Decline Curve Analysis In East Almabrouk Field-Case Study

Alfitouri Ibrahim Jellah, Mohamed Almabrouk Alhashi

Abstract: Production decline analysis is the analysis of the past trends of declining production performance, that is, rate versus time and rate versus cumulative production plots, for wells and reservoirs. In petroleum industry there are four methods to evaluate the reserves such as volumetric, material balance, numerical simulation and decline curve analysis. Decline curve analysis has been used to provide a best-fit equation for series of data point by least squares method. This method has been proved useful for decline curve analysis in order to estimate the initial decline rate (D), initial rate (qi) and the hyperbolic exponent (b), which can be used to plot the declining rate versus time after calculating the future rate at any desired time and calculating the reserves from certain time to an economic.

Index Terms: Analysis, Curve, Decline, Estimate, Production, Rate, Reserves.

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1 Introduction

In this work, type of reservoir decline will be investigated, in order to estimate the remaining reserves, total reserves; the productive life of wells or reservoir, and the future flow rate of the East Central Mabruk Field wells will be predicted. The selected production intervals are long enough so that the data will be sufficient to give good and reliable results. The production data points for each interval are analyzed separately to evaluate the effect of the change in the production and reservoir conditions on the remaining reserves. In this study production decline curve was analyzed for five producing wells. Production decline analysis is a traditional means of identifying well production problems and predicting well performance and life based on real production data. It uses empirical decline models that have little fundamental justifications. These models include;

- Exponential decline (constant fractional decline),
- Harmonic decline, and
- Hyperbolic decline.

These three models as shown in figure (1.1) are related through the following relative decline rate equation (Arps, 1945).

$$\frac{1}{q}\frac{dq}{dt} = b\, q^{d} \qquad \text{Eq. (1)}$$

Where b and d are empirical constants to be determined based on production data.

- *Alfitouri Jellah is currently the head of Oil & Gas Engineering Department, Azzaytuna University Bani-Walid/Libya, PH-00218-92-7345906.*
- *E-mail: aimj_2100@yahoo.com*

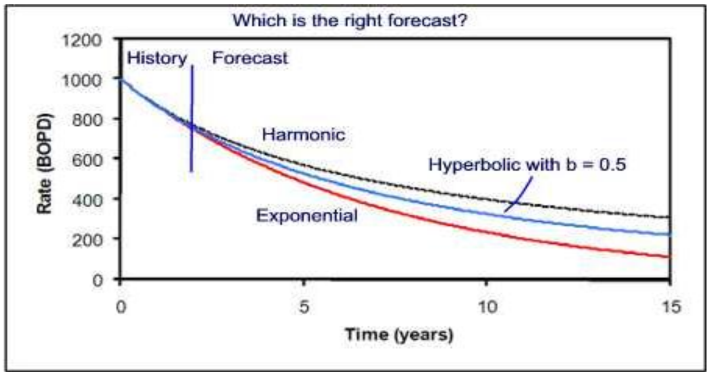

Figure (1): *Decline curve–rate/time (exponential, harmonic, and hyperbolic).*

2 Reservoir Description

2.1 East Central Mabruk (ECM) Reservoir

Almabrouk field was discovered in 1999 by the well A-03, which was put on production on 1999.The field stopped producing on the end of July 2013 due to SEDRA PORT STRIK and resumed production on 24th September 2014. As of December 31st 2014, ECM average production rate 244 bbl/day. As West Mabruk, this reservoir is highly heterogeneous. Following the results of the 2005 wells, the development strategy has been re-examined. This has involved heavy data acquisition and modeling programs. However, uncertainties remain, mainly on the detailed mapping of reservoir bodies and on the impact of faults/fractures on sweep efficiency. These uncertainties will be reduced by drilling and field observation. The approach to follow these steps started from beginning 2008, and is summarized below:

- First, to demonstrate water injection feasibility and effectiveness by an injection test with four pilot injector wells: two supporting A-07 and two supporting A-84. Each time, two directions of sweep will be tested, along and perpendicular to the field extent and main fracture direction.
- Then, following the analysis of these pilots, the water injection scheme using a step out strategy, will be progressively adapted to the results.

There are four pilot injector wells were already drilled and started injection on 2013 (A135i, A136i, A140i and A141i). A pressure acquisition campaign already performed, before the start of the injection in order to get a clear baseline.

