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Modeling the Oil reservoir in the "X" Field to understand its behavior, with focus on water influx impact

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ABSTRACT

Reservoir modeling is an important feature to understand the reservoir and predict its future performance using the available software. The main objective of this study is to estimate water influx, calculate OIIP thus the reserve and predict future performance (oil flow rate).

The model has been built using MBAL software (which is a material-balance based on software with several different tools). The MBAL software uses the data collected (from "X" Field concession XX-25 of with three producing wells) to design the model, which is used to achieve the project objectives.

The Oil initially in place (OIIP) was about 29.8 MMSTB (calculated by volumetric method and material balance equation gives 30 MMSTB). However, the nine models of water influx were tested. For water influx modeling with different techniques, all models show poor matching just the Fetkovitch model gave a good regression, with an error of about (0.8).

Several reservoir fluid models and reservoir rock models and history matching were made to fulfill the requirement to have good and matching results that was used in water injection prediction model. No good response obtained by injection gas, with MBAL oven the type of gas was not specified with the software, so it is recommended to use another software to forecast future prediction

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using any evaluation oil recovery method, especially the gas miscible process.
Keywords: Water influx, Oil Simulation, reservoir modeling, history matching

نمذجة خزان النفط في الحقل "X" لفهم سلوكه مع التركيز على تأثير تدفق المياه

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الملخص

تُعد نمذجة المكامن ميزةً مهمةً لفهم المكامن والتنبؤ بأدائها المستقبلي باستخدام البرامج المتاحة. الهدف الرئيسي من هذه الدراسة هو تقدير تدفق المياه، وحسابOIIP ، وبالتالي الاحتياطي، والتنبؤ بالأداء المستقبلي (معدل تدفق النفط). بُني النموذج باستخدام برنامج MBAL (وهو برنامج لموازنة المواد يعتمد على برامج متعددة الأدوات). يستخدم برنامج MBAL البيانات المُجمعة (من امتياز حقل "XX-25 "X، بثلاث آبار إنتاجية)، لتصميم النموذج، والذي يُستخدم لتحقيق أهداف المشروع.
كانت كمية النفط الموجود في البداية (OIIP) حوالي 29.8 مليون برميل نفط مكافئ (محسوب كذلك بالطريقة الحجمية ومعادلة توازن المواد والتى اعطت 30 مليون برميل نفط مكافئ). ومع ذلك، تم اختبار النماذج التسعة لتدفق المياه. بالنسبة لنمذجة تدفق المياه باستخدام تقنيات مختلفة، أظهرت جميع النماذج تطابقًا ضعيفًا، بينما أعطى نموذج فيتكوفيتش فقط انحدارًا جيدًا، مع خطأ يبلغ حوالي (0.8). تم تصميم العديد من نماذج سوائل المكمن ونماذج صخور المكمن واجراء المطابقة البيانية لتلبية متطلبات الحصول على نتائج جيدة و مطابقة بيانية جيدة، كل ذلك تم استخدامه في نموذج التنبؤ بحقن المياه. لم يتم الحصول على استجابة جيدة عن طريق حقن الغاز ، مع برنامج MBAL اذ لا توجد في البرنامج خاصية تحديد نوع الغاز ، لذلك يوصى باستخدام برنامج آخر للتنبؤ

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المستقبلي، على سبيل المثال استخدام أي طريقة من طرق تقييم استخلاص النفط، وخاصة عملية امتزاج الغاز.

الكلمات المفتاحية: تدفق المياه، محاكاة النفط، نمذجة الخزان، مطابقة التاريخ

Introduction & study objectives

The total estimated amount of oil in an oil reservoir is called initial oil in place OIIP or original oil in place OOIP (IHRDC, 1982), (Lyons, 2005).

It's known that, a part of OIIP is non-producible due to reservoir characteristics and limitations in petroleum extraction technologies, the other part which is producible called the reserve (only a fraction of this OIIP can be brought to the surface), the reserve amount is the most important parameter for reservoir engineers to make a quick decision about whether the discovered area is profitable or not, the ratio of reserves to OOIP in a particular reservoir is called the recovery factor. Several methods used to compute the hydrocarbon reserve, but all estimations of reserves have an uncertainty degree, that depends on the amount of reliability of geologic and petroleum data available at the time of estimation, a one of most important engineering data is the Water influx which impact severely on the estimated amount of oil reserve, thus the recovery factor (Ahmed, 2010). Generally، the main objectives of this study were summarized as following:

a. Design a water influx model (modeling) that can represent this field.
b. Examine the water influx model to verify that it could give a right estimation for water influx in this field.
c. Other additional objectives like:
    - Calculate the Oil Initial in Place (OIIP), oil reserve and so the recovery factor using the calculated water influx done by the designed model.
    - Understanding driving mechanisms for the reservoir.
    - Get a greater understanding of the current reservoir behavior and predict the future reservoir performance (up to its depletion) with different simulation scenarios.
    - Perform Pressure Volume Temperature (PVT) modeling for the selected field.
    - Compare the results that might be obtained by other well models (ten models).

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- Compare the results obtained by inject water or gas as injection fluid.

Methodology

The methodology of this study started by collecting the data needed to study the "X" field in concession XX-25, such as PVT, routine and special core analysis, production history and pressure history for the field.
The second step is building the reservoir model using the MBAL software Figure 1, (which is a material-balance based on software with several different tools), the MBAL software uses the previously mentioned data collected to design the model, which is used to achieve the project objectives.
In detail, building the model started with PVT modeling for the reservoir fluid then reservoir rock properties modeling, and the most intensive modeling was water influx modeling with different methods and techniques to reach the best match.

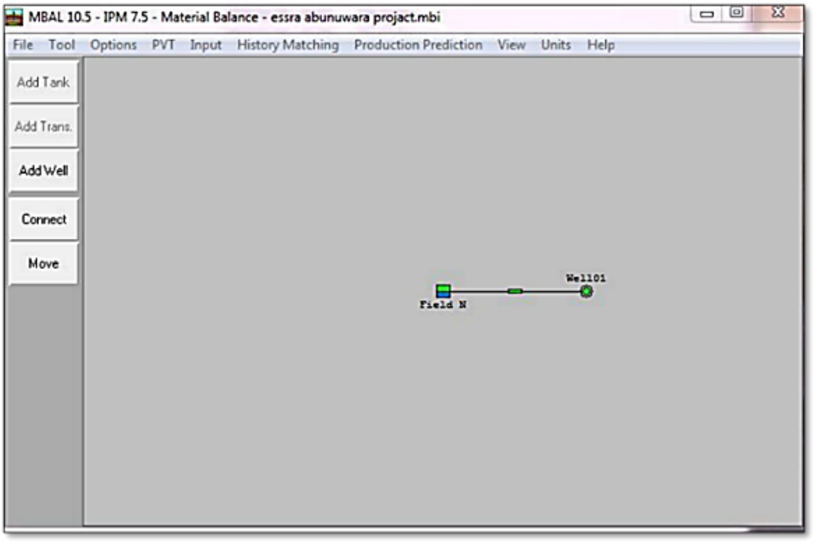

Fig. 1: shows the main tools of MBAL software.

