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العدد 22

مجلة التربوي

مجلة علمية محكمة تصدر عن

كلية التربية / الخمس

جامعة المرقب

العدد الثاني والعشرون

يناير 2023م

- المجلة ترحب بما يرد عليها من أبحاث وعلى استعداد لنشرها بعد التحكيم .
- المجلة تحترم كل الاحترام آراء المحكمين وتعمل بمقتضاها .
- كافة الآراء والأفكار المنشورة تعبر عن آراء أصحابها ولا تتحمل المجلة تبعاتها .
- يتحمل الباحث مسؤولية الأمانة العلمية وهو المسؤول عما ينشر له .
- البحوث المقدمة للنشر لا ترد لأصحابها نشرت أو لم تنشر .

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ضوابط النشر:

يشترط في البحوث العلمية المقدمة للنشر أن يراعى فيها ما يأتي :

-أصول البحث العلمي وقواعده .

-ألا تكون المادة العلمية قد سبق نشرها أو كانت جزءا من رسالة علمية .

-يرفق بالبحث تزكية لغوية وفق أنموذج معد .

-تعدل البحوث المقبولة وتصحح وفق ما يراه المحكمون .

-التزام الباحث بالضوابط التي وضعتها المجلة من عدد الصفحات ، ونوع الخط ورقمه ، والفترات الزمنية الممنوحة للتعديل ، وما يستجد من ضوابط تضعها المجلة مستقبلا .

تنبيهات :

-للمجلة الحق في تعديل البحث أو طلب تعديله أو رفضه .

-يخضع البحث في النشر لأولويات المجلة وسياستها .

-البحوث المنشورة تعبر عن وجهة نظر أصحابها ، ولا تعبر عن وجهة نظر المجلة .

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A case study of excessive water production diagnosis at Gialo E-59 Oil field in Libya

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Abstract :The main problem with Libyan oil fields is the excessive production of water.
The purpose of this paper is to diagnose excessive water production mechanisms. Chan approach, PIPESIM Software, and Vogel Equation were applied to the oil well (E-226) at the Gialo E-59 field in Libya. Considering an example of data from a Libyan oil well, the derivative method of the diagnostic charts is applied using Microsoft Excel format to calculate and plot the derivative response to understand the mechanisms causing the problem. As a result of this research, channeling is the main reason for water production, and normal with high water cuts is the other phenomenon for wells. Based on systematic numerical simulation studies of reservoir water coning and channeling, it was discovered that log-log plots of WOR (water/oil ratio) versus time show different characteristic trends for different mechanisms. The time derivatives of WOR have been found to be able to discriminate whether the well is experiencing water coning, high permeability, layer breakthrough, or channeling near the well. The technique of Chan (1995) was applied to well E-226 in Waha oil company s Gialo E-59 field in Libya. Similar to the results obtained by Chan (1995), it can be seen from our results that WOR plots for coning and channeling mechanisms can exhibit similar behavior. Also, this is no surface choke installed in this well, and a full open choke size can cause a variety of undesirable problems such as water/gas breakthrough, sand production, and erosion.
Keywords: excessive water production, Chan method, diagnostic, water production mechanisms, Gialo E-59 field, PIPESIM Software.

1. INTRODUCTION

In general, increasing water production is one of the most difficult problems facing Libyan oil fields.

Produced water is any water that is present in a reservoir with the hydrocarbon resource and is produced to the surface with crude oil or natural gas. This water could either come from an aquifer or from injection wells in the water flooding process. Water is produced in the well due to many different reasons. Water production can be related to mechanical problems, poor completion procedures, or reservoir conditions. The main obstacle in the management of water production studies is the correct diagnosis of the nature and the origin of the problems. Each problem type requires a different approach to control and treat the problem effectively. In reality, an oil well can experience a combination of different problem types. However, reservoir-related problems of coning and channeling through high permeability layers are more challenging to diagnose and treat [1].

The best completions and production practices can delay, but not stop this water production. Most cases where water production rates have become a problem could have been avoided or delayed. Understanding reservoir behavior provides a basis for determining whether excessive water production is a concern and to determine if current water production is excessive. Excessive water production is one of the major technical, environmental, and economical problems associated with oil and gas production. Water production can limit the productive life of the oil and gas wells and can cause severe problems including corrosion of tubular, fines migration, and hydrostatic loading. Produced water represents the largest waste stream associated with oil and gas production. The environmental impact of handling, treating, and disposing of the produced water can seriously affect the profitability of oil and gas production [2].

Reservoir rocks normally contain both petroleum hydrocarbons and connate water. Once the production starts, this water called connate water is also produced into the wellbore commingled with oil. In addition to the connate water contained in reservoir rocks, many petroleum reservoirs are bounded by or adjacent to large aquifers. These aquifers can provide the natural drive for petroleum production. Once the aquifer pressure is depleted, additional water is also injected into the reservoir to provide further pressure to the hydrocarbon reserves to move towards to production wells. Water from these various sources can flow into the wellbore and be co-produced with the hydrocarbon stream. Such water is referred to as produced water. The mechanism and the volume of the water produced into a wellbore mainly depend on petrophysical properties, pressure and temperature conditions of the reservoir, geometry, and conditions of the aquifers, trajectory and location of the drilled wells within reservoir structure, type of completion, and stimulation methods [3].