2.1 East Central Mabruk (ECM) Reservoir Summary

Below is a brief comparison of 2013 and 2014 performance and production data up to the end of the year:

Performance and Production Data	2013	2014	Unit
Average Oil Rate	771	244	STB/D
Water Cut	4.7	4	%
GOR	70	70	SCF/STB
Oil Produced	281.512	89.21	MSTB
Water Produced	13.925	3.763	MBBL

Table (1): *Reservoir Performance and Production Data*

Basic Reservoir Data	Parameter	Unit
Discovery Well	A-03	**
Date of First Production	1999	**
Original OWC	NA	ft S.S
Current OWC	NA	ft S.S.
Well Spacing	1,391	Acres
Average Reservoir Depth	3,300	ft/GL
Datum Level	2,530	ft S.S.
Original BHP	1,225	psia
Current BHP	600	psia

Table (2): *Basic Reservoir Data*

Rock Properties	Value	Unit
Formation	Mabruk	--
Lithology	Limestone	--
Porosity	20	%
Water Saturation	45	%
Rock Compressibility	4.00E-06	psi^{-1}

Table (3): *Rock Properties*

Reservoir Data	Value	Unit
Original Net Thickness	45	ft
Area @ Original OWC	NA	Acres
Bulk Reservoir Volume	3,400E06	m^3
Production Area	23645	Acres
Initial Gross Pay	60	ft
Porosity	20	%
Water Saturation	49.5	%
Oil Gravity	34	°API

Table (.4): *Reservoir Data Summary*

2.2 East Central Mabruk: Reservoir Management

East Central Mabruk field average oil rate since 1st of January 2014 up to 31st of December 2014 is 244 bbl/day with ~4 % water cut. The production rate is below the potential because the production duration is less than three months. The pressure measurements on East Central Mabruk have been taken as SGS and XPT in DSE development wells while crossing the Mabruk formation. The depletion trend is consistent throughout the East Central Mabruk wells area except A55 (ECM suspended well, far to the South) which is out of the trend with high pressure. The pressure points are dispersed due to the low reservoir permeability. The pilot injection started in January, 4th 2013 with two wells (A135Hi and A136Hi). The average water injection in A135Hi is 943 bwpd with 0 psi WHIP and A136Hi is 834 bwpd with 1110 psi WHIP. A135 has 0 psi WHIP could be due to the fracture area as the well is near to the fault. Later on, in the mid of 2013 another two wells were added to the ECM injection pilot (A140i and A141i).

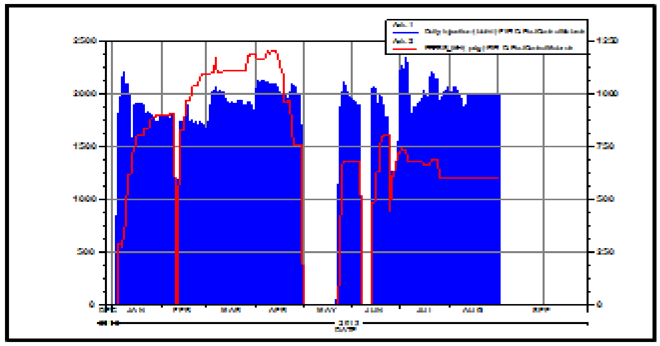

Figure (2): *A135i and A136i Injection Rate Performance*

3 METHODOLOGY

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap. The only software used In this work was Microsoft EXCEL following procedure was followed:

1. The production history of the field as well as the wells was collected.
2. The production history was plot as a flow rate versus time for each well and for the reservoir.
3. Then, the decline intervals were selected to perform the DCA.
4. The DCA was repeated under three scenarios: all data points were considered, averaging the data points and screening the data points.
   - Assume a certain value for (b) (e.g. 0).
   - Using the equations of the Least Squares methods given in Equations (2.21) and (2.22), evaluate (a_i) and (q_i).
   - Write the production decline equation using the values of (a_i) and (q_i) calculated in step (2) and the assumed value of (b).
   - Substitute the original data values of (t) in the equation and evaluate the "calculated rate, (q)".
   - Calculate the sum of squares of the discrepancies between the calculated rate values and measured rate values, i.e. $\sum_{k=1}^{n}(q_{cal} \quad q_k)^2$
   - Repeat steps (1-5) for different values of (b), preferably increments of (0.1) and calculate the sum of the squares of the discrepancies in each case.
   - Compare the sum values calculated, and choose the least sum. This will define the most appropriate values of (b), (q_i) and (a_i) which can be used for reserve calculation and future prediction
5. The results were interpreted and plotted in figures from (1 to 24).
6. The effect of operations done on the selected wells was studied.

