LJAST
Libyan Journal of Applied Science and Technology
مجلة ليبيا للعلوم التطبيقية والتقنية

Volume 12 Issue 02
December 2024
ISSN 2958-6119

Analysis of water Production and Reservoir Performance for A122 Oil Field

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ABSTRACT

Effective management of water production is a critical aspect of upstream oil and gas operations, as excessive water production can significantly impact the overall hydrocarbon recovery and profitability of a project. Two widely utilized diagnostic tools in water production analysis are the water-oil ratio (WOR) and the WOR derivative (WOR') plots, which were developed by K.S. Chan.

Production performance analysis is considered of the important tools of oil reservoir management. This can diagnose many problems and obstacles early in time, which enables curing than the problem in proper time to optimize oil production and maximize oil recovery.

Excessive water production is an essential problem in the oil and gas industry as it can be a limiting factor for the production capabilities, especially in offshore reservoirs where the available options to handling the accusive water production are limited or very costly, which might risk the oil production to drops below the economic limits. Therefore, determining the water source is a vital step before selecting the potential treatment. Diagnostic plots proved to be a valid tool for the assessment of water production sources. The sources of water include formation water aquifer and injected water. However, for oil production wells, the change in oil rate and water rate versus time can be used to evaluate water production characteristics for the oil reservoir and water source. The water-oil ratio (WOR), water-oil ratio derivative (WOR'), and X-Plot were used for the field production. The main objectives of this study are to investigate the existence of the water production problem, identifying the water production mechanism, and the source of the water production problem.

Results indicate excessive water production issues in four wells out of five wells that were included in this study. The diagnostic plots indicated that the main reason is the bottom water coning with later channeling in some wells.

Keywords: WOR, Chan method, diagnostic, water production mechanisms

Introduction

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. Water production is an inevitable consequence of oil or gas production. There is very little that can be done to reduce water production in the depleted reservoir. Generally, at the later stages of production, the focus of water control will shift from preventing water production to reducing the cost of produced water. In the United States, it is estimated that on average 8 barrels of water are produced for each barrel of oil. The environmental impact of handling, treating, and disposing of the produced water can seriously affect the profitability of oil and gas production. The annual cost of disposing of the produced water in the United States is estimated to be 5-10 billion dollars. Over the last 30 years, technical efforts for water control were mainly on the development and implementation of gels to create flow barriers for suppressing water production. Various types of gels were applied in different types of formations and to solve different types of problem. , Quite often, excessive water production mechanisms were not clearly understood or confirmed. Although many successful treatments were reported, the overall treatment success ratio remains low. The art of treatment job execution was progressively improved. Good practices in the process of candidate selection, job design, gel mixing and pumping and job quality control were recognized and adapted. More effective tools and placement techniques were also used. The desire to define different types of excessive water production problems began to surface.[1] [2]

In general, there were three basic classifications of the problems. Water coning, multilayer channeling and near wellbore problems are most noticeable among others.

Field experience showed successful job design would not be the same for different mechanisms. However, there are no effective methods to discern these differences. In reality, the problem could be very complex, and usually is the combination of several mechanisms taking place over a period of time and compounding .one with the other. [3]

Diagnosing the source of excessive produced water in a water-flooding reservoir gives important information which can be used to optimize development plan and to identify wells for possible remedial actions as well as for business planning. Especially in naturally-fractured carbonate reservoirs, early water breakthrough can occur through multiple ways such as water coning, multilayer channels, fractures/faults and near-well heterogeneities. [4]

Linear/semilog water cut (WC) or water-oil-ratio (WOR) vs. time plots are conventionally used by engineers to monitor excessive water production and/or to evaluate recovery efficiency4,5,6.

However, these plots are unable to show which part of the reservoir excess water comes from. Several diagnostic tools have been proposed for discriminating the source of excessive water. Chan7 reported a methodology based on the diagnostic plots of WOR and its time derivative (WOR') to quickly diagnose and evaluate the sources for excessive water production. Chan derived these diagnostic plots from systematically-designed three-dimensional black-oil numerical simulations for water-control. [5] [6]

Figure (1) shows a schematic of different Chan diagnostic plots. The plots have been applied by the industry for identifying whether the well is experiencing water coning, high-permeability layer breakthrough or near-well channeling.

