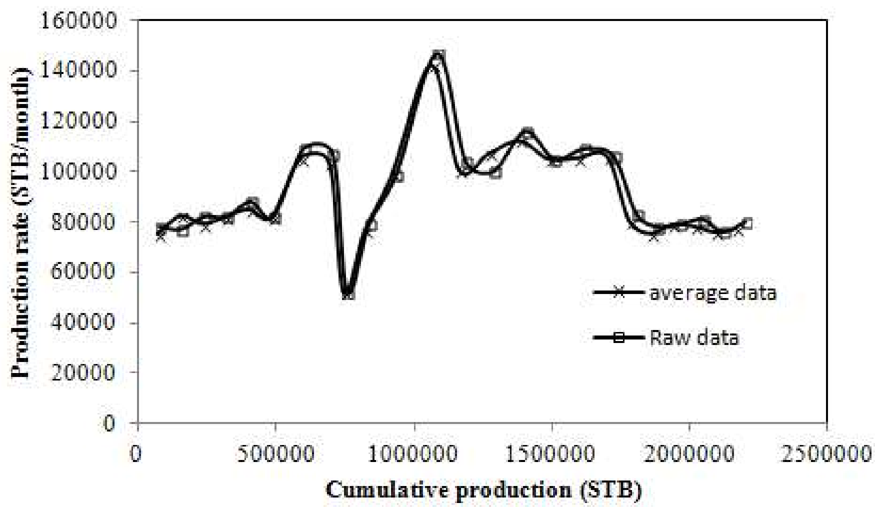

Fig. (5)Relationship between oil production rate and cumulative production of well Zb-147

After the Cartesian plots between the qt versus Np, the best straight line through the points was drawn and extrapolate the straight line on qt versus Np to qt= economic limit, which intercepts the x-axis with a cumulative production value that is identified as oil reserves.

The Figures (1-5) show that the production data have fluctuation in production decline rate due to the workover application to improve the production rate.

The production data for a well Zb-24 is shown in Figure 6. The best straight line through the points was drawn between the production rates versus cumulative production on Cartesian graph paper. There are two drawn lines, one before the workover and the second one after the workover. Although, there is no change in the total reserves, but only at the economic limit due to an increase in ultimate recovery. From the graph, the initial production rate (q_i) of this line was taken as 81972 (STB/Month), where the cumulative oil production or total oil reserve was 8.97×10^6 STB. The economic limit was taken as 300 (STB/Month), indicating an extra production of $8.97\times10^6 - 1.57\times10^6 = 7.40\times10^6$ STB, since the 1.57×10^6 (STB) represents the cumulative production during the years of 2006 and 2007.

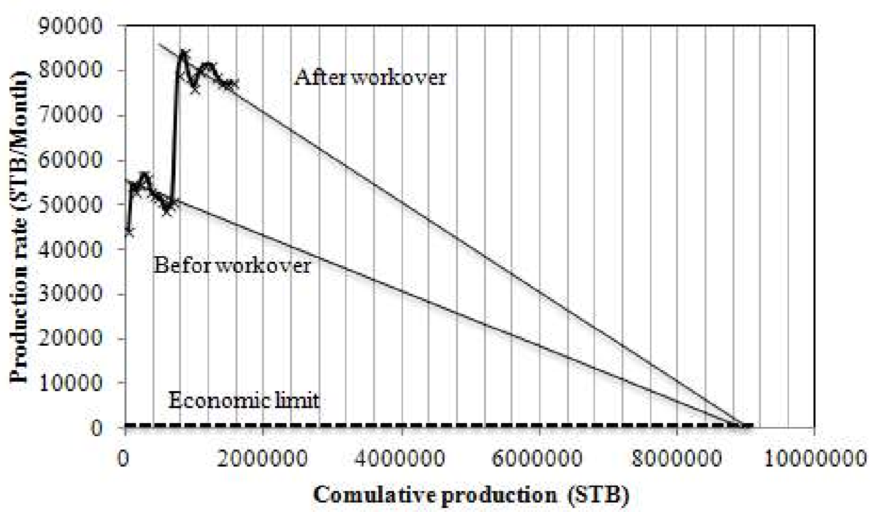

Fig.(6)Decline curve of well Zb-24 for forecasting total reserves from historical production data

The production decline rate (D) was calculated by selecting a point on the straight line and solving for (D) by applying the following equation:

$$D = \frac{q_i - q_t}{N_p} \qquad (2)$$

Where, the N_p is the cumulative production (STB).

