Reservoir Characterizations and Reservoir Performance of Mishrif Formation in Amara Oil Field

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ABSTRACT

Mishrif Formation is the main reservoir in Amara Oil Field. It is divided into three units (MA, TZ1, and MB12). Geological model is important to build reservoir model that was built by Petrel -2009. FZI method was used to determine relationship between porosity and permeability for core data and permeability values for the uncored interval for Mishrif formation. A reservoir simulation model was adopted in this study using Eclipse 100. In this model, production history matching executed by production data for (AM1, AM4) wells since 2001 to 2015. Four different prediction cases have been suggested in the future performance of Mishrif reservoir for ten years extending from June 2015 to June 2025. The comparison has been made between these different cases to select the best case for developing the field that gives the highest recovery factor. The case-4 was chosen to be the best case involved adding 20 vertical production wells, 5 horizontal production wells and 5 vertical injection wells in the reservoir with plateau rate of 50MSTB/D in starting of prediction and dropping to reach 13.5 MSTB/D in end of the prediction and the cumulative production from the reservoir equal to 82 MMSTB and recovery factor reaching 9.06% at the end of 2025.

Key words: Amara field, geological model, history matching, reservoir performance prediction.

الخواص المكمنية والأدائية المكمنية لتكوين المشرف / حقل العمارة

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الخلاصة

يعتبر مكمن المشرف المكمن الرئيسي في حقل العمارة النفطي حيث يقسم الى ثلاث وحدات (MA, T.Z1, MB11) . الموديل الجيولوجي مهم جداً لبناء الموديل المكمني حيث ينفذ الاول بواسطة برنامج Petrel-2009 . طريقة FZI تستخدم لايجاد العلاقة بين المسامية والنفاذية لبيانات اللباب والقيم النفاذية الناتجة توزع على كافة مناطق المكمن. الموديل المكمني ينفذ بواسطة برنامج ECLIPSE 100 حيث تم في هذا الموديل ربط تاريخي للبيانات الانتاجية للبئرين (AM1, AM4) وبيدأ في العام 2001وينتهي في 2015. تم أقتراح اربع حالات للتنبأ المستقبلي لسلوك المكمن ولمدة عشرة سنوات بين الفترة (2015-2025) . المقارنة بين الحالات الاربعة أظهرت أن الحالة الرابعة هي من أفضل الحالات للسلوك المكمني بالاعتماد على أعلى عامل أستخلاص حيث شملت حفر 20 بئر عمودي أنتاجي، 5 بئر أفقي أنتاجي، 5 بئر عمودي لحقن الماء مع معدل سقف أنتاجي وصل الى 50 الف برميل/يوم عند بداية التنبأ وأنخفض الى 13.5 الف

برميل/يوم عند نهاية التنبأ وتراكم أنتاجي وصل الى 82 مليون برميل مع عامل أستخلاص 9.06 % عند نهاية العام 2025.
الكلمات الرئيسية: حقل العمارة، الموديل الجيولوجي، الربط التاريخي، التنبأ المستقبلي لسلوك المكمن .

1. GENERAL BACKGROUND

In the oil industry, reservoir modeling involves the construction of a computer model for a petroleum reservoir to improve estimation of reserves and making decisions regarding the development of the field. The purpose of simulation studies is to predict of the field performance under one or more producing schemes. Observation of the model performance under different producing conditions aids the selection of an optimal set of producing conditions for the reservoir.

1.1 Brief Idea about the Field

- Amara field locates at south east of Iraq in Missan province, about 10 Km south west of Amara city. It is surrounded by different oil fields as Al-Rafedain (Abu-Amoud), Al-Kumait**, Khanawi, et al, 2010** and a shown in **Fig.1**.
- Mishrif structure consist of single anticline with axis trending North West – South East, with structural length of about 18km and its width is 4.5km and overlain by the Khasib formation and underlain by the Rumaila formation**, Al-Khadimi, 1996**.
- Six wells were selected for this study because the available data when this study had been selected to build a geological and dynamic models.

1.2 Aims of Current Study

1. To build a geological model by using (***Petrel)*** software to simulate the structure in 3D and dividing the hydrocarbon strata according to the rock properties.
2. To build a reservoir model for the studied formation by using (***Eclipse 100***) software**.**
3. Improving and validating the reservoir model through history matching.
4. Suggesting development plans according to different scenarios for Amara field/Mishrif formation to maximize the oil production.

1.3 Previous Studies on Amara Field

Basra Oil Company conducted a seismic survey of the area Amara–Halfaya in 1957/1958 and the structure of Amara field. The results show that Amara structure in north-east from the structure of Halfaya. National Oil Company conducted a seismic survey of the area Amara-Halfaya in 1974 and structural image shown in Amara structure closed in lower Faris and Tanuma formations. In 1980, a study prepared to reinterpretation of area Amara-Halfaya and this study is clarified only part of eastern extension for Amara structure. A study prepared by Italian contractor (AGIP), in 1981 and explained differences in characteristics of Amara structure and the final appeared in closed form**, Khanawi, et al, 2010**. Another study is the pre-feasibility study for Amara oil field development by Vietnam oil and Gas Company was prepared in 1998**, Petro Vietnam, 1998.** This study described the three productive reservoirs in Amara oil field from a geological and reservoir perspective, and also included calculations for the stock tank initially oil in place for each reservoir (Khasib, Mishrif and Nahr Umr). The final study was prepared in 2010**, Khanawi, et al, 2010**, which included evaluation of Mishrif and Nahr Umr formations and calculation of oil in place.

2. DEVELOPMENT OF HYDRAULIC FLOW UNIT CONCEPT (HFU)

A hydraulic flow unit is defined as the representative volume of total reservoir rock within which geological properties that control fluid flow are internally consistent and predictably different from properties of other rocks**, Abbaszadeh, 1996**.

2.1 FZI Technique

Amaefule, et al, 1993, addressed the variability of Kozeny’s constant by dividing Equation 2.1 by the effective porosity, $\emptyset_e$ and result in Equation 2.2.

$$k = \left[\frac{\emptyset_e^3}{[1-\emptyset_e]^2}\right]\frac{1}{F_s \tau^2 S_{gv}^2} \qquad (2.1)$$

$$0.0314\sqrt{\frac{k}{\emptyset_e}} = \left[\frac{\emptyset_e}{1-\emptyset_e}\right]\frac{1}{\sqrt{F_S \tau S_{gv}}} \qquad (2.2)$$

Where the constant (0.0314) is the permeability conversion factor from μm^2 to md

Defining flow zone indictor FZI as:

$$FZI = \frac{1}{\sqrt{F_S \tau\, S_{gv}}} \qquad (2.3)$$

Reservoir quality index RQI as:

$$RQI = 0.0314\sqrt{\frac{k}{\emptyset_e}} \qquad (2.4)$$

Normalized porosity $\emptyset_z$ as:

$$\emptyset_z = \left[\frac{\emptyset_e}{1-\emptyset_e}\right] \qquad (2.5)$$

Equation 2.2 becomes

$$FZI = \frac{RQI}{\emptyset z} \quad (2.6)$$

Taking the logarithm of both sides of equation 2.6 yields

$$\text{Log RQI} = \text{Log } \emptyset_z + \log \text{FZI} \quad (2.7)$$

The basis of HFU classification is to identify groups of data that form unit-slope straight lines on a log-log plot of RQI versus $\emptyset_z$. The permeability of a sample point is then calculated from a pertinent HFU using FZI value and the corresponding sample porosity using the following equation, **Al-Ajmi, 2000.** :

$$k = 1014 \, FZI^2 \left[\frac{\emptyset_e^3}{[1-\emptyset_e]^2}\right] \quad (2.8)$$