Depending on the characteristics of the reservoir, the type of the diagnosed problem, and the objectives of the water production treatment, a variety of mechanical, chemical, and well construction techniques can be applied to stop or reduce the flow of water into the wellbore. Incorrect, inadequate, or lack of proper diagnosis usually leads to ineffective water control treatments. Several analytical and empirical techniques using information such as production data, water/oil ratio, and logging measurements have been developed to determine the type of water production problem, locate the water entry point in the well, and choose the candidate wells to perform treatment methods. Water/oil ratio diagnostic plots are probably the most widely used technique in reservoir performance studies [4].

A larger amount of produced water contributes to high operating costs and is a major environmental concern for oil production [5].

The production of water from oil-producing wells is a common occurrence in oil fields, which results from one or more reasons such as the normal rise of oil-water contact, water coning, and water fingering [6]. In general, coning or cresting is the term used to describe the mechanism underlying the upward movement of water and/or the downward movement of gas into the perforations of a producing well [7]. This phenomenon is a result of fluid segregation according to their densities when gravitational forces are exceeded by the flowing pressure – viscous force. In most oil and gas fields over the world, produced water due to coning is normally present in the reservoir even before production starts; as in bottom water aquifers and/or in artificially improved recovery schemes, and as in water injection [8]. Therefore, the production of excessive water and/or gas has been a continuing problem for operators since the beginning of the petroleum industry [9]. In addition, water coning depends on the properties of the porous media, oil-water viscosity ratio, distance from the oil-water interface to the well, production rate, densities of the fluids, and capillary effects [10]. Unlike conventional reservoirs, a coning phenomenon in fractured reservoirs is more challenging and complicated due to the intrinsic difference in them along with the heterogeneity and high permeable medium of the fractures compared to matrixes [11].

Nevertheless, Menouar and Hakim noted that most experimental studies performed on scaled petrophysical models may not provide all the answers to reservoir engineering problems due to the difficulty of scaling some of the reservoir parameters. Thus, the empirical approach of water coning studies is also faced with the mentioned challenges, Figure 1. Shows water coming into a well [12, 13].

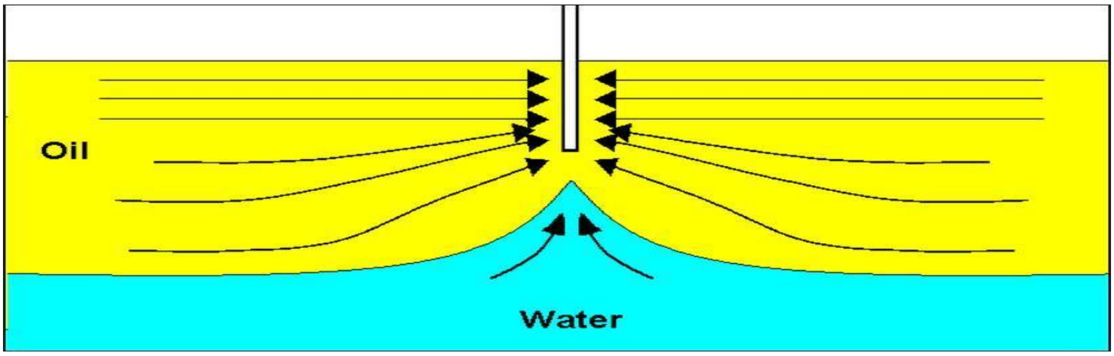

Figure 1. Schematic of water coning into a well [13]

According to Chan (1995), the log-log plots of WOR (Water-Oil Ratio) versus time show different characteristic trends for different mechanisms. The time derivatives of WOR were found to be capable of differentiating whether the well is experiencing water and gas coning, high-permeability layer breakthrough, or near wellbore channeling. Chan identified the three most noticeable water production mechanisms, namely water coning, near well-bore problems, and multi-layer channeling [14, 15].

2. RESEARCH METHOD

Depending on the characteristics of the reservoir, the type of the diagnosed problem, and the objectives of the water production treatment, a variety of mechanical, chemical, and well construction techniques can be applied to stop or reduce the flow of water into the wellbore. However, the water production mechanism (WPM) must be properly investigated and accurately diagnosed in order to design an appropriate and effective treatment method. Incorrect, inadequate, or lack of proper diagnosis usually leads to ineffective water control treatments. Several analytical and empirical techniques using information such as production data, water/oil ratio, and logging measurements have been developed to determine the type of water production problem, locate the water entry point in the well, and choose the candidate wells to perform treatment methods. Water/oil ratio diagnostic plots are probably the most widely used technique in reservoir performance studies. Many oil companies to date rely on log/log plots of WOR and its derivative against time to identify WPMs caused by water coning or channeling [16,17].