Selecting (N_p) of 8.97×10^6STB, at (q_t) of 300 STB/day, gives (D)

$$D = \frac{82972 - 300}{8.97 * 10^6} = 0.0091(1/Month)$$

Finally, the following equation was used for estimating the producing life at the economic flow rate (q_t) or any rate for a well Zb-24:-

$$t_f = \frac{\ln(q_i/q_t)}{D} \qquad (3)$$

$$t_f = \frac{\ln(82972/300)}{0.0091} * \frac{1}{12} = 51.37\ years$$

Where, t_f is the producing life (Month), N_p is the oil reserves (STB), q_i and q_t are the initial and final production rate (STB/Month).

A similar procedure was used on the other wells, and the results are summarized in Table (3).

Table (3). Summary of total reserves and producing life of the studied wells

Well No	Remaining reserves (STB)	Producing life (Year)	Production decline rate (1/month)
ZB-24	$7.40*10^6$	51.37	0.0091
ZB-139	$7.61*10^6$	47.65	0.0100
ZB-53	$14.49*10^6$	71.16	0.0070
ZB-143	$14.37*10^6$	70.45	0.0070
ZB-147	$6.67*10^6$	44.65	0.0110

The exponential decline presentation of the flow rate versus time on a semi-log scale will produce linear relationships as shown in Figure 7 and is described mathematically by the following equation:

$$q_t = q_i e^{(-Dt)} \qquad (4)$$

Where: q_t = well's production rate at time t, STB/day, q_i = well's production rate at time 0, STB/day D = exponential decline rate, 1/day t = time, day

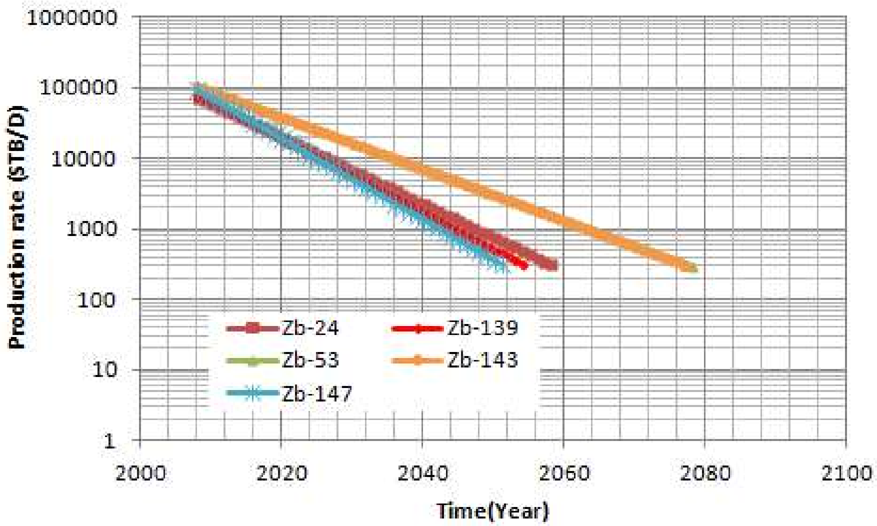

Fig. (7) Exponential decline curve of the studied wells

Also, equations 2 and 4 were used to predict the future production performance of the oil well. Figure 8 shows the prediction decline curve data for a well Zb-24. Appendix A shows the other predicted decline curve data for the other wells

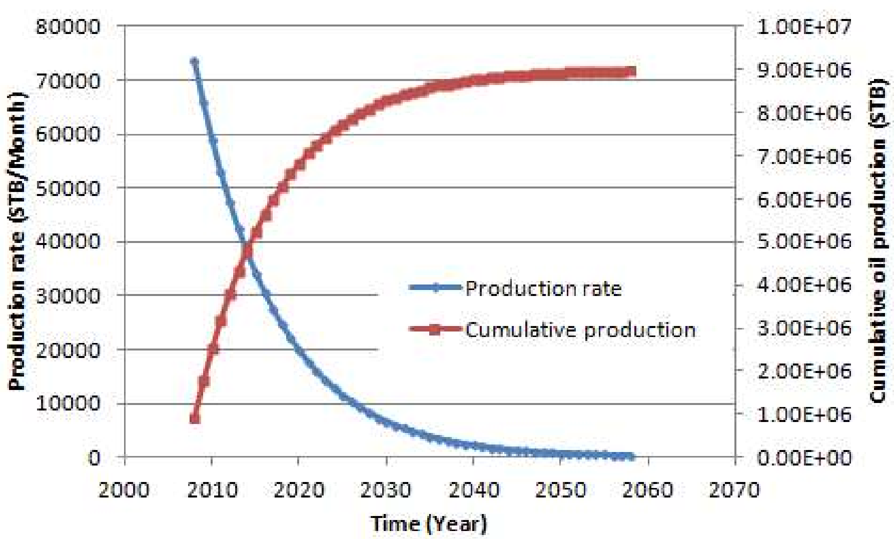

Fig. (8) Predicted decline curve data for a well Zb-24

Conclusions:

Decline curve models are the most common means of forecasting oil production. The typical decline curves can be applied in any oil field and it requires only dynamic wells data, mainly the change in oil production rate with time. In this study the exponential decline model was used to estimate the remaining reserves and producing life of five oil wells in Zubair field in southern Iraq. The values of the maximum oil recovery, oil producing life, and the decline production rate for the studied oil wells were evaluated. Also, the prediction decline curve data for each well were built. The results of the remaining reserve obtained by this scenario are ranging from (7.4×10^6 - 14.49×10^6) STB and these estimated recoverable reserves aren't changing due to a workover process. Finally, the study recommends making complete estimation of decline curve analysis for other wells to evaluate the total reserves for the whole the oil field and to compare with the results of the decline curve analysis with the other estimation methods.