Reservoir Modeling technique and results

Introduction

When the MBAL software is provided with the reservoir data, it would give two options (when it comes to the type of the model) as follows:

Single tank: In this mode MBAL software will run a single tank reservoir model.

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Multi tanks (Emmanuel, 2015): In this mode MBAL will run a multiple tank reservoir model with potentially different, PVT per tank can be defined.

The reservoir model used in this study is a single tank model. Additional reservoir information is provided to the system using screen as shown in Figure 2.

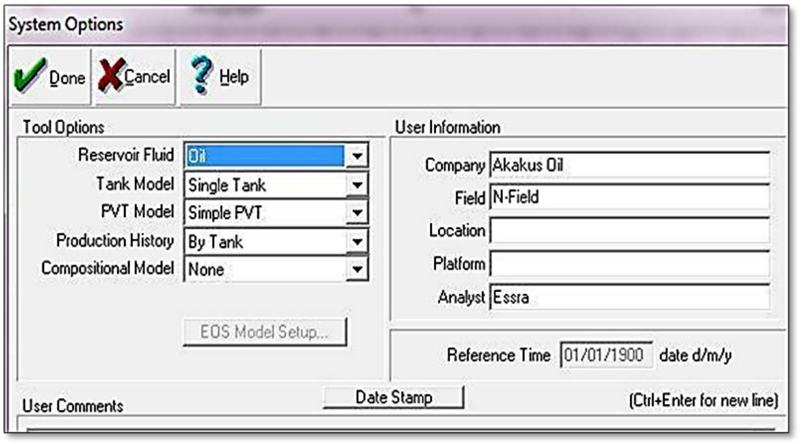

Fig. 2: System option tool

Input data

The input data in any model is building block, it enables the model to produce the required history matching.

The data is entered into the software through the following screen Figure 3 that includes different reservoir parameters required. The data tabs are classified as appears in Figure 3.

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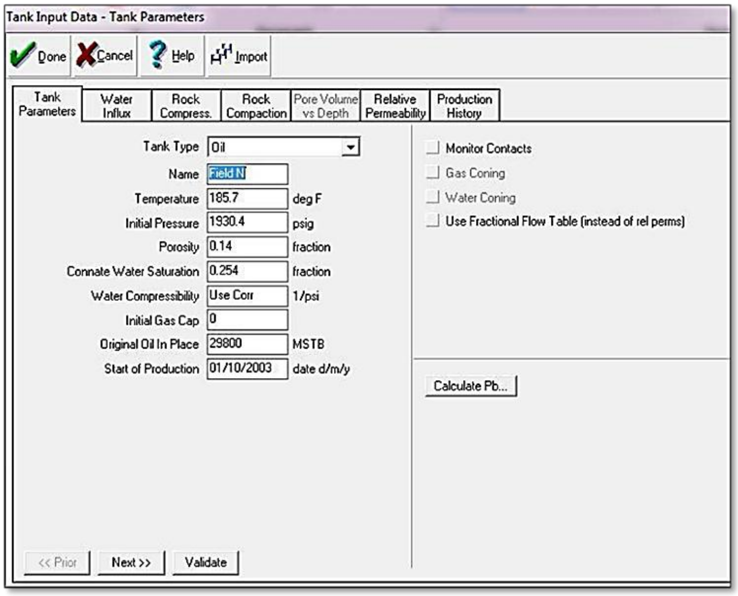

Fig. 3: reservoir parameters input data sheet

Relative permeability data (Entering & converting)

The relative permeability data was entered as tables then it was converted to Corey function for the fractional flow curve as a part of history matching, Figures 4 & 5.

