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Estimation of Original Oil in Place & Aquifer Characterization of Ghani Field – Farrud Reservoir

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Abstract

The material balance MB method is a powerful technique used to study reservoir performance and describing the important properties of the reservoir, including the estimates of original oil in place, and the strength of aquifer. It also provides the understanding of drive mechanisms at work, such as solution gas, water influx, and gas cap.

This study aims to determine the original oil in place of the Farrud reservoir using both Volumetric & Material Balance methods using MBAL Software. Also, diagnostic the aquifer influx presents into the reservoir and their strength. Two scenarios involved in this study; the first scenario is building a reservoir model without aquifer connecting. The second scenario, three aquifer models were selected to achieve the matching between observed reservoir and simulation data.

The Original Oil in Place Ghani-Farrud reservoir estimated by volumetric method was 735.24 MMSTB and the material balance used by Campbell Method was 920.8 MMSTB, the different between two values was about 21.8 %; that due to the uncertainty and lack of the data collected at the early lifetime, as well as the heterogeneities in the average reservoir parameter calculations. MBAL software led to the best analytical Matching between measured reservoir and simulation pressure which is improved by Hurst-van Everdingen Modified model with minimum standard deviation of 0.635. Based on the diagnostic plot of the Campbell, the a moderate strength aquifer is associated with the Farrud reservoir model. The Hurst-van Everdingen Modified model described the aquifer properties.

Keywords: Farrud Reservoir, MBAL Software, Original oil in place.

1. Introduction

One of the most important tasks of a reservoir engineer is to continuously monitor and understand the performance of the reservoir, collect data and interpret them to be able to determine the present conditions of the reservoir, predict future conditions, and control the flow of fluids through the reservoir to increase recovery factor. The main concern of the engineer is to carry out a study on the reservoir in order to adequately simulate the reservoir with the minimum effort. The knowledge of a reservoir is not accurately known since the reservoirs are large complex systems with irregular geometries that are found in subsurface layers with several uncertainties. [1]

Material Balance is one of the most important reservoir engineering tools. It requires pressure data, PVT data, and production/injection data, and aquifer parameters, so that original oil in place and drive mechanism can be determined. These data required should be accurate and more consistent. If the quality of data is not precise and doubtful, the material balance results will carry out with uncertainty. [2]

Reservoir pressure is somehow uncertain since limited well measurements are usually available and averaging procedures might introduce some uncertainty in the computed reservoir pressure history. PVT data can be also uncertain since some reservoirs have no representative fluid samples for a complete PVT analysis and correlations are used instead for material balance calculations. Usually, it

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is expected that oil and gas production is measured with confidence since industry revenues are based on oil and gas sales, and consequently error in production data can be considered minimal. [3]

2. MATERAIL BALANCE & WATER INFLUX

One of the important functions of the reservoir engineer is the periodic calculation of the reservoir oil (and gas) in place and the recovery anticipated under the prevailing reservoir mechanism (s). In some companies, this work is done by a group that periodically renders an accounting of the company's reserves together with the rates at which they can be recovered in the future. The company's financial position depends primarily on its reserves, the rate at which it increases or loses them, and the rates of recovery is also important in the scale or exchange of oil properties. The calculation of reserves of new discoveries is particularly important because it serves as a guide to sound development programs. Likewise, an accurate knowledge of the initial contents of reservoirs is invaluable to the reservoir engineer who studies the reservoir behavior with the aim of calculating and/or improving primary recoveries, for it eliminates one of the unknown quantities in equations.
Oil reserves are usually obtained by applying recovery factors to the oil in place. They are also estimated from decline curve studies and by applying appropriate barrel-per-acre-foot recovery figures obtained from experience or statistical studies. The oil in place is calculated either (a) by the volumetric method or (b) by material balance studies, both of which presented in this study. [4] [5]

2.1 Volumetric & Material Balance Equations

The volumetric method for estimating oil in place is based on log and core analysis data to determine the bulk volume, the porosity and the fluid saturations, and on fluid analysis to determine the oil volume factor. Under initial conditions 1 ac-ft of bulk oil productive rock contains

Stock tank oil (STB) $$\frac{7758 \times A \times h \times \emptyset \times (1 - Sw)}{Boi} \quad (1)$$

Where 7758 barrels is the equivalent of 1 ac-ft, Øis the porosity as a fraction of the bulk volume, A is the reservoir area (Acres), h is the net pay thickness (feet), Sw is the interstitial water as a fraction of the ore volumes, and Boi is the initial formation volume factor of the reservoir oil. [6]

3. The Description of Ghani Field (Farrud reservoir)

The Ghani Field is located in the south-western part of Harouge's Area 87/88/103 in the western Sirte Basin. The Farrud reservoir is a structural high, covering 7200 acres, between the Maamir trough and the Ramla syncline. The most striking features of Ghani Farrud reservoir are the NW-SE trending faults and sudden increase in pay in the centre of the Field.

The field was discovered in January 1978 by completing wildcat RRR1-11 in the Farrud formation. Wells with initial production rates of more than 3000 BOPD were common. Peak production, of 44,000 BOPD occurred in April 1981.

