Design Engineering

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

Reservoir Model for an Iraqi Oil Field

Farah Nabeel Abdulrazzaq /University of Baghdad

f.abdulrazzaq1908m@coeng.uobaghdad.edu.iq

Omar Al-Fatlawi /University of Baghdad

Omar.Al-Fatlawi@coeng.uobaghdad.edu.iq

Abstract:

The research creates a reservoir model for an oil field based on data from 15 exploration wells in the region.The major goal of the paper was to assess the initial oil in place value and to evaluate the difference between initial oil in place that is calculated by volumetric method for the reservoir and dynamic models before making a final investment decision for the oilfield's further development.

The log readings were interpreted and calibrated with the core data. The software Interactive Petrophysics (IP) was used for log interpretation. A geological model for the Mishrif layer in this reservoir was created, based on the interpretations of the log readings analysis, laboratory measurements of the fluid properties, and core reports for fifteen well. This was followed by the creation of a reservoir model to represent the movement of fluids through the reservoir and the consequent change in reservoir pressure. The PETREL platform (v.2017) platform was utilized to construct the model.

The mismatch between the initial oil in place that is calculated by the static and dynamic models was 0.3 % which indicates good match since maximum acceptable mismatch is 1%.

The reservoir has large initial oil in place, according to the findings of geological and dynamic models. The importance of developing this oilfield is verified by its very high IOIP.

Introduction:

Reservoir modeling is an important step in the development strategies for increasing hydrocarbon recovery. It can be used to anticipate a variety of production and depletion scenarios depending on various variables. Reservoir geological model, which is considered as the initial phase in the modeling process, is a 3D representation of the structure and stratigraphy of the reservoir based on the core data analysis, well log data interpretation and seismic data. It is important to identify hydrocarbons volume and provides a base for the dynamic model's initialization for effective reservoir management(Al-Fatlawi, 2018, Mattax & Dalton, 1990).

The reservoir structural framework, reservoir zonation and flow units, and local reservoir heterogeneity are all included in these models, which are often large and complicated(King et al., 1999, Jean-François et al., 2010, Lv et al., 2020, Nguyen et al., 2021, Al-Fatlawi et al., 2016).

The oil-bearing Mishrif formation in Iraq represents shallow-shelf carbonate deposition; regular increases in sea level resulted in occurrence of deeper-water sedimentation, during which the Formation's outer-shelf and basinal sediments were put down. The Mishrif is overlain by the Khasib

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

formation, which contains continuous and vast shale in the bottom portion, which is thought to constitute the structure's primary seal(Miraglia et al., 2015, Rodrigues et al., 2016).Full field models were developed to study Mishrif formation (Al-Jawad et al., 2014, Holden et al., 2014, Yixiang et al., 2017, Al-Ali et al., 2019).

The following data was used to create the reservoir model for Mishrif formation in an oil field in the southern of Iraq.

- Contour map for Mishrif formation.
- For 15 wells, well heads well positions and well completions.
- The well tops cross with the tops of several horizons.
- Well logs (porosity, water saturation and permeability).
- The PVT properties and a SCAL report.
- production data (oil flow rate, water production, water injection rate, bottom hole pressure, and static pressure).

The goal of this study is to create a reservoir model for Mishrif formation in an Iraqi oilfield in order to determine the oil initially in place (IOIP). The geological model was used to create a simulation model that best represents reservoir behavior and can be used to simulate many development strategies and operating conditions in order to optimize oil production. The IP software was used to determine petrophysical properties based on well logs measurements and core data.The PETREL 2017 platform was used to build structural model, stratigraphic model, petrophysical model and dynamic model in this study.

Methodology:

Log interpretation

The main inputs well logs data to PETREL program are porosity, permeability in vertical and horizontal directions and water saturation. These inputs are the basic data to build the structural model, thus the log measurements such as GR, SP, porosity logs, caliber and resistivity logs should be interpretation.

Porosity is collected from Density-Neutron logs of fifteen well in Mishrif reservoir after correction of shale volume. In order to obtain correct porosity readings, core porosity was calibrated with log readings to avoid depth mismatch problem in some core samples by using curve depth shift.