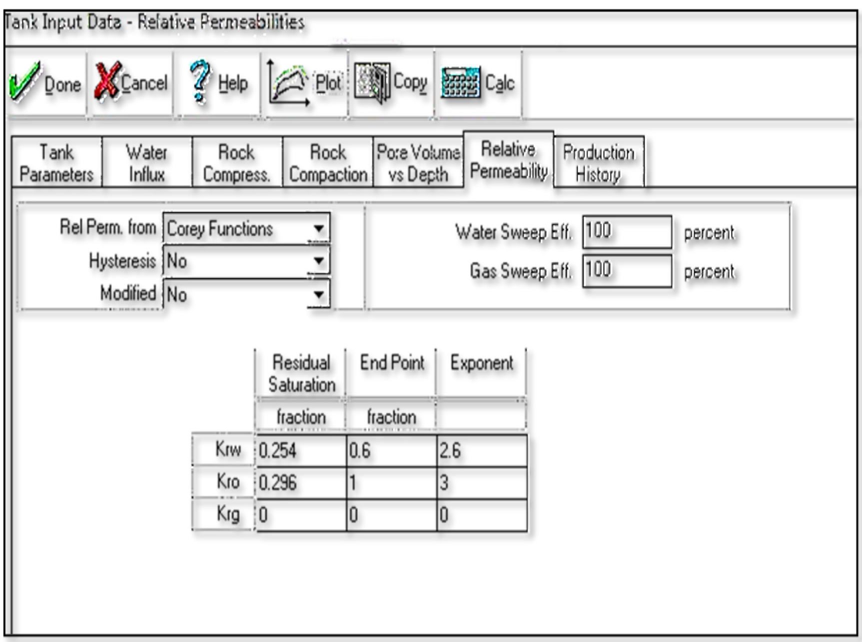

Fig.4: Entering relative permeability data with using Corey Coefficient

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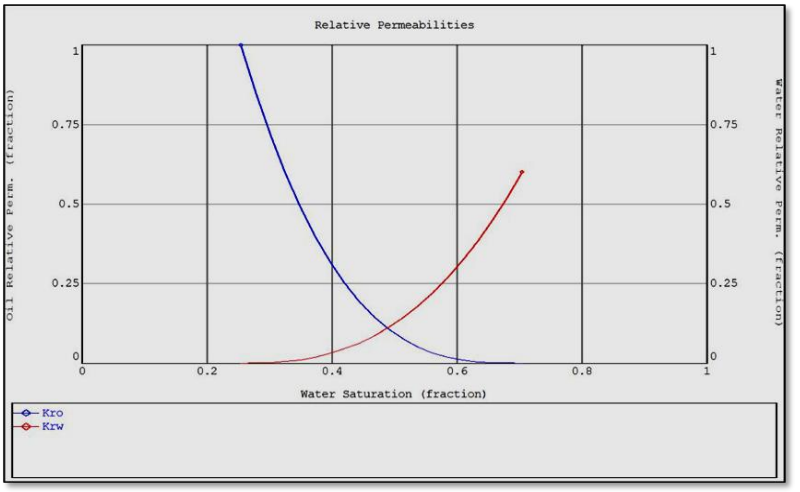
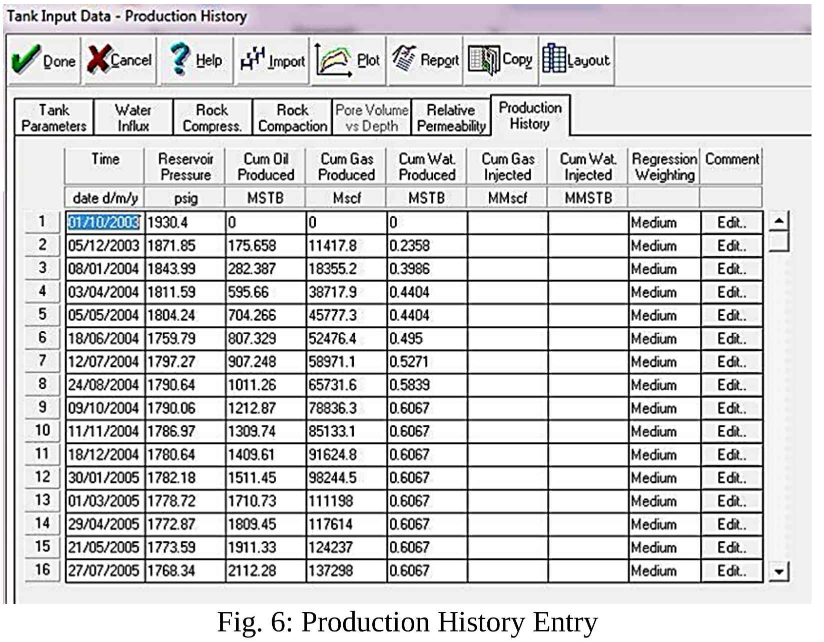


Fig.5: Oil and Water Relative Permeability curve shape.

Production history

The production history is the most critical data used on the model, it’s the building block for the history match, the well production history data entered in the “Well Data” section within production history screen Figures 6,7 and 8, the production data provided was for the oil and the water, whereas the gas production was zero.



	Time	Reservoir Pressure	Cum Oil Produced	Cum Gas Produced	Cum Wat. Produced	Cum Gas Injected	Cum Wat. Injected	Regression Weighting	Comment
	date d/m/y	psig	MSTB	Mscf	MSTB	MMscf	MMSTB		
1	01/10/2003	1930.4	0	0	0			Medium	Edit..
2	05/12/2003	1871.85	175.658	11417.8	0.2358			Medium	Edit..
3	08/01/2004	1843.99	282.387	18355.2	0.3986			Medium	Edit..
4	03/04/2004	1811.59	595.66	38717.9	0.4404			Medium	Edit..
5	05/05/2004	1804.24	704.266	45777.3	0.4404			Medium	Edit..
6	18/06/2004	1759.79	807.329	52476.4	0.495			Medium	Edit..
7	12/07/2004	1797.27	907.248	58971.1	0.5271			Medium	Edit..
8	24/08/2004	1790.64	1011.26	65731.6	0.5839			Medium	Edit..
9	09/10/2004	1790.06	1212.87	78836.3	0.6067			Medium	Edit..
10	11/11/2004	1786.97	1309.74	85133.1	0.6067			Medium	Edit..
11	18/12/2004	1780.64	1409.61	91624.8	0.6067			Medium	Edit..
12	30/01/2005	1782.18	1511.45	98244.5	0.6067			Medium	Edit..
13	01/03/2005	1778.72	1710.73	111198	0.6067			Medium	Edit..
14	29/04/2005	1772.87	1809.45	117614	0.6067			Medium	Edit..
15	21/05/2005	1773.59	1911.33	124237	0.6067			Medium	Edit..
16	27/07/2005	1768.34	2112.28	137298	0.6067			Medium	Edit..

Fig. 6: Production History Entry

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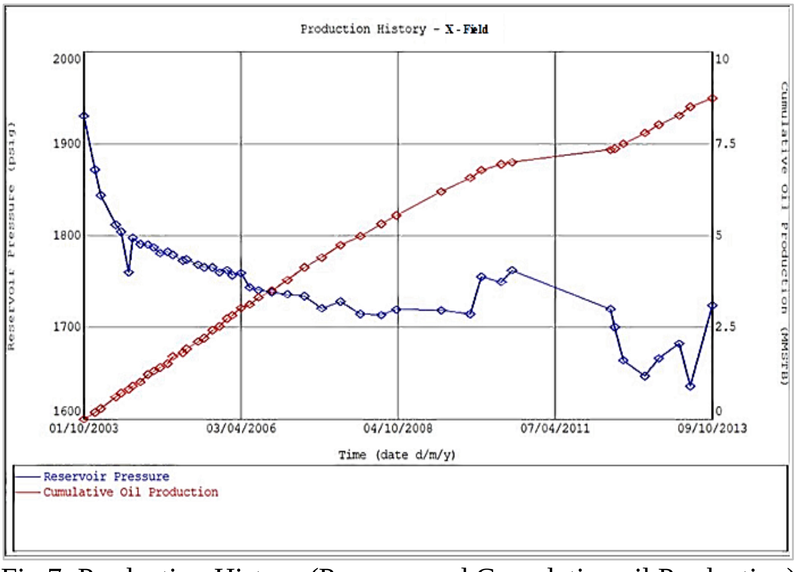

Fig.7: Production History (Pressure and Cumulative oil Production)

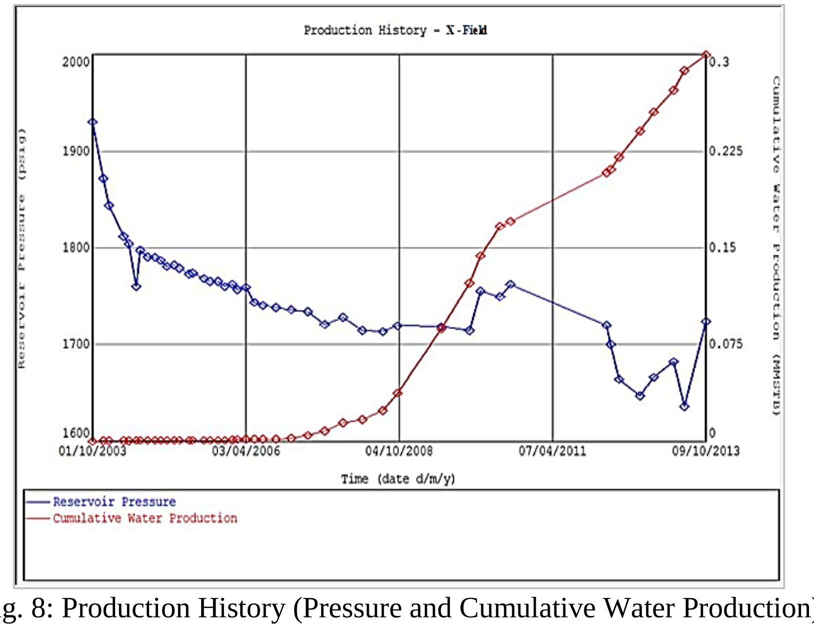

Fig. 8: Production History (Pressure and Cumulative Water Production)

Fluid Properties

The MBAL software need set of fluids properties data that were entered through the screen as shown in Figure 9.