Acknowledgements

This work was supported by the University of Baghdad, the petroleum engineering department which is gratefully acknowledged. Also, the authors gratefully acknowledge the help rendered by the team of South Oil Company, Basrah, Iraq, for providing the information.

References

[1] Boniface Obah, Aniefiok Livinus, Chima M. Ezugwu (2102) "Simplified models for forecasting oil production: Niger Delta Oil Rim Reservoirs Case", Petroleum Technology Development Journal, Vol. 2, 1-12.

[2] Arps, J.J. (1945) "Analysis of Decline Curves" Trans. AIME 160, 228-247.

[3] Arthur W. McCray, (1975) "Petroleum evaluations and economic decisions", Prentice Hall Inc., Englewood Cliffs, New Jersey.

[4] Fetkovich, M. J., (1980) "Decline Curve Analysis Using Type Curves" SPE 4629, SPE Journal.

[5] T.A. Blasirqame, J.L. Johnston, W.J. Lee, (1989) "Type-Curve Analysis Using the Pressure Integral Method", Society of Petroleum Engineers.

[6] Kewen Li, Roland N. Horne, (2003) "A Decline Curve Analysis Model Based on Fluid Flow Mechanisms" Society of Petroleum Engineers.

[7] H. Pratikno, J. A. Rushing, T.A. Blasingame, (2003) "Decline Curve Analysis Using Type Curves — Fractured Wells", Society of Petroleum Engineers.

[8] Boyun Guo, Willam C. Lyons, Ali Chalambor, (2007) "Petroleum Production Engineering, A computer Assisted Approach", Elsevier science Technology books.

[9] Mohammad Shahedul Hossain, Mohammad Asad Ibne Hossain, (2011) "A Study of commonly used conventional methods for gas reserve estimation", Journal of Chemical Engineering, IEB Vol. Ch. E. 26, No. 1.

[10] Khulud M. Rahuma, H. Mohamed, N. Hissein, S. Giuma, (2013) "Prediction of Reservoir Performance Applying Decline Curve Analysis", International Journal of Chemical Engineering and Applications, Vol. 4, No. 2.

[11] Ahmed Tarek, (2006) "Reservoir Engineering Handbook", Elsevier Inc. 30 Corporate Drive, Suite 400, Burlington, MA 01803, USA.