3. STATIC MODEL (GEOLOGICAL MODEL)

Geological model is the main step of this study. It describes the underground formations and explains fault or fold effect if they found and it includes petrophysical properties distribution (porosity, permeability and water saturation). Petrel, 2009 software was used to build this model by loading the required data which are: well tops, well head, contour map, core data for some wells, Computer Processing Interpretation results (CPI) for some wells. As we know, the production capacity of a reservoir depends on its geometrical/ structural and petro physical characteristics. The availability of a representative static model is therefore an essential condition for the subsequent dynamic modeling phase. The procedure to build static model is as follows:

3.1 Structural Modeling

Mishrif structure consists of single anticline with axis trending North West – South East according to **Fig. 2** and **3.**

3.2 Stratigraphic Model

The development of the stratigraphic model is, without doubt, one of the most traditional tasks of the geologist, who must perform a well-to-well correlation with the aim of defining the stratigraphic horizons bounding the main geological sequences within the hydrocarbon formation, **Cosentino, 2001**. These data are used to create stratigraphic section and correlations, in terms of real depth or with respect to a reference level, through which we can generally identify the lines corresponding to significant geological variation. A cross-section through wells Am-1, Am-2, Am-3, Am-4, Am-5, Am-6 as shown in **Fig.4** was picked to correlate between them.

3.3 Petrophysical Model

This model has been done for each petrophysical property from CPI, **Salman, 2015**. It reflects the distribution of petrophysical properties which change in each zone of the Mishrif formation with depth along Amara field and also calculation of oil in place. The static or geological model output data was used to build a dynamic model using Eclipse-100 software. Petrophysical model can be classified into:

A- Porosity model: Porosity data from output of logging process interpretation CPI of Mishrif reservoir, over the whole model (between node wells) were created using the sequential Gaussian simulation as executed in Petrel. The porosity model for units MA, T.Z1&MB11 of Mishrif formation is shown in **Fig. 5, 6, 7.**
B- Permeability model: Permeability model for the Mishrif reservoir was created by using sequential Gaussian simulation method for permeability data which were calculated using FZI technique for un-cored wells. The porosity model for units MA, T.Z1&MB11 of Mishrif formation is shown in **Fig. 8, 9, 10.**
C- Water saturation model: Water saturation values from Computer Processed Interpretation (CPI) of Mishrif formation were used. The same method of sequential Gaussian simulation as in the porosity model was adopted to build the saturation model as shown in **Fig. 11, 12, 13**.

3.4 Net to Gross Reservoir Estimation

Net pay is a key parameter in reservoir evaluation, because it identifies the penetrated geological sections that have sufficient reservoir quality and interstitial hydrocarbon volume to function as significant producing intervals. It contributes to the estimation of the hydrocarbon in place volume. Net Pay is quantified through the use of petrophysical cut-off that is applied to well log interpretation data. Cut-off is limiting values of formation parameters that remove non-contributing intervals, **Paul, 2009.** Petrel software was used to calculate net pay per gross for all wells, where the main input data were cut-off (porosity cut off=0.083, water saturation cut off=0.75) by equation in Peter software properties (NTG=if (prosity>0.083 and Saturation<0.75.1.0)).

3.5 Volumetric calculation

The volumetric method was applied to compute the hydrocarbon initially in place (HIIP). It was calculated for each unit of the reservoir by using the equation below:

$$HIIP = \frac{VB \times \emptyset \times (1 - Swi) \times NET/GROSS}{Boi} \qquad (3.5)$$

HIIP: Original hydrocarbon in place (OIIP), sm^3.
VB: bulk volume, m^3.
$\emptyset$: Porosity, fraction.
Swi: Initial water saturation expressed as a fraction of the pore volume.
Boi: formation volume factor, under initial conditions, (Boi=1.4386 rm^3/sm^3, Rsi=134.91 rm^3/sm^3).
Table1. Shows the OIIP for Mishrif formation and a comparison of the results with estimates from previous studies.

4. DYNAMIC MODEL

Dynamic model is the second step of this study that it is considered the science of collecting mathematics, physics, computer programming, and reservoir engineering to improve a tool for predicting hydrocarbon reservoir performance under different operating strategies, **Aziz, 1979.**

4.1 History Matching

Generally, history matching is an inverse problem that involves adjusting model parameters (eq. permeability, porosity and other flow properties) until the simulation results from the reservoir model "fit" the observed (or dynamic) data, such as pressure and production data. Choosing the appropriate parameterization is helpful to obtain reliable production forecasting for reservoir development planning and optimization. The history matching of the wells performance for the reservoir under study was obtained by running the numerical model after changing the permeability distribution at every run (multiply permeability by certain factor for the reservoir under study) until a good matching between measured and calculated data was reached. History matching accomplished between calculated and measured data of production and pressure for wells (Am-1 and Am-4) after adjustment in permeability and rock compressibility values by multiplying the horizontal permeability of the reservoir by a factor of (2) and the vertical permeability by a factor of (1.8) for the model while the rock compressibility value was adjusted to $5*10^{-5}$ (bar^{-1}). The result is shown in **Fig.14, 15, 16, 17**.

5. PERFORMANCE PREDICTION

To accomplish the objective of this study, the future behavior of the reservoir under different conditions must be predicted after the reservoir modeling complete and consider that the model is representing the actual reservoir depending on the history matching, we will suggest four cases to monitor the reservoir behavior in the future under some conditions regarding the depletion of pressure, production plateau, recovery factor and water cut. All the scenarios are beginning from 2015 to 2025 regarding the minimum bottom hole flowing pressure equal to the bubble point pressure (228 kg/cm^2) or (3242psi) to avoid the two phase production at the sand face. We can classify future development plan to four cases:

1- Case-1: Adding 10 new vertical wells with production rates of Mishrif reservoir begin with 21 KSTB/D in June 2015 and decline to 9.2 KSTB/D at the end of prediction period in 2025. The water cut increased in this scenario to 9 % at end period of prediction with recovery factor 5.55% for the reservoir at end period of prediction. The result of this scenario is shown in **Fig. 18**.

2- Case-2: Adding 15 new vertical wells with production rates of Mishrif reservoir begin with 27.5 KSTB/D in June 2015 and decline to 10 KSTB/D at end of prediction period in 2025. The water cut increased in this case to 9 % at end period of prediction with recovery factor 6.1% for the reservoir at end of prediction. The result of this scenario is shown in **Fig. 19.**

3- Case-3: Adding 25 new vertical wells with production rates of Mishrif reservoir begin with 40.5 KSTB/D in June 2015 and decline to 14 KSTB/D at end of prediction in 2025. The water cut increased through this case to 13.5 % at end of prediction time with recovery factor 8.2% for the reservoir in end of prediction. The result of this scenario is shown in **Fig. 20**.