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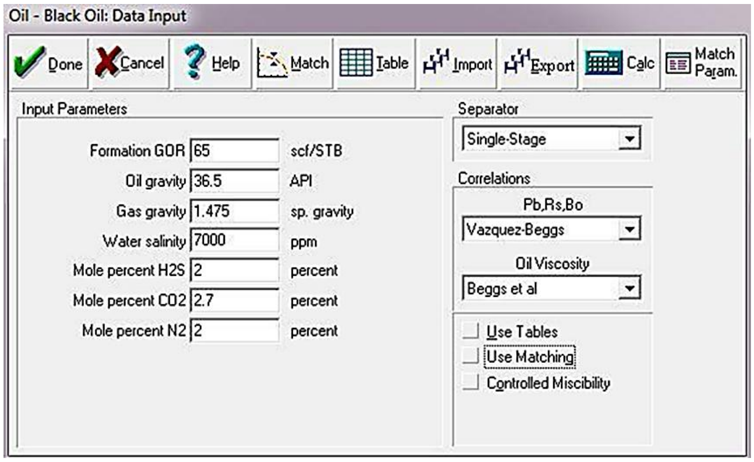
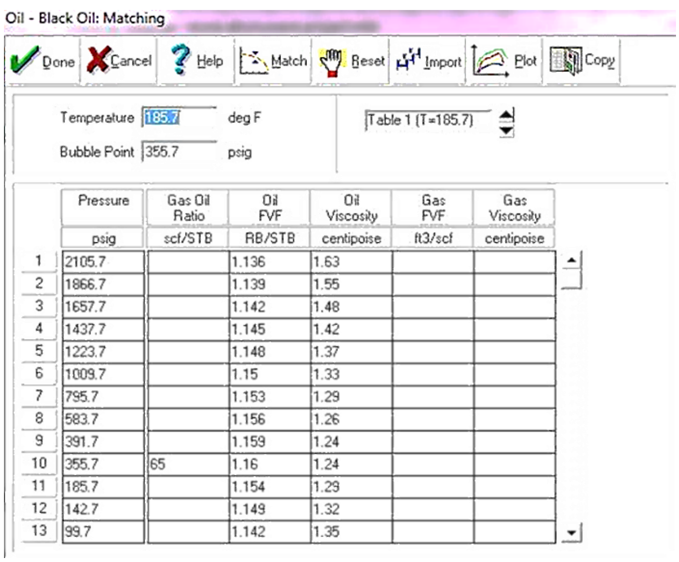


Fig. 9: PVT input data parameters

As shown, these parameters will be introduced first to the software, the rest PVT data will be matched using the future match as shown in Figure 10.



	Pressure	Gas Oil Ratio	Oil FVF	Oil Viscosity	Gas FVF	Gas Viscosity
	psig	scf/STB	RB/STB	centipoise	ft3/scf	centipoise
1	2105.7		1.136	1.63		
2	1866.7		1.139	1.55		
3	1657.7		1.142	1.48		
4	1437.7		1.145	1.42		
5	1223.7		1.148	1.37		
6	1009.7		1.15	1.33		
7	795.7		1.153	1.29		
8	583.7		1.156	1.26		
9	391.7		1.159	1.24		
10	355.7	65	1.16	1.24		
11	185.7		1.154	1.29		
12	142.7		1.149	1.32		
13	99.7		1.142	1.35		

Fig. 10: Matching table for the rest of the PVT data

The software will perform a match based on the PVT table provided, the software uses different tables with different temperature in order to match the rest PVT data with high certainty, the next dialog shows the results after making the match via the "Calc" button, Figures 11, 12 and 13.

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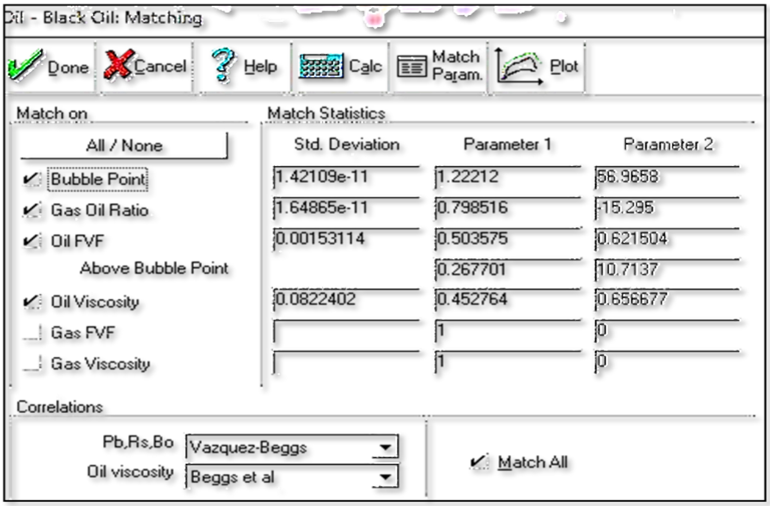

Fig. 11: Fluid propriety for matched by MBAL software.

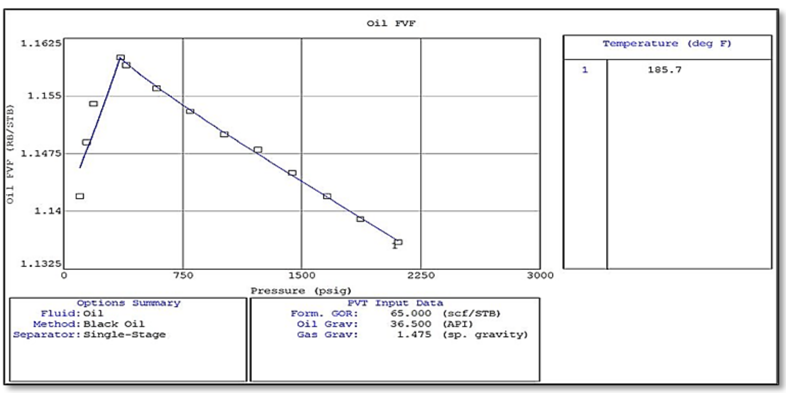

Fig. 12: Matched of Oil Formation Volume Factor by MBAL software.

