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Geological Modeling and Resource Estimation for Mishrif Formation in Nasiriyah Oilfield

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Abstract— Resource estimation is an essential part of reservoir evaluation and development planning which highly affects the decision-making process. The available conventional logs for 30 wells in Nasiriyah oilfield were used in this study to model the petrophysical properties of the reservoir and produce a 3D static geological reservoir model that mimics petrophysical properties distribution to estimate the stock tank oil originally in place (STOOIP) for Mishrif reservoir by volumetric method. Computer processed porosity and water saturation and a structural 2D map were utilized to construct the model which was discretized by 537840 grid blocks. These properties were distributed in 3D Space using sequential Gaussian simulation and the variation in OWC depth was represented by 3 initialization regions for better characterization. The total STOOIP of Mishrif reservoir in Nasiriyah oilfield was estimated to be 8951 MMSTB which is divided between two reservoir units: MB1 and MB2 in which the first contains approximately 75% of total STOOIP and the latter has the remaining 25%.

Keywords—: Mishrif reservoir, Nasiriyah oilfield, geological modelling, resource estimation.

1. Introduction

Hydrocarbon in-place is the parameter that dominates the decision-making process in which it determines whether the discovered reservoir is profitable or not [4],[6],[10]-[11]. The most widely used resource estimation approach is the volumetric method which depends mainly on Reservoir fluid and rock properties. Despite being simple in terms of implementation, a lot of uncertainties cover this approach which requires modellers with considerable experience in the study area as well as high quality static and dynamic data to reduce these uncertainties as much as possible. The main goal of this work is to construct a 3D static geological model for Mishrif reservoir in Nasiriyah oilfield that represents the spatial properties distribution of the reservoir in which oil resource and modelled oil-water contact (OWC) depth values were the main outcomes of this model.

1.1 *Field of Study*

Nasiriyah oilfield is located in the Mesopotamian Zone which is oriented in NW-SE direction and extends across the plains of the Euphrates & Tigris valleys, about 38 km northwest of Thi Qar city as shown in **Figure (1)**. The field dimensions are (34 x13) Km and it is of slightly inclined fold towards Northeast-southwestern (1^o-2^o) [14] The field was discovered by seismic surveys conducted by the Iraqi National Oil Company in 1975. The first exploration well Ns-1 was drilled in 1978 which proved the existence of oil in (Mishrif, Yamama, Nahr-Umr) formations, correspondingly weak oil shows were found in Zubair formation. The actual production from the field started in August 2009 from three wells.

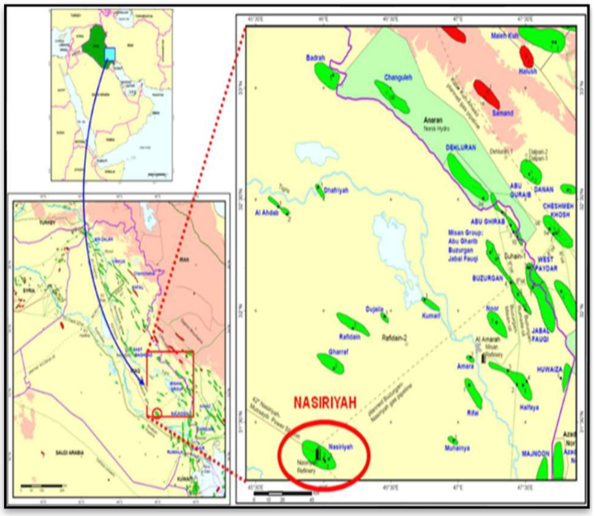

Figure 1: Field location

1.2 *Mishrif Geological Overview*

The early cretaceous Mishrif formation is a heterogeneous organic detrital limestone formation with beds of rudist, algal, and coral-reef which is capped by freshwater limestones [7]. In Nasiriyah oil field, the average thickness is about 180 m as the depth is in the range between 1902 and 2100 m SSL. It is characterized by fine to coarse bioclastic limestone's deposited in a shallow depositional domain. It can be subdivided into two major units the upper one is MA and the lower is MB separated by a 10-12 m thick shale layer. The MB unit is the oil-bearing section of the reservoir and is characterized by a gross thickness of approximately 110 m [13]. The Mishrif formation can be further divided into five main units (from latest to oldest) [9] :

- **CapRock Unit (CR. I)**

It is the upper part of Mishrif formation which consists mainly of clay-limestone. It represents a good seal due to its very low porosity and permeability which can be defined as a caprock.

