The performance production analysis of Gialo Paleocene

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Abstract:

Production performance analysis is considered of the important tools of oil reservoir management. This can diagnosis many problems and obstacles early in time, which enable curing then problem in proper time in order to optimize oil production and maximize oil recovery. The performance production analysis of Gialo Paleocene reservoir is done through two parts. The first part of this study attempts to predict critical rate and post-breakthrough performance in vertical and horizontal wells as a result of water coning. The second part includes post breakthrough performance analysis in terms of the Water Oil Ratio (WOR). Gialo Paleocene reservoir studied to predict the oil critical rate, including the correlations of (Meyer-Garder Method, Hoyland-Papatzacos-Skjaeveland Method, Schols Method and Craft and Hawkins Method) in a vertical well and the correlations of (Efros Method, Karchers Method and Joshis Method) in a horizontal well. PVT and Relative permeability data for reservoir were used in the correlations. From result, the critical oil flow rate was calculated by four correlations given different values due to effect of permeability and the pressure depletion effect was neglected in three correlations (Meyer-Garder, Hoyland-Papatzacs-Skjaeveland, Schols). While in horizontal well, the correlations where given small values or inaccurate values for the critical oil rate due to the permeability effect and pressure depletion effect was neglected through the calculations. Finally of this study considers the use of plots of water/oil ratio versus time to diagnose excessive water production mechanisms. From result, Water production in all studied wells was classified based on cause of problem such as coning, channeling.

Keywords: Critical Oil Rate, Empirical Correlations, Production Performance Analysis, Water Channeling, Water Coning, WOR Diagnostic Plots.

الملخص:

يُعد تحليل أداء الإنتاج من الأدوات المهمة لإدارة مكامن النفط، حيث يمكن تشخيص العديد من المشاكل والعقبات في الوقت المناسب، مما يُمكّن من معالجة المشكلة في الوقت المناسب من أجل تحسين إنتاج النفط وزيادة استخلاصه. يتم تحليل إنتاج أداء مكمن جيالو الباليوسيني من خلال جزئين، في الجزء الأول من هذا البحث يتم التنبؤ بالمعدل الحرج والأداء بعد الاختراق في الآبار الرأسية والأفقية نتيجةً لتكوين الماء. بينما يتضمن الجزء الثاني تحليل أداء ما بعد الاختراق من حيث نسبة الماء إلى الزيت (WOR). لقد تمت دراسة مكمن جيالو الباليوسيني للتنبؤ بالمعدل الحرج للنفط، من خلال معدلات (طريقة ماير-غاردر، وطريقة هويلاند-باباتزاكوس-سكيفيلاند، وطريقة شولز، وطريقة كرافت وهوكينز) في بئر رأسي ومعدلات (طريقة إفروس، وطريقة كارشرز، وطريقة جوشيس) في بئر أفقي.

تم استخدام بيانات PVT والنفاذية النسبية للمكمن في المعادلات. ومن خلال النتائج، تم حساب معدل تدفق النفط الحرج من خلال أربعة معادلات أعطيت قيماً مختلفة بسبب تأثير النفاذية وتم إهمال تأثير استنزاف الضغط في ثلاثة معادلات (ماير-غاردر، هويلاند-باباتزاكس-سكيفيلاند، شولز). بينما في البئر الأفقي، اعطيت المعادلات قيم صغيرة أو قيم غير دقيقة لمعدل النفط الحرج بسبب تأثير النفاذية وتم إهمال تأثير استنزاف الضغط من خلال الحسابات. وأخيراً، تناول هذا البحث استخدام مخططات نسبة الماء إلى النفط مقابل الوقت لتشخيص آليات إنتاج المياه المفرطة. ومن خلال النتائج، تم تصنيف إنتاج المياه في جميع الآبار المدروسة بناءً على سبب المشكلة.

الكلمات المفتاحية: تحليل أداء الإنتاج، تكوّن المخروط المائي، التوجيه المائي، مخططات تشخيص نسبة الماء إلى الزيت، المعادلات التطبيقية، المعدل الحرج لإنتاج النفط.

1. Introduction

The Gialo Paleocene reservoir consists of three oil accumulations. The Main E Pool, the largest of these oil accumulations, lies in the southeast and was discovered in 1961. Up to March 2004, 44 wells have penetrated the accumulation and 33 are still completed in the reservoir. The second oil accumulation, the 4E Pool, was discovered in 1973. So far, only five wells have been drilled into this accumulation. Of these, one was D&A and one has been plugged and re-completed up-hole. A small accumulation between the Main E and the 4E Pools was discovered in 1985 with the drilling of well E289. This well penetrated the formation, but it was plugged back and re-completed up-hole after a short production period. This latter accumulation was not part of the project scope and has not been studied.

The Main E Pool is a structural trap in the Zelten Formation (limestone). The reservoir is delineated by faults and underlain by an aquifer that is believed to be common to all three oil accumulations. The Main E Pool was put on production in 1964. The main production mechanism is a bottom water drive with strong aquifer support. As of March 2004, a total of 27 wells were producing oil from within the Main E Pool at a rate of 17 MSTB/day and at a total field water-cut of 75%. Cumulative oil production to March 2004 was 157.6 MMSTB. This represents an overall recovery factor of 17.1% of the total OOIP of 923 MMSTB.

The 4E Pool was put on production in 1973. One well was a dry hole. Production from the four pool wells peaked at an oil rate of about 10,000 BOPD in early 1974 and then declined sharply to 500 BOPD in 1977 due to rapid water encroachment. As of March 2004, only 2 wells within the 4E Pool were still producing at a rate of 820 STB oil per day at a total water-cut of 88%. Cumulative oil production had reached 16.8 MMSTB. The estimated OOIP is about 72.8 MMSTB, resulting in a current oil recovery factor of about 23%.

2. Objectives of the Study

The performance production analysis of Gialo Paleocene reservoir is done through two parts:

- The first part of this study attempts to predict critical rate and post-breakthrough performance in vertical and horizontal wells as a result of water coning.

- The second part includes post breakthrough performance analysis in terms of the Water Oil Ratio (WOR).

3. Methodology of Study

- Reviewing Production history for each well in Gailo Paleocene reservoir.
- Calculate the Critical oil flow rate for each well.
- Compare between the critical oil flow rate and the actual oil rate for each well.
- Compare between WOR diagnostic plots and WOR plot for Chan. to determine the mechanism for excessive water production.

4. Result and Discussion

4.1. Vertical well study's

This study's includes production performance analysis for oil wells from gialo Paleocene reservoir concentrating on water production problem. The first step of this analysis was to investigate the critical production rate for the studied wells. This was done using empirical correlation as it has been mentioned in the following table 1;

Table (1): The calculating methodologies of critical production rate [1,2].

Methods	Formula	remark
Meyer Garder	$Q_{oc} = 0.246 \times 10^{-4}\left[\frac{\rho_o - \rho_g}{\ln(r_e/r_w)}\right]\left(\frac{k_o}{\mu_o B_o}\right)\left[h^2-(h-D_t)^2\right]$	isotropic
Hoyland-Papatzacs-Skjaeveland	$Q_{oc} = 0.924 \times 10^{-4}\frac{k_o(\rho_w - \rho_o)}{\mu_o\ B_o}\left[1-\left(\frac{h_P}{h}\right)^2\right]^{1.325} \times h^{2.238}\ [\ln\ (r_e)]^{-1.99}$	isotropic
Schols’	$Q_{oc} = 0.0783 \times 10^{-4}\left[\frac{(\rho_w - \rho_o)\ k_o\ (h^2 - h_p^2)}{u_o\ B_o}\right] \times \left[0.432 + \frac{3.142}{\ln(r_e/r_w)}\right](h/r_e)^{0.14}$	isotropic
Craft and Hawkins	$q_{oc} = \frac{0.00708 K_o h(P_{ws}^{'} - P_{wf}) \times PR}{\mu_o B_o \ln\left(\frac{r_e}{r_w}\right)}$ $PR = b^{'}\left[1 + 7\sqrt{\frac{r_w}{2b^{'}h}}\cos(b^{'} \times 90)\right]$	isotropic

4.2. Well by Well Analysis:

The wells of Gialo Paleocene reservoir (E-85, E-89, E-93, E-192, E-209, E-210) were all studied for critical rate analysis and diagnostic plots investigation.

4.2.1. WELL E-85

4.2.1.1. Well Data

Table (2): shown well and reservoir data for well E-85.

Factor	Symbol	Value
Effective oil permeability	Ko	61.3 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	80 ft
Perforated interval	hp	31 ft
Well pore radius	rw	0.292 ft
Drainage radius	re	

4.2.1.2. Production history of Well E-85

Well, E85 started production in July 1965 with good oil production rate 812 bbl/day and start oil production up to 1600 BOPD in October 1977 as shown in figure (1) due to ESP pump was installed in well, where in June 1981 the oil production decline to 900 BOPD due to increasing water cut to 58 %. The oil rate subsequently declined until it reached 250 BOPD in late 2010 due to increasing water cut to about 91% as shown in Figure (1).