4- Case-4: Adding20 new vertical wells, 5 horizontal wells and 5 injection wells with production rates of the reservoir begin with 50 KSTB/D in June 2015 and decline to 13.5 KSTB/D at end period of prediction in 2025. The water cut increased in this scenario to 43 % in end of prediction with recovery factor 9.06% for the reservoir in end period of prediction. The result of this scenario is shown in **Fig. 21**.

We can notice from the result that the case-4 is better than other cases with 20 vertical producer wells with 5 horizontal producer wells and 5 water injection wells with rate equal 50 MSTB/D at starting of prediction and 13.5MSTB/D at ending of prediction with recovery factor 9.06% and W.C equal 43% and shown in **Table 2**.

6. CONCLUSION

1- Geological model for Mishrif reservoir /Amara field has been constructed by PETREL program (version 2009) depending on data and Dynamic model has been constructed by Eclipse software.
2- The original oil in place (OIIP) estimation in geological model is $905*10^6$ STB. The value OOIP in this study that estimated is closely to the OOIP value in the OEC/2010 ($987*10^6$ STB)**.**
3- The history match was obtained by multiplying the horizontal permeability of the reservoir by a factor of (2) and the vertical permeability by a factor of (1.8) for the model while the rock compressibility value was adjusted to $5*10^{-5}$ (bar^{-1}) .
4- The best development plan for the reservoir is production from 20 vertical producer wells with 5 horizontal producer wells and 5 water injection wells at plateau rate 50 MMSTB at starting of prediction and decreased to 13.5 MMSTB at ending of prediction.

REFERENCES

- Abbaszadeh, M.D., Hikari Fujii, Fujio Fujimoto Dec., 1996: *Permeability Prediction by Hydraulic Flow Units-Theory and Applications*. SPE Formation Evaluation.

- Al-Ameri, T.K., Pitman, J., Naser, M.E., Zumberge, J., and Al-Haydari, H.A., 2010. Program oil generation of the Zubair Formation, Southern Iraq oil fields. Arab Journ. Geosc.p.4.

- Al-Khadimi, J. A., Sissakian, V. K., Fattah, A. S., and Deikaran, D. B., 1996. *Tectonic map of Iraq, (Scale: 1:1000000) S. E. of Geological Survey and, Mining,* Iraq.
- Al-Ajmi A.Fahad, Holditch A. Stephen, October, 2000: *Permeability Estimation Using Hydraulic Flow Units in a Central Arabia Reservoir*". SPE 63254, SPE Annual Technical Conference and Exhibition held in Dallas, Texas. 1-4.

- Amaefule, J.O., Altunbay, D., Tiab, D., Kersey, D.G., and Keelan, D.K., 1993: "*Enhanced Reservoir Description: Using Core and Log Data to Identify Hydraulic (Flow) Units and Predict Permeability in Uncored Intervals/Wells*". SPE 26436.

- Amaefule, J.O., Altunbay, D., Tiab, D., Kersey, D.G., and Keelan, D.K., 1993: "*Enhanced Reservoir Description: Using Core and Log Data to Identify Hydraulic (Flow) Units and Predict Permeability in Uncored Intervals/Wells*". SPE 26436.

- Aziz, K. and Settari, A., 1979 "*Petroleum Reservoir Simulation*" Applied Science Publishers.
- Vietnam Oil and Gas Corporation (Petro Vietnam), 1998, *Pre-Feasibility Study for Amara Oil Field Development*, Hanoi.
- Cosentino L: 2001"Integrated reservoir studies", Paris, Technip,.
- Khanawi, M.A, Abdu-Alahad, R.J., Sari, J.R., Abdu-Asaheb, H., Mohamed, A.H., Jaafer, K.H., Salman, S.J., 2010, *Geological evaluation study for Amara field*, Iraqi Oil Explorations Co.
- Paul F. Worthington, 2009 "*Net pay: what is it? What does it do? How do we quantify it? How do we use it?*", Gaffney, Cline & associates, SPE.
- Salman, Suhad Jawdat, 2015, *three dimensions geostatistical of Mishrif carbonate reservoir in Amara oil field*, M.SC. Thesis, Petroleum Engineering, University of Baghdad.