- **Upper Mishrif (MA)**

It is an important reservoir in southern Iraqi oil fields other than Nasiriyah where this unit is saturated with water. Despite its good porosity of 17%, it is poorly permeable due to its deteriorated facies.

- **Continental Shale Unit (CR. II)**

This unit is located at the bottom of unit MA and it can be distinguished by Gamma Ray (GR) and acoustic logs response through the high readings of these logs. It acts as a barrier between the upper and lower Mishrif reservoir, the average thickness of this unit is about (11 m) along the Nasiriyah oil field.

- **MB1**

It is the main important reservoir unit, it has very good reservoir properties in which its average porosity is 20%. The upper part of this unit consists mainly of fossilized bioclastic Rudest-rich limestone, molluscs, algae and some corals.

- **MB2**

This unit represents a transitional part (Rumaila- Mishrif) where oil accumulation only exists in the upper part of the unit. It is of shallow organic lagoonal facies which gave it poor petrophysical characteristics, especially in the lower part. Both reservoir units MB1 and MB2 are connected since no barrier layer existed between them.

2. Methodology

The method of this work similarly utilizes SLB Petrel to that described by Suhail et al. [12] in **Figure (2).** The model is constructed by discretizing the area covered by the structural 2D maps and petrophysical properties obtained by interpreting well log data in interactive petrophysics (IP 2019) software.

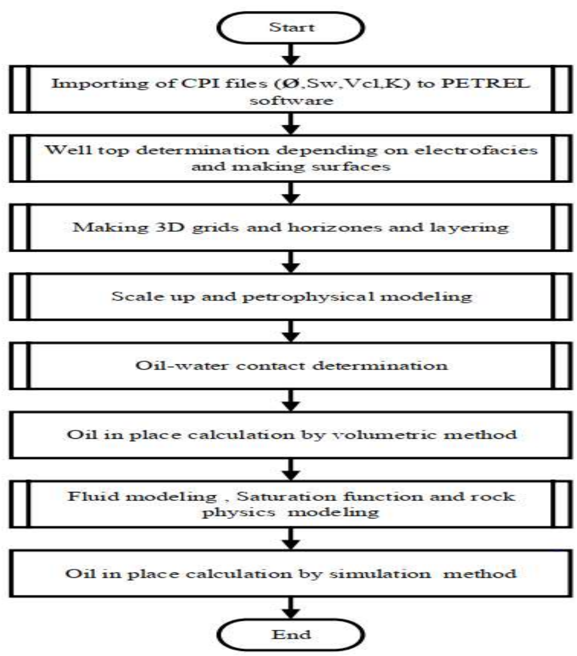

Figure 2: Research methodology [12]

Clay volume was calculated from Gamma-ray logs and the combination of neutron and density logs were used to calculate total porosity while water saturation is acquired using Archie's equation. **Table (1)** shows the Parameters used to calculate the CPI properties. In which effective porosity was calculated by the following equation:

$$\varphi_e = \varphi_t \times (1 - V_{sh})$$

Where φ_e and φ_t are effective and total porosities respectively while V_{sh} is shale volume which is calculated by an empirical equation for old rocks [2] in which I_{Gr} is the gamma-ray index:

$$V_{sh} = 0.33 \times (2^{2\times I_{Gr}} - 1)$$

Table 1: Parameters used for formation evaluation

R_w (Ω.m)	a	m	n
0.022	1	2.06	2.43
Gr_{max} (API)	Gr_{min} (API)	Φ_{Nsh} (%)	ρ_{matrix} (g/cc)
75-100	5-10	40-45	2.71

Among the geometric and harmonic averaging methods, the arithmetic average is preferred for water saturation and porosity upscaling [8] which was applied in this study to preserve the vertical petrophysical properties variation during 3D modelling. Then these upscaled properties were distributed in 3D using sequential Gaussian simulation (SGS). The net-to-gross ratio was calculated for each grid block by first calculating the NTG ratio log from porosity and water saturation logs through cutoff values imposed in this study (φ_{cutoff}=5.6%, Sw_{cutoff}=75%). Then this NTG log is upscaled to the 3D model layers and is distributed in 3D space through SGS which is biased to porosity. Finally, the fluids contacts were represented which enabled the calculation of STOOIP for each grid block in the model.