The Ghani Farrud reservoir was discovered under saturated at the initial pressure of 2357 psia, and

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the solution GOR of 668 SCF/STB. Reservoir fluid bubble point pressure was determined to be 2115 psia. Solution gas drive is considered to be the predominant mechanism for primary depletion, although some water influx is anticipated. Crude is 410 API gravity and is sweet. Depletion of the reservoir below the bubble point pressure had created a secondary gas cap near structural highs. The need for pressure maintenance had been realized in the early stage of the primary depletion. As a result, water injection pilot was initiated in November 1986. Based on the success of this pilot, water injection was expanded to a full-scale peripheral injection in February 1994 with 11 injectors. In order to support the reservoir pressure in the sink area, two injectors (RRR105 and RRR106) were drilled in 2007, 2008 respectively and later in January 2009 (RRR66) was converted to injector. The last pressure surveys run during the month of June 2014 average reservoir pressure without injectors was 2087 psia at datum depth of 5070 ft.

Cumulative production to 31 December 2014 was 161.719 MMSTB of oil, 34.288 MMSTB of water and 113.369 BSCF of gas.

3.1 Ghani Farrud reservoir data

The main source of these data is form Harogue oil co. The reservoir data are collected from different sources (Cores, logs, PVT ,etc). The table 1 included the data required for this study.

Table 1: Farrud Reservoir Data

Area	9760	Acres
Average Net Pay Thickness	76	ft
Porosity	22	%
Oil Saturation	86	%
Original reservoir pressure	2335	Psia
Original formation volume factor	1.424	bbl/STB
Original solution gas-oil ratio	668	Scf/STB
Original bubble point pressure	1900	Psia
Oil Gravity	41.05	Deg. API
Temperature	186	Deg. F

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The reservoir pressure performance of the Ghani-Farrud reservoir is shown in the Figure 1. The production and injection performance of the field are shown in Figure 2.