NOMENCLATURE

3D= three dimension

Boi= oil formation volume factor

rm^3= cubic meter in reservoir condition

sm^3= cubic meter in surface condition

CPI= computer process interpretation

FPR= average reservoir pressure

FPRH= average reservoir pressure history

FOPRH= field oil production rate history

FZI= flow zone indicator

K= permeability

OIIP= oil initially in place

Ø = porosity

Øe= effective porosity

Øz= normalized porosity

Rsi= solubility

STB= stock tank barrel

SCF= standard cubic foot

WOPR= well oil production rate

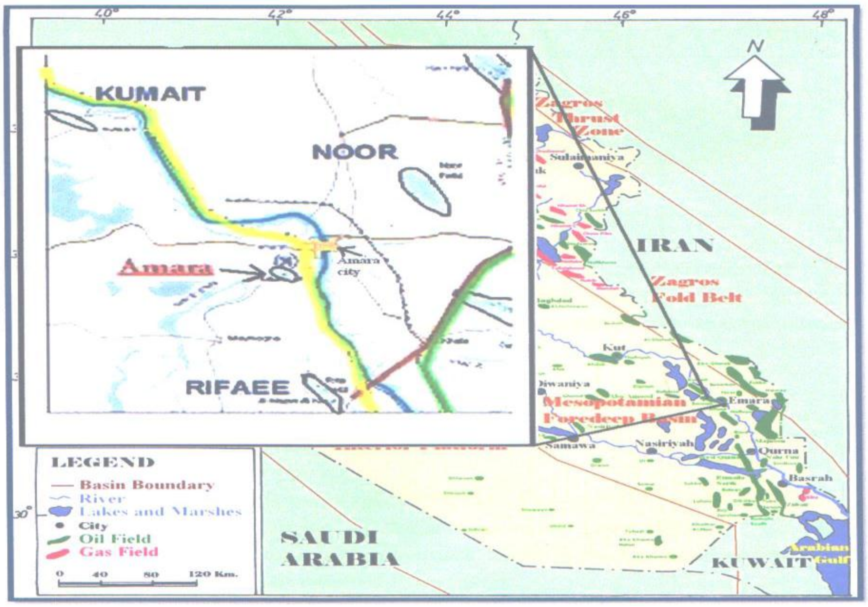

Figure 1. The map of the area showing Amara field, **Al-Ameri, 2010.**

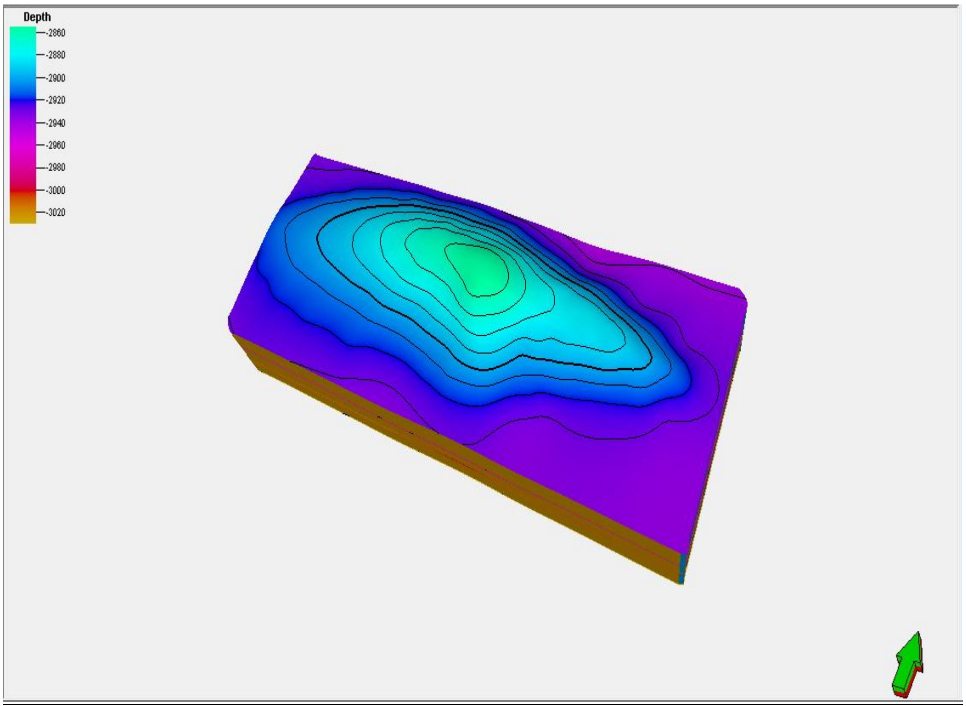

Figure 2. 3D structural reservoir model.

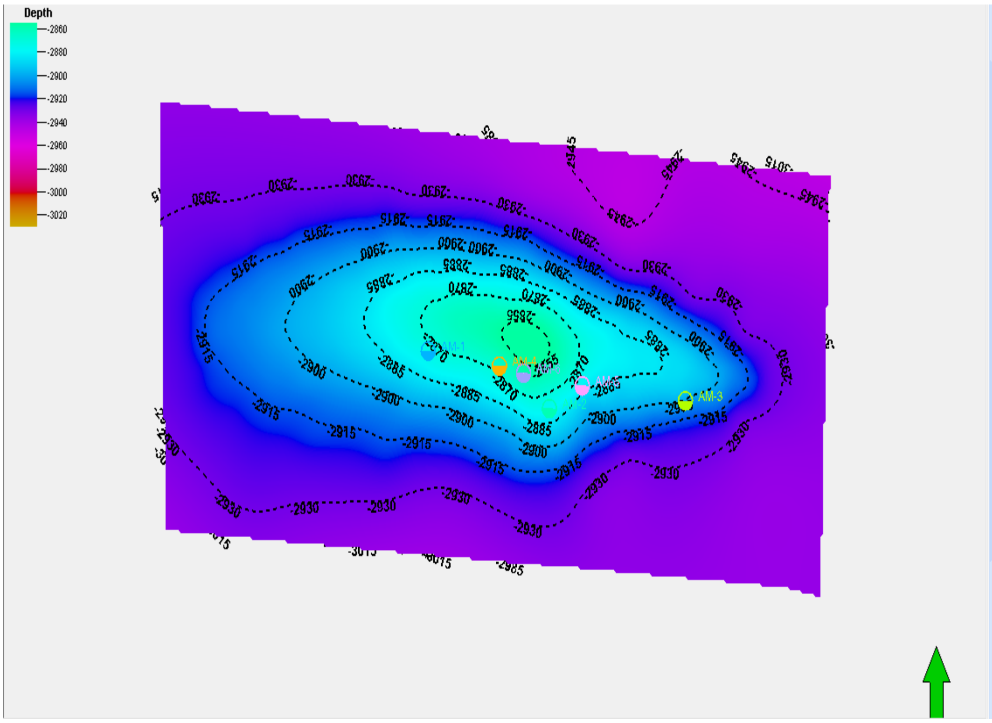

Figure 3. Contour map on top of Mishrif reservoir.

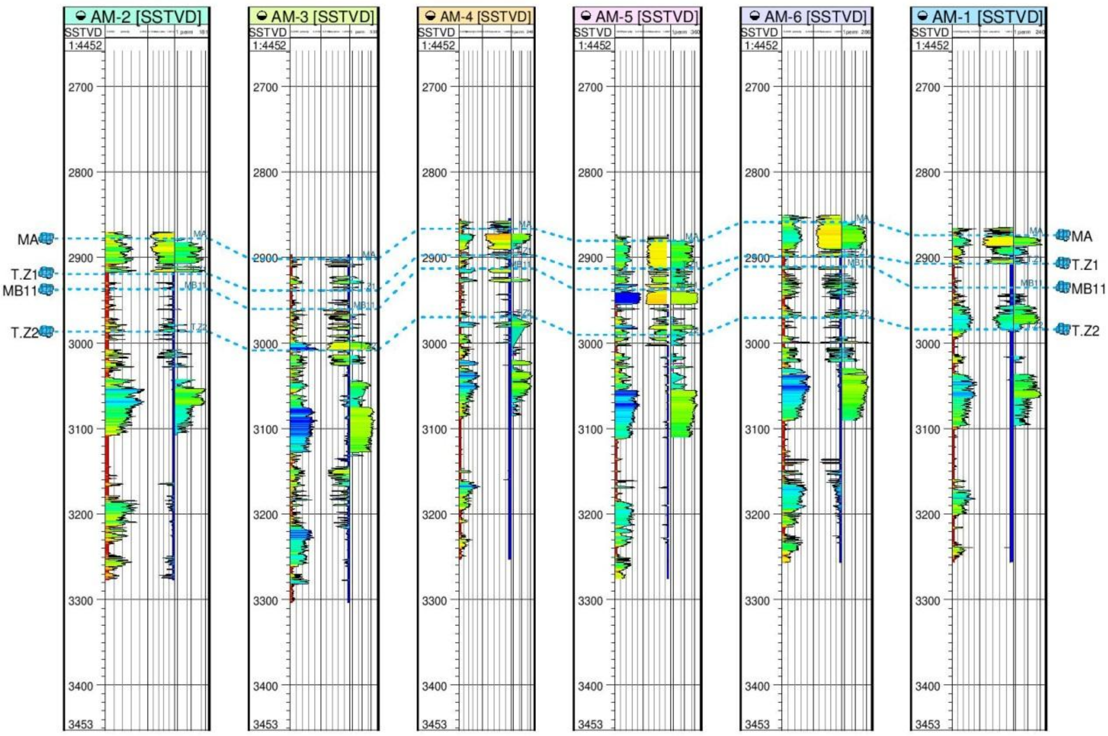

Figure 4. Well correlations for (AM-1, AM-2, AM-3, AM-4, AM-5, and AM-6) Mishrif formation**.**