3. Results and Discussion

Each step mentioned in section 2 has its corresponding results as they contribute to volumetric calculations of the hydrocarbon resources. The following subsections show the results of each step in constructing the static model and calculating STOOIP.

3.1 *Structural Modeling*

Modelling the reservoir structure is the first step in the workflow and probably the most crucial in terms of representing the large-scale geology of a field [3]. Basically, it requires a structural map of the reservoir which is the only information available from seismic data in this study which was updated from well tops. **Figure (3)** shows the updated structural contour map of the top of Mishrif formation while **Figure (4)** is a well correlation section.

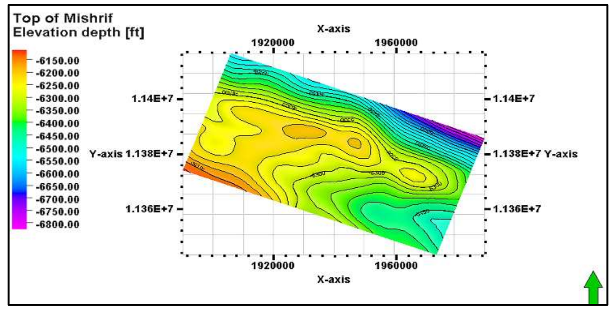

Figure 3: Structural contour maps for tops of Mishrif formation (coordinates are in feet)

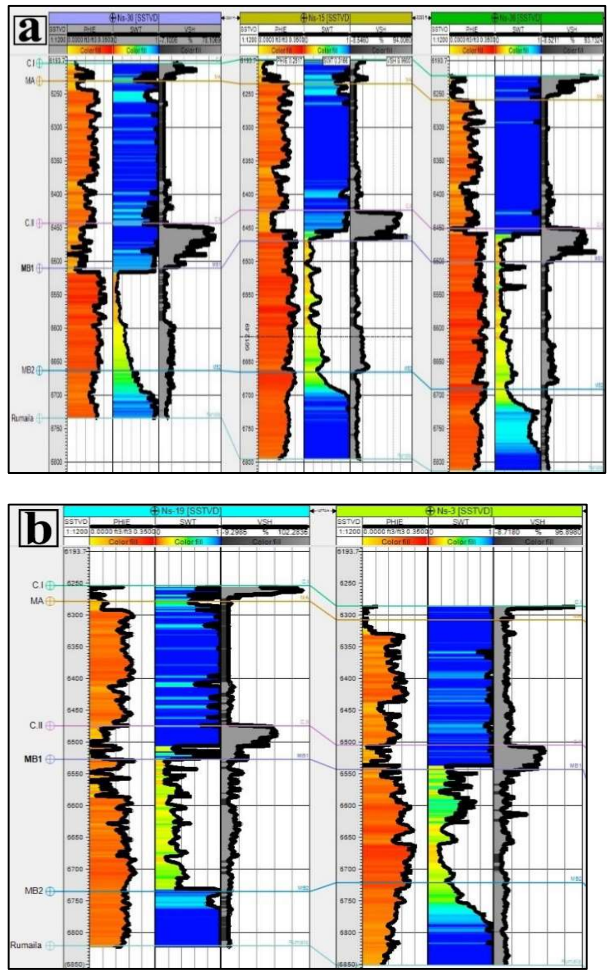

Figure 4: well correlation section (depth in feet) for wells: (a) Ns-30, Ns-15 and Ns-38;(b): Ns-19 and Ns-3

3.2 *Gridding and Layering*

A 162x82x40 with 537840 total grid blocks model was constructed represent the reservoir properties. Grid size varies across the reservoir with more concentration of the developed area by wells in which finer grids were used to provide a computationally feasible model for dynamic reservoir simulation. **Figure (5)** shows the model 3D skeleton where details of its grid blocks dimensions are listed below:

1. X-axis: is discretized by 162 grid blocks, 145 are 150 x 150 m size for the region developed with the current wells and 300 x 300 m outside that region (8*300,144*150,10*300).