For Mishrif reservoir reservoir permeability was calculated by HFU concept starting with modified Carman-Kozeny equation:

$$K = \frac{Øe^3}{(1-Øe)^2}\frac{1}{F_s\tau^2 {S_{gv}}^2} \quad (1)$$

where;

K: permeability (μm^2)

F_s: shape factor

τ^2: Tortuosity

S_{gv}: Surface area to grain volume ratio (μm^{-1})

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

$Øe$: effective porosity (fraction)

(Amaefule et al., 1993) developed Carman-Kozeny equation by dividing both sides of equation (1) by effective porosity $Øe$ and afterwards taking the square root of both sides to overtake the ratio of surface area to grain volume (S_{gv}) and shape factor (F_s) terms , the result equation is:

$$\sqrt{\frac{K}{Øe}} = \frac{Øe}{(1-Øe)}\left(\frac{1}{\sqrt{F_s}\ \tau\ S_{gv}}\right) \qquad (2)$$

This equation contains two terms which are Reservoir Quality Index RQI and Flow Zone Indicator FZI and they are given as

$$RQI = 0.0314\sqrt{\frac{K}{Øe}} \qquad (3)$$

The constant 0.0314 is for the transformation of permeability units from micrometer to millidarcy

$$Øz = \frac{Øe}{1-Øe} \qquad (4)$$

$$FZI = \left(\frac{1}{\sqrt{F_s}\ \tau\ S_{gv}}\right) = \frac{RQI}{Øz} \qquad (5)$$

where;

RQI: Reservoir Quality Index (μm)

Øz: Pore volume to the grain volume ratio (fraction)

FZI: Flow Zone Indicator (μm)

Equation (2) can be put in the logarithm form:

$$Log\ (RQI) = Log\ (Øz) + Log\ (FZI) \qquad (6)$$

For core samples with equal FZI values, plotting RQI versus $Øz$ on log-log paper gives a straight lines and that was a unit of hydraulic flow (HFU). The intercept of this straight line with the vertical line at value of $Øz$ equal to one determines the FZI values for each of these flow units.

Mishrif formation has five stratigraphic sequences MHF1, MHF2, MHF3, MHF4 and MHF5.

Figure (1) shows that Mishrif reservoir has five HFU each one of these has different FZI value. FZI values have been allocated among the reservoir main units based on well log analysis and final well report (FWR). Mostly the unit with good properties, i.e. high porosity and low clay volume, receives a higher FZI rating, and vice versa.

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

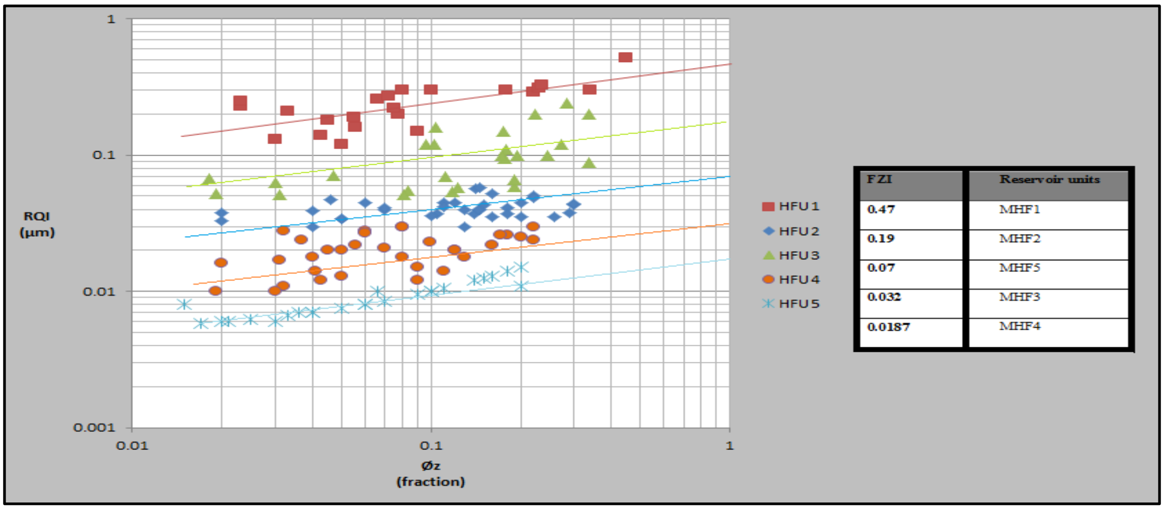


Figure (1) FZI calculation

Equation (5) can be solved for permeability calculation to the whole reservoir by using FZI value for each unit and this yield:

$$K = 1014\ FZI^2 \frac{Øe^3}{(1-Øe)^2} \qquad (7)$$

Permeability can differ dramatically in the horizontal and vertical directions. Therefore, it affects the reservoir's directional flow potential. The correlation that was used to calculate vertical permeability, Kv, as a function of horizontal permeability, Kh, as determined by core analysis is:

$$Kv = \left(\frac{Kh}{1.33}\right)^{1.04} \qquad (8)$$

Water saturation is measured by Resistivity logs analysis, which evaluates both the mobile and clay-bound water in the pore space.For Mishrif formation water saturation was calculated by Archie equation:

$$S_w{}^n = \frac{R_w}{\emptyset^m R_t} \qquad (9)$$

where;