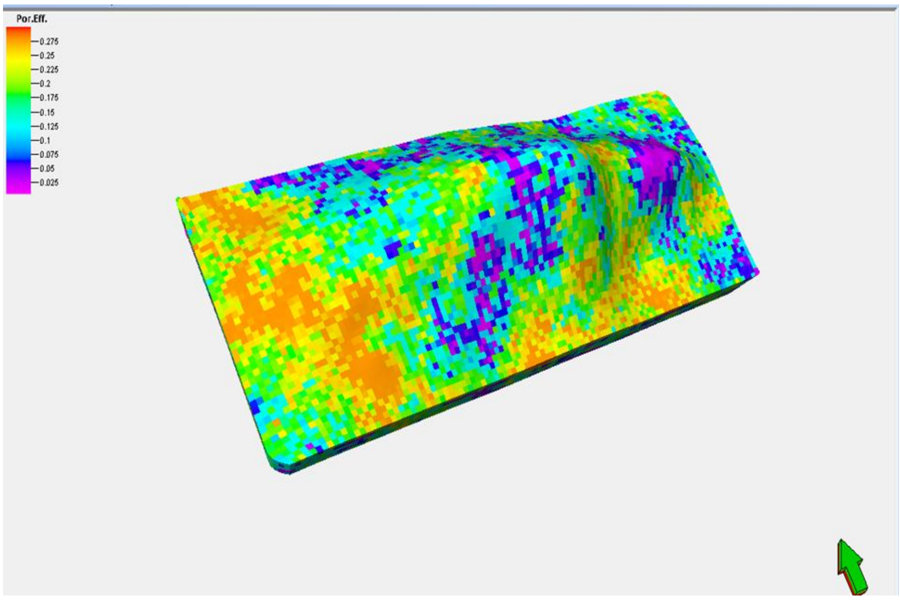

Figure 5. Porosity model for unit MA.

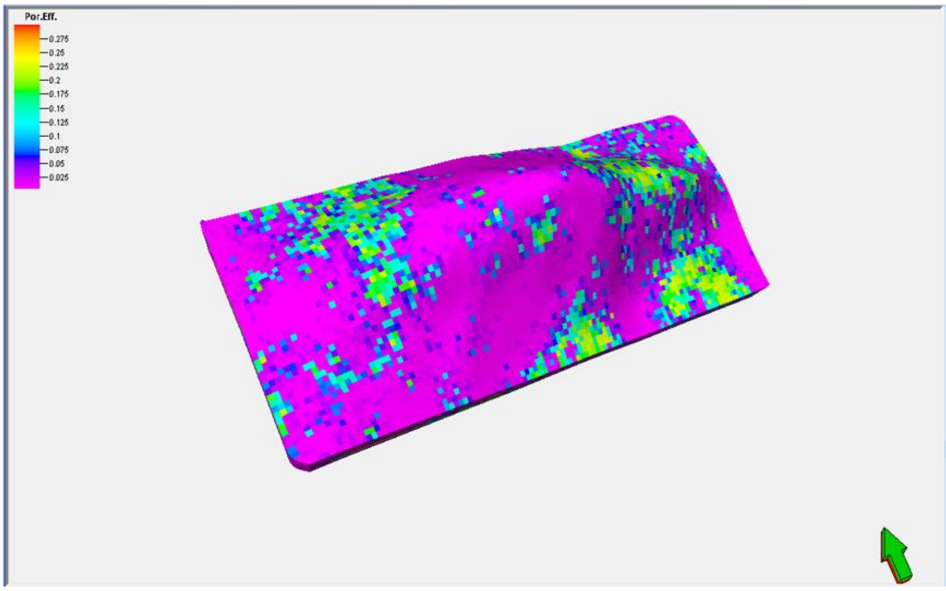

Figure 6. Porosity model for unit T.Z1**.**

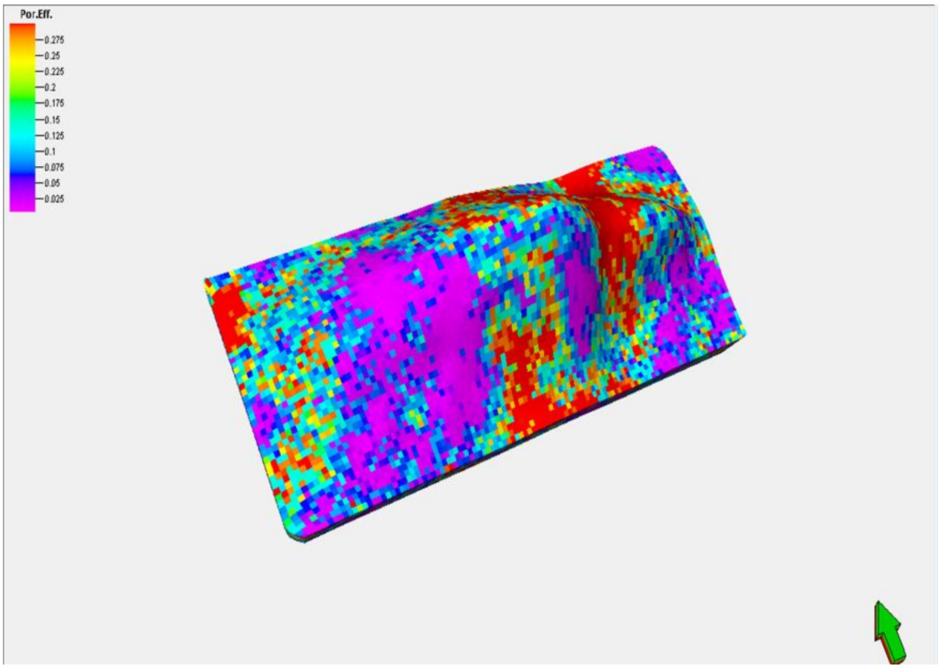

Figure 7. Porosity model for unit MB11.

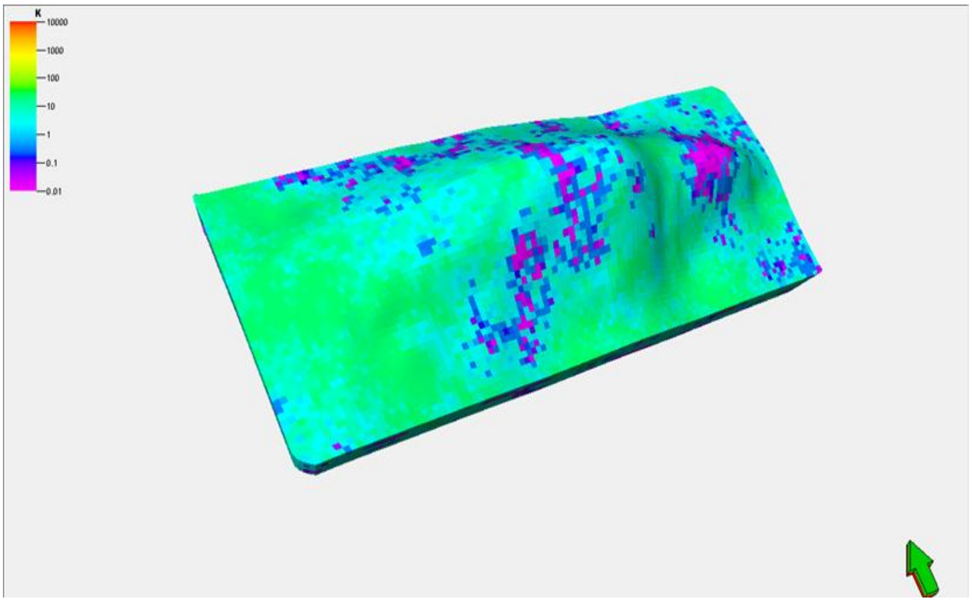

Figure 8. Permeability model for unit MA.