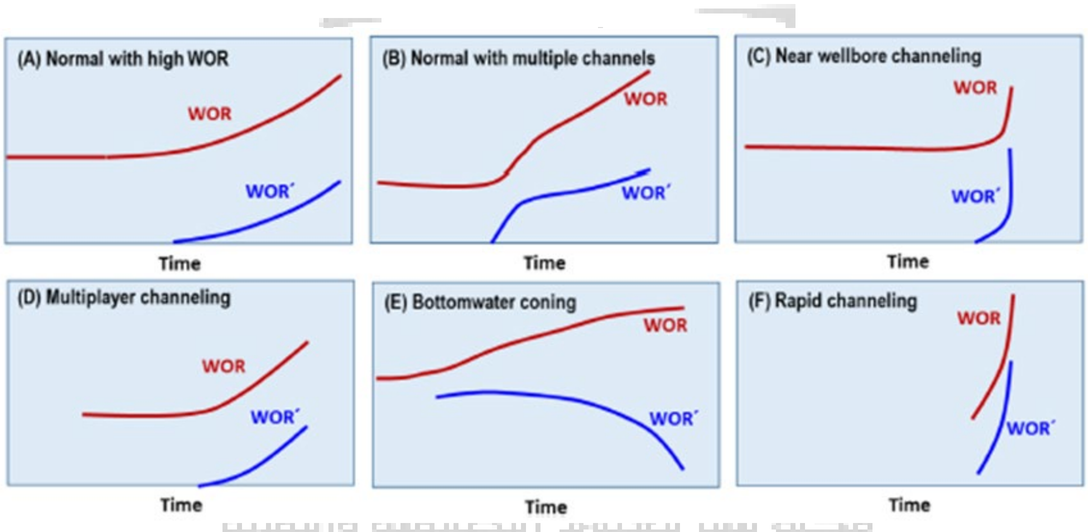

Figure 1: Schematic of Chan diagnostic plots [7]

WOR & WOR' Diagnostic Plots

Water/oil ratio (WOR) and gas/oil ratio (GOR) diagnostic plots have been proposed as an easy, fast, and inexpensive method to identify excessive water and gas production mechanisms. According to this method, a log-log plot of WOR or GOR versus time will show different behavior for the varying mechanisms. Log-log plots of WOR and GOR time derivatives versus time are said to be capable of differentiating whether a production well is experiencing water or gas coning, channeling due to high-permeability layers, or near-wellbore channeling. If these diagnostic plots can be used to determine the mechanism for excessive water production, they will be useful for identifying wells where gel treatments may be effective for water shutoff. According to Chan figures (2) through (5) illustrate how the diagnostic plots are supposed to differentiate among the various water production mechanisms. figure (5) 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 production start 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. [8]

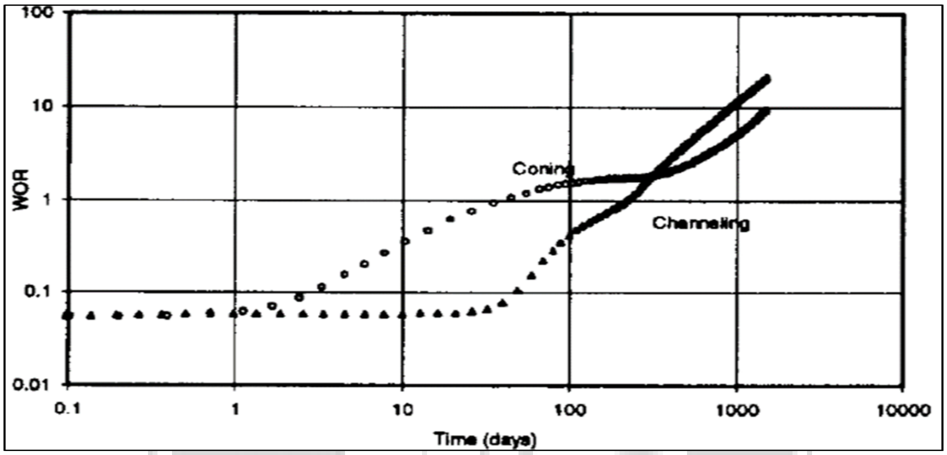

Figure 2: Water coning and channeling WOR comparison[8]