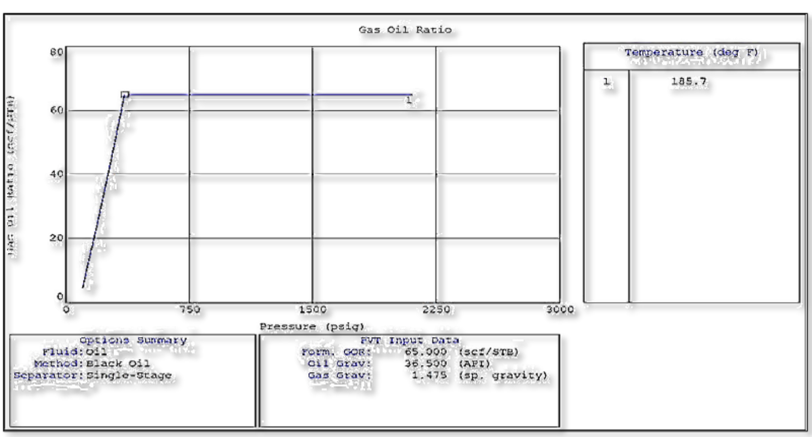

Fig. 13: Matched of Gas Oil Ratio by MBAL software.

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Now, the software uses the match option for the fluids properties that was calculated as mentioned see Figure 14.

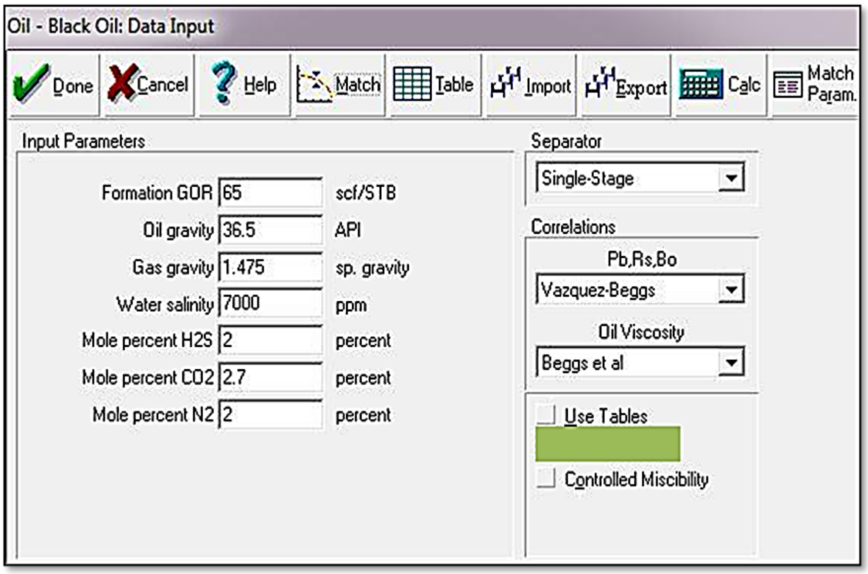

Fig. 14: Match option shown by MBAL

Water Influx

It is used to define the type and properties of an aquifer[1], the particular input variables depend on: the model, system and boundary type selected. This option can be used to execute different water influx models and select an optimum one of them.

The plot always displays at least one curve and the history data points. This curve defines the following:

- The calculated cumulative production using the reservoir & aquifer parameters of the last regression (a solid line), Figure 15.
- The calculated cumulative production of the reservoir without aquifer (by default this is a blue line although the color can be changed), Figure 15.

The Figure (15) show the matching process for Small Aquifer water influx modeling, whereas Figures 16 & 17 show the matching process for Fetkovich- Semi Steady/Steady State Water Influx Models, the following Figures 18,19,20,21,22 and 23 showed the matching process for other different Water Influx Models, and what was found is that, all models show poor matching just the Fetkovitch steady state model gave good matching.

[1] It's the amount of water collected underneath the oil reservoir.

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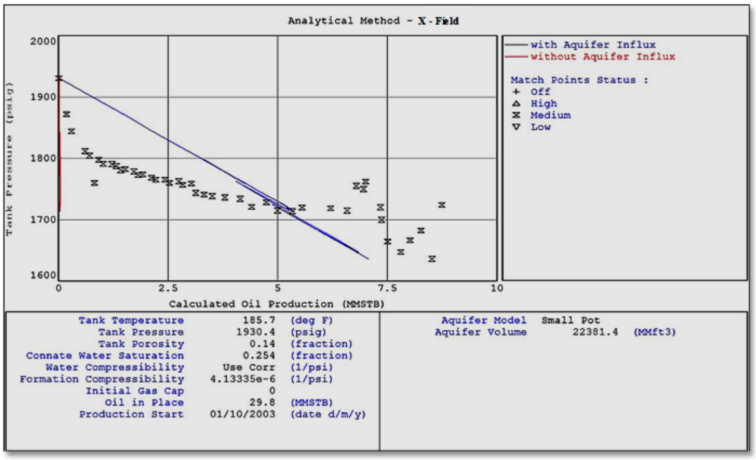