The production data required for these plots are routinely collected and the accuracy of these data is usually reliable. Nevertheless, without taking other important reservoir parameters into account, the WOR diagnostic plots could easily be misinterpreted and it has been demonstrated that applying these plots on their own could be misleading [18,19,20, 21]. In view of the fact that a proper diagnosis of water production mechanism (WPMs) is a vital step in reservoir performance studies and considering that water/oil production data are the most commonly available data. The reservoir-related problems of coning and channeling are the two major causes of excess water production in oil wells [22, 23].

Chan (1995) proposed a new methodology to analyze the log-log plot of WOR and the derivative of WOR against time in order to differentiate between two common and more complicated water problems of water channeling and water coning. Chan (1995) used various drive mechanisms and water flooding scenarios using a three-dimensional, three-phase black oil reservoir simulator to demonstrate the WOR plots differential mechanism. Based on

Chan's report, three behavior periods can be observed in the WOR versus time plot for both coning and channeling. During the first period from the start of the production to water breakthrough time, the WOR is constant for both mechanisms. However, this period called the departure time is usually shorter for coning than channeling [15].
Figures (2) through Figure (5), (Chan, 1995) illustrate how the diagnostic plots are used to differentiate among the various water production mechanisms. Fig. (2), shows a comparison of WOR diagnostic plots for coning and channeling. The WOR behavior for both coning and channeling is divided into three periods; the first period extends from the start of production to water breakthrough, where the WOR is constant for both mechanisms. When water production begins, Chan claims that the behavior becomes very different for coning and channeling. This event denotes the beginning of the second time period.

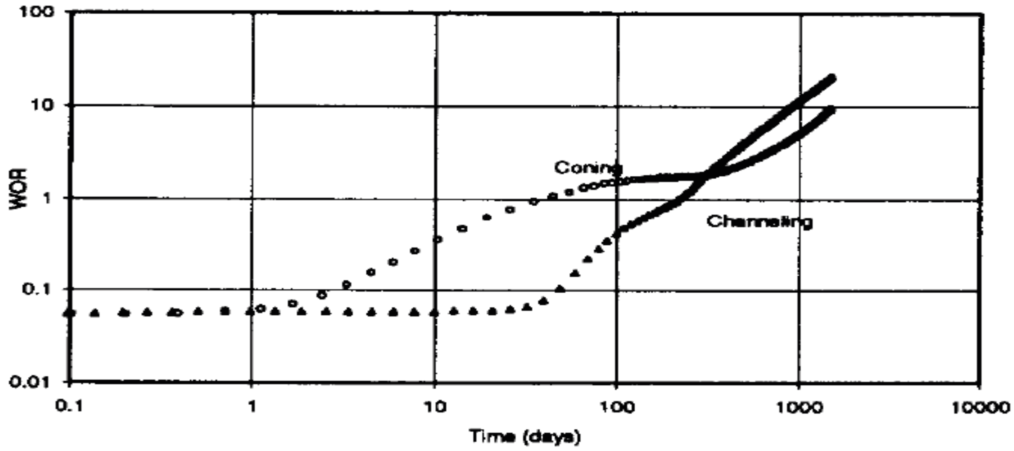

Fig 2. Water coning and channeling WOR comparison. Chan (1995)

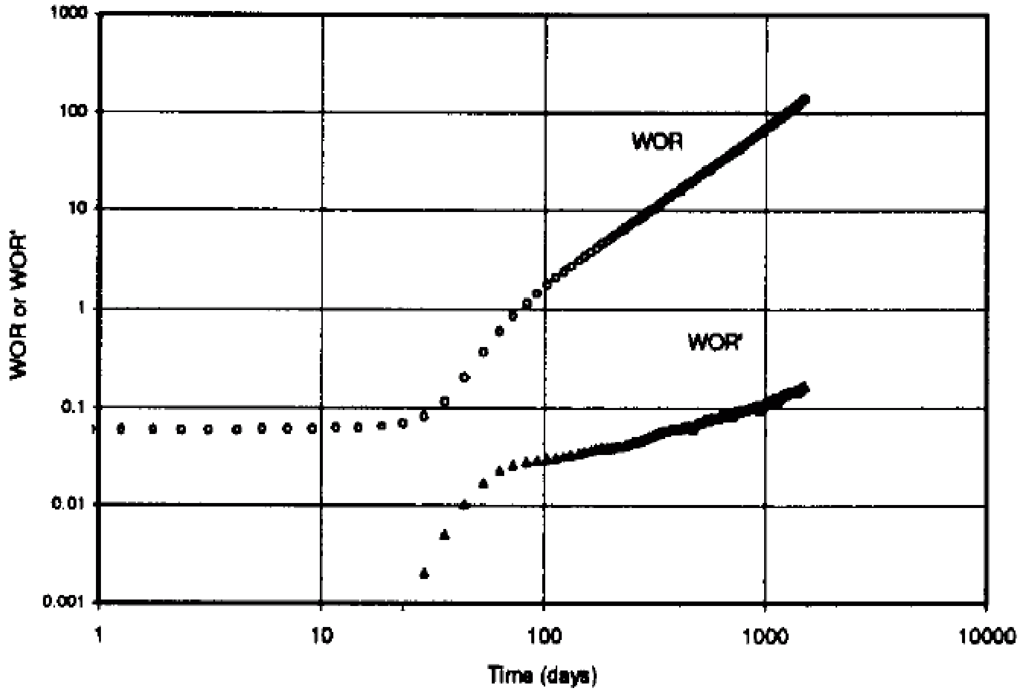

Fig 3. Multi-layer channeling WOR and WOR derivatives. Chan (1995)