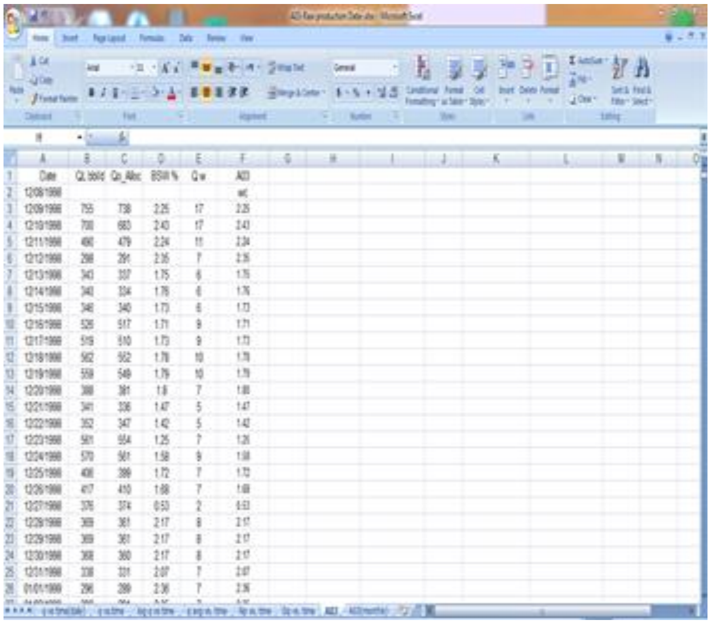

Figure (3): *Production History Raw Data*

4 Results Analysis & Discussion

Well A03_Production Decline Analysis

Decline curve analysis was applied on production data of Well A03. The production history was divided into two main periods:

- ➔ Period (1): for time from 31st of December 1999 to 31st of May 2001.
- ➔ Period (2): for time from 31st of December 1999 to 31st of May 2003.

Then DCA technique was applied in order to determine decline type, decline factor and initial decline rate which are then used to determine other evaluation parameters such total reserves, remaining reserves and abandonment time. Calculations and results are shown in the following figures and tables.

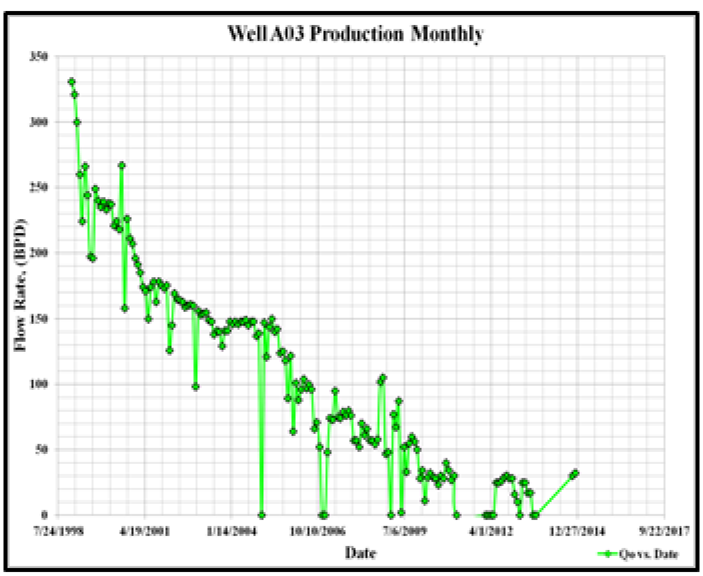

Figure (4): *Well A03, Oil Production History.*

Decline Type	Harmonic	
b =	1.00	
q_i =	278.41	bpd
a_i =	0.223494	/ year
$q_{cal.}$ at end of Period	177.58	bpd