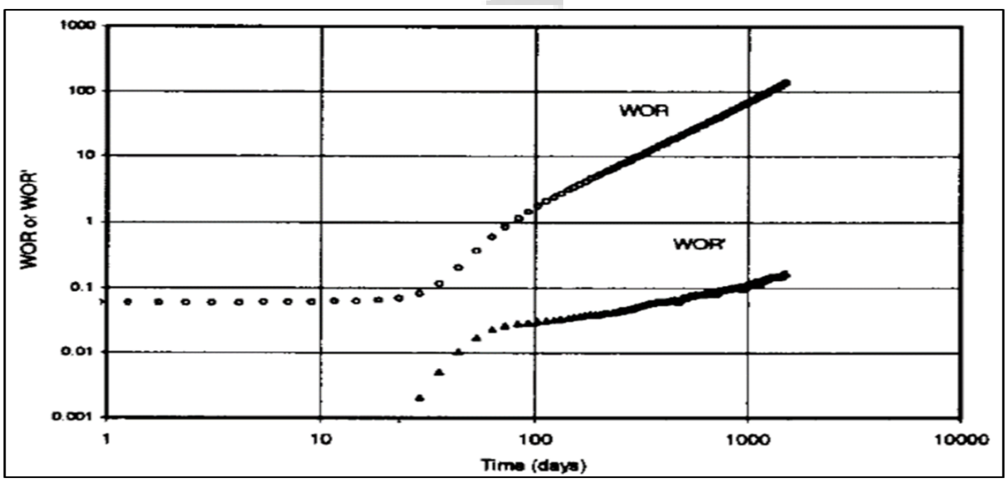

Figure 3: Channeling, WOR, and WOR' derivatives[8]

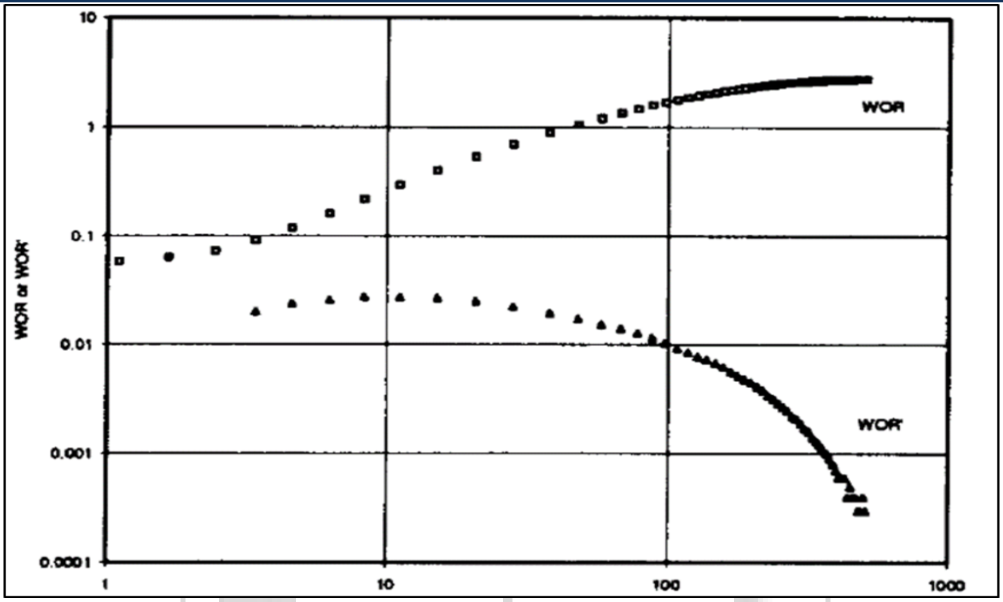

Figure 4: Bottom-water coning WOR and WOR derivatives[8]