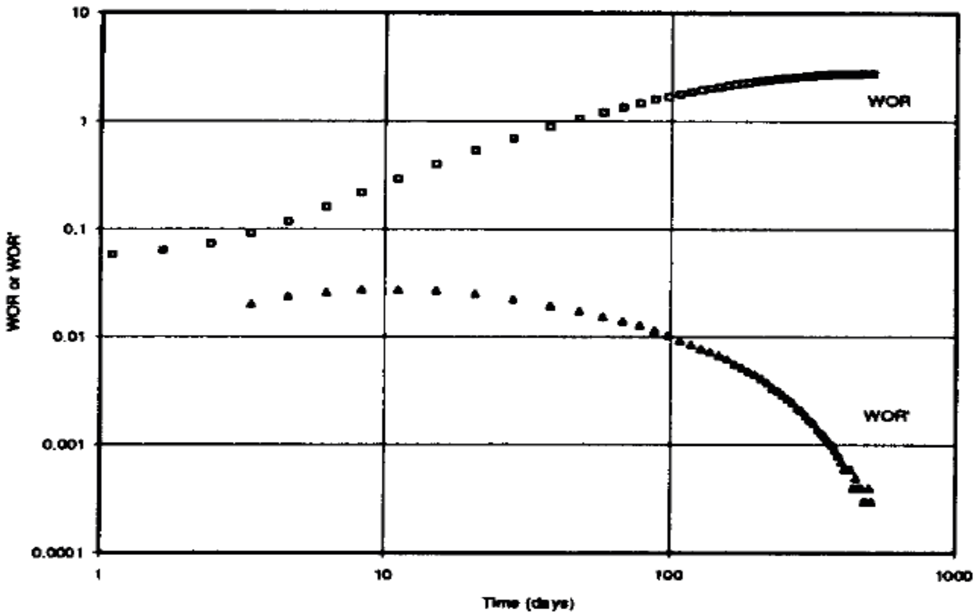

Fig 4. Bottom-water coning WOR and WOR derivatives. Chan (1995)

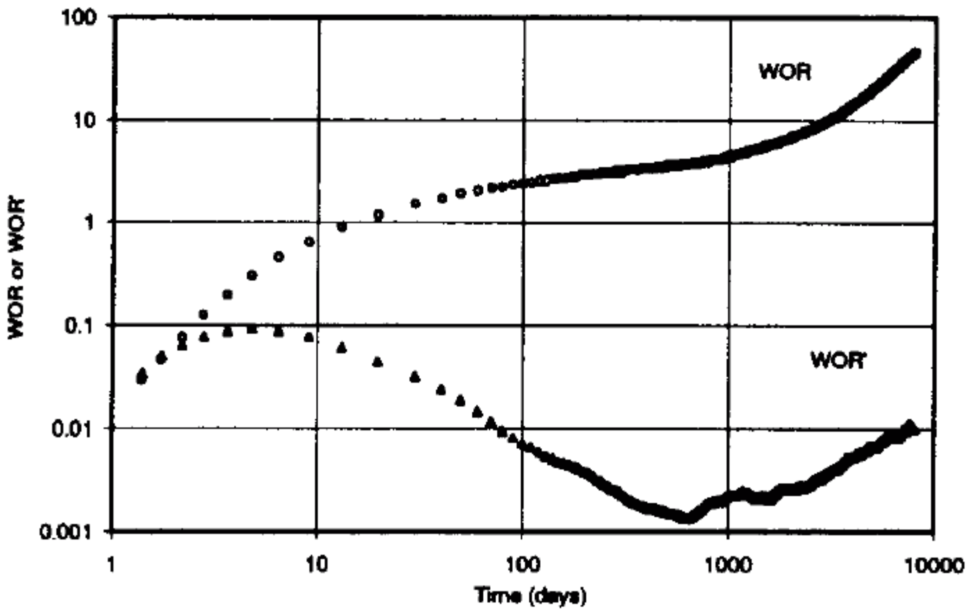

Fig 5. Bottom water coning with late time channeling. Chan (1995)

By using Microsoft Excel format for calculating and plotting the derivative response.