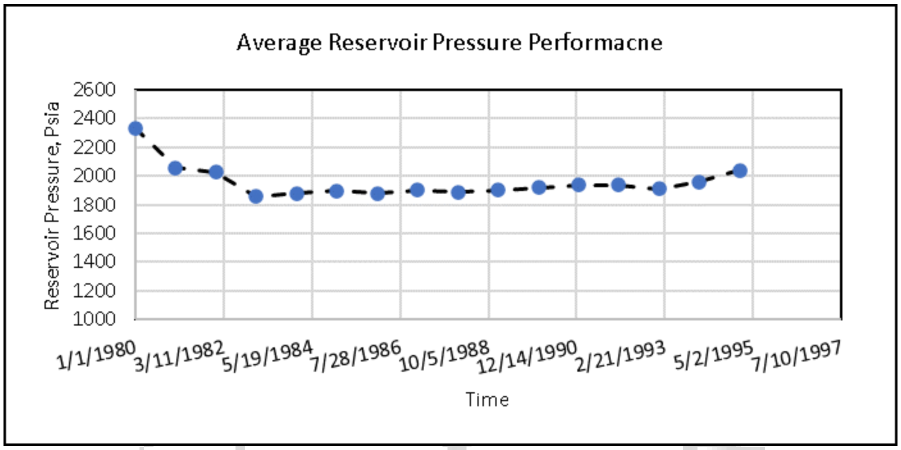

Figure 1: Reservoir Pressure Performance

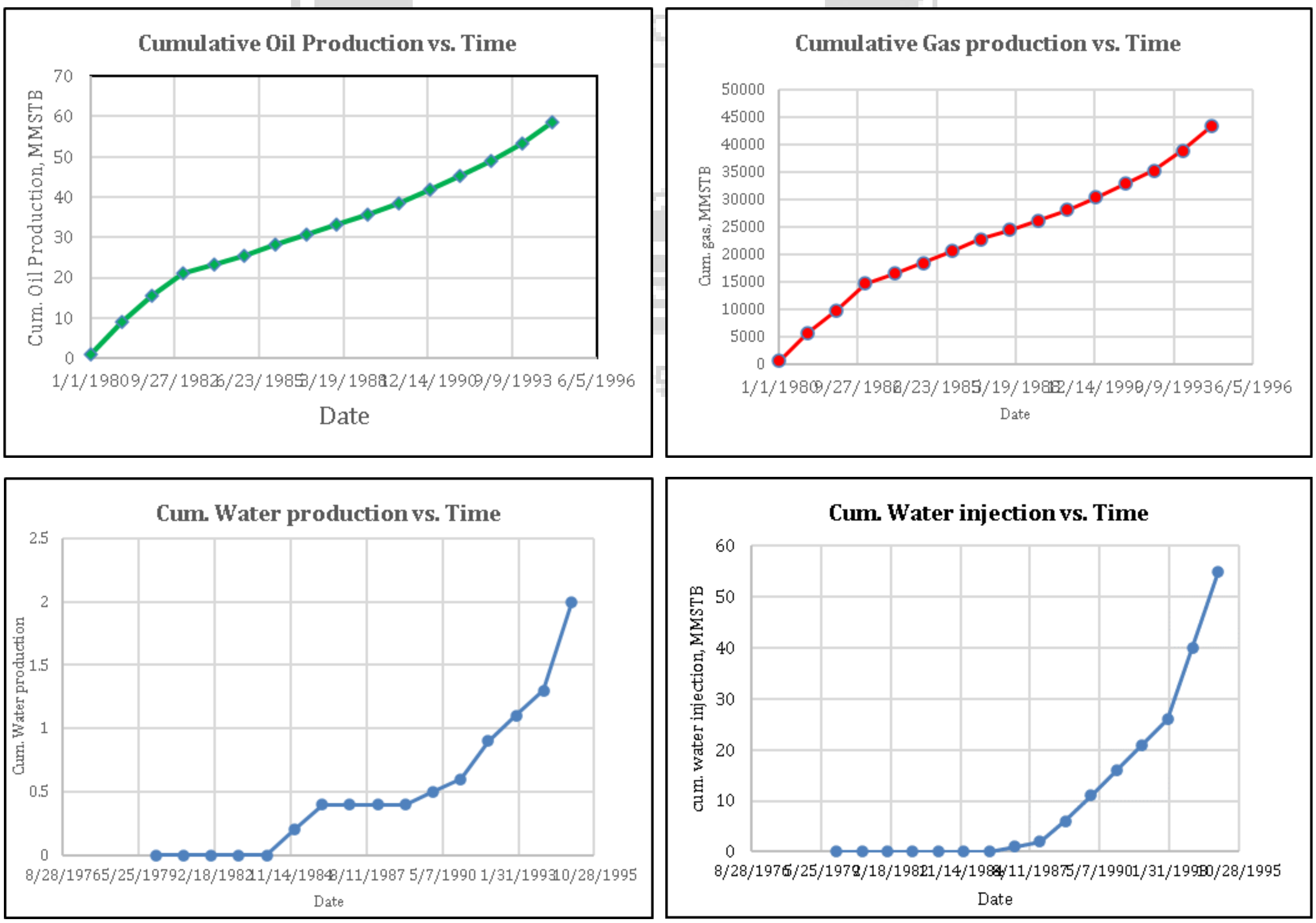

Figure 2: Production and Injection Performance

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4. Results and disscussion

The results show that the history matching processing, assuming two reservoir models. The first model was building a tank model (without aquifer), this is the first assumption used to distinguish if the reservoir is in contact with aquifer influx or the reservoir layer isolated. The second assumption is associated reservoir model with aquifer models to evaluate the original oil in place, accomplish the matching between reservoir pressure and simulation pressure. The final model will be a real case to understand the reservoir performance, as well asanalyze the drive mechanisms, them run a reservoir model simulation result (Aquifer influx volumes, recovery factor, etc.)

4.1 Volumetric Method

The first method used in this study to determine the oil in place of the Ghani-Farrud reservoir is the volumetric method. Based on the accurate and average reservoir properties of the following parameters; Area, Porosity, water saturation, Boi, the equation can be applied;

$$\text{Oil in Place} = \frac{7758 \times A \times h \times \emptyset \times (1 - Swi)}{Boi}$$

$$\text{Oil in Place} = \frac{7758 \times (9760) \times (76) \times (0.22) \times (1 - 0.173)}{1.424} = 735.24 \text{ MMSTB}$$

4.2 History Matching

The essential step to generating a reservoir model process is the History Matching. The analytical matching between observed reservoir pressure data and simulation must be proved. Then, the original oil in place value will be determined. Two assumptions supposed in this study, the first one is no aquifer influx attached with the Farrud-reservoir tank model, and the second is aquifer model is involved with the model. [7] [8]

4.2.1 History Matching (Analytical model-without aquifer)

Based on the first assumption, build a tank reservoir model without aquifer model. In MBAL Software, there is a section of History matching that uses a non-linear regression method to improve history matching. Figure 3, represents the match points observed data (Points) and the blue line which represent reservoir model without presence of aquifer. As seen, the match points status is matching along with blue line in some points. Regression Option is help to improve Analytical Method with good match.

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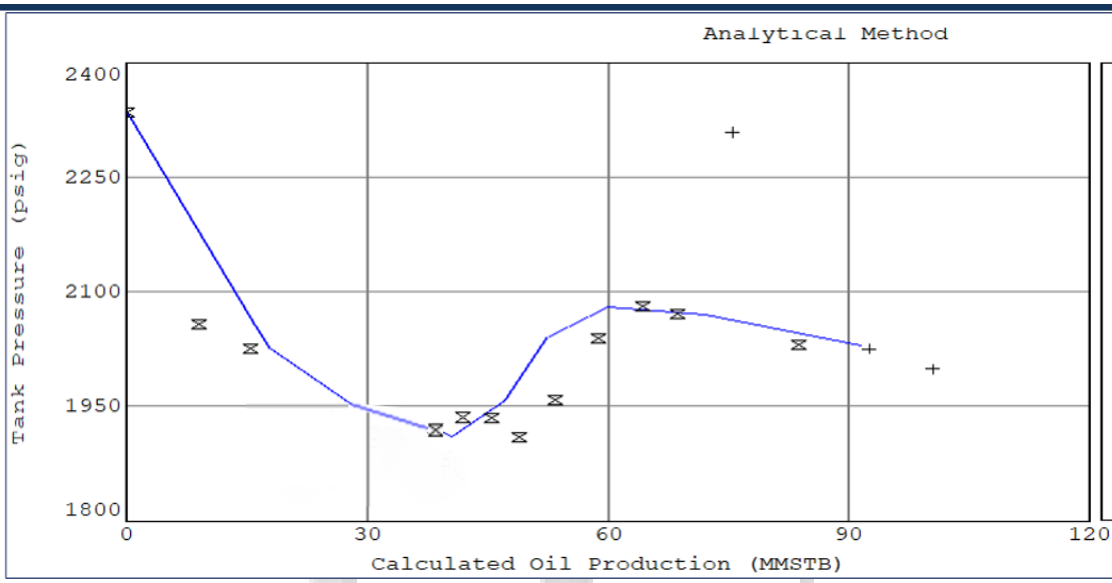

Figure 3: Analytical match without aquifer

The analytical model is constructed by this assumption is not precise due to large standard deviation between the actual data and the simulated. The second assumption must be applied to validate the analytical model with aquifer influx attached into the reservoir.