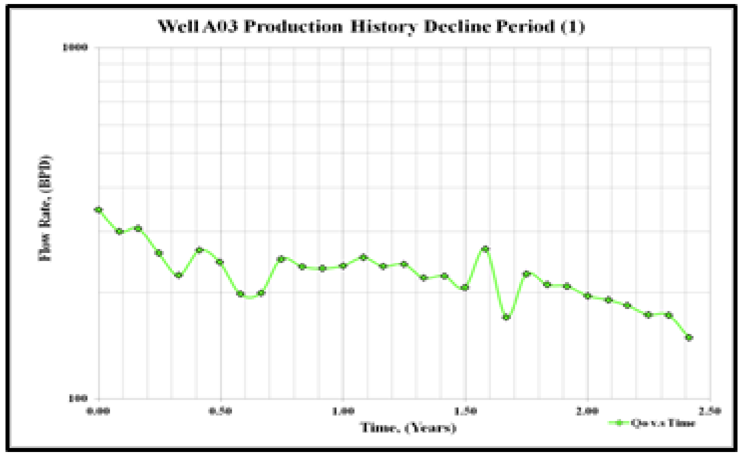

Figure (5): *Well A03 -Decline Period (1) Semi-Log Plot.*

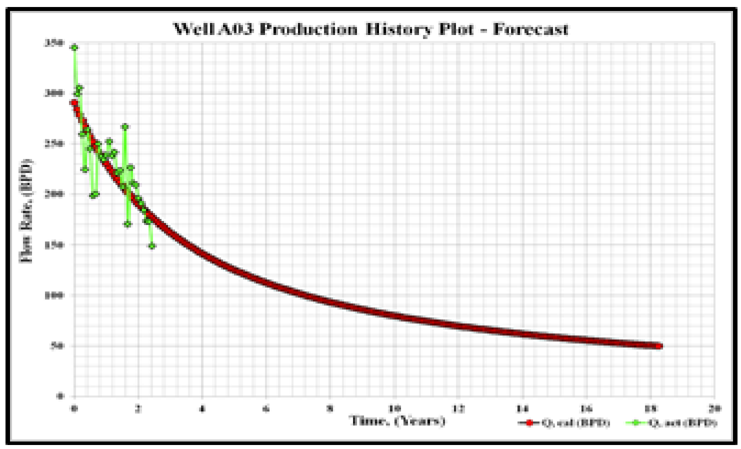

Figure (6): *Well A03 - Decline Period with Forecast.*

Well Name	A03	
Period of Analysis	Period	
Period	From	To
	31/12/98	31/05/01
Decline Type	Harmonic	
b =	1.00	
q_i =	278.41	bpd
a_i =	0.223494	/ year
q cal. at end of Period	177.58	bpd
Np at end of Period	200,911	bbl
Assumed q_e	50	bpd
Remaining Reserves	576,658	bbl
Total Reserves	777,569	bbl
time	31.58	years

Table (0): *Well A03 Period Production Decline Analysis Results*

WELL A07_PRODUCTION DECLINE ANALYSIS

Well Name	A07	
Period of Analysis	1	
Period	From	From
	31/05/99	30/04/00
Decline Type	Harmonic	
b =	1.00	
q_i =	603.98	603.98
a_i =	0.141905	0.141905
q cal. at end of Period	227.38	227.38
Np at end of Period	1,656,553	1,656,553
Assumed q_e	50	50
Remaining Reserves	2,354,595	2,354,595
Total Reserves	4,011,148	4,011,148
Time	128.9306053	128.9306053