- First, the value of the water/oil ratio (WOR) is calculated by using the actual oil and water production, and the equation is:

$$WOR = \frac{Qw}{Qo} \qquad \text{Eq. (1)}$$

- Then, the derivative value of the water/oil ratio (WOR) is calculated by the following equation:

$$WOR' = \frac{d(WOR)}{dt} = \frac{(WOR2-WOR1)}{(t2-t1)} \qquad \text{Eq. (2)}$$

$$Q_t = Q_o + Q_w \qquad \text{Eq. (3)}$$

$$Np = Qt * 30.5\ days \qquad \text{Eq. (4)}$$

- Finally, the water problem is diagnosed with the help of Chan's method.

3. THE CASE STUDY

3.1 Field Description

The study area is located in the Gialo Field, concession NC 59E in the eastern Sirte basin, Libya. Gialo 59E field produces 95,000BOPD against 380, 000 BWPD. The Gialo Paleocene Limestone Reservoir was first discovered in March 1961 by drilling of well E1 and put into production in November 1964. The Gialo Paleocene reservoir produces from the Zelten Limestone member of the Upper Paleocene Epoch. Three Facies with insignificant differences in properties have been identified. The well used in this case study will be designated as E-226 [24].

3.2 Reservoir data summary

Paleocene Zelten Limestone Reservoir - Gialo Conc. 59E

Table1.0 Basic reservoir data

Formation Producing	Paleocene Limestone
Top of Pay Formation	6300 ft. KB
Datum Depth	5900ft. SS
Productive Acreage	15,008Acres
Average Net Pay	47.6 ft
Original BHP at Datum	2726psig
Reservoir Temperature at Datum	186deg F

Table 2.0 Average rock properties

Porosity	25.2 %
Permeability (horizontal)	14.5 md
Water Saturation	37.4 %

Table 3.0 Fluid properties

Saturation Pressure	927psig
Differential Solution GOR	440 scf/stb
Flash Solution GOR	300scf/stb
F.V.F. at Original Pressure	1.282RB/STB
Current Reservoir Pressure	2238psig
API Gravity at 60 deg F	39.4deg API

3.3 Wells Data.

3.3.1 E-226 Well.

The Configuration and Completion data for this well as the following;
Location: 28° 42' 22" N 21 25' 26" E
Elevation: 332' GL 340 KB
Depth: 6340' TD 6300' (PBTD)

Table 4.0 Well completion data.

Casing	Size (in)	Weight (Ib/ft)	Grade	Depth (ft)
Surface	13 3/8	61	J55	831
Production	9 5/8	40	J55	2753
Production Liner	7	23	N80	2572 - 6338

The Cumulative Oil production is 2.57 MMBBL
The oil production rate is 140 STB/D and the water cut is 92%.
The SBHP is 2086 psig and the P.I is 0.169 BOPD/psig.

3.3.2 Inflow and Outflow Performance Calculations for the well at original conditions

Stable point: Q = 2287 (STB/DAY), P_{WF} = 1401psig, Reservoir pressure =2700 psig

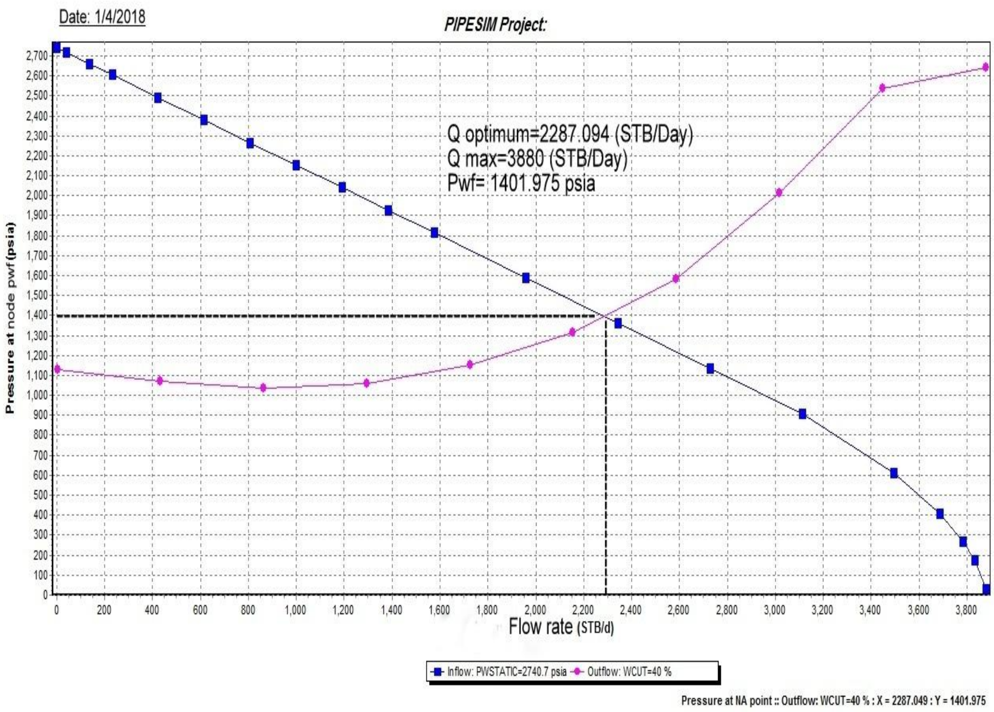

Figure (6), Shows inflow and outflow performance relationship curve for the well at original conditions.