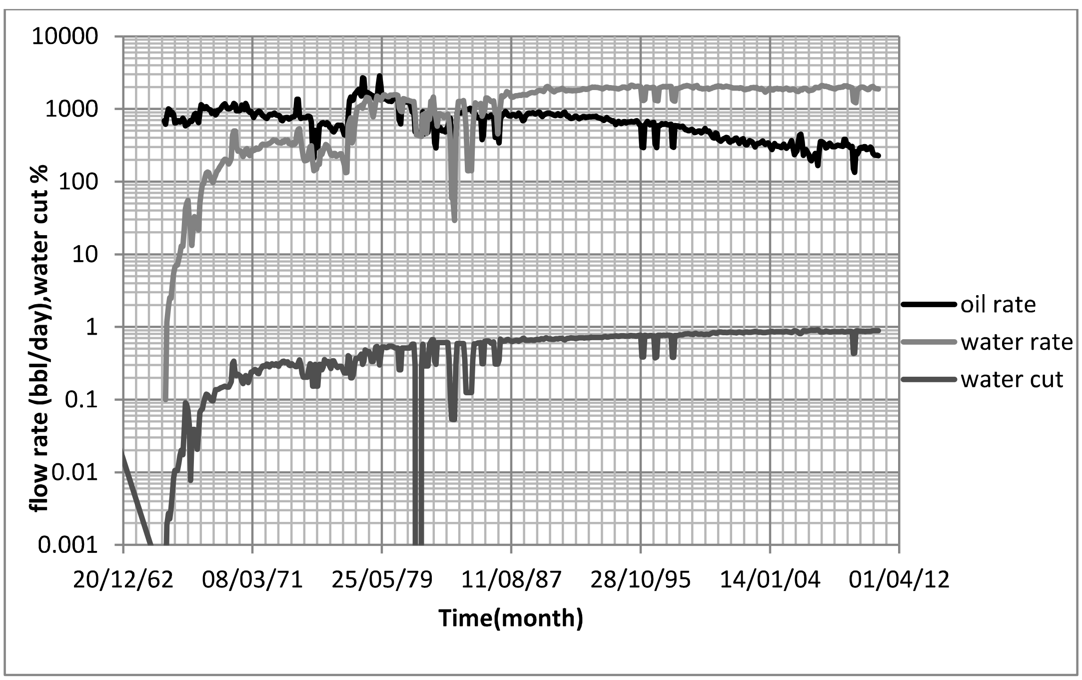

Fig (1): shows production history for well E-85.

4.2.1.3. Calculate the Critical oil flow rate of Well E-85.

Table (3) Shows the critical oil rate for well E-85.

Method	value
Meyer Garder	Qoc=23 bbl/day
Hoyland-Papatzacs- Skjaeveland	Qoc=37 bbl/day
Schols’	Qoc=33 bbl/day
Craft and Hawkins	Qoc=1784 bbl/day

4.2.1.4. Results analysis of Well E-85.

This table 3 shows the results of the critical oil flow rate for well E-85 by four correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Meyer-Garder, Hoyland-Papatzacs Skjaeveland and Schols). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (23 to 37) BOPD. These figures are considered unrealistic due to the actual high productivity of this well where result of Craft and Hawkins was considered good result compared with actual oil rate due to considering the effect of pressure depletion in the calculation.

4.2.1.5. Compare between the critical rate and the actual liquid rate of Well E-85.

As it is shows in figure (2) comparison between the critical oil flow rate and the actual liquid rate showed, at start of well production in 1965 rate was under the critical rate, at 1977 the actual liquid rate increased above the critical rate with increases in water cut, the actual liquid rate decline at 1981 lower than critical rate with decreases in water cut and at 1986 the actual liquid rate rise again above the critical rate with high water cut value and high water production rate continues to 2010.

In general, well E-85 was produced most time with production rate that is higher than it is critical rate.

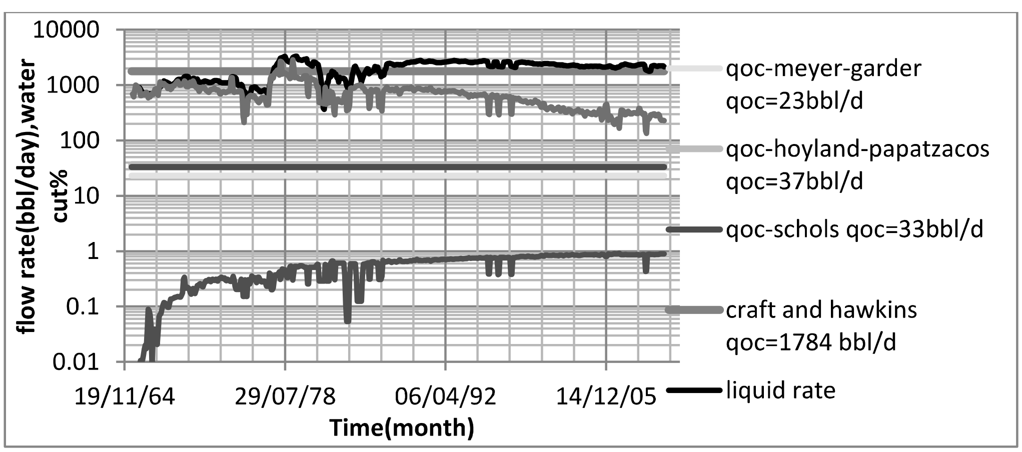

Fig (2): shows compare between the critical rate and actual liquid rate for well E-85.

4.2.1.6. Compare between WOR diagnostic plots and WOR plot for chan of Well E-85.

In order to further investigate the water production problem in well E-85 the technique of water diagnostic plots as presented by chan was applied.

The diagnostic plot fig (3) shows a jump from 100 to 7000 days (about from three month to twenty-three years from start of well production) within a general upward trend on both WOR and WOR". This was interpreted as rapid channeling with production changes through a formation layer. And at 7000 to 10000 days (about from twenty-three to thirty-two years from start of well production) a general downward on both WOR and WOR". This was interpreted as coning through the well completion. And after 10000 to 14400 days (about from thirty-two years to forty-five years from start of well production) was interpreted as rapid channeling through a formation layer.

In general, the water production problem in this well appears as result of combination of channeling and coning.

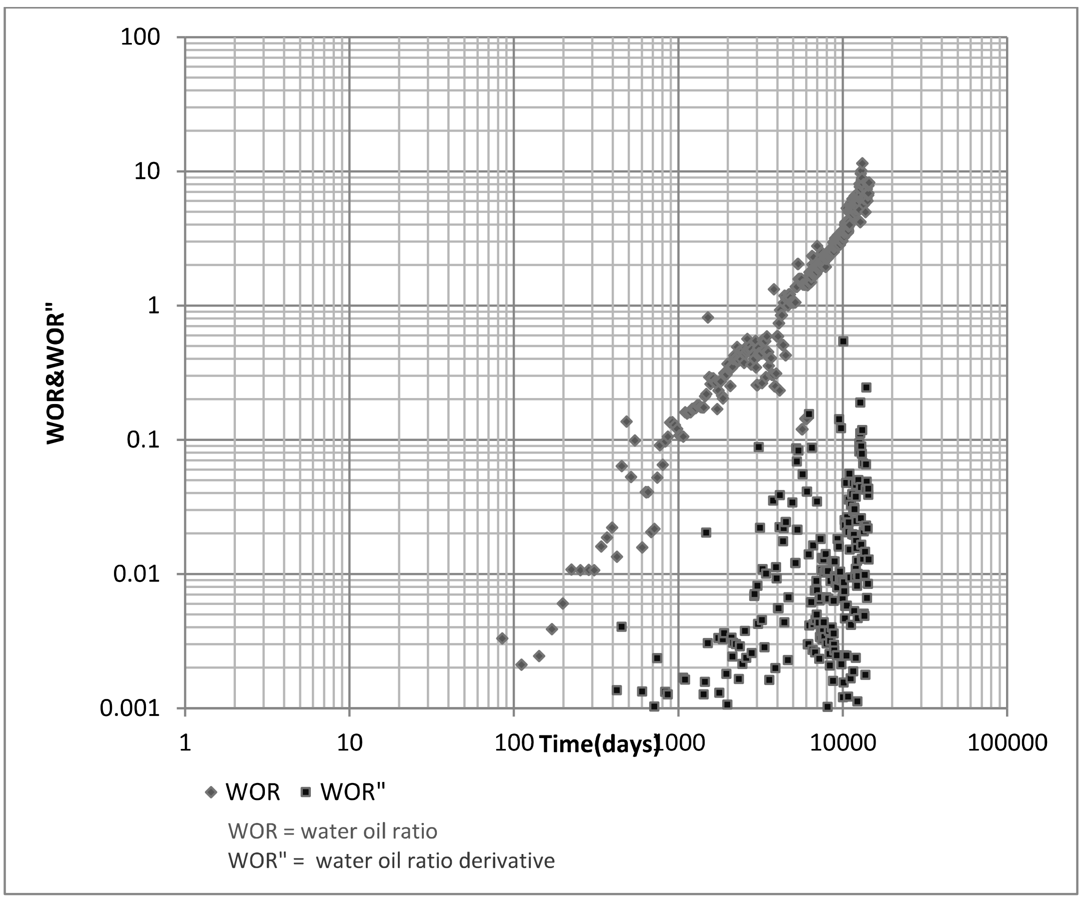

Fig (3): shows (WOR) diagnostic plots for well E-85.

4.2.2. WELL E-89

4.2.2.1. Well Data

Table (4): shows well and reservoir data for well E-89.

Factor	Symbol	Value
Effective oil permeability	Ko	42 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	97 ft
Perforated interval	hp	15 ft
Well pore radius	rw	0.292 ft
Drainage radius	re	

4.2.2.2. Production history of Well E-89

Well E-89 was started production in June 1965 with good oil production rate 1100 BOPD and start oil production up to 4000 BOPD in December 1977 as shown in figure (5.4) due to pump was installed in well, where oil production decline to 1600 BOPD due to increasing water cut to 50 % in May 1990. The oil rate subsequently declined until it reached 500 BOPD in late 2010 due to increasing water cut to about 78% as shown in (Figure (4)).