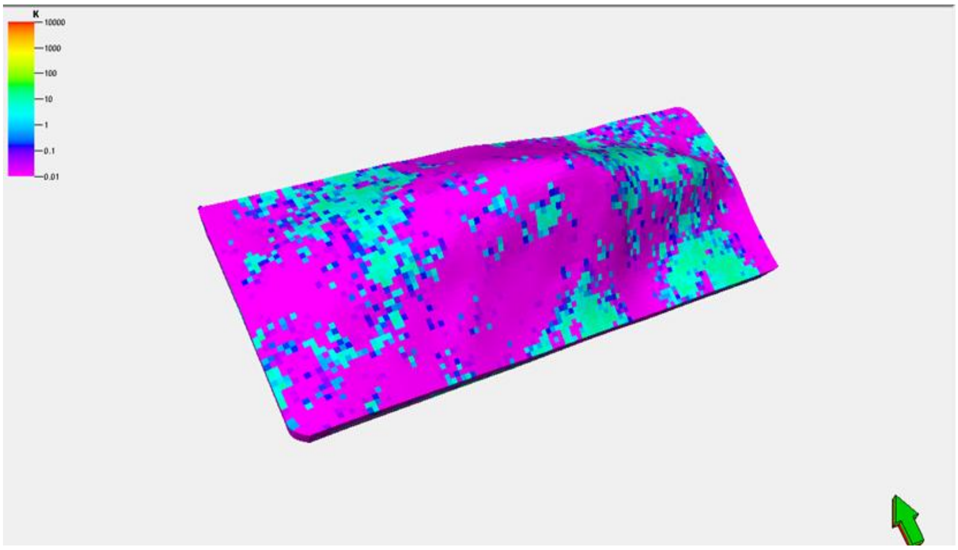

Figure 9. Permeability model for unit T.Z1.

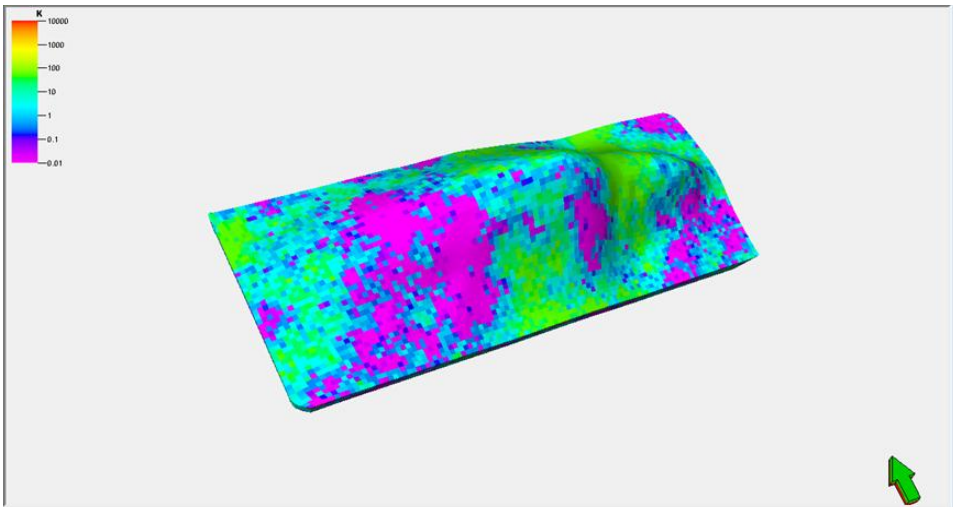

Figure 10. Permeability model for unit MB11.

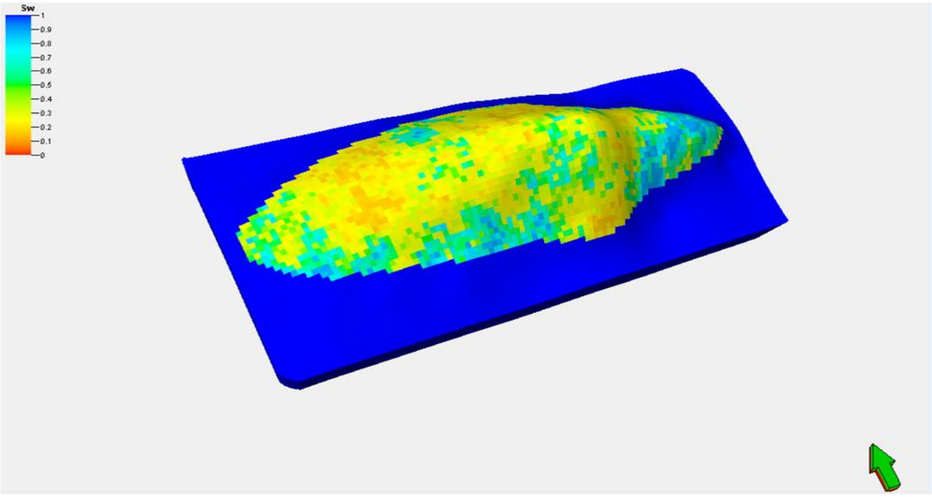

Figure 11. Water saturation model for unit MA.

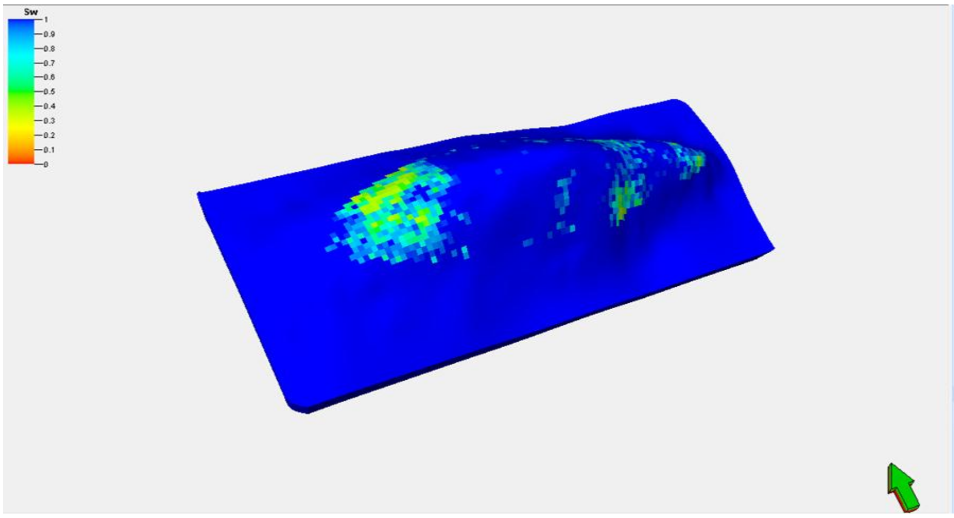

Figure 12. Water saturation model for unit T.Z1.