S_w: water saturation (fraction)

n: saturation exponent

R_w: formation water resistivity at formation temperature (ohm-m)

$\emptyset$: Porosity (fraction)

m: cementation exponent

R_t: true formation resistivity, corrected for invasion (ohm-m)

Design Engineering

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

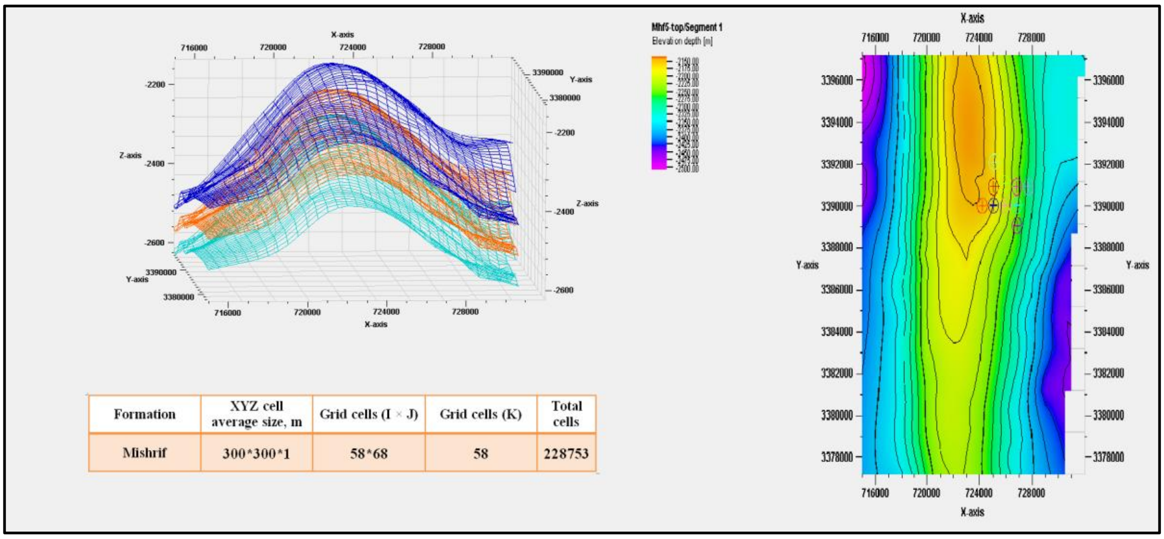
Structural model

The main purpose of the structural model is to create a reservoir framework including the main reservoir heterogeneities impacting reservoir flow that may be used in 3D geological and dynamic simulations of Mishrif reservoir.

First, Mishrif formation divided into five stratigraphic sequences MHF1, MHF2, MHF3, MHF4 and MHF5based on contour map and wells data.The second step is the horizon modeling that divides the bulk model into grid cellswith dimensions of 300 m by 300 m in the X and Y directions and grid rotation is set to 0 degrees with total number of cells equal to 228,752 as shown in figure (2).

Stratigraphic modeling

Mishrif formation has five stratigraphic sequences MHF1, MHF2, MHF3, MHF4 and MHF5 that are subdivided into smaller layers to accomplish an accurate vertical resolution. MHF5 zone is divided into 4 layers. MHF4 has two parts, non-reservoir unit which was left as single layer and the second part is subdivided into 5 layers. MHF3 and MHF2 each one is subdivided into 15 layers and MHF1 is subdivided into 18 layers.



Formation	XYZ cell average size, m	Grid cells (I × J)	Grid cells (K)	Total cells
Mishrif	300*300*1	58*68	58	228753

Figure (2) Structural model

Petrophysical modeling

For each 3D grid in the model specific value of reservoir characteristics are allocated throughout this stage.The results obtained from the well log data analysis were distributed over the entire reservoir by scaling up the petrophsical properties that were calculated in step one as shown in figure (3) for two wells as an example.