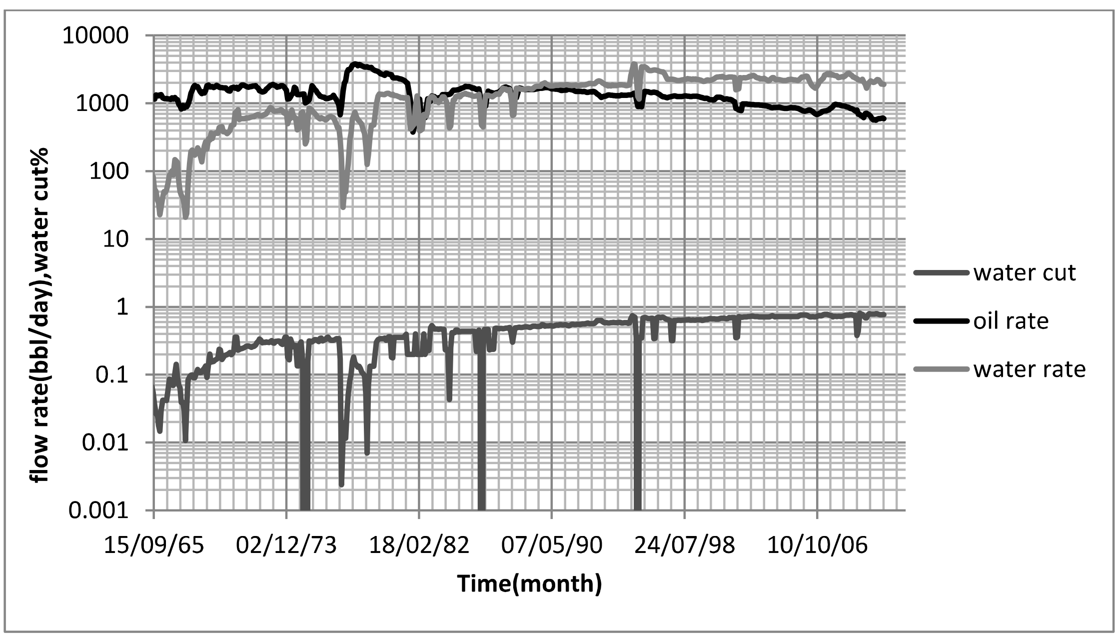

Fig (4): shows production history for well E-89.

4.2.2.3. Calculate the Critical oil flow rate of Well E-89.

Table (5): Shows the critical oil rate for well E-89.

Method	value
Meyer Garder	Qoc=27 bbl/day
Hoyland-Papatzacs- Skjaeveland	Qoc=47 bbl/day
Schols'	Qoc=39 bbl/day
Craft and Hawkins	Qoc=630 bbl/day

4.2.2.4. Results analysis of Well E-89

This table shows the results of the critical oil flow rate for well E-89 by four correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Meyer-Garder, Hoyland-Papatzacs Skjaeveland and Schols). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (27 to 47) BOPD. These figures are considered unrealistic due to the actual high productivity of this well where result of Craft and Hawkins was considered good result compared with actual oil rate due to considering the effect of pressure depletion in the calculation.

4.2.2.5. Compare between the critical oil rate and the actual liquid rate of Well E-89.

As it shows in figure (5) comparison between the critical oil rate and the actual liquid rate showed, at start of well production in June 1965 rate was above the critical rate. The water cut subsequently increased until it reached 76% in late 2010 due to increasing the water production as shown in (Figure (5)).

In general, well E-89 was produced most time with production rate that is higher than it is critical rate.

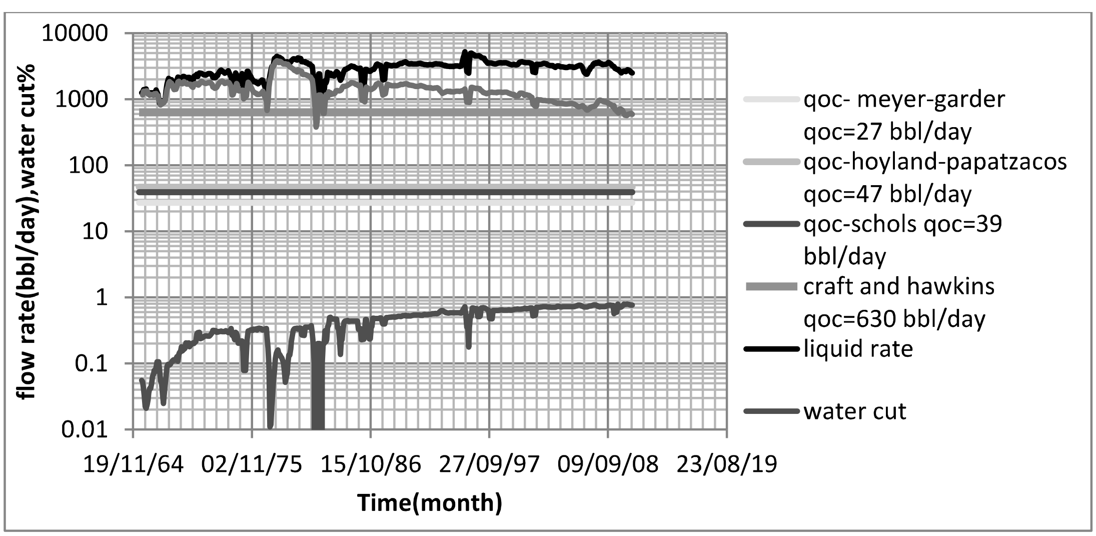

Fig (5): shows compare between the critical rate and actual liquid rate for well E-89

4.2.2.6. Compare between WOR diagnostic plots and WOR plot for chan of Well E-89

In order to further investigate the water production problem in well E-89 the technique of water diagnostic plots as presented by chan was applied.

The diagnostic plot fig (6) shows bottom water drive coning problem in Well E89.

In general, the water production problem in this well appears as a result of coning.

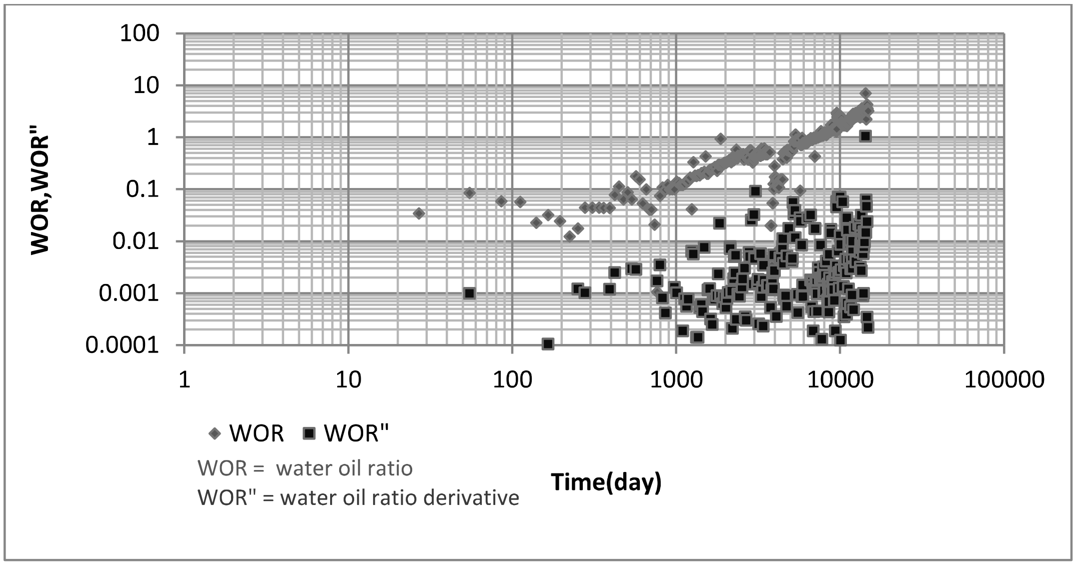

Fig (6): shows (WOR) diagnostic plots for well E-89.

4.2.3. WELL E-93

4.2.3.1. Well Data

Table (6): shows well and reservoir data for well E-93.

Factor	Symbol	Value
Effective oil permeability	Ko	44 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	81 ft
Perforated interval	hp	10 ft
Well pore radius	rw	0.292 ft
Drainage radius	re	

4.2.3.2. Production history of Well E-93

Well E-93 was started production in January 1966 with oil production rate 645 BOPD and start oil production up to 2400 BOPD in February 1978, the oil rate subsequently declined until it reached 100 bbl/day in late 2000 due to increasing water cut to about 94% as shown in (Figure (7)). And production rate was shut in from may in 2000 to February in 2002. Oil production rose again to 360 BOPD in 2003. The oil rate subsequently declined until it reached 75 BOPD in late 2010 due to increasing water cut to about78% as shown in (Figure (7)).

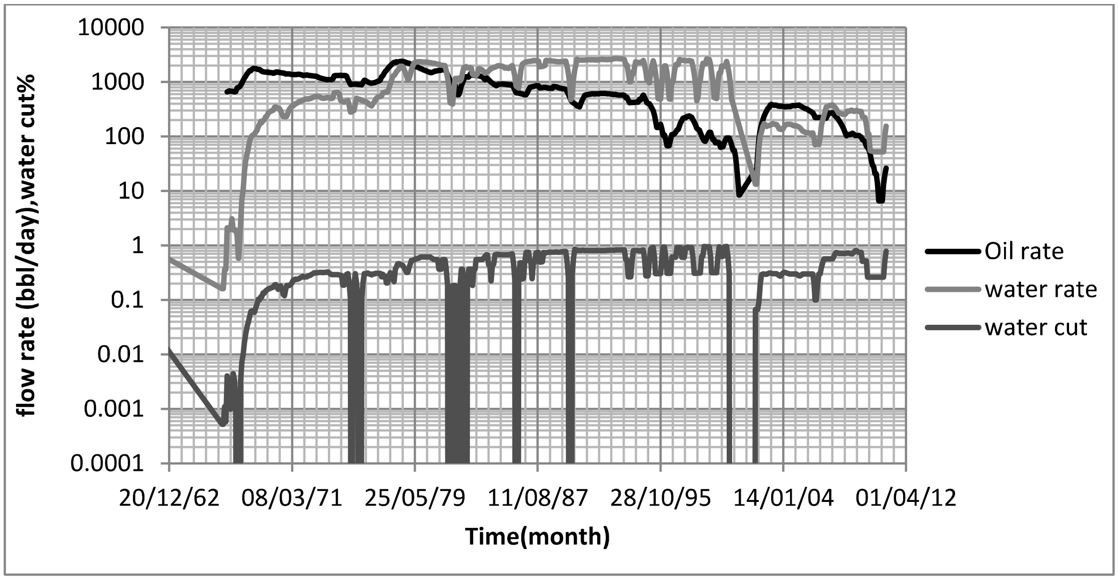

Fig (7): shows production history for well E-93.

4.2.3.3. Calculate the Critical oil flow rate of Well E-93

Table (7): Shown the critical oil rate for well E-93.