Fig. 15: Small Aquifer Water Influx Model

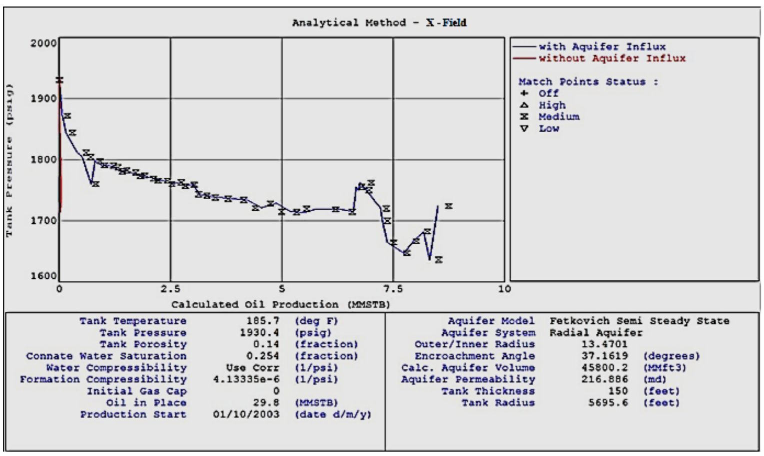

Fig. 16: Fetkovich- Semi Steady State Water Influx Model

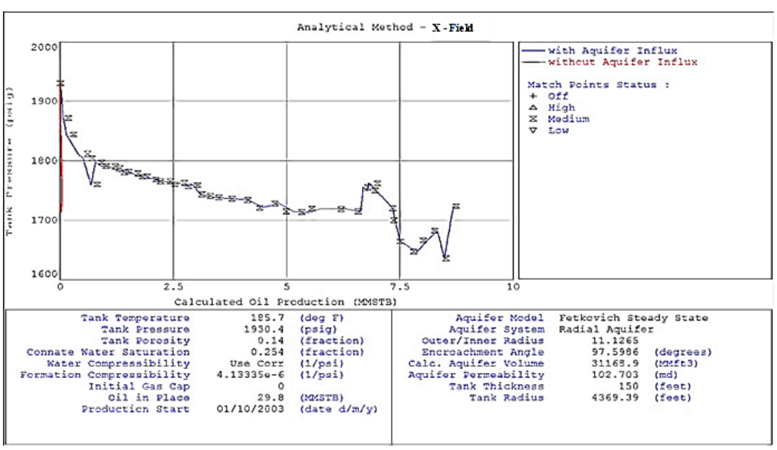

Fig. 17: Fetkovitch Steady State Water Influx Model

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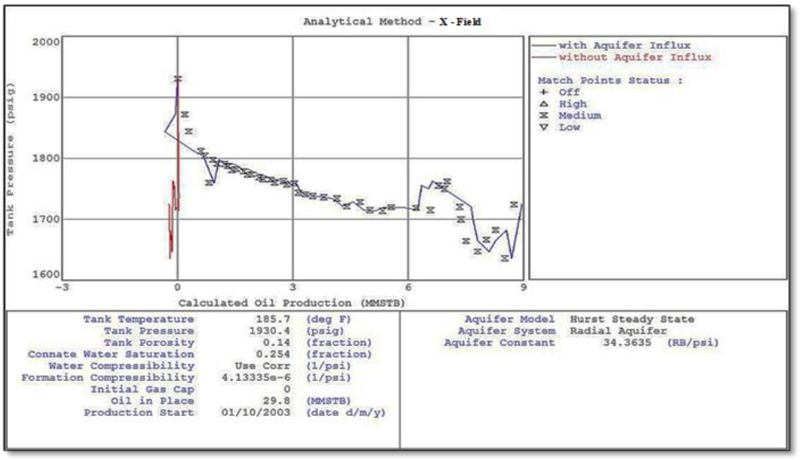

Fig. 18: Hurst Steady State Water Influx Model

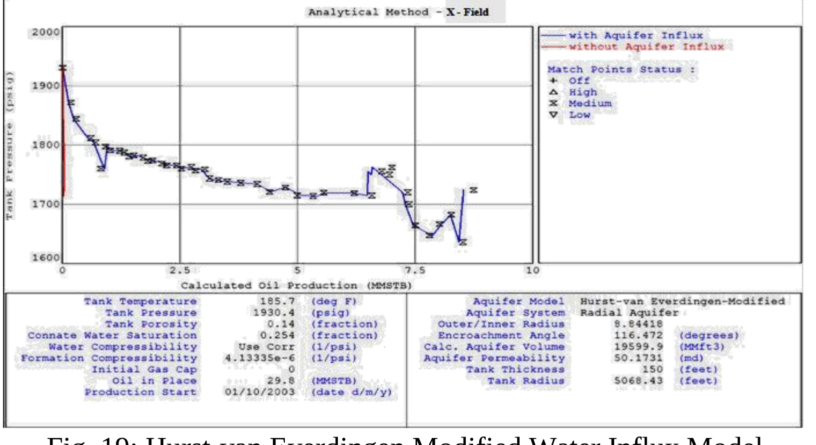

Fig. 19: Hurst-van Everdingen Modified Water Influx Model

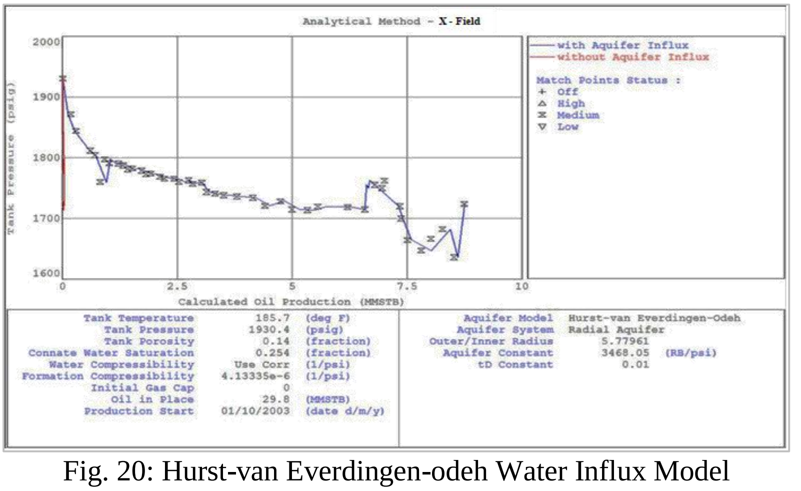

Fig. 20: Hurst-van Everdingen-odeh Water Influx Model

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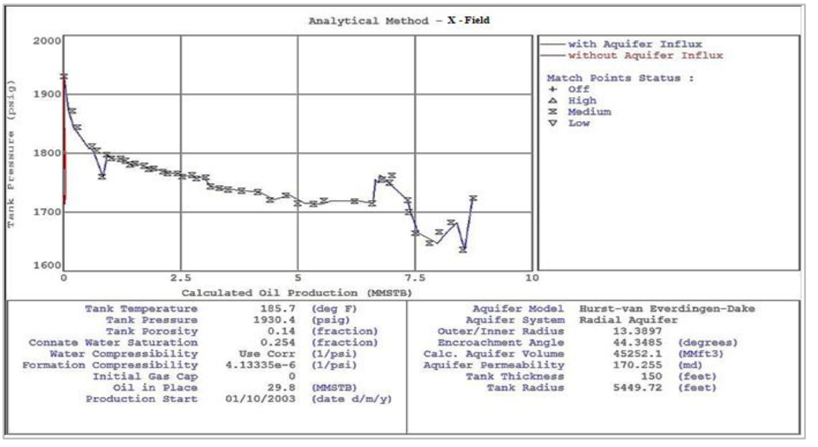