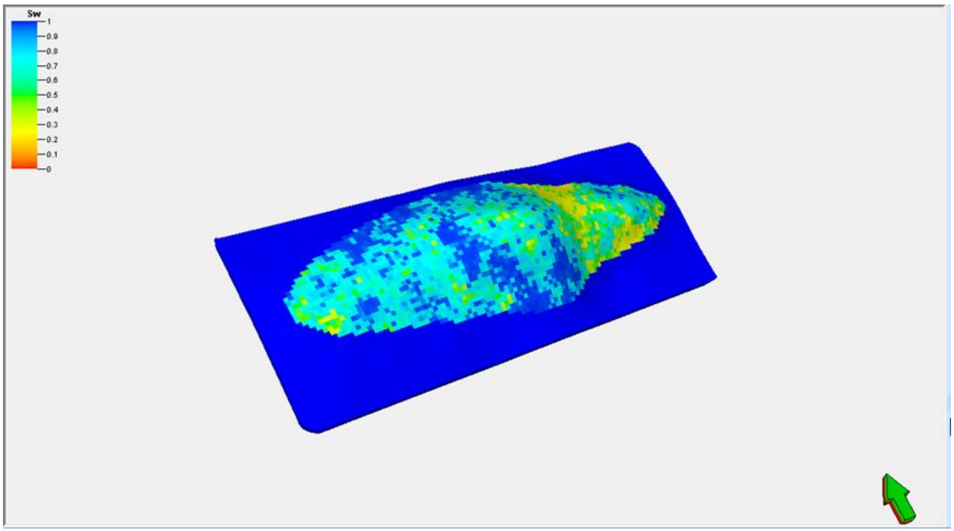

Figure 13. Water saturation model for unit MB11.

Table1. OIIP for Mishrif formation, **Khanawi, et al, 2010.**

OIIP in study 1986 (STB)	OIIP in study 1991 (STB)	OIIP in study 1994 (STB)	OIIP in study 2010(STB)	OIIP in current study(STB)	Formation
$232*10^6$	$979*10^6$	$747*10^6$	$987*10^6$	$905*10^6$	Mishrif

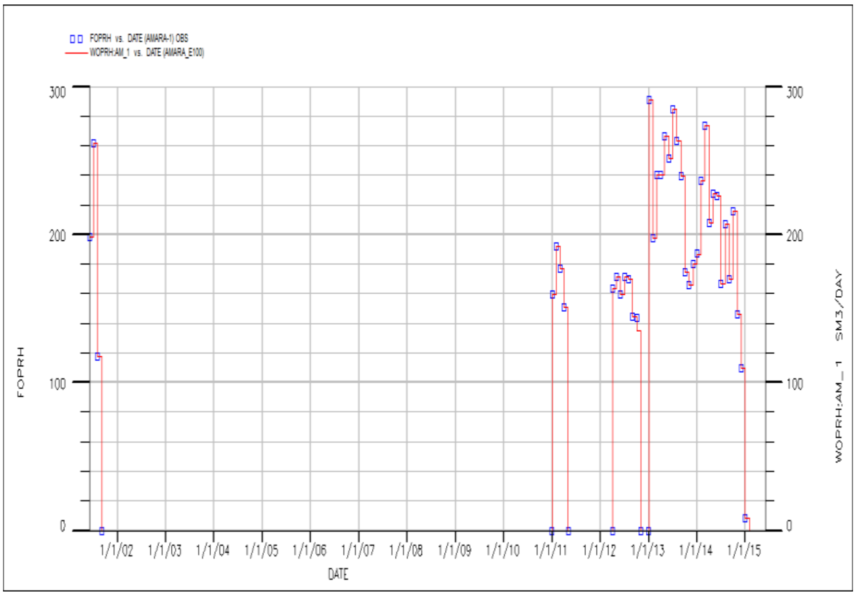

Figure 14. Field oil production rate history (FOPRH), calculated field oil production rate (WOPR) with time for well AM-1.

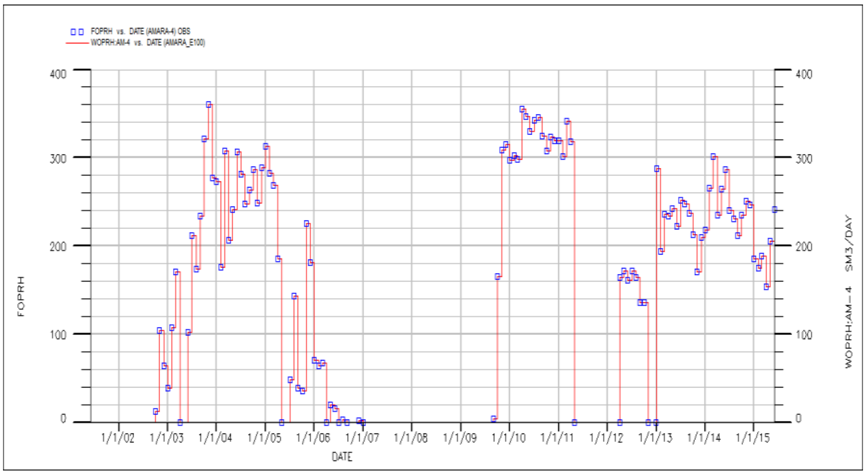

Figure15. Field oil production rate history (FOPRH), calculated field oil production rate (WOPR) with time for well AM-4.

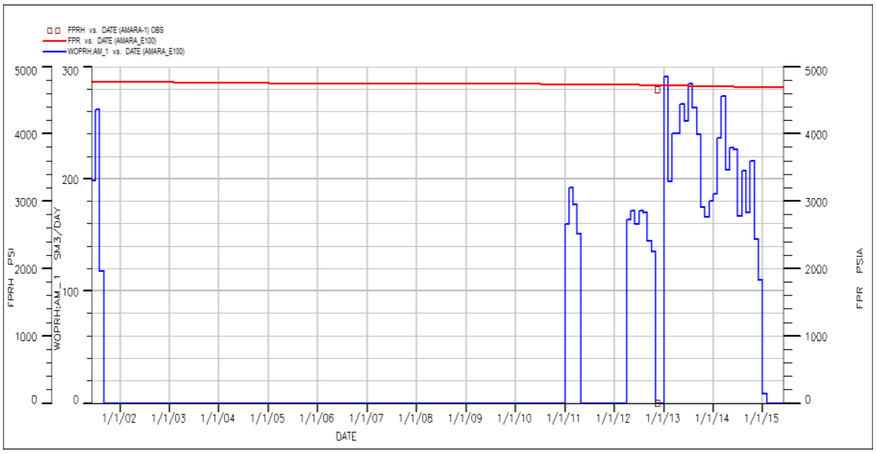

Figure 16. Calculated average reservoir pressure (FPR), average reservoir pressure history (FPRH) (psia) with time for well-1.

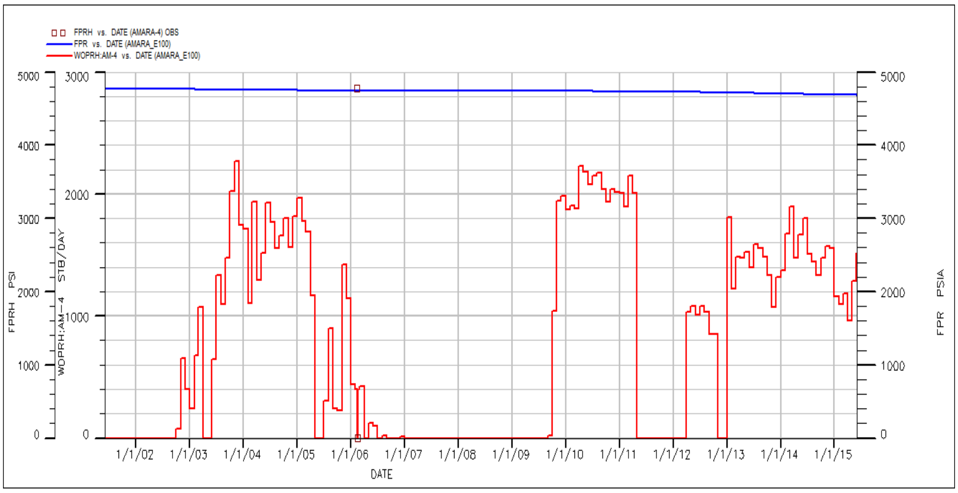

Figure 17. Calculated average reservoir pressure (FPR), average reservoir pressure history (FPRH) (psia) with time for well-4.