Method	value
Meyer Garder	Qoc=20 bbl/day
Hoyland-Papatzacs- Skjaeveland	Qoc=34 bbl/day
Schols'	Qoc=28 bbl/day
Craft and Hawkins	Qoc=409 bbl/day

4.2.3.4. Results analysis of Well E-93

This table shows the results of the critical oil flow rate for well E-93 by four correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Meyer-Garder,Hoyland-Papatzacs Skjaeveland and Schols). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (20 to 34) BOPD. These figures are considered unrealistic due to the actual high productivity of this well where result of Craft and Hawkins was considered good

result compared with actual oil rate due to considering the effect of pressure depletion in the calculation.

4.2.3.5. Compare between the critical rate and the actual liquid rate of Well E-93

As it shows in figure (8) comparison between the critical oil rate and the actual liquid rate showed, at start of well production in January 1966 rate was above the critical rate and from 2009 to 2010 the actual liquid rate decreased below the critical rate with decreasing water cut to about 76% as shown in (Figure (8)).

In general, well E-93 was produced most time with production rate that is higher than it is critical rate.

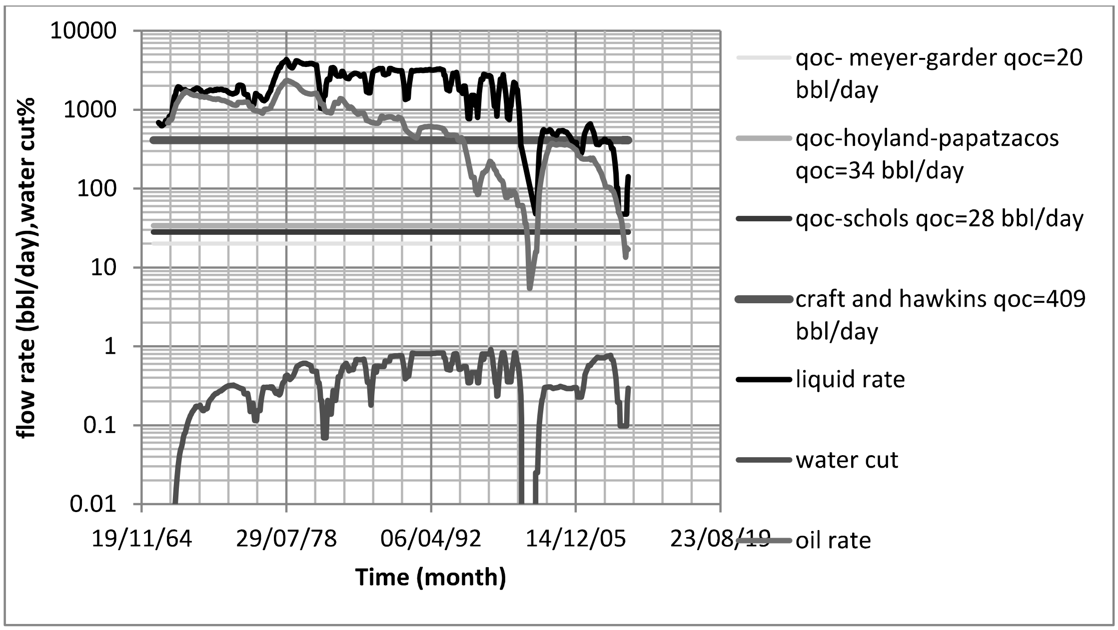

Fig (8): shows compare between the critical rate and actual liquid rate for well E-93.

4.2.3.6. Compare between WOR diagnostic plots and WOR plot for chan of Well E-93

In order to further investigate the water production problem in well E-93 the technique of water diagnostic plots as presented by Chan was applied.

The diagnostic plot fig (5.9) shows a jump after 700 to 4000 days (about from two to twelve years from start of well production) a general downward on both WOR and WOR". This was interpreted as bottom water drive coning through the well completion. And after 4000 days (about twelve years from start of well production) within a general upward trend on both WOR and WOR". This was interpreted as rapid channeling through a formation layer. In general, the water production problem in this well appears as result of combination of channeling and coning.

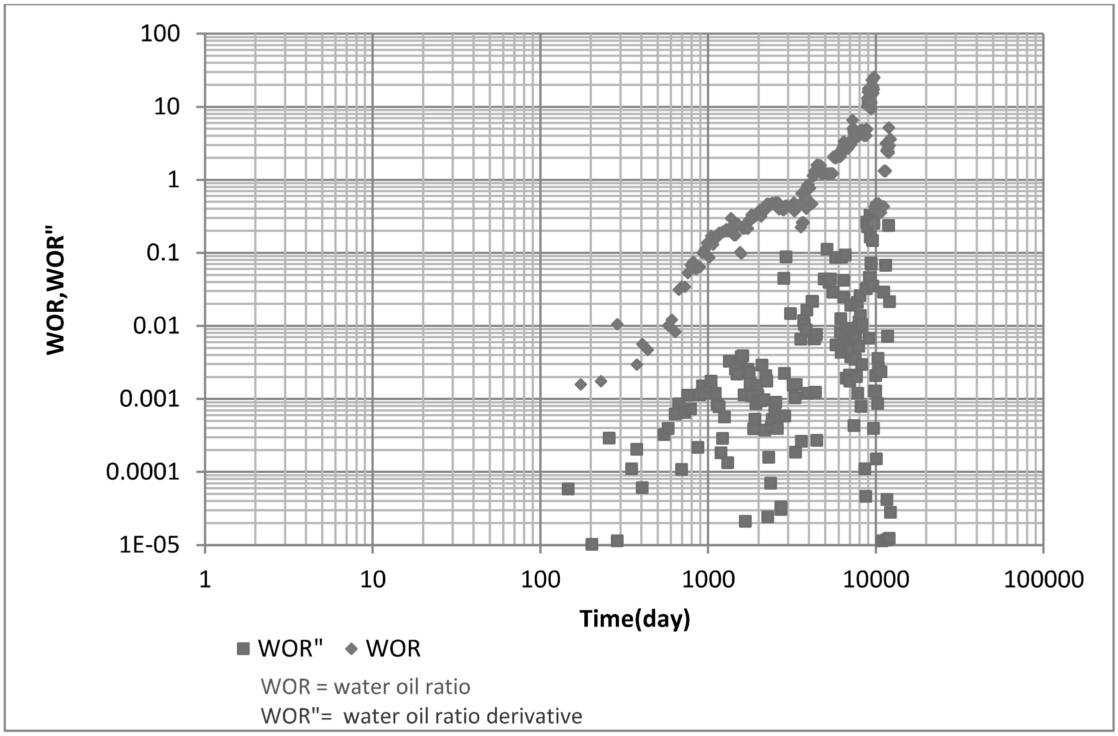

Fig (9): shows (WOR) diagnostic plots for well E-93.

4.2.4. WELL E-192

4.2.4.1. Well Data

Table (8): shows well and reservoir data for well E-192.

Factor	Symbol	Value
Effective oil permeability	Ko	62 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	87 ft
Perforated interval	hp	46 ft
Well pore radius	rw	0.292 ft
Drainage radius	re	1766 ft

4.2.4.2. Production history of Well E-192

Well E-192 was started production in November 1974 with good oil production rate 2000 BOPD and start oil production up to 3000 BOPD in May 1978.The oil rate subsequently declined until it reached 680 BOPD in late 1992 With water cut about 34% as shown in (Figure

(5.10)). Oil production rose again to 1000 BOPD in 1996. The oil rate subsequently declined until it reached 390 BOPD in late 2010 due to increasing water cut to about 81% as shown in (Figure (10)).

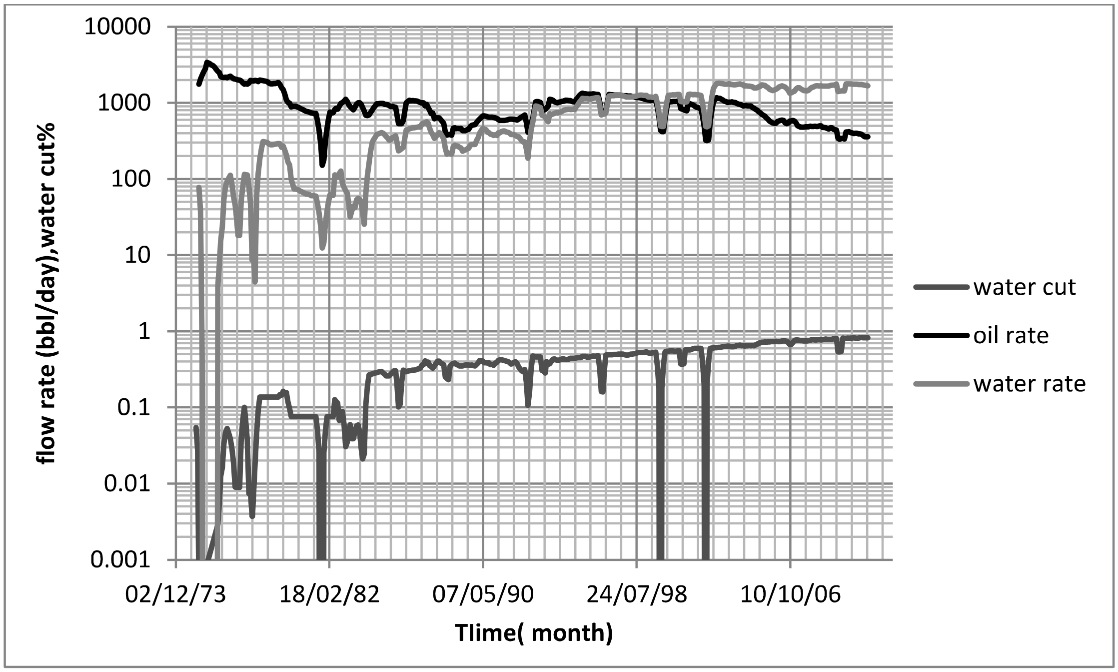

Fig (10): shows production history for well E-192.

4.2.4.3. Calculate the Critical oil flow rate of Well E-192

Table (9): Shows the critical oil rate for well E-192.

Method	value
Meyer Garder	Qoc=23 bbl/day
Hoyland-Papatzacs- Skjaeveland	Qoc=36bbl/day
Schols'	Qoc=34 bbl/day
Craft and Hawkins	Qoc=2044 bbl/day

4.2.4.4. Results analysis of Well E-192

This table shows the results of the critical oil flow rate for well E-192 by four correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Meyer-Garder, Hoyland-Papazians Skateland and Schols). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (23 to 36) BOPD. These figures are considered unrealistic due to the actual high productivity of this well where result of Craft and Hawkins was considered good result compared with actual oil rate due to considering the effect of pressure depletion in the calculation.