Fig. 21: Hurst-van Everdingen- Dake Water Influx Model

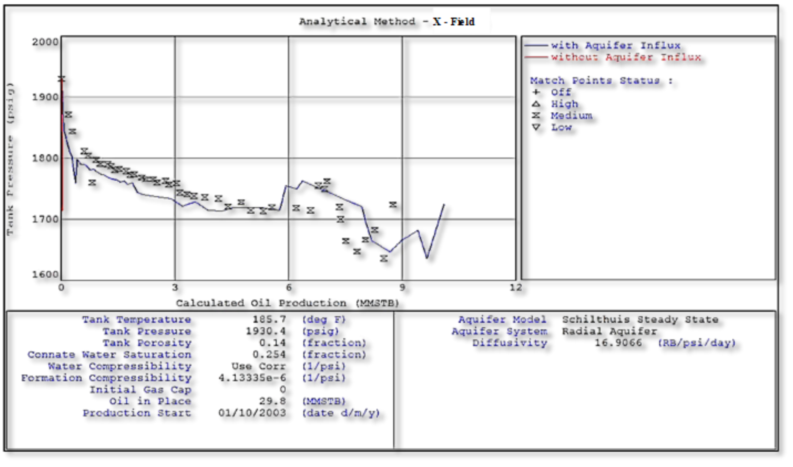

Fig. 22 : Schilthuis-Steady State Water Influx Model

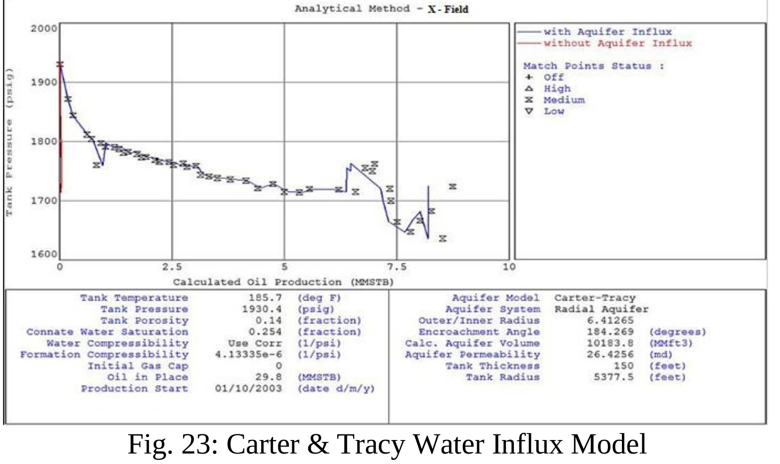

Fig. 23: Carter & Tracy Water Influx Model

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Table 1 shows the results of different water influx models with error percentage. The Fetkovitch steady sate model was the best, it illustrated the least error percentage (0.80%) for water influx regression.

Table 1: different models used to calculate water influx.

Model	Error (%)	Model	Error (%)
Hurst Steady State	5.54	Fetkovitch Semi Steady	1.17
Hurst-van Everdingen-odeh	0.95	Hurst-van Everdingen Modified	0.84
Hurst-van Everdingen-Dake	0.89	Carter and Tracy	0.87
Vogt and Wang	0.86	Fetkovitch Steady State	0.80
Schilthuis-Steady State	33.7	Small pot	20.1

History Matching

History matching is identifying those reservoir properties subjected to the greatest uncertainty and adjusting them to bring the simulated and measured to an acceptable degree of correspondence. History matching is often an iterative process, in which steps are repeated several times with variations in reservoir characterization (Craft C, 1991). The MBAL software uses four methods in order to bring the simulated values to the measured values, these methods as following:

Analytical Method

It is the process of adjusting reservoir and aquifer parameters using closed-form mathematical solutions (a non-linear regression analytical models) in order to make the calculated production rates and/or the calculated pressures both match the measured historical field data.

This technique has many advantages like:

- Simple & Transparent: the engineer relies on simplified reservoir flow equations (Darcy’s law, material balance, type-curves, decline curves) to reproduce observed behavior.
- Speedy & Low Cost: No need for using a full heavy expensive numerical simulator, the task Can be done with simple software (Excel, MBAL)

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- Data Efficiency: Works well with limited production data (typical in early production periods), and when geological data are uncertain.
- Practical in the Field, often preferred by operating engineers when they need a fast answer

In this study and in order to match the production history, different water influx models had been performed, the Fetkovitch steady state water influx model (Fetkovich, 1971) was selected as it illustrated the best results, Figure 17.

Table 2: illustrates the main parameters of Fetkovich Steady State model.

Aquifer Model	Fetkovich Steady State	
Aquifer System	Radial Aquifer	
Outer Radius/Inner Radius	6.49	
Encroachment Angle	195	degrees
Aquifer Permability	33.77	md

Graphical Method

This graphical method plot is used to visually determine the different reservoir and aquifer parameters. Figure 24 shows the typical graphical method plot for a good history matched reservoir.

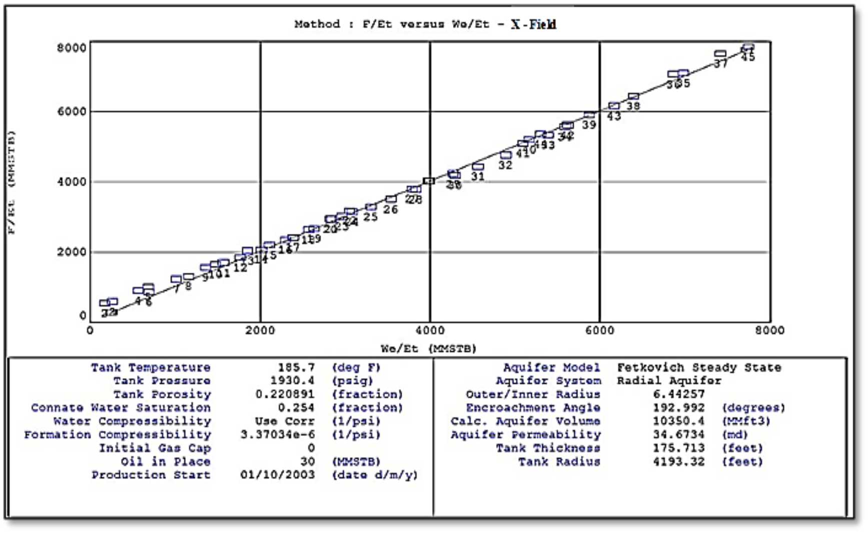

Fig. 24: Typical graphical method

Predicting OIIP

As known estimating hydrocarbon reserves is a complex process that involves integrating geological and petroleum engineering data,

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the certainty of reserve estimation is depending on the amount and quality of data available.

The first thing estimated by the MBAL software, after model history matching, is the oil initial in place (OIIP), the value of the OIIP depends on the accuracy of the model which appears as the quality degree of the history match.

The XX-25 reservoir model had a big success. The OIIP has been computed by using MBAL application, it's about 30 MMSTB.

Energy Plot

This plot shows the relative contributions of the main sources of energy in the reservoir and aquifer system. It does not in itself provide the user with detailed information but indicates very clearly which parameters and properties should be focused on. (i.e. PVT, Formation Compressibility, Water Influx.).

In the XX-25 reservoir, the primary drive mechanism is compressibility and water influx as shown in figure 25.