Table (1): *Results of Well A07 Decline Period .*

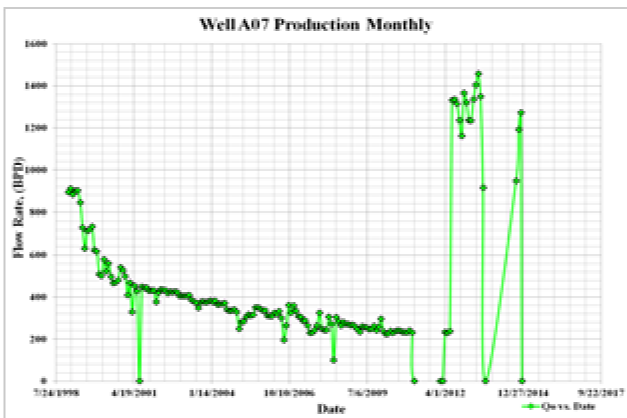

Figure (7): *Well A07 Oil Production History, Monthly.*

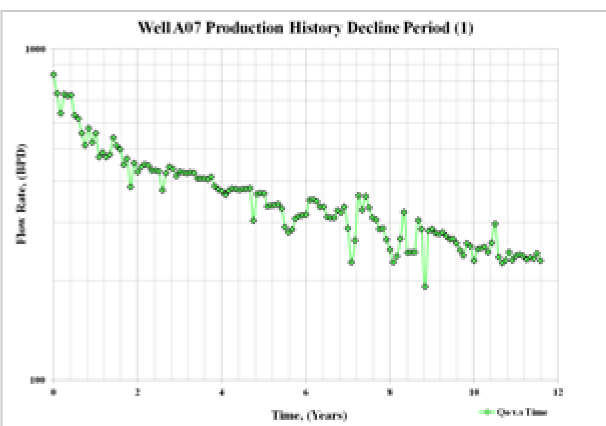

Figure (2): *Well A07 Decline Period (1) (Semi-Log)*

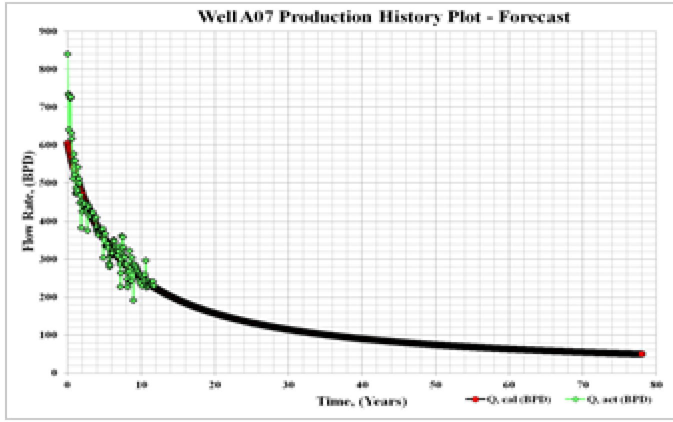

Figure (3): *Well A07 Production History Plot - Forecast*

WELL A58_PRODUCTION DECLINE ANALYSIS

Well Name	A58	
Period of Analysis	1	
Period	From	From
	31/10/07	31/07/09
Decline Type	Harmonic	
b =	1.00	
q_i =	224.82	224.82
a_i =	0.7384695	0.7384695
q cal. at end of Period	109.92	109.92
Np at end of Period	668,719	668,719
Assumed q_e	50	50
Remaining Reserves	87,593	87,593
Total Reserves	756,312	756,312
Time	4.796325092	4.796325092