4.2.4.5. Compare between the critical rate and the actual liquid rate of Well E-192

As it shows in figure (11) comparison between the critical rate and the actual liquid rate showed, at start of well production in November 1974 rate was above the critical rate. The actual liquid rate subsequently decreased below the critical rate until late 1995 as shown in (Figure (11)). The actual liquid rate from 1995 until 2010 increased above the critical rate with high water cut.

In general, well E-192 was produced most time with production rate that is lower than it is critical rate.

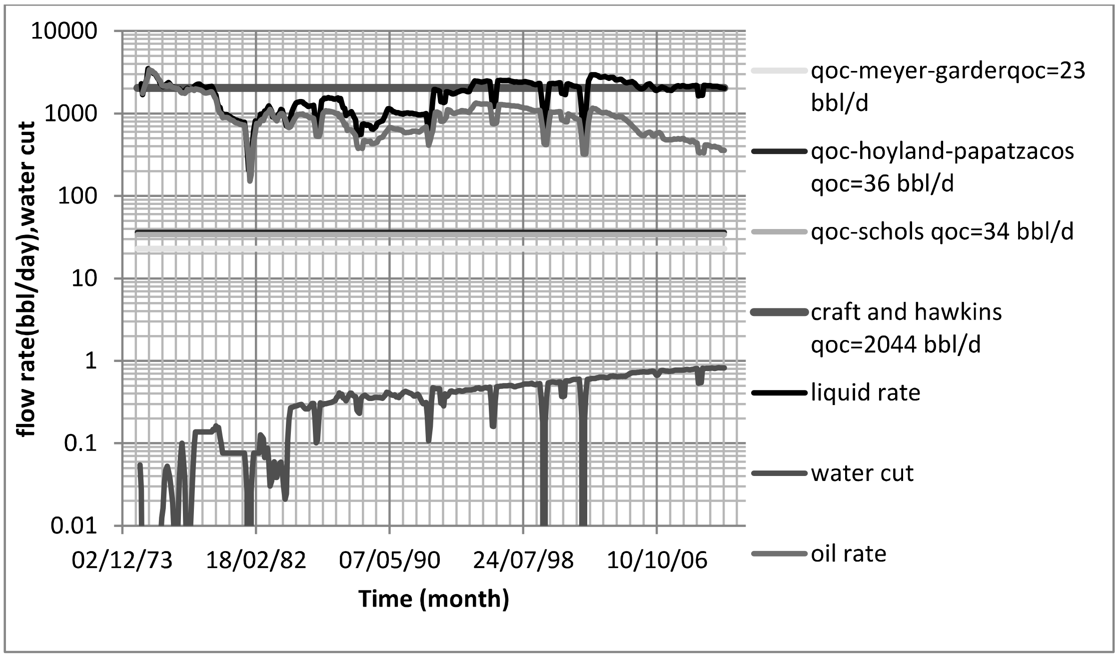

Fig (11): shows compare between the critical rate and actual liquid rate for well E-192.

4.2.4.6. Compare between WOR diagnostic plots and WOR plot for chan of Well E-192

In order to further investigate the water production problem in well E-192 the technique of water diagnostic plots as presented by Chan was applied.

The diagnostic plot fig (12) shows from 800 to 7000 days (about from two and halve to twenty-two years from start of well production) was interpreted as bottom water drive coning, and after 7000 to 12000 days (about from twenty-two to thirty-five years from start of well production) was interpreted as rapid Channel through a formation layer.

In general, the water production problem in this well appears as result of combination of channeling and coning.

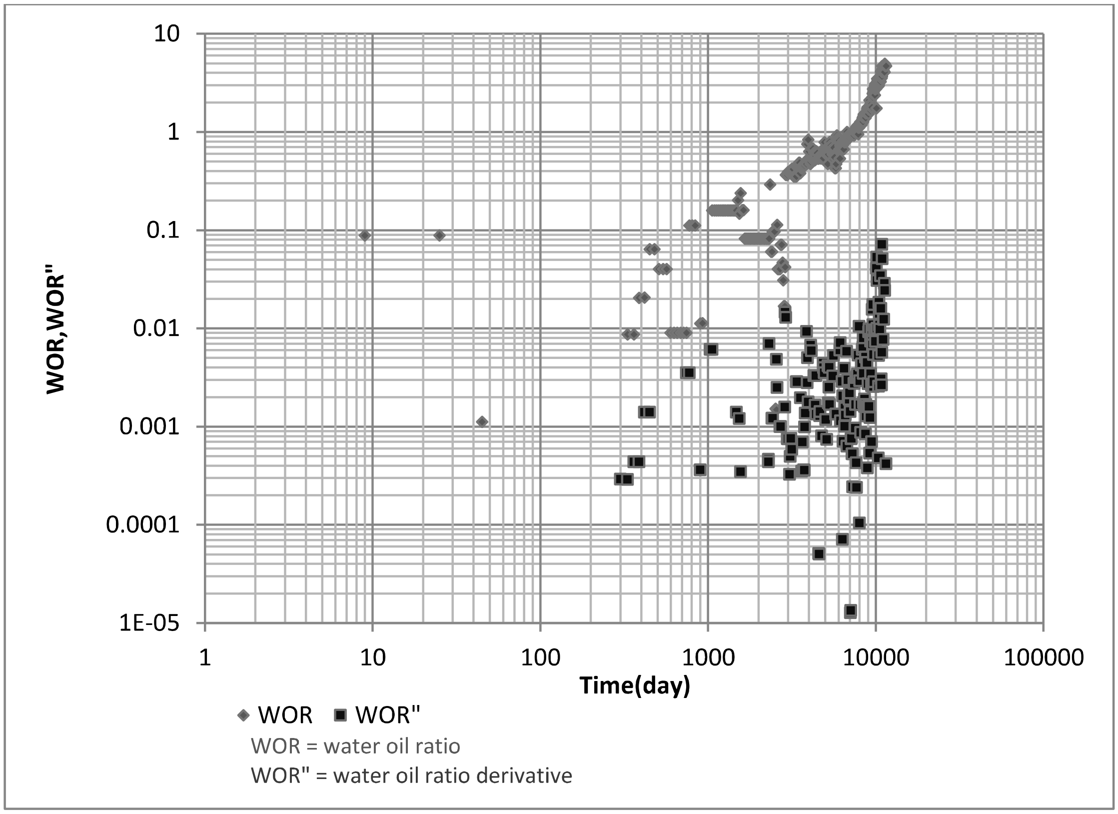

Fig (12): shows (WOR) diagnostic plots for well E-192.

4.2.5. WELL E-209

4.2.5.1. Well Data

Table (10): shows well and reservoir data for well E-209.

Factor	Symbol	Value
Effective oil permeability	Ko	114 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	113 ft
Perforated interval	hp	42 ft
Well pore radius	rw	0.292 ft
Drainage radius	re	1766 ft

4.2.5.2. Production history of Well E-209

Well, E209 was started production in April 1977 with good oil production rate 3530 BOPD, the oil rate subsequently declined until it reached 790 BOPD in late 1992 With water cut about 46% as shown in (Figure (13)) and the Oil rate rose again to 3250 BOPD in 1993. The oil rate subsequently declined until it reached 800 BOPD in late 2010 due to increasing water cut to about 78% as shown in (Figure (13)).

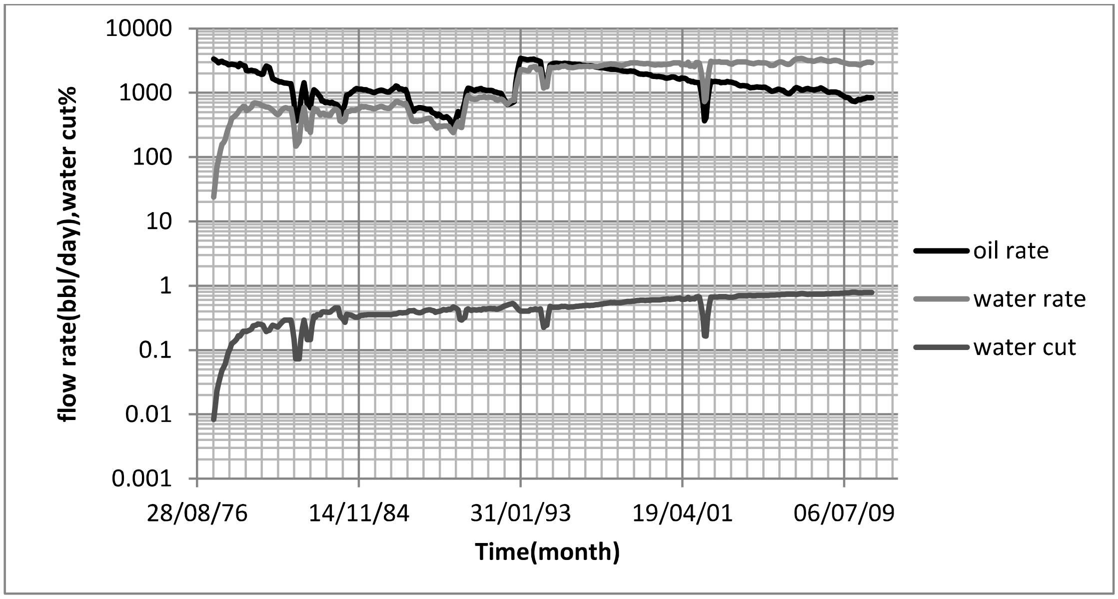

Fig (13): shows production history for well E-209.

4.2.5.3. Calculate the Critical oil flow rate of Well E-209.

Table (11): Shows the critical oil rate for well E-209.