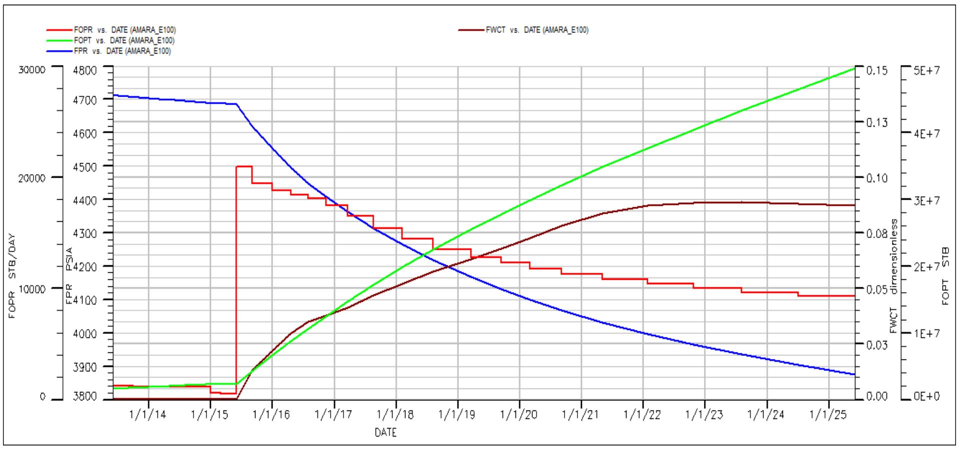

Figure 18. Field Oil Production, Total Oil Production (Cumulative production), W.C, and Field pressure versus Date for Case 1.

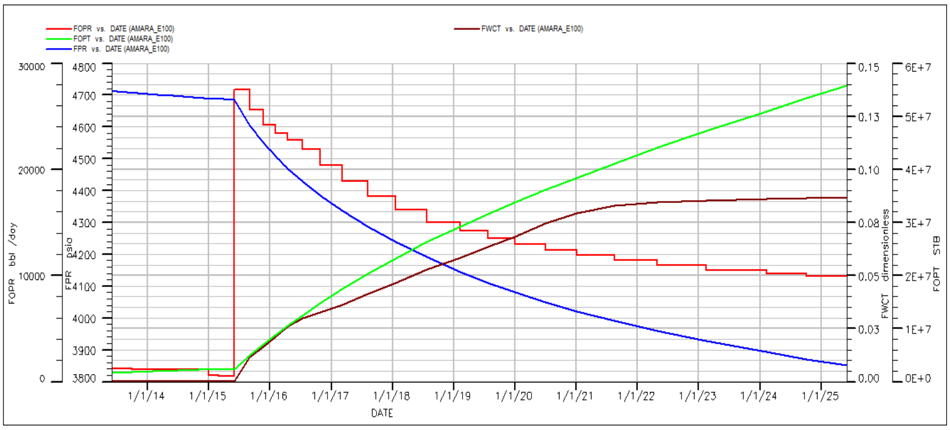

Figure 19. Field Oil Production, Total Oil Production (Cumulative production), W.C, and Field pressure versus Date for Case 2.

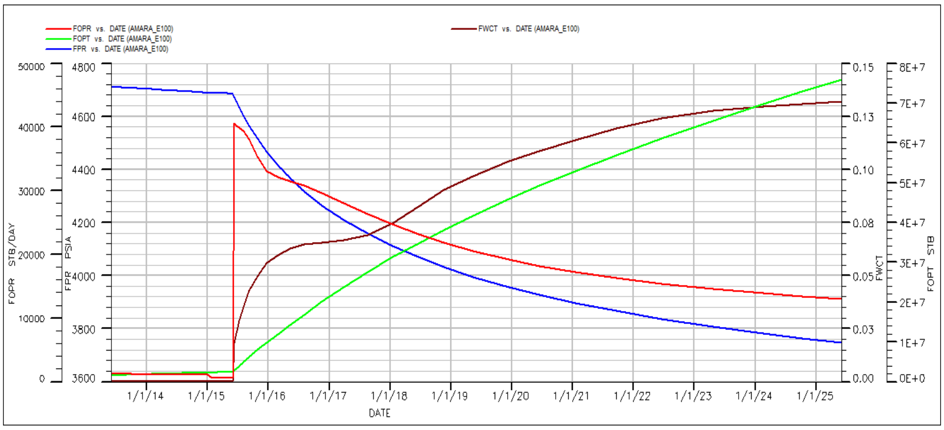

Figure 20. Field Oil Production, Total Oil Production (Cumulative production), W.C, and Field pressure versus Date for Case 3.

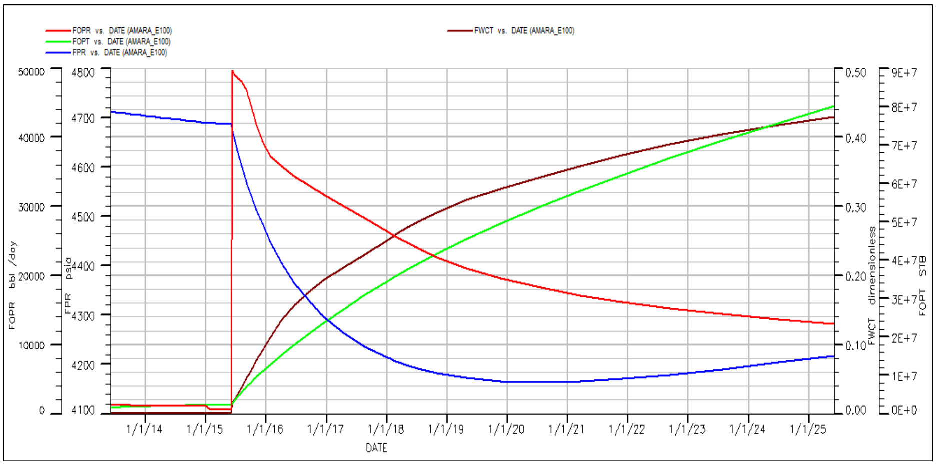

Figure 21. Field Oil Production, Total Oil Production (Cumulative production), W.C, and Field pressure versus Date for Case 4.

Table 2. Results of the cases for development the reservoir.

Case No.	*No. of All Wells*	*Prod. at end 2025, (MSTB/D)*	*Cumulative Oil prod. (MMSTB/D)*	*Field Press. ,psia*	*W.Cut %*	*R.F %*
Case 1	10 V, Production	9.2	50	3850	9	5.52
Case 2	15 V, Production	10	56	3830	9	6.1
Case 3	25 V, Production	14	76	3675	13.5	8.2
Case 4	20V, Prod., 5H, Prod.,5V, Inj.	13.5	82	4215	43	9.06