3.3.3 Inflow and Outflow Performance calculations for the well at actual conditions

Stable point: Q = 1728 (STB/DAY), P_{WF} = 1282psig, Reservoir pressure =2300 psig

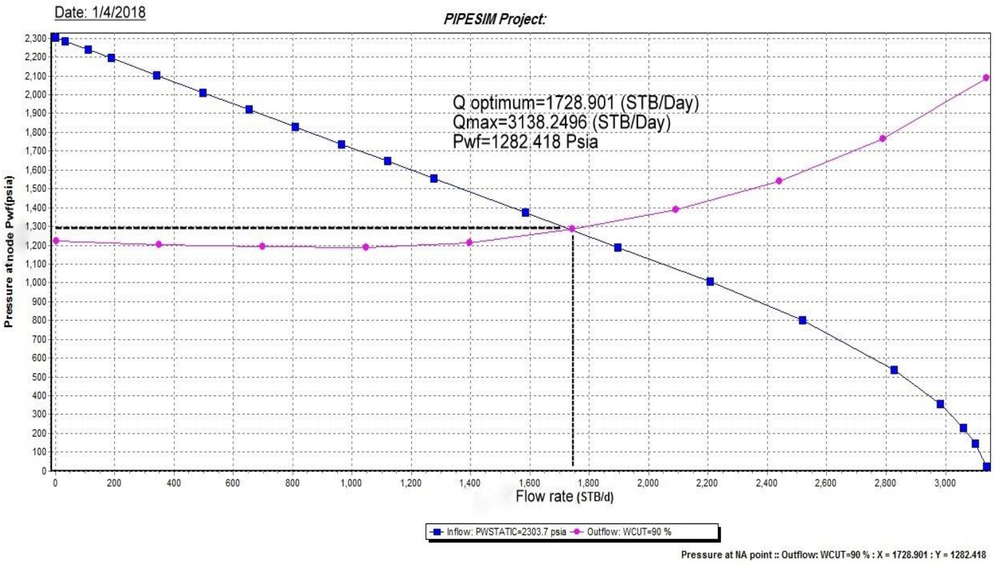

Figure (7), Shows inflow and outflow performance relationship curve for the well at actual conditions.

4. RESULTS AND DISCUSSION

The calculations of inflow and outflow performance relationship curve for the well at original conditions.
Stable point where, Q = 2287 (STB/DAY), PWF = 1401 psig, Reservoir pressure = 2700 psig
Draw down pressure 2700 – 1401 = 1299 psig
The calculations of inflow and outflow performance relationship curve for the well at actual conditions;
Stable point where, Q = 1728 (STB/DAY), PWF = 1282 psig, Reservoir pressure = 2300 psig,
Draw down pressure 2300 – 1282 = 1018 psig
Currently, the well production rate is about 1728 STB/D with a 90 % water cut.
Oil = 172.8 bbl/d
Water = 1555.2 bbl/d
At original conditions were Draw down, reservoir pressure, and flow rate higher than actual conditions at the present time the reasons are water coning. The results for differentiating and diagnosing water problems are expressed below:

- Finally, the water problem is diagnosed with the help of Table (5.0), different patterns of sources of producing water in the reservoir

WOR slope	WOR' slope	Reason for water production
positive	Positive	Channeling
positive	Negative	coning
Positive linear slope	Horizontal line	Water/oil contact rising

Then obtaining the necessary production information and diagnosing the reason for water production. For coning, the rate of the WOR increases relatively slowly and gradually. For channeling, the water production increases quickly depending on the relative permeability functions.

مجلة التربوي
Journal of Educational
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معامل التأثير العربي 1.63
العدد 22

The time derivative of WOR can be used to differentiate coning from channeling. A constant positive slope is an indication of water channeling, whereas a changing negative slope is an indication of water coning. From the actual production history data, log-log plots of WOR and WOR' derivative versus time were generated. These plots give a picture of past and current production behaviors. This method can be an effective tool for selecting water control treatment candidates since there is a different job design for different mechanisms.
Concerning the application of the diagnostic plots derivative methods to the targeted data, the study provides an example of a single oil well. Using Microsoft Excel format, the production data and a simplified computation WOR' derivative are given in tables (5). Figure (21), shows WOR and WOR' derivatives plots for well E-226
Figure(8) represents WOR and WOR' derivatives plot for the E-226 well. Commonly the diagnostic plot figures show the WOR increasing with time. The rate of increase differs for a different problem mechanism. The degree of sharp or gradual rate of increase presents a signal difference between coning and channeling. The other mechanisms can be recognized through derivative response.