Table (7): *Results of Well A58Decline Period*

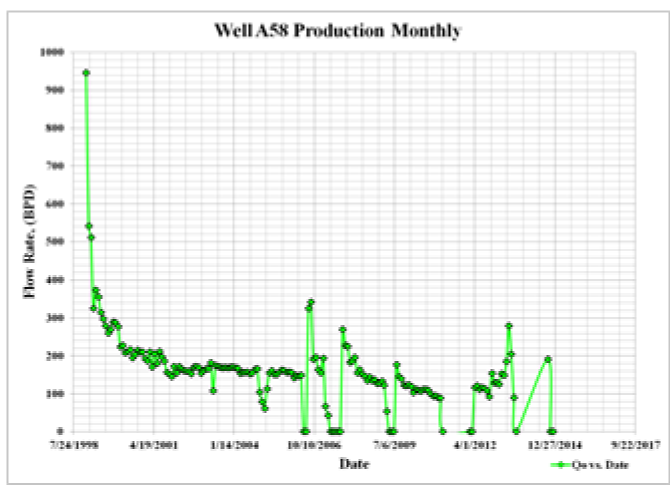

Figure (4): *Well A58 Oil Production History, Monthly*

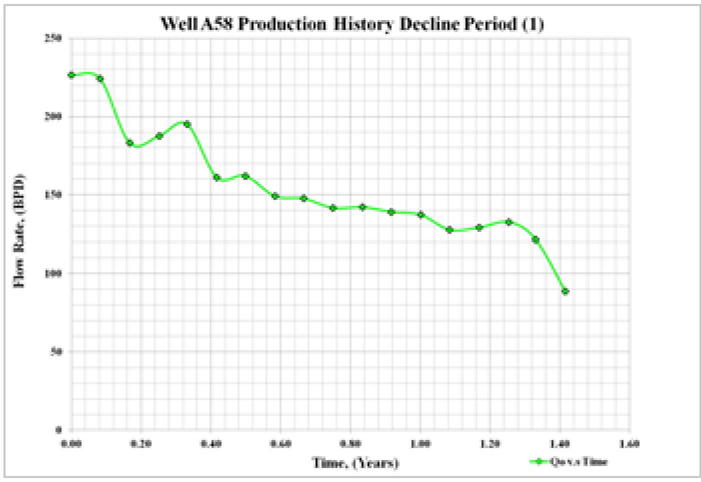

Figure (11): *Well A58 Oil Production History Decline Period*

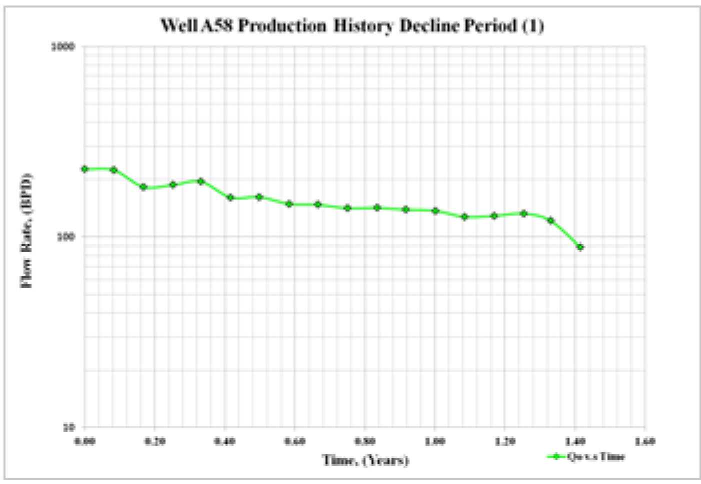

Figure (125): *Well A58 Oil Production History Decline Period (Semi-Log)*

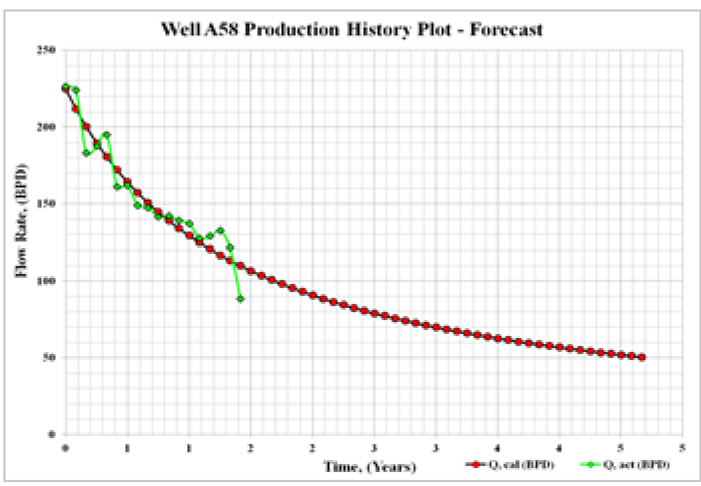

Figure (13): *Well A58 Production History Plot - Forecast*

WELL A101H_PRODUCTION DECLINE ANALYSIS

Well Name	**A101H**	
Period of Analysis	First Period	
Period	From	From
	31/01/05	31/01/05
Decline Type	Harmonic	
b =	1.00	
q_i =	421.34	421.34
a_i =	0.3839532	0.3839532
q cal. at end of Period	238.40	238.40
Np at end of Period	252,081	252,081
Assumed q_e	50	50
Remaining Reserves	626,049	626,049
Total Reserves	878,130	878,130
ta	34.28058806	34.28058806