Method	value
Meyer Garder	Qoc=88 bbl/day
Hoyland-Papatzacs- Skjaeveland	Qoc=153bbl/day
Schols'	Qoc=131 bbl/day
Craft and Hawkins	Qoc=3576 bbl/day

4.2.5.4. Results analysis of Well E-209.

This table shows the results of the critical oil flow rate for well E-209 by four correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Meyer-Garder, Hoyland-Papatzacs Skjaeveland and Schols). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (88 to 153) BOPD. These figures are considered unrealistic due to the actual high productivity of this well where result of Craft and Hawkins was considered good

result compared with actual oil rate due to considering the effect of pressure depletion in the calculation.

4.2.5.5. Compare between the critical rate and the actual liquid rate of Well E-209

As it shows in figure (14), comparison between the critical rate and the actual liquid rate showed, at start of well production in April 1977 rate was below the critical rate. The actual liquid rate subsequently below the critical rate until late 1993 as shown in (Figure (14)). The actual liquid rate from 1993 until 2010 increased above the critical rate with increasing water cut to about 78%.

In general, well E-209 was produced most time with production rate that is higher than it is critical rate.

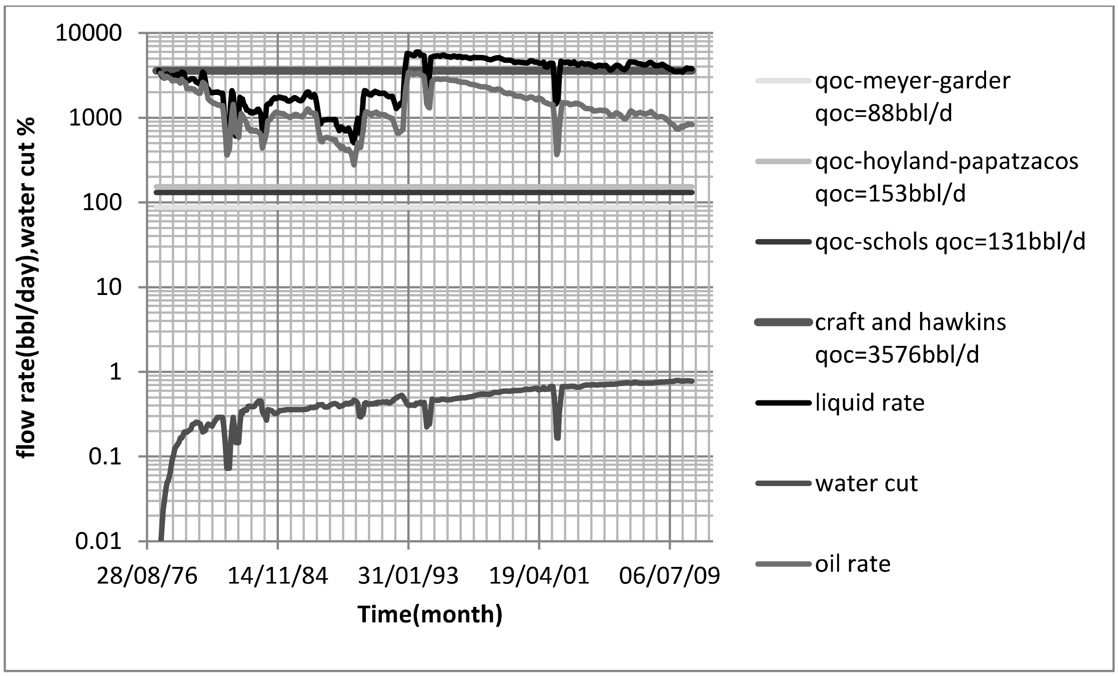

Fig (14): shows compare between the critical rate and actual liquid rate for well E-209.

4.2.5.6. Compare between WOR diagnostic plots and WOR plot for chan of Well E-209

In order to further investigate the water production problem in well E-209 the technique of water diagnostic plots as presented by chan was applied.

The diagnostic plot fig (5.15) shows a jump after 100 to 7000 days (about from three month to twenty-two years from start of well production) a general downward on both WOR and WOR". This was interpreted as bottom water drive coning through the well completion. And after 7000 to 11000 days (about from twenty-two to thirty-three years from start of well production) within a general upward trend on both WOR and WOR". This was interpreted as channeling.

In general, the water production problem in this well appears as result of combination of channeling and coning.

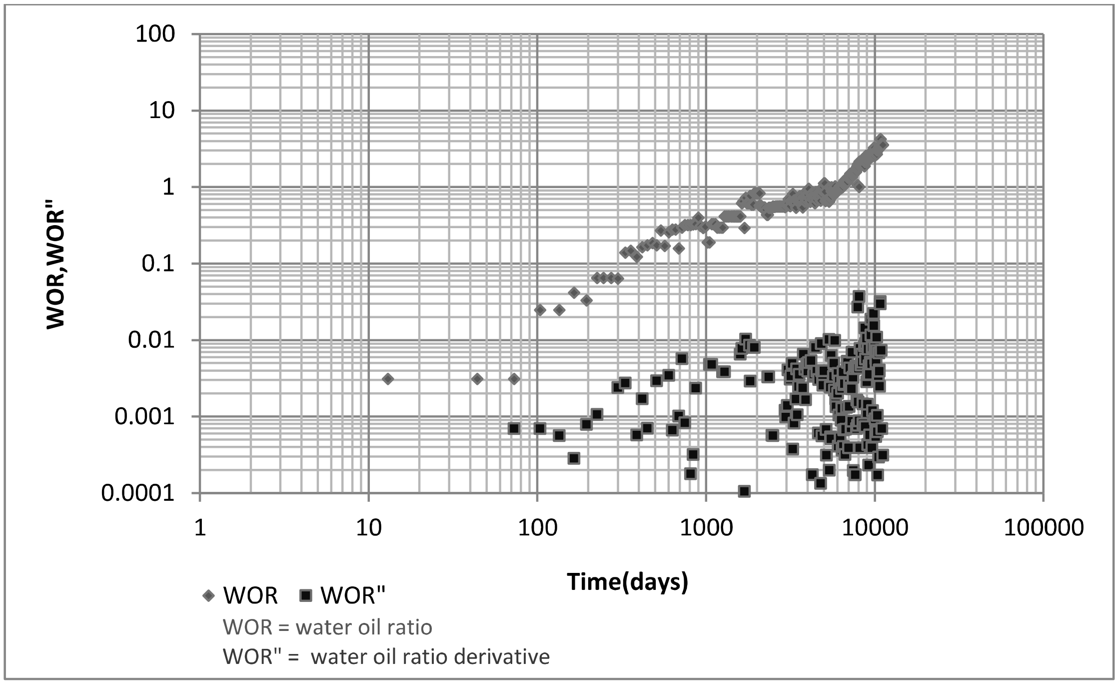

Fig (15): shows (WOR) diagnostic plots for well E-209

4.2.6. WELL E-210

4.2.6.1. Well Data

Table (12): shows well and reservoir data for well E-210

Factor	Symbol	Value
Effective oil permeability	Ko	57.5 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	76 ft
Perforated interval	hp	48 ft
Well pore radius	rw	0.292 ft
Drainage radius	re	1766 ft

4.2.6.2. Production history of Well E-210

Well E210 was started production in October 1977 with good oil production rate 1220 BOPD and the Oil production rose again to 1670 BOPD in 1977. The oil rate subsequently declined until it reached 100 BOPD in late 1991 With water cut about 92% as shown in (Figure (16)). And oil production was shut-in in 1992. The oil rate subsequently declined until it is reached to 220 BOPD in late 2010 due to increasing water cut to about 88% as shown in (Figure (16)).

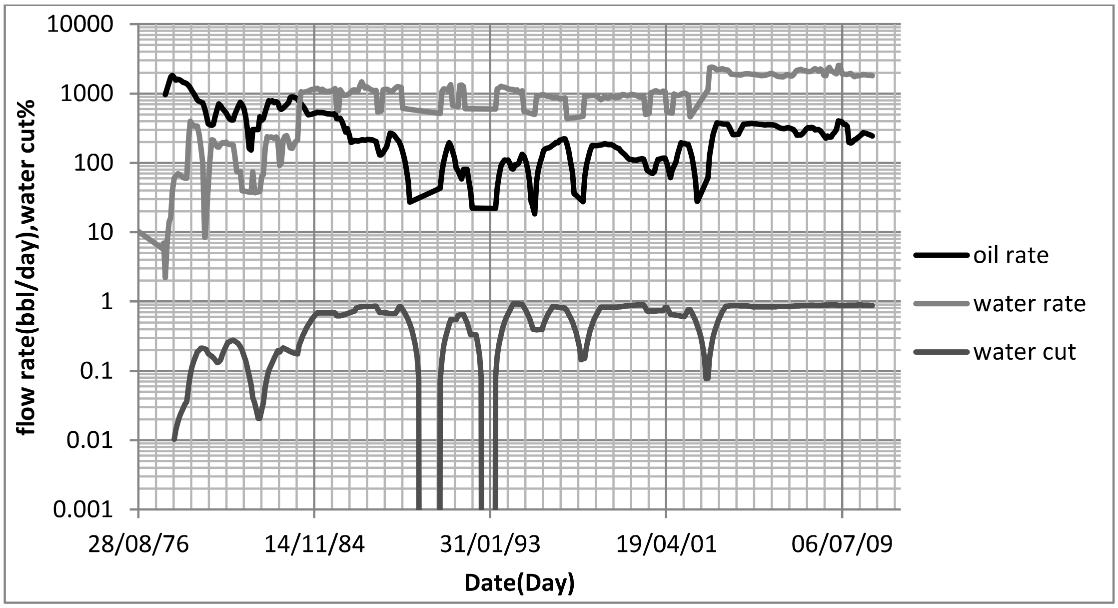

Fig (16): shows production history for well E- 210

4.2.6.3. Calculate the Critical oil flow rate of Well E-210

Table (13): Shown the critical oil rate for well E-210

Method	value
Meyer Garder	Qoc=14 bbl/day
Hoyland-Papatzacs- Skjaeveland	Qoc=20 bbl/day
Schols'	Qoc=20 bbl/day
Craft and Hawkins	Qoc=2487 bbl/day

4.2.6.4. Results analysis of Well E-210

This table shows the results of the critical oil flow rate for well E-210 by four correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Meyer-Garder, Hoyland-Papatzacs Skjaeveland and Schols). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (14 to 20) BOPD. These figures are considered unrealistic due to the actual high productivity of this well where result of Craft and Hawkins was considered good

result compared with actual oil rate due to considering the effect of pressure depletion in the calculation.