2. Y-axis: is discretized by 83 grid blocks, 74 are 150 x 150 m for the region developed with the current wells and 300 x 300 m outside that region (3*300,74*150,6*300).

3. Z-axis: is represented by 40 layers in which **Figure (6)** shows upscaled properties against the original logs.

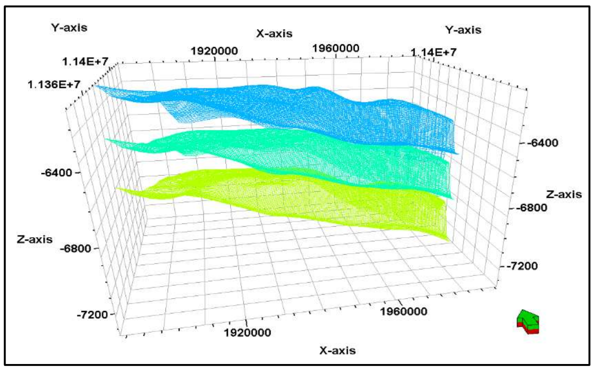

Figure 5: Reservoir gridding (coordinates are in feet)

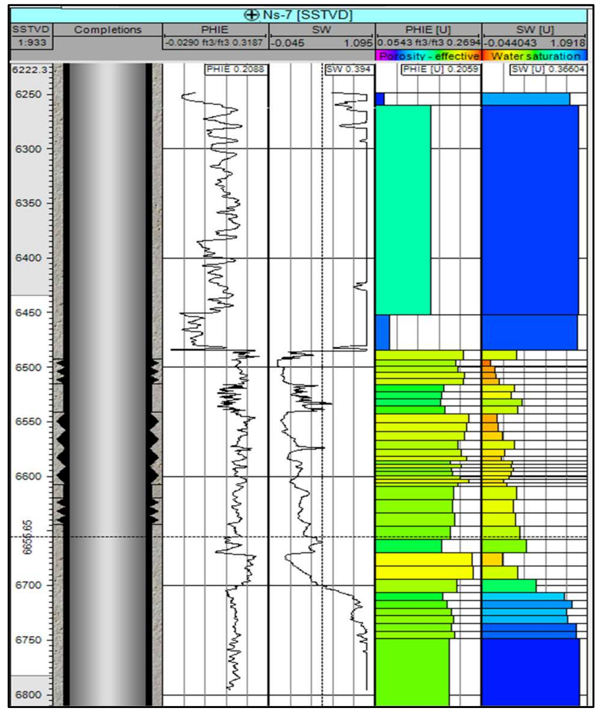

Figure 6: Upscaled properties against the original logs (depth is in feet)

3.3 *Property Modeling*

3D property modelling preserves property variation in the vertical direction and uses it to populate the inter-well volume through geostatistical methods [3]. In this study, the SGS algorithm is used for this purpose because it’s simple, reasonably efficient and flexible [5]. Among all of the important petrophysical properties, effective porosity and water saturation are the main focus in 3D reservoir modelling [1] in which the following subsections show their modelling results along with NTG described in section 2 .

A. Porosity

As mentioned above SGS algorithm is used to distribute the arithmetically averaged upscaled property. In MB1, porosity looks normally distributed as in **Figure (7)** with a good average value of 21.46 % in which the main spatial trend of porosity for MB1 is the degradation in quality from north-west to north-east which is shown in **Figure (8)**. As for MB2, It follows the same trend of MB2, but with slightly lower values of porosity distribution as the average value is lower by 31.13% than that of MB1, refer to **Figure (9)** and **Figure (10)**.