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

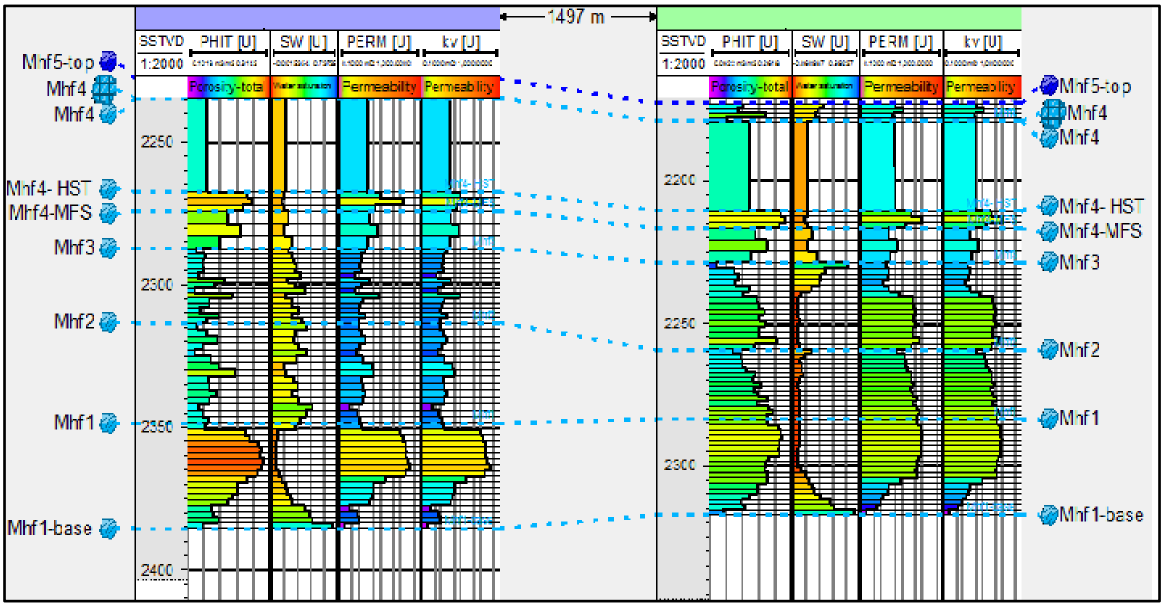


Figure (3) scale up of porosity, vertical and horizontal permeability, and water saturation for two wells

Dynamic Model

Because the reservoir fluids in this model are regarded as immiscible phases that are isolated from one another, and the Mishrif formation is a black oil reservoir, the black oil simulator is the appropriate model for this work.The numerical model's inputs are:

1- Grid block shape, size, and elevation, are entered as mentioned in the preceding part.

2- Porosity, horizontal permeability, vertical permeability and water saturation are distributed to each grid block by upscalling the well logs.

3- Capillary pressure and relative permeability data were used to initialize the model and to describe connate water saturation and fluid flow behavior, for this reason a SCAL are attached in the model.

4- The PVT properties of Mishrif formation tested for an exploration well has been included to the model to describe the hydrocarbons and formation water properties of the reservoir model

5- For each individual well in the model, production data (oil flow rate, water production, water injection rate, bottom hole pressure, and static pressure) was collected.

6- Wells locations, perforation interval and completion for each well were included in the model to provide better description of the production history.

7- Mishrif reservoir's initial state states the depth of oil-water contact in the Mishrif formation, which is 2447 mKB, and the reservoir's initial pressure at this depth, which is roughly 3900 psi.

The last step is to run the model using Petrel 2017 and ECLIPSE 100 after defining all of the aforementioned input data to the reservoir model.

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

Results and Discussion:

The geological and field data gathered for the Mishrif formation has now reached the level of field follow-up exploration. The in-place volumes were calculated with sufficient precision using data from 15 exploratory wells and petrophysical investigations. The geological model and the IOIP were validated by drilling producing wells in the Mishrif formation.

Equation (5) shows that surface area, pore size distribution, median pore throat size, irreducible water saturation, and other petrophysical properties that characterize the fluid behavior of porous media have a close association with the FZI. As a result the FZI appears to be a reliable indicator of permeability in porous rocks since these properties regulate permeability.

One of the practical methods that are used to test the match between the static and the dynamic model is the calculation of initial oil in place by the static and the dynamic method then the mismatch is calculated by the following equation:

$$\text{mismatch} = \frac{\text{IOIP}_{\text{Dynamic method}} - \text{IOIP}_{\text{static method}}}{\text{IOIP}_{\text{Dynamic method}}} \quad (10)$$

where:

$\text{IOIP}_{\text{Dynamic method}} = 3511099317\ m^3$

$\text{IOIP}_{\text{static method}} = 3494000000\ m^3$

mismatch = 0.3 % which indicates good match since maximum acceptable mismatch is 1%

Conclusions

The STOIIP of the Mishrif formations was determined using the volumetric approach. The IOIP for the Mishrif formation in the chosen oilfield was assessed at 3511099317 m3. The high IOIP of this oilfield validates the significance of further research, and this model is regarded the initial stage in reservoir dynamic model design, demonstrating the value of this study. The FZI appears to be a reliable indicator of permeability in porous rocks since these properties regulate permeability.