4.2.6.5. Compare between the critical rate and the actual oil rate of Well E-210

As it shows in figure (17), comparison between the critical rate and the actual liquid rate showed, at start of well production in October 1977 rate was under the critical rate. The actual liquid rate subsequently below the critical rate until late 2010 with high water cut it is reached to 88% as shown in (Figure (17)).

In general, well E-210 was produced most time with production rate that is lower than it is critical rate.

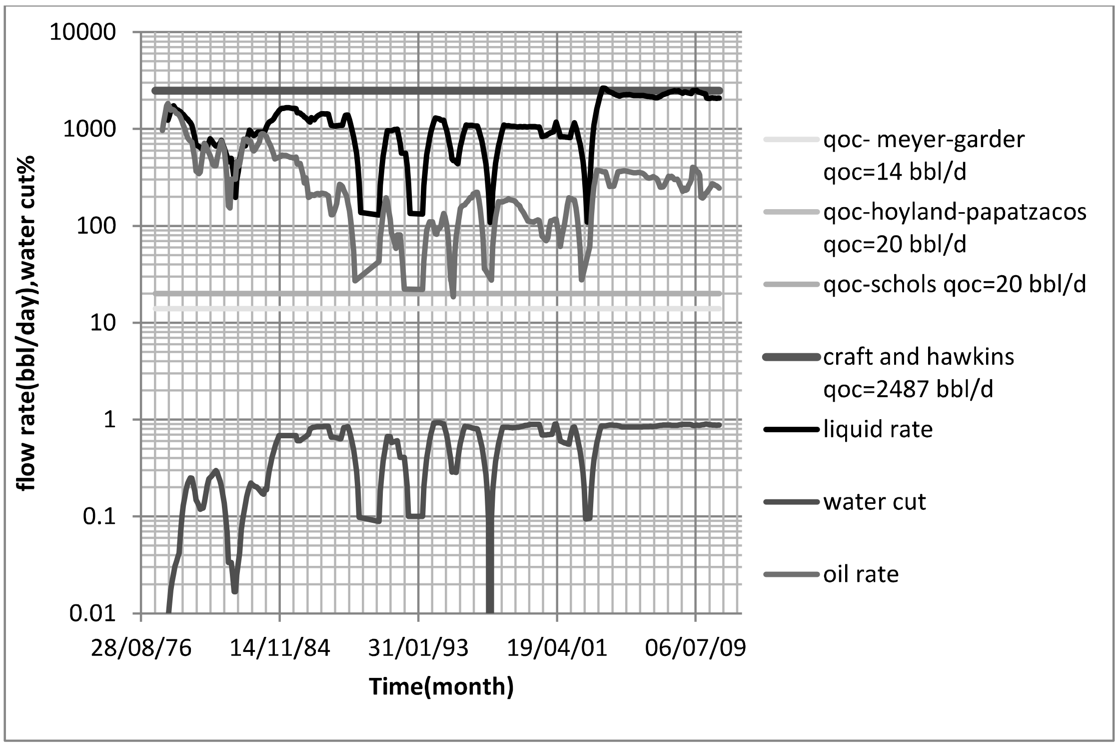

Fig (17): shows compare between the critical rate and actual liquid rate for well E-210

4.2.6.6. Compare between WOR diagnostic plots and WOR plot for Chan of Well E-210

In order to further investigate the water production problem in well E-209 the technique of water diagnostic plots as presented by Chan was applied.

The diagnostic plot fig (18) was interpreted as multi-layer channel with production change in Well E210.

In general, the water production problem in this well appears as result of combination of channeling and coning.

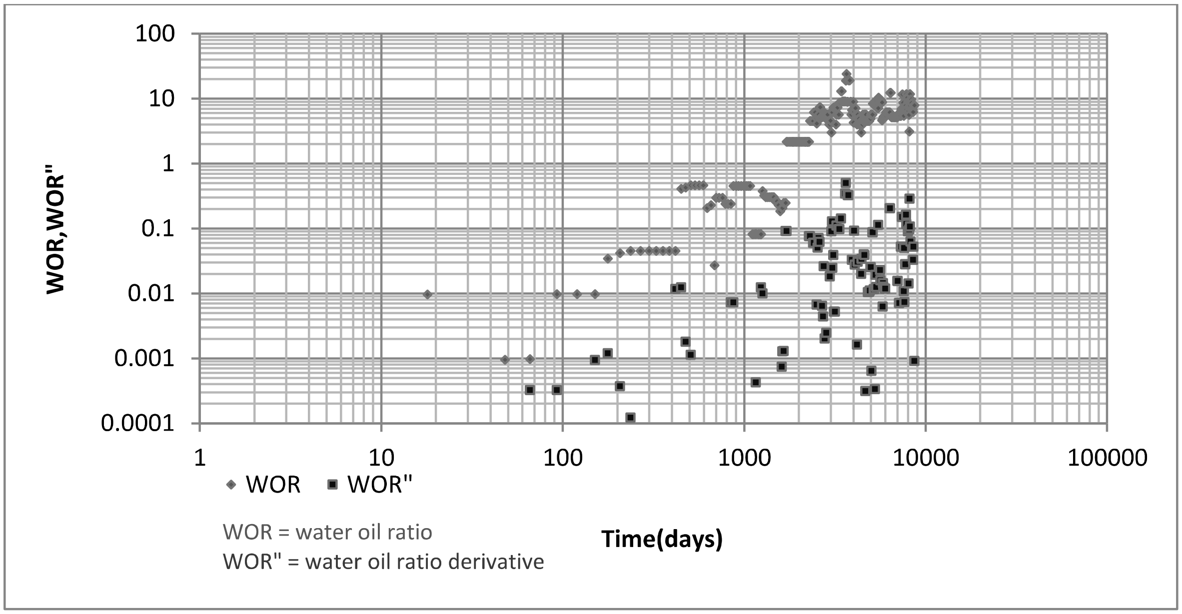

Fig (18): shows (WOR) diagnostic plots for well E-210

4.3. Horizontal well study's

This study's includes production performance analysis for oil wells from Gialo Paleocene reservoir, concentrating on water production problem. The first step of this analysis was to investigate the critical production rate for the studied wells [3].

Table (14): The calculating methodologies of critical production rate [4], [5]

Methods	Formula	remark
1. Efros' Method	$Q_{oc} = 0.0783 \times 10^{-4} \dfrac{k_h\ (\rho_w - \rho_o)\,[h-(h-D_b)]^2 L}{\mu_o B_o \left[y_e + \sqrt{y_e^2 + (h^2/3)}\right]}$	isotropic
2. Karchers Method	$Q_{oc} = 0.0783 \times 10^{-4} \dfrac{k_h (\rho_w - \rho_o)\ (h-B)^2\ L}{\mu_o\ B_o\ (2 y_e)} \times \left[1 - \left(\dfrac{h-B}{y_e}\right)^2\ (1/24)\right]$	isotropic
3. Joshis Method	$Q_{oc} = 0.0246 \times 10^{-3} \dfrac{(\rho_w - \rho_o)\ k_h\,[h^2 - (h-D_b)^2]}{\mu_o\ B_o \ln (r_{eh} / r'_w)}$ $a = (L/2)\left[0.5 + \sqrt{0.25 + (2r_{eh}/L)^4}\right]^{0.5}$ $r'_w = \dfrac{r_{eh}\left[\dfrac{L}{2a}\right]}{\left[1+\sqrt{1-[L/(2a)]^2}\right][h/(2r_w)]^{h/L}}$	isotropic

4.3.1. WELL E 330

4.3.1.1. Well Data

Table (15): shows well and reservoir data for well E-330

Factor	Symbol	Value
Effective oil permeability	Ko	40.2 md
Oil density	ρo	51.9 Ib/ft³
Water density	ρw	68.7 Ib/ft³
Oil formation volume factor	Bo	1.282 rbbl/stb
Oil viscosity	μo	0.68 cp
Oil column thickness	h	81 ft
Length of horizontal well	L	1686 ft
distance between the WOC and the horizontal well	Dp	85 ft
half distance between two lines of horizontal wells	ye	1766 ft
Horizontal drainage radius	reh	2147 ft
Vertical drainage radius	rev	1766 ft

4.3.1.2. Production history of well E330

Well E330 was started production in July 2007 with oil production rate 620 BOPD and the oil rate subsequently decreased until it reached 504 BOPD in December 2008 With water cut about 0.6 % as shown in **(Figure (19**). Oil well was shut-in through April in 2008 to November in 2008. Well E330 again start of well production in January 2009 with good oil production rate 1490 BOPD. The oil rate subsequently decreased until it reached 620 BOPD in late 2010 due to increasing water cut to about 56 % as shown in **(Figure (19)).**

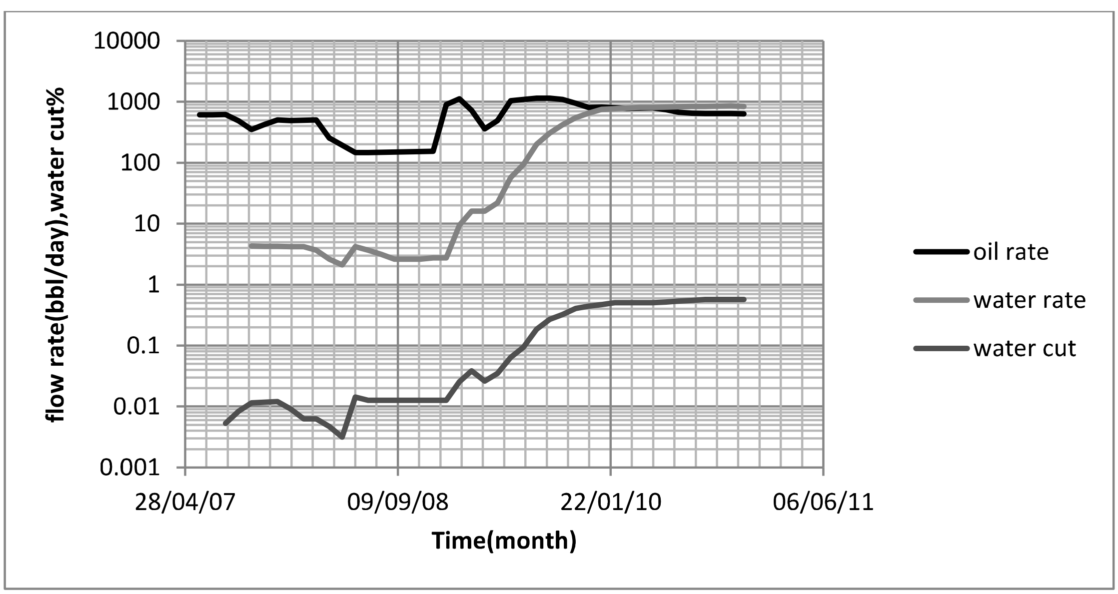

Fig (19): shows production history for well E-330

4.3.1.3. Calculate the Critical oil flow rate of Well E-330

Table (16): Shows the critical oil rate for well E-330

Method	value
Efros' Method	Qoc=29 bbl/day
Karchers Method	Qoc=29 bbl/day
Joshis Method	Qoc=101 bbl/day