Appendix: A

Appendix A shows the other predicted decline curve data for the other wells

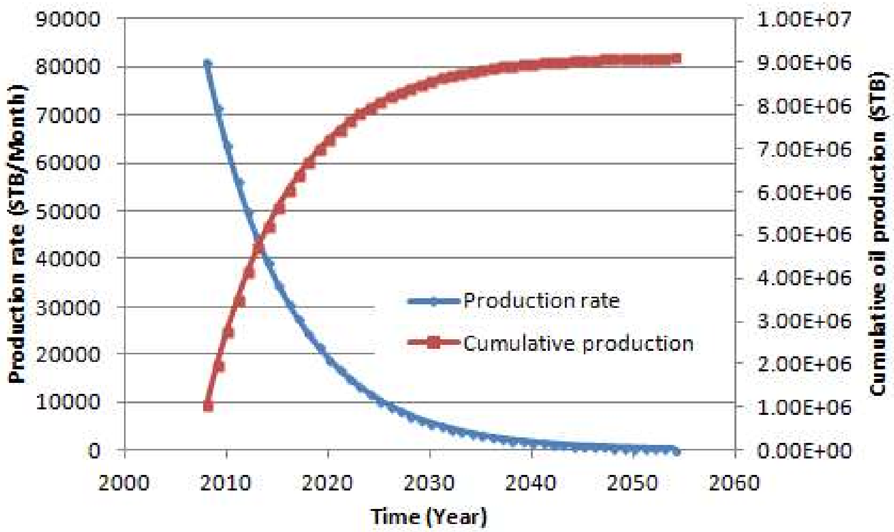

Fig. (9) Predicted decline curve data for a well Zb-139

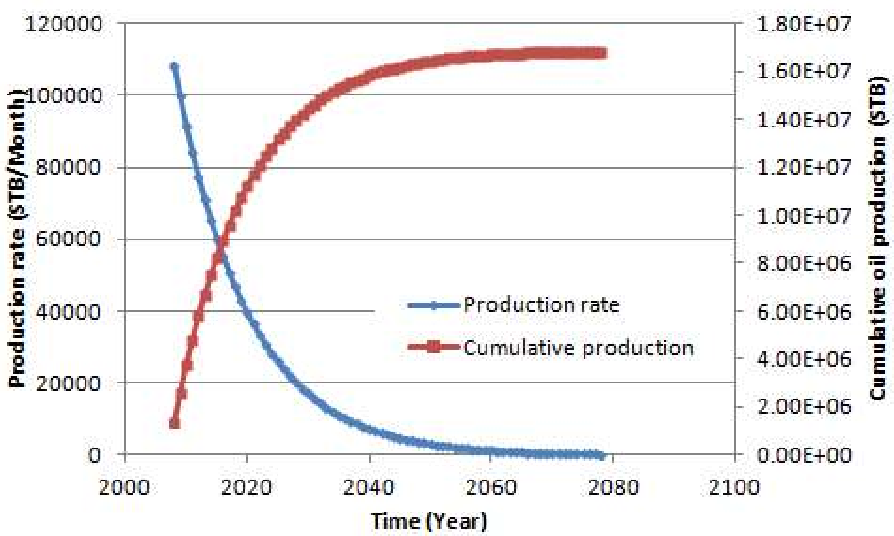

Fig. (10) Predicted decline curve data for a well Zb-53

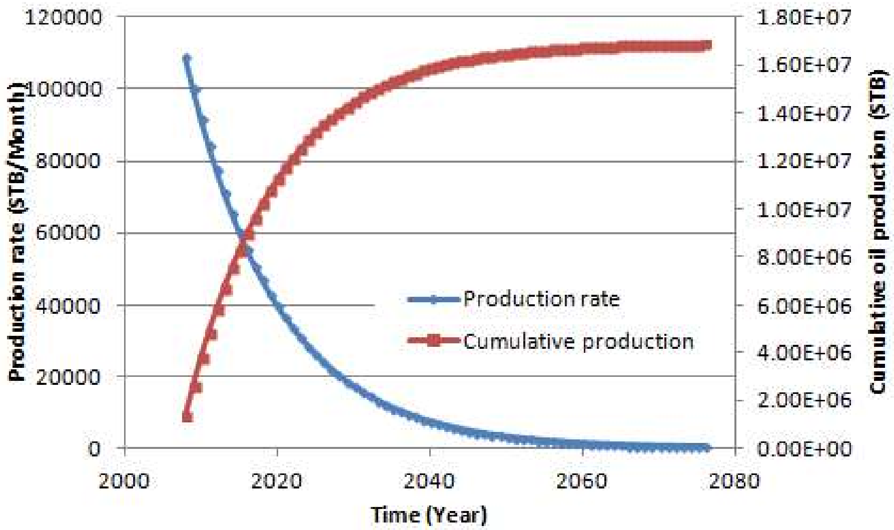

Fig. (11) Predicted decline curve data for a well Zb-143

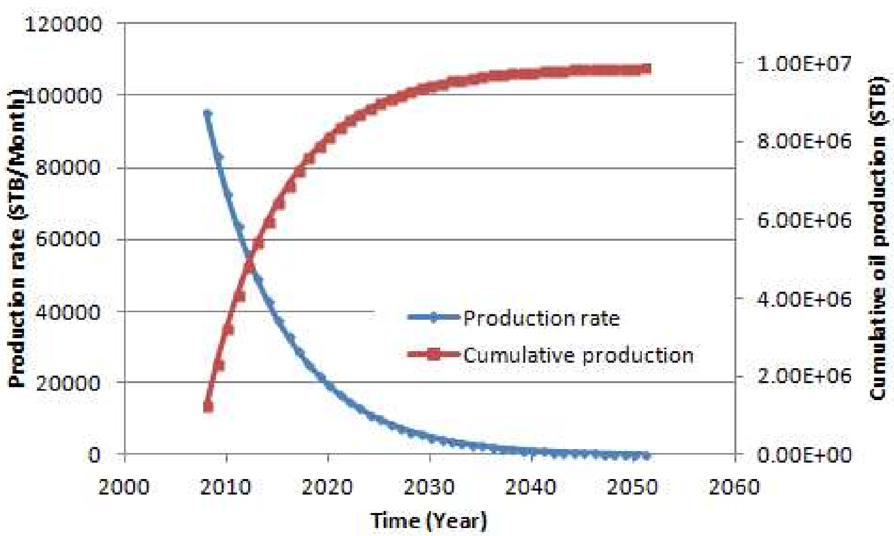

Fig. (12) Predicted decline curve data for a well Zb-147