4.2.2 History Matching (Analytical model-with aquifer)

The mis-matching in the first assumption is cannot be carried out due determine the original oil in place and run simulation results. The first aquifer model selected to trying improve the analytical matching is Hurst-Van Everdingen-Modified model with radial system

The matching between observed data (points) and the simulation (blue line) is very closed, with minimum standard deviation of 0.635. The Figure 4 shows the analytical match.

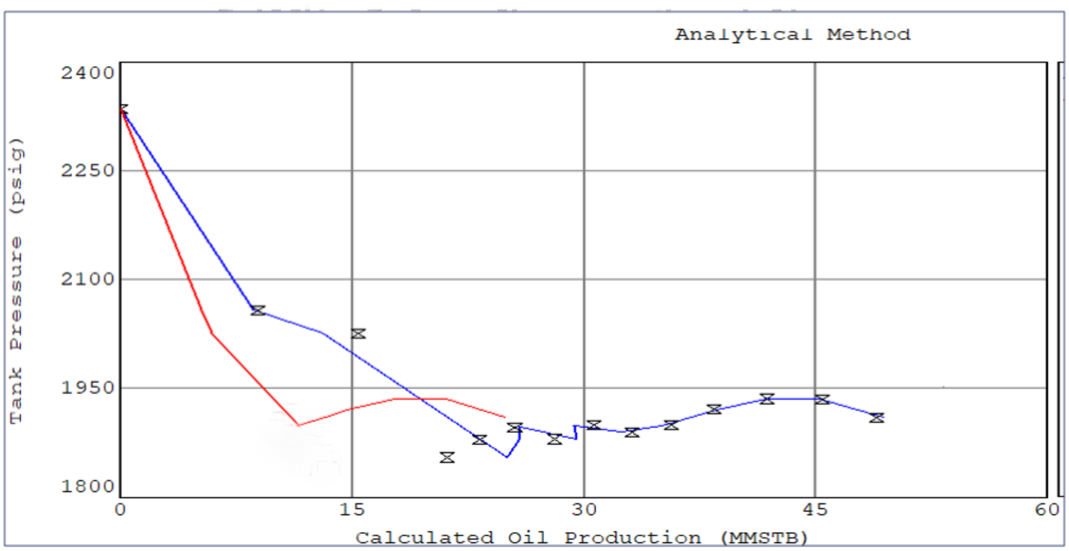

Figure 4: Analytical match with (Hurst-van Everdingen Modified aquifer model)

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The second aquifer model selected to improve the mis-match analytically is Fetkovitch-Semi steady state aquifer model. After many regressions on some aquifer parameters, the match is enhanced. The Figure 5 display the analytical matching after regressed the parameters.

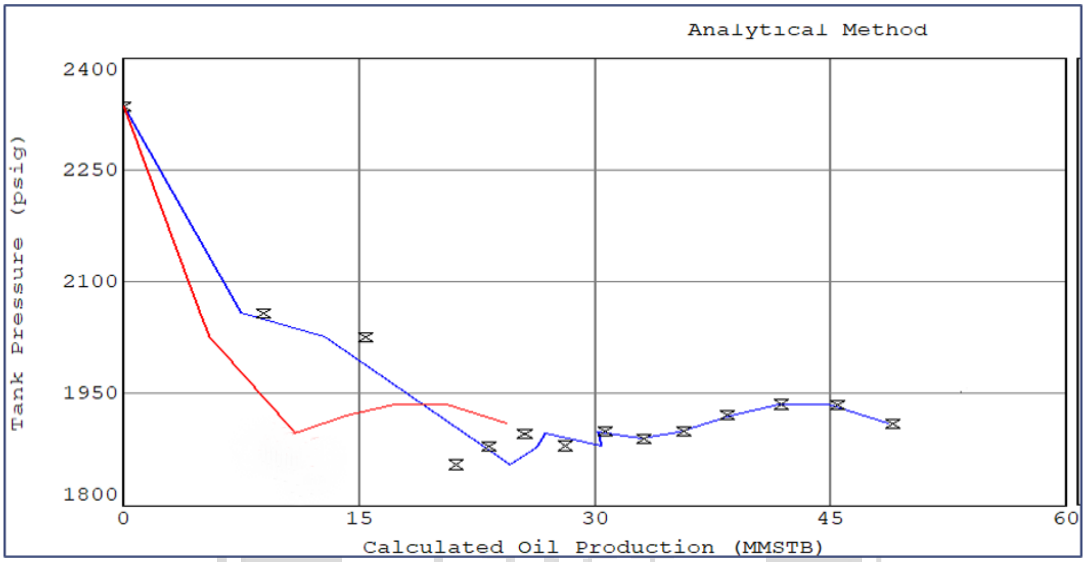

Figure 5: Analytical match with (Fetkovitch-Semi steady state aquifer model)

The last aquifer model attached analytical with the reservoir is Carter Tracy aquifer model. Figure 6 shows the results of the analytical plot with Carter Tracy model.