4.3.1.4. Results analysis of Well E-330

This table shows the results of the critical oil flow rate for well E-330 by three correlations and illustrates the difference between the results due to effect of isotropic permeability and neglected pressure depletion effect in three correlations (Efros Method, Karchers Method and Joshis Method). It is noted that the three correlations gave an estimation of critical rate that is very low in range of (29 to 101) BOPD. These figure are considered unrealistic due to the actual high productivity of this well.

4.3.1.5. Compare between the critical rate and the actual liquid rate of Well E-330

As it is shows in **figure (20)** comparison between the critical rate and the actual liquid rate showed, at start of well production in July 2007 rate was above the critical rate. The actual liquid rate subsequently above the critical oil rate until late 2010 with water cut about 56% as shown in **(Figure (20))**.

In general, well E-330 was produced all time with production rate that is higher than it is critical rate.

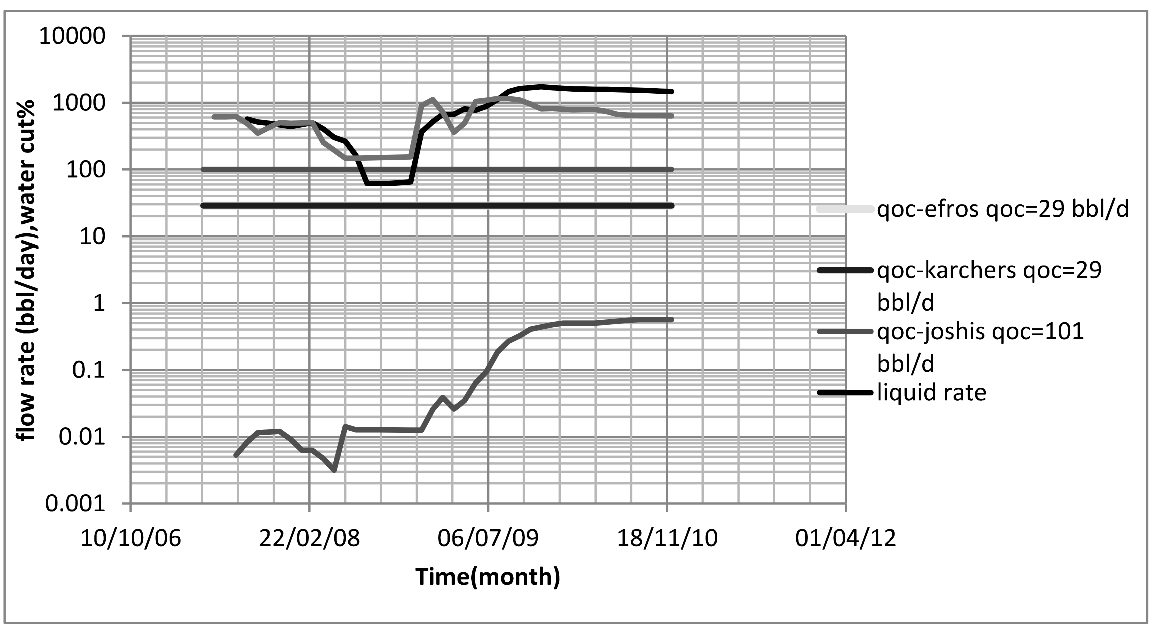

Fig (20): shows compare between the critical rate and actual liquid rate for well E-330

4.3.1.6. Compare between WOR diagnostic plots and WOR plot for chan of well E-330

In order to further investigate the water production problem in well E-330 the technique of water diagnostic plots as presented by chan was applied.

The diagnostic plot **fig (21)** does not show clear trend of water production performance, and there for cannot be interpreted using chan plots. This is may be due to short production time of this well, and not enough history of data to give conclusive results.

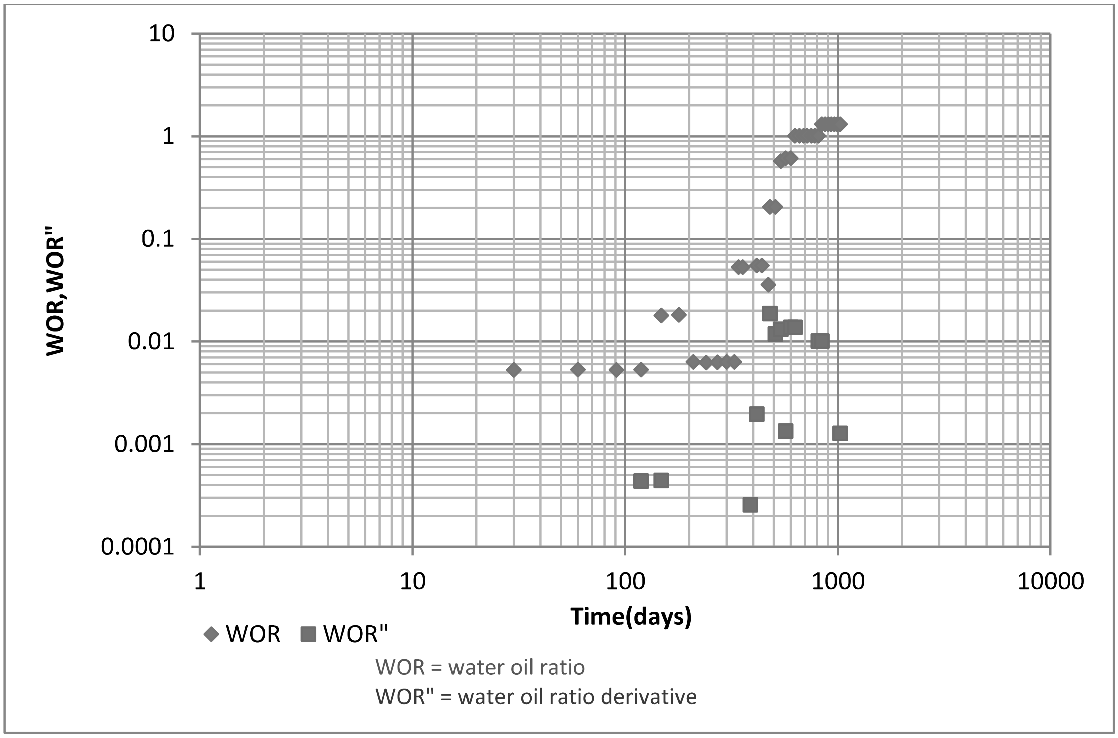

Fig (21): shows (WOR) diagnostic plots for well E330

5. Conclusion

1. Gialo Paleocene reservoir is very potential reservoir with oil reserves of 992.8 MMSTB and daily production rate of 17.82 MSTB/day. The reservoir production performance has been showing noticeable increasing trend of water production for individual wells and total reservoir performance.
2. The production performance of vertical and horizontal wells of Gialo Paleocene reservoir was studied for critical rate analysis and water production problem diagnosis.
3. The critical rate analysis using four empirical correlations (Meyer-Garder, Hoyland-Papatzacs-Skjaeveland, Schols and Craft and Hawkins) was showed below the actual liquid rate for all wells in gialo Paleocene reservoir.
4. The critical oil flow rate was calculated by four correlations given different values due to effect of permeability and the pressure depletion effect was neglected in three correlations

(Meyer-Garder, Hoyland-Papatzacs-Skjaeveland, Schols). This result is very small values of critical rate. Which considered unrealistic compared to actual well production. Where result of Craft and Hawkins was considered more representative result as compared with actual oil rate due to the pressure depletion effect was taken in the critical oil rate calculation. After the compare between the critical oil rate and the actual liquid rate for wells in Gialo Paleocene reservoir was interpreted as all wells producing above the critical rate.

5. The performance of water production for Gialo Paleocene reservoir was studied using diagnosis plot. Summary of analysis can be summarized in the following table:

Well Name	Well Location	Well Problem
E85	This well is located structurally low in the east reservoir area	The water production problem in this well appears as result of combination of channeling and coning
E89	This well is located structurally high in the east reservoir area	The water production problem in this well appears as result of coning
E93	This well is located structurally high in the east reservoir area	The water production problem in this well appears as result of combination of rapid channeling and coning
E192	This well is located structurally high in the east reservoir area	The water production problem in this well appears as result of combination of channeling and coning
E209	This well is located structurally high in the east reservoir area	The water production problem in this well appears as result of combination of rapid channeling and coning
E210	This well is located structurally high in the east reservoir area	The water production problem in this well appears as result of multilayer channeling with production change

6. The same steps that were applied to problem identification for three horizontal wells in Gialo Paleocene reservoir. Where the correlations that was used to calculate the critical oil, rate are different on vertical well correlations. This correlation includes Efros method, Karchers method and Joshis method. The correlations were given small values or inaccurate values for the critical oil rate due to the permeability effect and pressure depletion effect was neglected through the calculations.

7. The analysis of water problem in horizontal wells may be insufficient analysis due to short production period because the horizontal wells were all drilled and put on production after 2005.

6. Recommendation

Apply the "WOR" diagnostic plots for all wells in Gialo Paleocene reservoir to identity water production problem and suggest the solution in proper time.

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