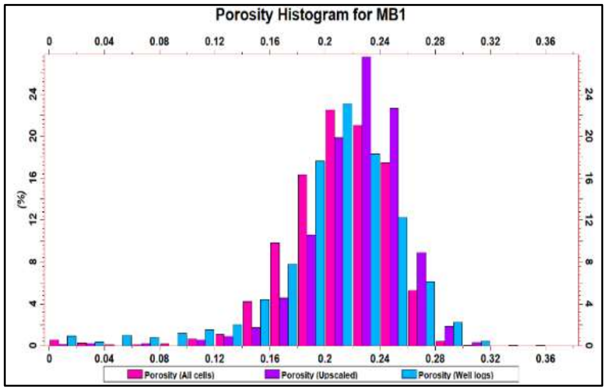

Figure 7: Porosity histogram in MB1

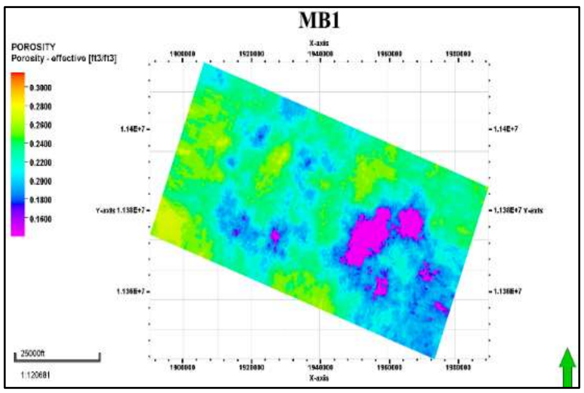

Figure 8: Porosity distribution for the top of MB1 (coordinates are in feet)

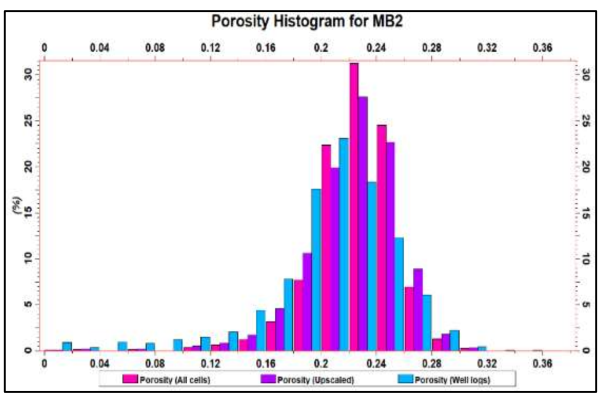

Figure 9: Porosity histogram for MB2

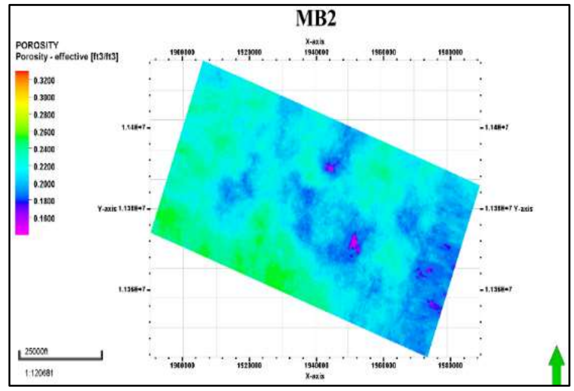

Figure 10: Porosity distribution for the top of MB2

B. Water Saturation

Similarly, water saturation is also modelled in 3D for each grid block. Statistically, MB1 has the highest contribution to oil resource indicated in **Figures (11&12)** followed by MB2 in which **Figures (13&14)** indicate that it is mostly saturated with water whereas the geological description and well logs show that the other units are none reservoir units.