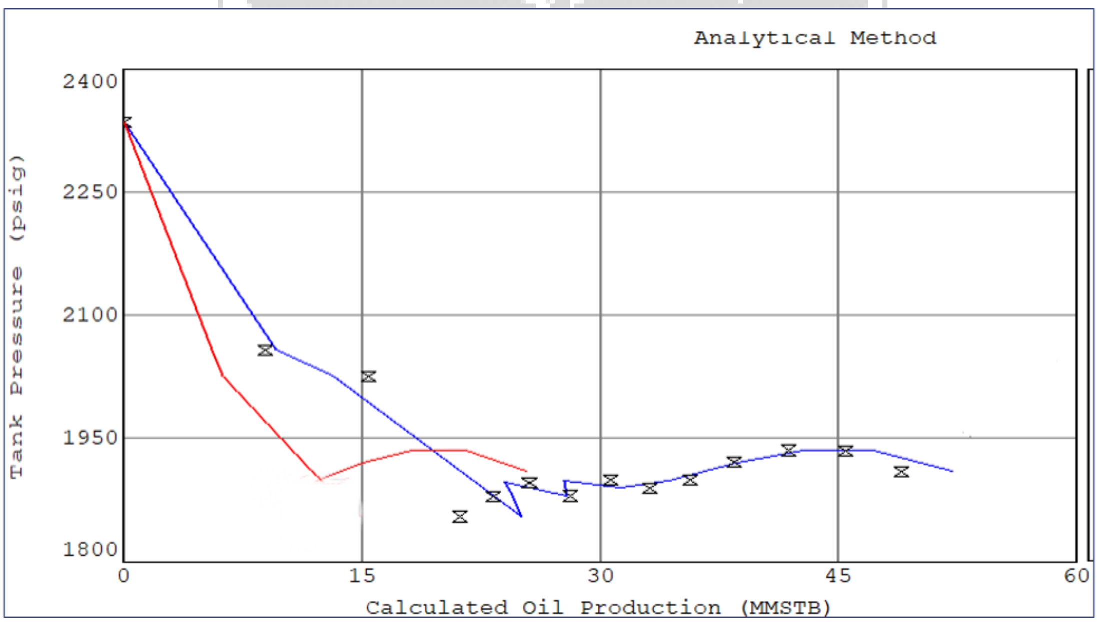

Figure 6:Analytical match with (Carter Tracy aquifer model)

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4.3 Graphical method

There are Five graphical methods commonly are used to calculate OOIP:

1- Campbell – No Aquifer (F/Et vs. F)
2- Campbell with aquifer.

Each method applies to a specific type of reservoir.

1- Campbell – No Aquifer (F/Et vs. F)

Campbell plot are used as diagnostic tools to identify the reservoir type based on the signature of production and pressure behavior. The plots are established based on the assumption of a volumetric reservoir, and deviation from this behavior is used to indicate the reservoir type.

In the Campbell plot, the withdrawal is plotting against over total expansion, while the water influx term is neglected. If there is no water influx, the data will plot as a horizontal line. If there is water influx into the reservoir, the withdrawal over total expansion term will increase proportionally to the water influx over total expansion. Result shown in Figure 7.

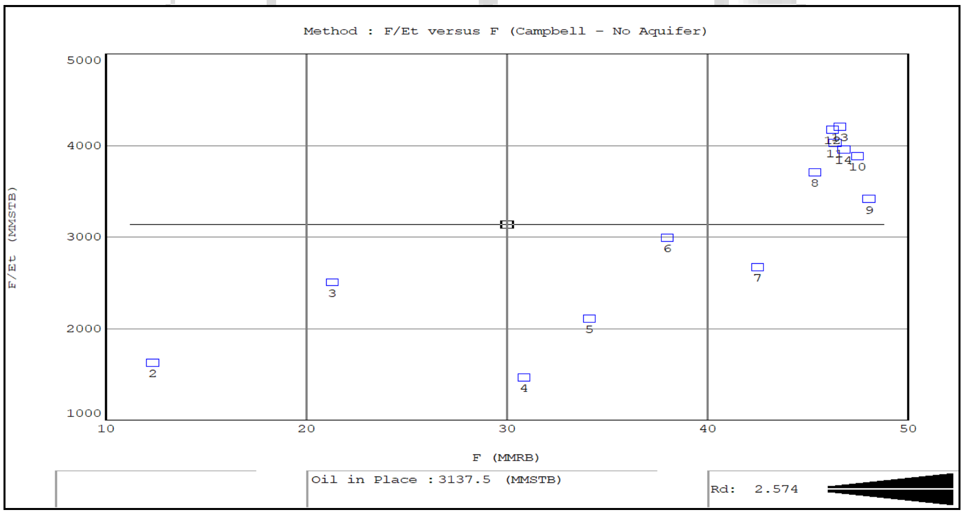

Figure 7: Campbell no aquifer

2- Campbell with Aquifer

The results of OOIP based on horizontal straight-line of Campbell plot with aquifer. The Figure 8 shows the result of OOIP by using the Hurst-van Everdingen Modified, Figure 9 estimate OOIP by using Fetkovitch Semi-Steady State, and Figure 10 estimate the OOIP for Carter Tracy Model.