The interpretation of logging data, the defining of petrophysical relationships using core research information, and the drilling of production wells all have a role in the formation's IOIP distribution. The in-place volumes were determined with sufficient precision using data from 15 wells and petrophysical investigations.

References:

1. Al-Ali MM, Mahdi MM and Alali RAJTIGJ (2019). MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF MISHRIF FORMATION, NORTH RUMAILAOILFIELFD, SOUTHERN IRAQ. 91-104.
2. Al-Fatlawi O, Mofazzal MH, Hicks S and Saeedi A (2016). Developed material balance approach for estimating gas initially in place and ultimate recovery for tight gas reservoirs. *Abu Dhabi International Petroleum Exhibition & Conference.* OnePetro.
3. Al-Fatlawi OF (2018). Numerical simulation for the reserve estimation and production optimization from tight gas reservoirs. Curtin University.
4. Al-Jawad SN, Saleh AH, Al-Dabaj AAA and Al-Rawi YTJAJoG (2014). Reservoir flow unit identification of the Mishrif formation in North Rumaila Field. **7**: 2711-2728.

ISSN: 0011-9342 | Year 2021
Issue: 8 | Pages: 7573 - 7580

5. Amaefule JO, Altunbay M, Tiab D, Kersey DG and Keelan DK (1993). Enhanced reservoir description: using core and log data to identify hydraulic (flow) units and predict permeability in uncored intervals/wells. *SPE annual technical conference and exhibition.* Society of Petroleum Engineers.
6. Holden A, Lehmann C, Ryder K, Scott B and Almond K (2014). Integration of production logs helps to understand heterogeneity of Mishrif reservoir in Rumaila. *SPWLA 55th Annual Logging Symposium.* Society of Petrophysicists and Well-Log Analysts.
7. Jean-François L, Jean-Marie M, Jean-Luc R, Martin G, Laurent D, Stanislas J and Jean-Claude D (2010). Efficient quality control on complex horizon-fault network interpretation through geological modeling and 3D volumic restoration. *SEG Technical Program Expanded Abstracts 2010.* Society of Exploration Geophysicists, pp. 1540-1544.
8. King MJ, Mansfield MJSRE and Engineering (1999). Flow simulation of geologic models. **2**: 351-367.
9. Lv Z, Song H, Wang P, Fang N and Zheng B (2020). Geological Modeling of Semideep Reservoir Based on Seismic Frequency Division Processing and Sedimentary Numerical Simulation. *Offshore Technology Conference.* OnePetro.
10. Mattax CC and Dalton RLJJoPT (1990). Reservoir Simulation (includes associated papers 21606 and 21620). **42**: 692-695.
11. Miraglia S, Borromeo O, Maragliulo C, Rodrigues J and Sartorio D (2015). Architecture, facies distribution and reservoir properties of the Mishrif Formation (Zubair Field, Southern Iraq): an example of integration of seismic interpretation with well data. *Abu Dhabi International Petroleum Exhibition and Conference.* OnePetro.
12. Nguyen S, Nguyen T, Tran H and Ngo Q (2021). Integration of 3D Geological Modeling and Fault Seal Analysis for Pore Pressure Characterization of a High Pressure and High Temperature Exploration Well in Nam Con Son Basin, a Case Study Offshore Vietnam. *International Petroleum Technology Conference.* OnePetro.
13. Rodrigues J, Fervari M, Luoni F, Monte AA, Miraglia S and Banoori S (2016). Seismic Reservoir Characterization of Carbonate Reservoirs The Case Study of Mishrif Formation Zubair Field, Iraq. *Abu Dhabi International Petroleum Exhibition & Conference.* OnePetro.
14. Yixiang Z, Xinmin S, Benbiao S, Shuiqing H, Changbing T, Yan G, Weimin Z, Yong L, Zhuo L and Chengji W (2017). Genesis of High Permeable Thief-zones and Integrated Reservoir Modeling of Intense Heterogeneous Reef-flat Carbonates: A Case Study for the Mishrif Formation of the Rumaila Oilfield, Iraq. *SPE Annual Technical Conference and Exhibition.* Society of Petroleum Engineers.