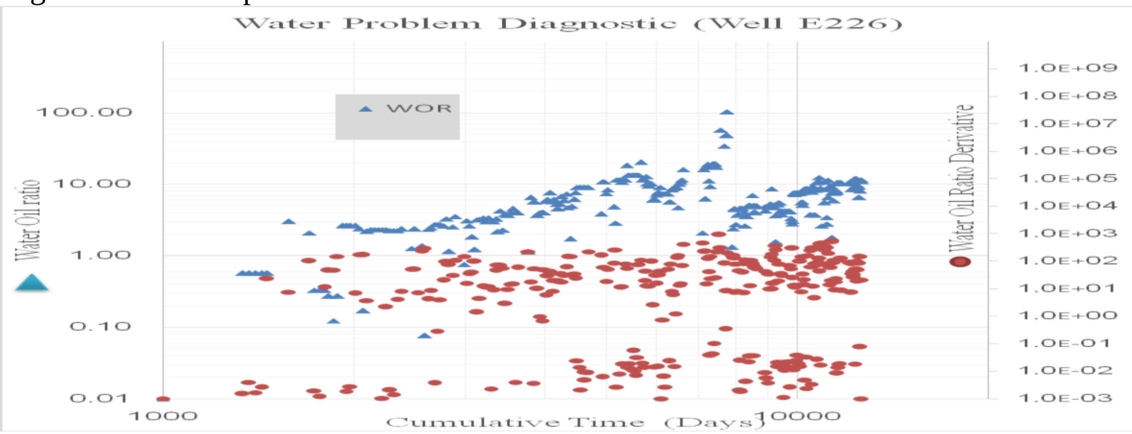

Figure (8), shows WOR and WOR' derivatives plot for well E-226

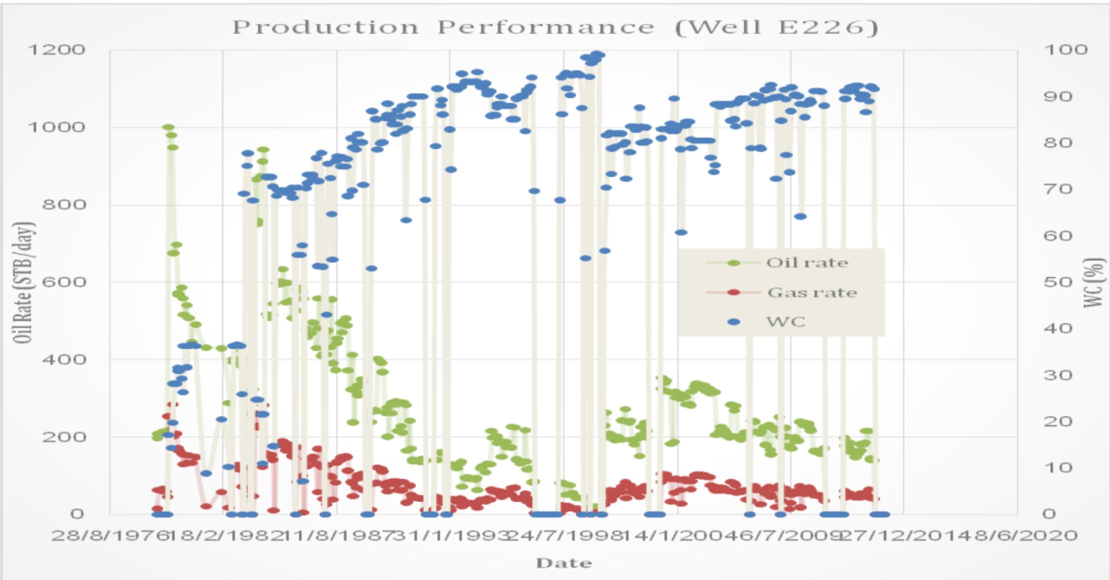

Figure (9), shows production performance for well E-226

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معامل التأثير العربي 1.63
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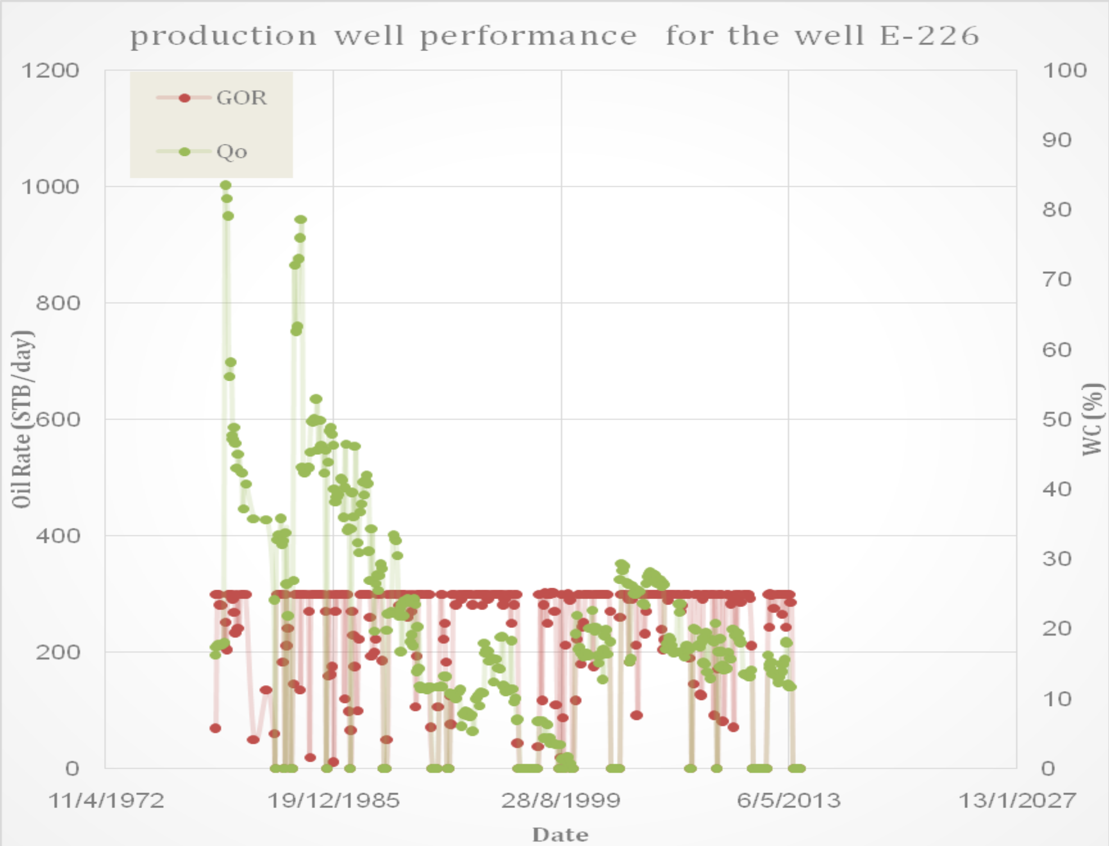

Figure (10), shows Gas oil ratio and oil production for the well E-226

4.1 The Analysis result:

● Reservoir depletion may occur when water cut increases until 90% water cut with 10 % oil production,

● Characteristics of reservoir fluids and rocks have changed during the production period during the water coning problem.

●There is no plan to maintain reservoir pressure

●The water coning is the result of water production from the upward movement of water like a cone due to high-pressure differential as a result of high drawdown.

●The water fingering occurs as a result of the fast movement of water in a higher permeability layer than the layer with lower permeability within the producing zone.

●This well doesn't have a surface choke installed, Withdrawing fluid at higher than optimum rates with a fully open choke size may create a host of unwanted problems like water/gas breakthrough, sand production, erosion, etc.

5. CONCLUSION AND RECOMMENDATIONS

First and foremost, this well doesn't have a surface choke installed. Theoretically, wells on artificial lifts should not have chokes installed on them. Chokes are normally used to control fluid flow rate or downstream system pressure.

Reservoirs and by extension, wells have an optimum production rate, which depends on numerous factors like reservoir pressure, drive mechanism, permeability, viscosity, porosity, the thickness of the oil column, etc. Withdrawing fluid at higher than optimum rates with a fully open choke size may create a host of unwanted problems like water/gas breakthrough, sand production, erosion, etc.

This study focused on the problem of excess water production in vertical oil wells. Changing in choke size will eventually change FBHP and flow rate, which will change Tubing Head Pressure. To model that, you need to consider the wellhead and flow-line performance curves. For water coning, similar to the results obtained by Chan (1995), it is evident from our results that WOR plots for coning and channeling mechanisms can exhibit similar behavior.