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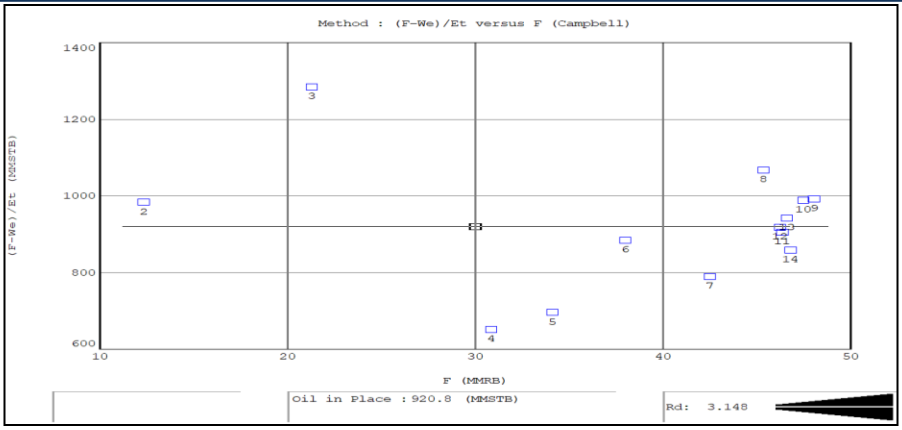

Figure 8: Campbell plot for estimate OOIP by using Hurst-van Everdingen Modified

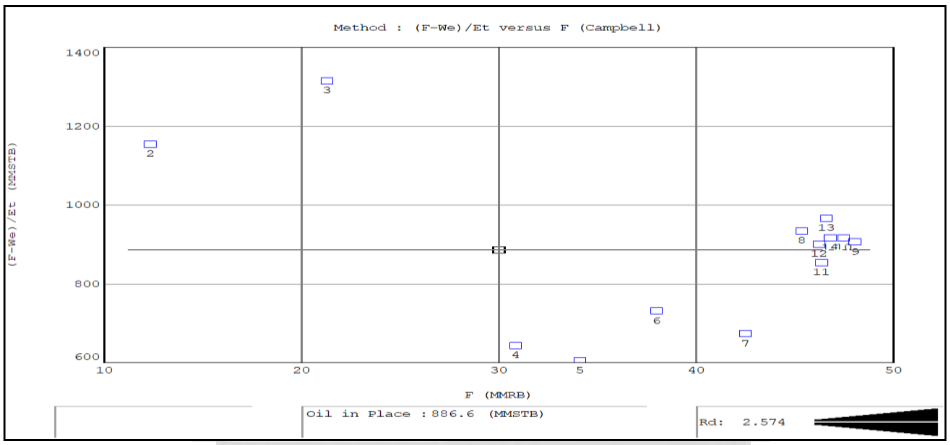

Figure 9: Campbell plot for estimate OOIP by using Fetkovitch Semi-Steady State Tables, Figures and Equations

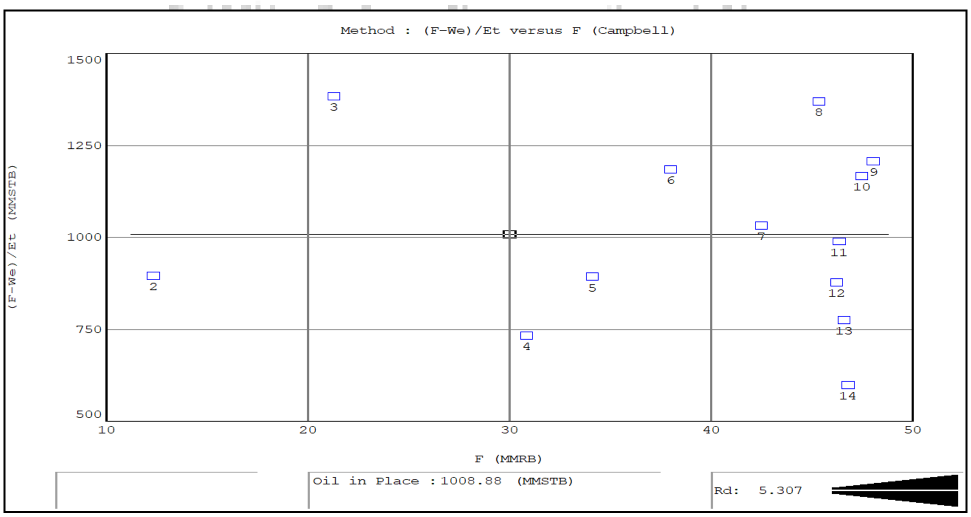

Figure 10: Campbell plot for estimate OOIP by using Carter Tracy Model

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The OOIP results are summarized in table 2.

Table 2:OOIP

TYPE	Campbell, MMSTB
Campbell (without aquifer)	3137.5
Hurst-van Everdingen Modified	920.8
Fetkovitch Semi-Steady state	886.6
Carter Tracy Model	1008.8

Table 3 conclude all results of OOIP estimation for Ghani-Farrud Reservoir. These results depend upon the Quality of History Matching. The best match was estimated with Hurst van Everdingen modified model,so the best estimation of OOIP can determined from This Model. Aquifer properties are shown in Table 3 and Table 4.