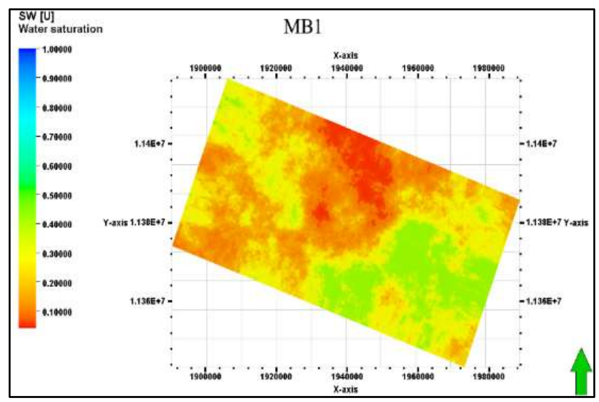

Figure 11: water saturation distribution for the top of MB1 (coordinates are in feet)

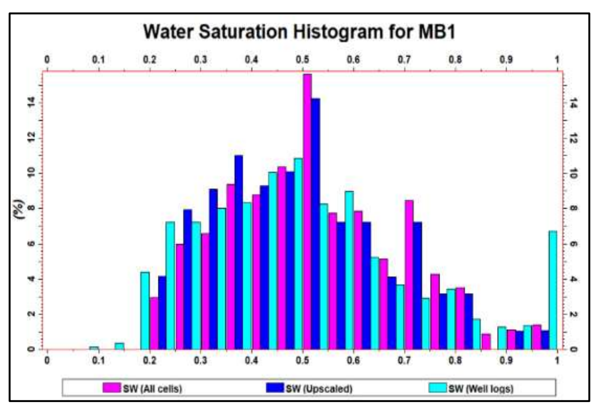

Figure 12: water saturation histogram in MB1

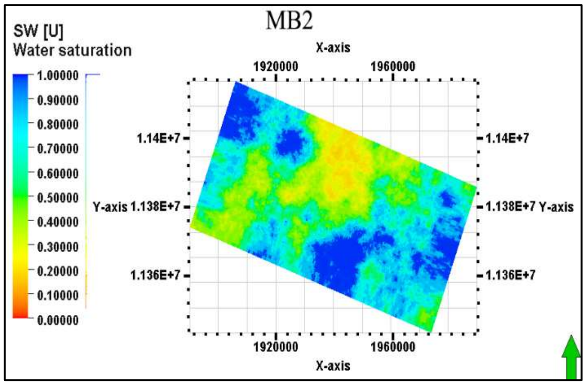

Figure 13: Water saturation distribution for the top of MB2 (coordinates are in feet)

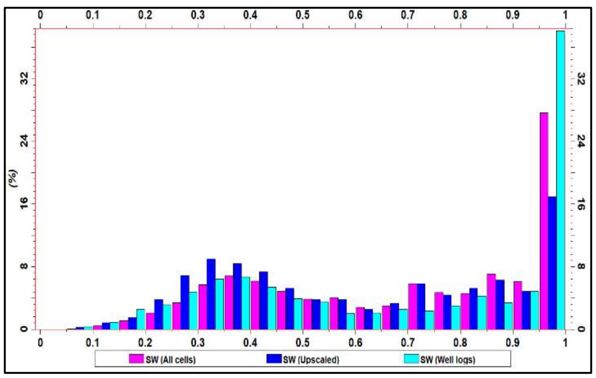

Figure 14: water saturation histogram in MB2

A. Net-To-Gross Ratio

As in section 2, **Figures (15 - 18**) show the 3D distribution of this property and its statistics. This distribution clearly distinguishes oil zones in Mishrif reservoir to be MB1 and MB2 which enables creating a representative model.

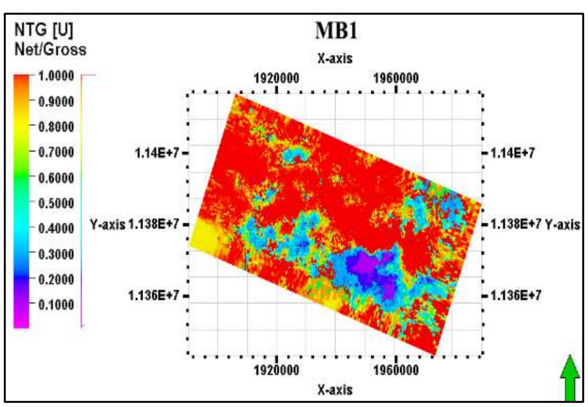

Figure 15: NTG distribution for the top of MB1 (coordinates are in feet)