5.1 The advantages of the derivative method:

- It mainly uses available production history data.
- It can be used to rapidly screen a great number of wells.
- It entails the best reservoir engineering principles and practices.
- It could yield results to form the basis for conducting a production mechanism survey, comparing mechanisms between adjacent wells, good production wells versus problematic production wells, and by area or by well pattern.
- With the WOR versus cumulative oil production plot and the oil rate decline curves, it would become an effective methodology to select candidate wells for water control treatments.

5.2 The disadvantages of the derivative method:

- The diagnostic plots showed a random and noisy trend on both the WOR and WOR' plots, hence they provide a controversial basis for characterizing water production based on surface observation of production trends.
- The derivative method can't be valid for all cases because WOR and its derivatives are plotted versus time, not versus dimensionless time. Dimensionless groups are commonly used to generalize problems or plots, e.g., type curves in well testing.
- Multi-layer channeling problems can easily be mistaken as bottom water coning, and vice versa, if WOR diagnostic plots are used alone to identify an excessive water production mechanism.

5.3 Future work

While this research provides an innovative technique for successfully diagnosing the type of excess water production in vertical oil wells, the major future extensions to the current work could include the following:

- Updating the current database and evaluating the system with real field data is the primary future work foreseen for this study.
- Another consideration is to include other reservoir characteristics such as pressure and temperature in the analysis and examine whether any significant relation between these new parameters and WPMs can be identified.
- This study focused on the problem of excess water production in vertical oil wells. A possible extension to this work is to examine the water production in horizontal wells. Additionally, one could consider the problem of excess water production in gas fields and examine gas-oil ratio (GOR) plots.

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