Table 3 Model ranking based on standard deviation after regression analysis on average reservoir pressure of Ghani-Farrud reservoir for 100 iterations

Table 3:Model Ranking

Model	Standard deviation	Ranking
Hurst-van Everdingen Modified	0.635	1
Fetkovitch Semi-Steady state	0.847	2
Carter Tracy Model	0.947	3

Table 4 shows the Aquifer properties selected based on model with small standard deviation. Red colors are estimated parameters

Table 5:Selcted Aquifer Properties

Property/Parameter	Value	Units
Aquifer permeability, k_a	15	md
Dimensionless aquifer radius, r_D	3.14	
Aquifer Porosity, Φa	0.17	Fraction
Encroachment angle,	192	Degree
Aquifer thickness, ha	265.17	ft
Reservoir radius, re	10464.9	ft

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4.4 Energy Plot (Analyze the drive Mechanisms)

The plot describes the prevalent energy system present in the reservoir; water influx, Pore volume compressibility, fluid expansion, water injection. It describes the fractional contributions of these energy systems present in the reservoir and the most prominent at various date. From Figure 25, it can be seen that there are four drives affecting the recovery of oil which are Pore Volume Compressibility (represented in green),Fluid Expansion (in the blue section), aquifer (in purple section) and water injection (in yellow section).

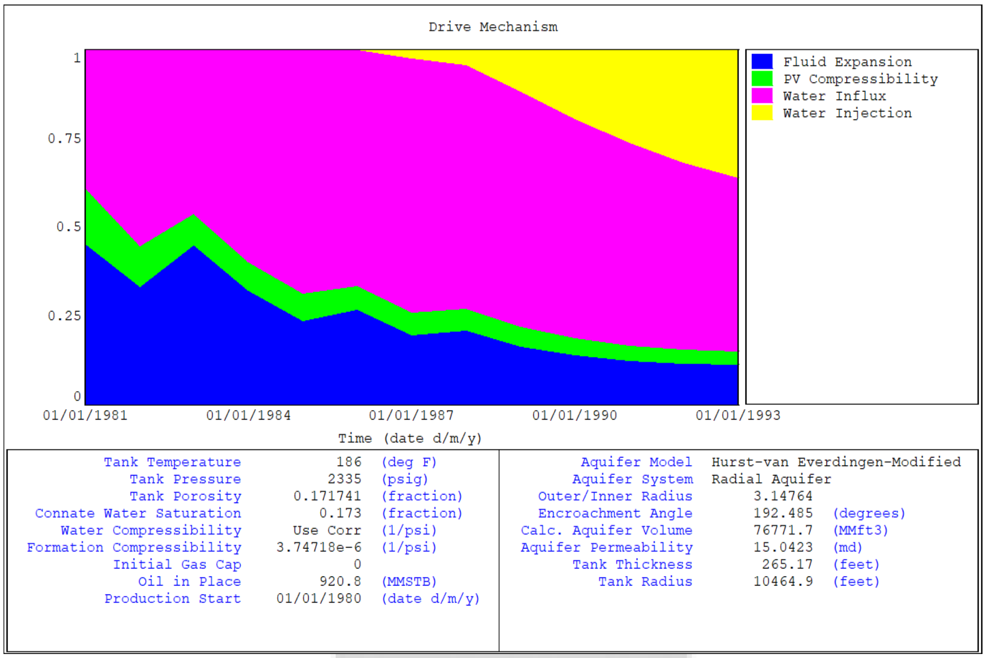

Figure 3: Energy Plot

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4.5 Simulation Results

After obtained a history match, the validity of the match was established by running a simulation with the final material balance model. The results obtained from the simulation were compared with the historical input data of pressure. The Figures 4, 5, 6 Shows the comparison between Historical and Simulation results of pressure

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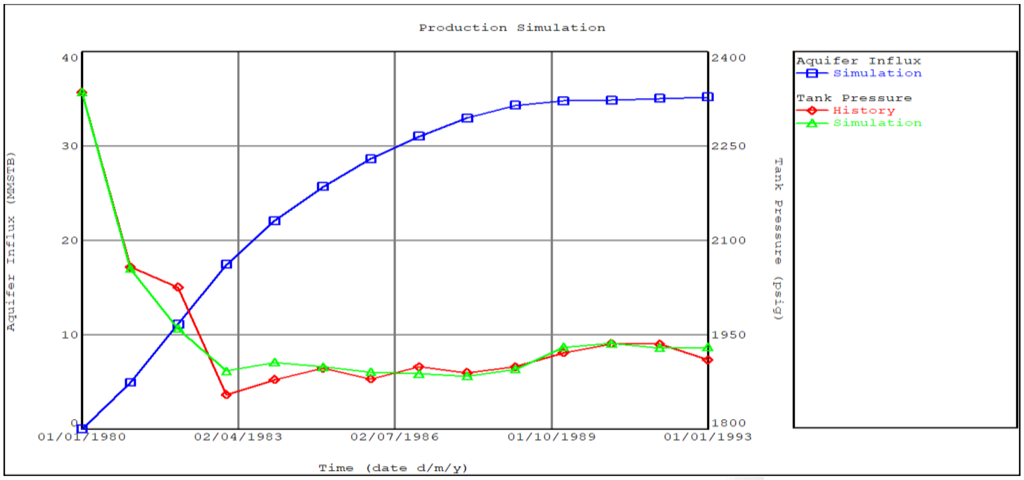