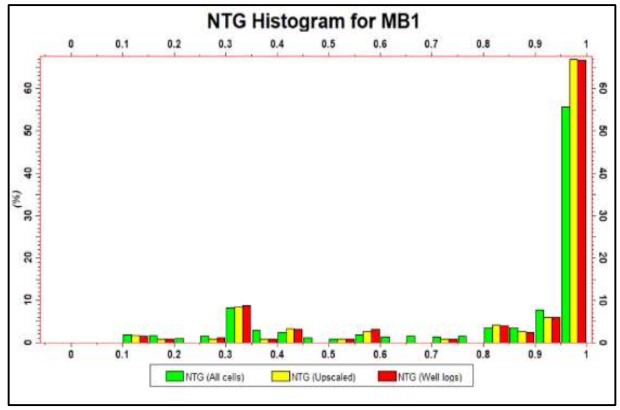

Figure 16: NTG histogram in MB1

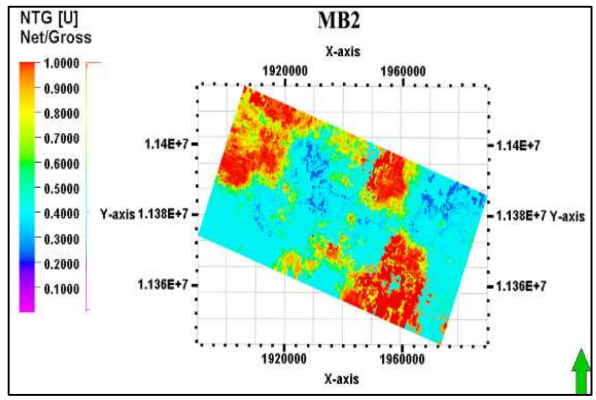

Figure 17: NTG distribution for the top of MB2 (coordinates are in feet)

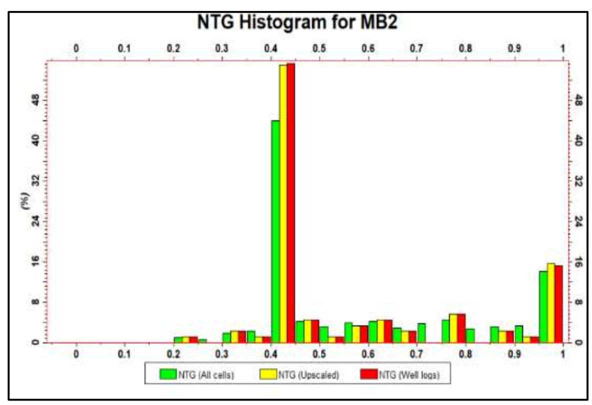

Figure 18: NTG histogram in MB2

3.4 *OWC Representation*

Figure (19) shows OWC depths taken from sea level for 30 wells with available CPI, it is shown that there is a difference in OWC between wells in the reservoir. To model this variation, 3 Initialization regions illustrated in **Figure (20)** each were assigned OWC value representing the average of OWC for wells bounded by that region.

These values are 2046m, 2050m, 2060m from north-west to south-east.

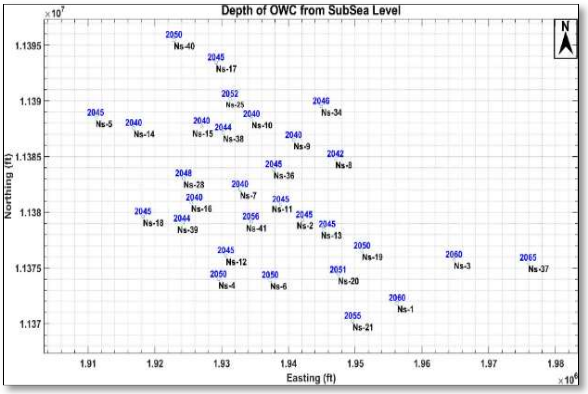

Figure 19: OWC depth (m) distribution in the drilled wells measured from sea level.