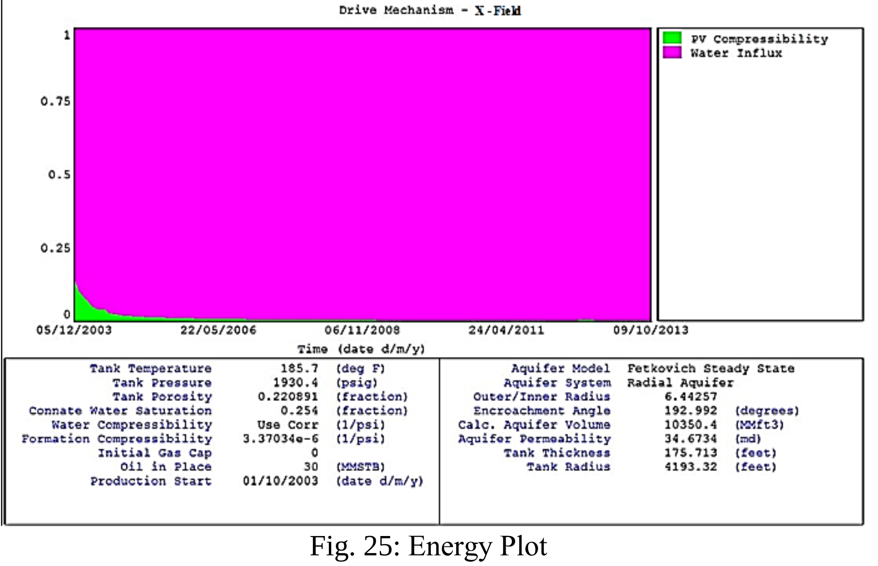

Fig. 25: Energy Plot

Running the Prediction

Prediction of the future performance in the XX-25 reservoir is the final step on the MBAL software, using the exact workflow recommended in the manual of the software as follows:

Predicting Setup

This is the first prediction dialogue box. It defines the type of prediction to be performed, the start and end of the prediction, and the reporting frequency, showed in Figure 26.

http://www.doi.org/10.62341/moxi1016

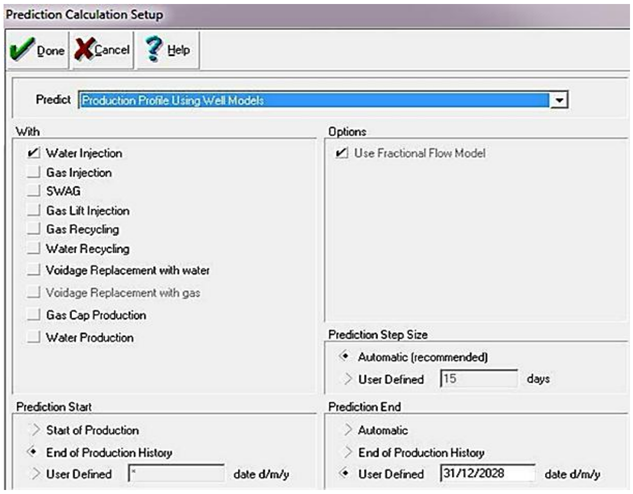

Fig. 26: Predicting Set-Up dialog

Production and Constraints

This dialogue box describes the production and injection constraints for the tank. The number and content of the columns will vary depending on the prediction mode and injection options selected in the Prediction Set-up dialogue box.

This dialog is the most critical dialog when it comes to the accuracy of the result, where constrains are made to the production of the reservoir, maximum and minimum values for the predicted flow rate are entered as shown in Figure 27.

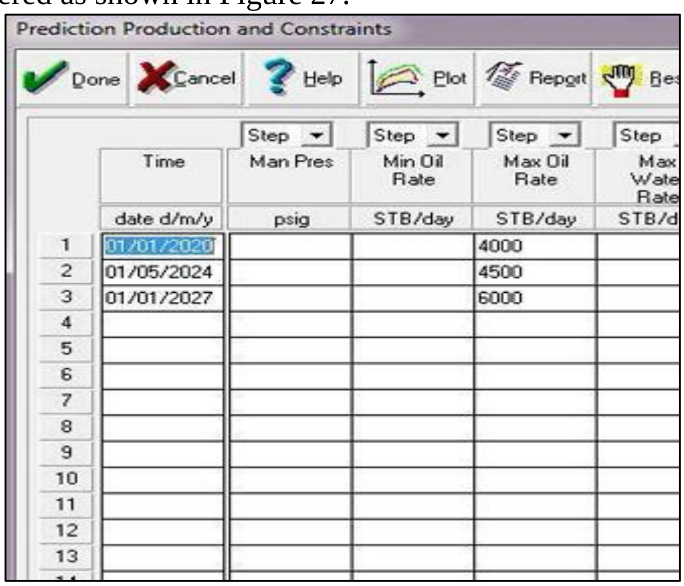

Fig. 27: Prediction Constraints

http://www.doi.org/10.62341/moxi1016

In this study, two scenarios have been made:

1. Water injection wells: it includes a water injection well in order to support of pressure. In this case, the cumulative oil production reaches about 11.85 MMSTB. Figure 28 shows the cumulative oil production versus time.

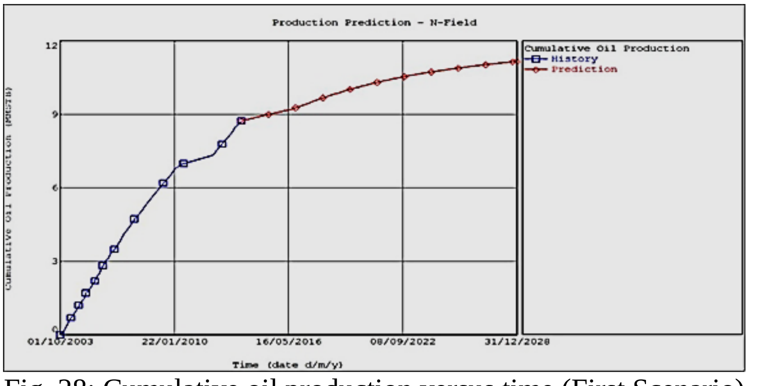

Fig. 28: Cumulative oil production versus time (First Scenario)

2. Gas Injection wells; they include a gas injection well in order to support pressure. An attempt was made to study the possibility of injection gas, several trials were made to test and predict the response of injection gas, and the results gained fail.

Conclusion

Several important features were gained and withdrawal from this study, and are:

- Comparison between two different methods of estimation of oil initially in place (volumetric and material balance equation), the utilized MBAL showed very close results of (30 MMSTB).
- For water influx modeling with different techniques, all models show poor matching just the Fetkovitch steady state water influx model which produced a good regression, thus matching.
- Formation volume factor (B_o) model was made with less percentage of error using the correlation of Al-Marhoun with an error of 0.19%. Moreover, gas in solution (Rs) was modeled using Al-Marhoun correlation with 0.57% error, the bubble point model with Vasquez and Beggs with an error of 1.22% (Vazquez & Beggs, 1977).

http://www.doi.org/10.62341/moxi1016

- Oil viscosity matched with Beggs et al. model, it given least error (0.45%) as compared with other known models.
- Corey's function was the best model used to obtain the relative permeability curves (Kro, Krw) based on the available data (Farshid Torabi, 2016).
- Future prediction of oil production rate was obtained based on the production history matching by injection water. However, the ten models of water influx were tested; the best was the Fetkovitch steady state, which is used in this future prediction with an error of about 0.8 (Fetkovich, 1971).
- The gas injection was tried with MBAL software to study the response of gas injection, but didn't make any response due to no gas cap in the reservoir.

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