Figure 4: Simulation results (Hurst-van Everdingen modified model)

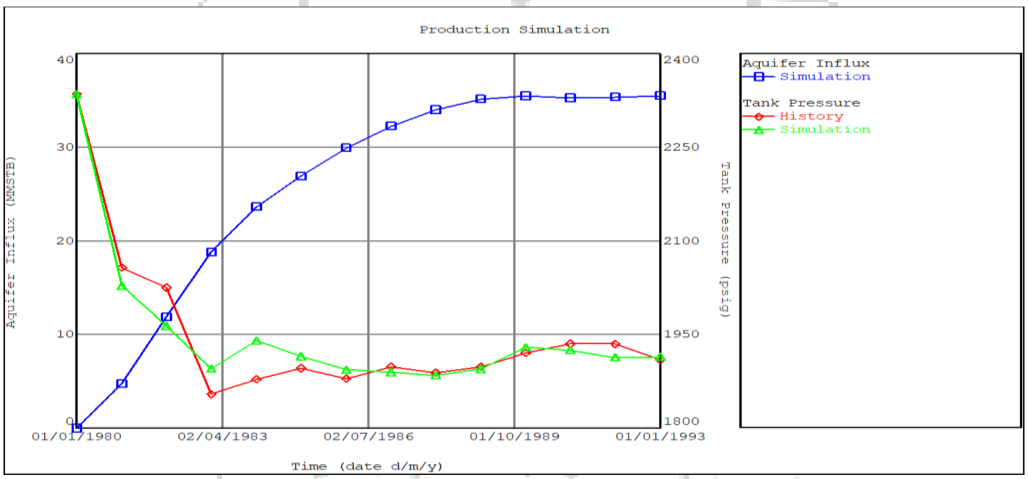

Figure 5: Simulation results (Fetkovitch Semi-Steady state)

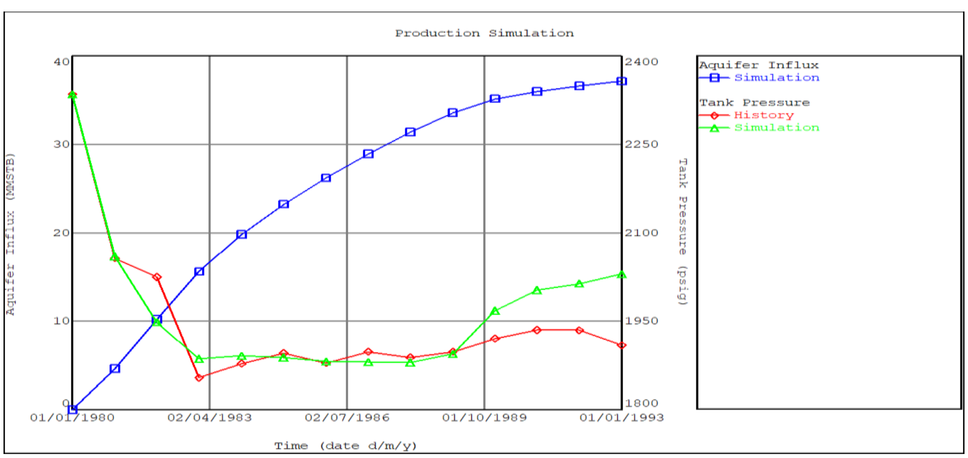

Figure 6: Simulation results (Carter Tracy model)

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4.6 Assessment of Water influx volumes

The cumulative water influx into Ghani-Farrud reservoir is considered by Hurst-van Everdingen modified model. Figure 6 shows the cumulatve water influx versus time and the total volume of water influx invided into the reservoir at 01/01/1993 was 35.24 MMSTB.

5. Conclusions and Recommendations

5.1 Conclusions.

1. The initial value of oil in place estimated by volumetric method based on the average reservoir parameters. The oil in place of the Ghani-Farrud reservoir was 735.24 MMSTB.
2. OOIP of Ghani-Farrud reservoir by Campbell Method is 920.8 MMSTB.
3. Matching measured reservoir and simulation pressure is improved by Hurst-van Everdingen Modified model.
4. Based on the diagnostic plot of the Campbell, the aquifer is connected with the reservoir model, and their strength is classified as a moderate strength.
5. The Hurst-van Everdingen Modified model described the aquifer properties with minimum standard deviation of 0.635; see Table 4
6. The main source of energy maintained the reservoir pressure is the water injection volumes; because the natural of water influx volumes was low.
7. The average absolute error between of the original oil in place by volumetric and material balance of the Ghani-Farrud reservoir was 16 %, due to the uncertainty in the reservoir heterogeneities.

5.2 Recommendations

1. MBAL may not be accepted as accurate rather a more robust approach by building dynamic models may be considered as a more reliable option for further examination since the dynamic model considers the interferences in the reservoir resulting from operational changes occurring in the reservoir (pressures, rates) which in turn affect other PVT parameters.
2. Where the variance between volumetric estimate and MBAL estimate is very high, a dynamic model like Eclipse Software is recommended for further analysis of the reservoir

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