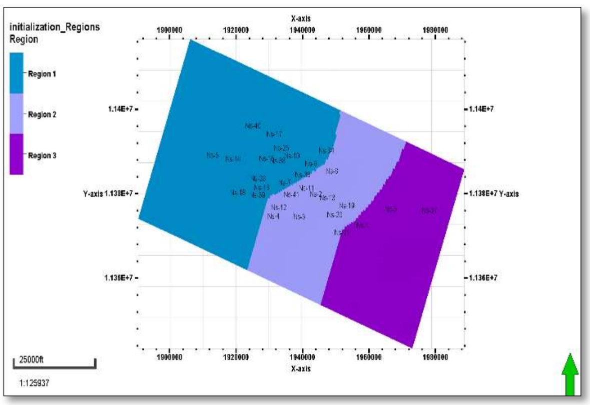

Figure 20: OWC values implemented in the model (coordinates are in feet)

3.5 *STOOIP Calculations*

After conducting the above workflow, the next step is to calculate STOOIP using the volumetric approach in which the total STOOIP for Mishrif reservoir in Nasiriyah oilfield is 8951 MMSTB where MB1 unit contributes to 75% (6384 MMSTB) while MB2 has 25% of total oil resource. **Table (2)** is a comparison of STOOIP calculated in this study and the previous field studies [13]

Table 2: STOOIP comparison with previous studies

Study	STOOIP (MMSTB)
SOC 2003	14779
ENI 2007	7518.7
NIPPON 2008	6756
S. Wali 2020	7945
This work	8951

4. Conclusion

A 3D static Geocelluar model was established to represent petrophysical properties variation in space and to calculate STOOIP the following points are the main results of the study:

1. The total STOOIP of Mishrif reservoir in Nasiriyah oilfield was estimated to be 8951 MMSTB. The model shows that MB1 contains approximately 75% of the total reserve while the remaining 25 % is found in MB2.
2. OWC depth was shown to be variable from well to well across the reservoir. An approach was suggested to represent this variation by 3 initialization regions each region is assigned an average OWC depth for wells bounded by it.

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Nomenclature

V_{sh}	Shale volume
I_{Gr}	Gamma-ray index
a	tortuosity
m	Cementation factor
n	Saturation exponent

Greek symbols

φ	porosity (%)
ρ	density (g/cc)

Subscripts

sh	shale
e	effective
t	total

Abbreviations

STOOIP	Stok tank oil originally in place
SGS	Sequential Gaussian simulation
OWC	Oil-water contact
GR	Gamma-ray
NTG	Net-to-gross

النمذجة الجيولوجية وتقدير الموارد لتكوين مشرف في حقل الناصرية النفطي

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الخلاصة – يعد تقدير الخزين النفطي جزءًا أساسيًا من تقييم المكمن و وضع خطط التطوير الذي يؤثر بشكل كبير على عملية صنع القرار. تم استخدام السجلات التقليدية المتوفرة لـ 30 بئراً في حقل نفط الناصرية في هذه الدراسة لنمذجة الخصائص البتروفيزيائية للمكمن وعمل نموذج مكمني جيولوجي ثلاثي الأبعاد يحاكي توزيع الخواص البتروفيزيائية لتقدير الخزين النفطي (STOOIP) لمكمن المشرف بالطريقة الحجمية. تم استخدام مجسات المسامية وتشبع الماء المفسرة بالكمبيوتر وخريطة هيكلية ثنائية الأبعاد لإنشاء موديل جيولوجي يتكون من 537840 خلية. تم توزيع هذه الخصائص في مساحة ثلاثية الأبعاد باستخدام محاكاة غوسية متسلسلة وتم تمثيل التباين في عمق نقطة تماس النفط مع الماء (OWC) بثلاث مناطق. تم تقدير إجمالي STOOIP من مكمن مشرف في حقل نفط الناصرية بـ 8951 MMSTB مقسمة بين وحدتين مكمنين: MB1 وMB2 حيث تحتوي الأولى على ما يقرب من 75 ٪ من إجمالي STOOIP والأخيرة تحتوي على النسبة المتبقية 25 ٪.

الكلمات الرئيسية – مكمن المشرف، حقل الناصرية النفطي، النمذجة الجيولوجية، تقدير الموارد