Table (8): *Results of Well A101 Decline Period*

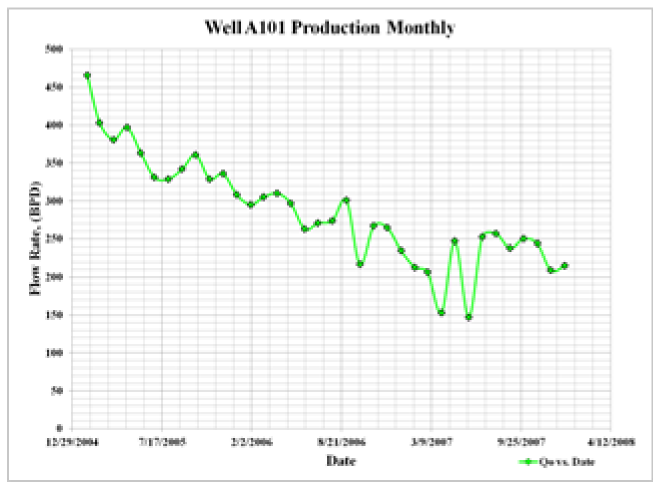

Figure (6): *Well A101H Oil Production History ,Monthly*

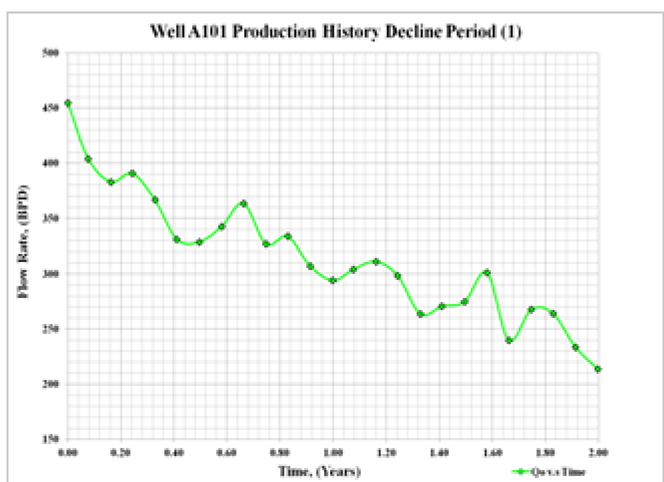

Figure (15): *Well A101H Oil Production History Decline*

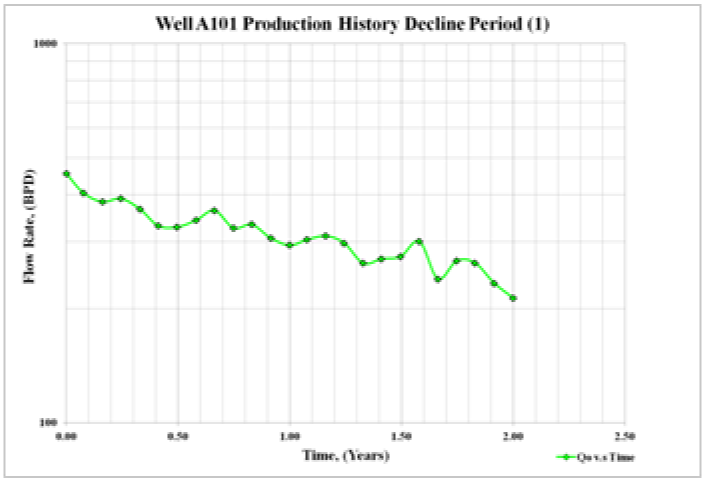

Figure (7): *Well A101H Oil Production History Decline Period (Semi-Log)*

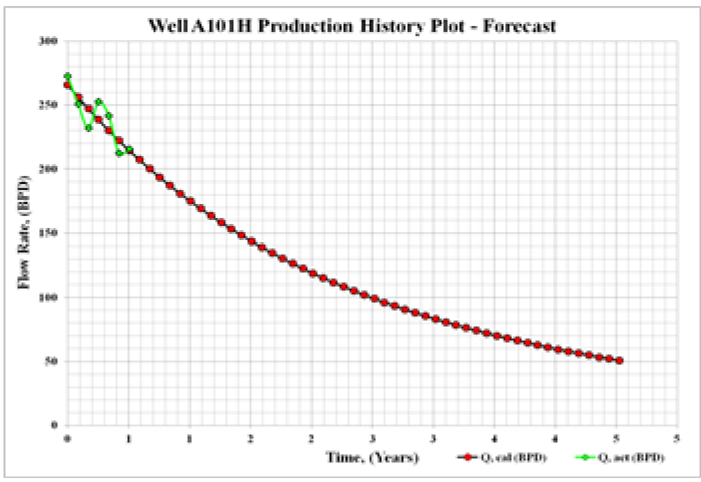

Figure (178): *Well A101H Production History Plot - Forecast*

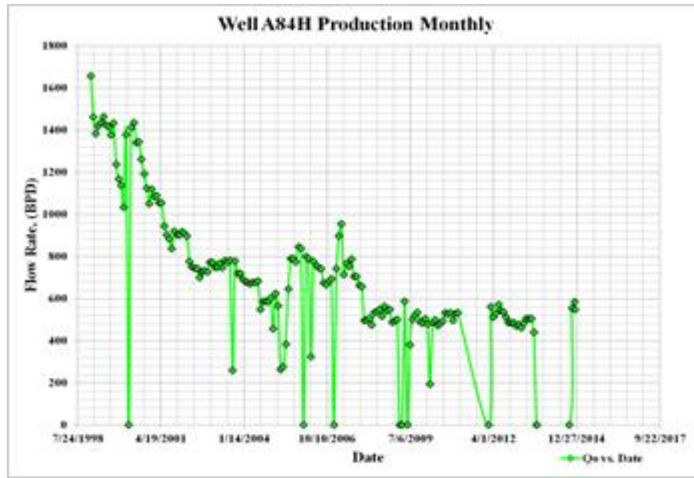

Figure (18) *Well A84H Oil Production History ,Monthly*

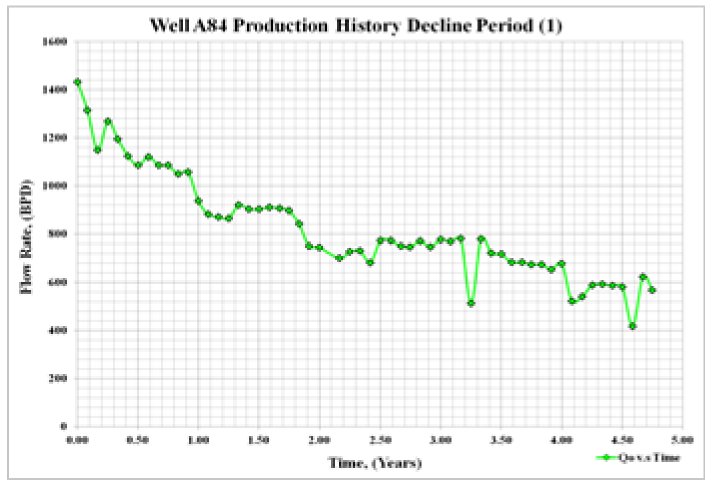

Figure (199): *Well A84H Oil Production History Decline*

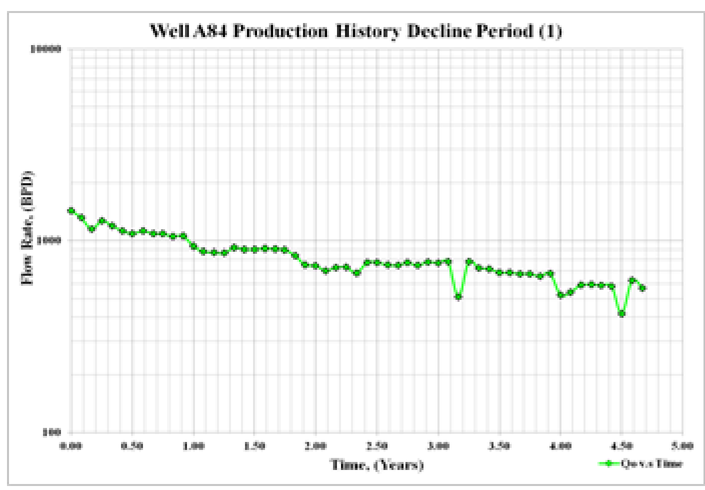

Figure (20): *Well A84H Oil Production History Decline Period (Semi-Log)*

WELL A84_PRODUCTION DECLINE ANALYSIS

Well Name	**A84 H**	
Period of Analysis	First Period	
Period	From	From
	31/05/00	31/05/00
Decline Type	Harmonic	
b =	1.00	
q_i =	1,257.96	1,257.96
a_i =	0.2661211	0.2661211
q cal. at end of Period	555.79	555.79
Np at end of Period	2,123,049	2,123,049
Assumed q_e	50	50
Remaining Reserves	4,158,150	4,158,150
Total Reserves	6,281,199	6,281,199
ta	227.6879041	227.6879041

Table (9): *Results of Well A84 Decline Period.*

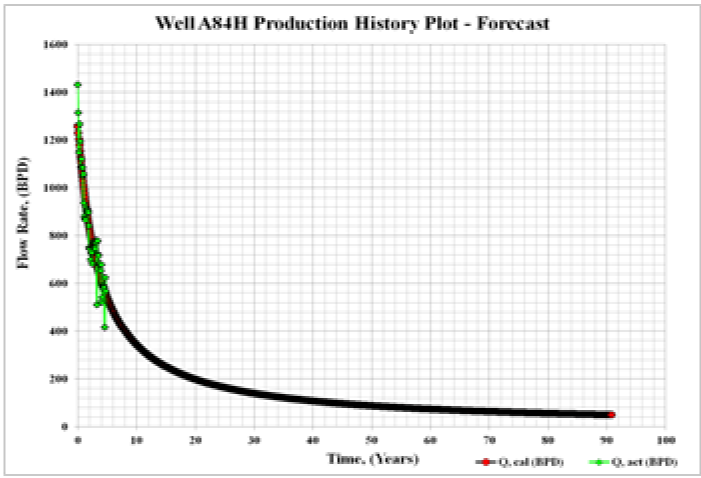

Figure (21): *Well A84H Production History Plot - Forecast*

3. Conclusion

The main Conclusions of this project can be summarized as follows:

1. The value of reservoir factor (b) is almost equal to one which means the reservoir is working as volumetric; solution gas drives mechanism.
2. It was noticed that the value of reservoir factor (b) differs from one well to the other within the reservoir, this is a result of that the some of the wells are far from the injector wells.
3. The wells which located near to the water injection wells have a value of (b) equal to zero which mean the water injection project was successful.
4. The other factors effected in production decline analysis including (b) factor, or (reservoir factor) are:
   - ➔ Human factors.
   - ➔ Production conditions.
5. The degree of uncertainty is inversely proportional to the duration of the production decline range. Consequently, the problem of uncertainty is most evident at the start of the production period (i.e. decline period < 2years).
6. The major gradual decline in the production rate of wells caused by rapid decrease in the reservoir pressure.

Acknowledgment

The authors wish to thank Almabrouk Company (TOTAL-Libya) for providing the data required to complete this work.

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