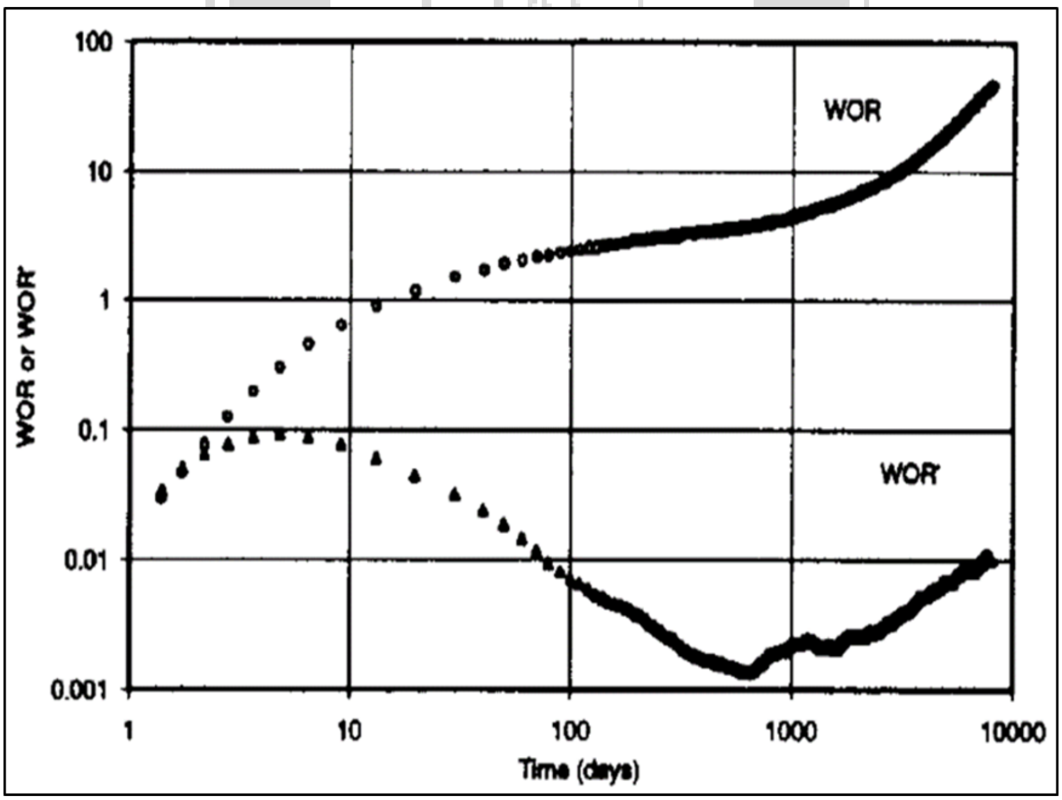

Figure 5: Bottom water coning with late time channeling[8]

For coning, the departure time is often short (depending on several variables), and corresponds to the time when the underlying water has been drawn up to the bottom of the perforations. According to

Chan, the rate of WOR increase after water breakthrough is relatively slow and gradually approaches a constant value. This occurrence is called the transition period. [8]

For channeling, the departure time corresponds to water breakthrough for the most water conductive layer in a multi-layer formation and usually occurs later than for coning. Chan claims that the WOR increases relatively quickly for the channeling case, but it could slow down and enter a transition period, which is said to correspond to production depletion of the first layer. Thereafter, the WOR resumes the same rate as before the transition period. This second departure point corresponds to water breakthrough for the layer with the second-highest water conductivity. According to Chan, the transition period between each layer breakthrough may only occur if the permeability contrast between adjacent layers is greater than four.

After the transition period(s), Chan describes the WOR increase to be quite rapid for both mechanisms, which indicates the beginning of the third period. The channeling WOR resumes its initial rate of increase since all layers have been depleted. The rapid WOR increase for the coning case is explained by the well producing mainly bottom water, causing the cone to become a high-conductivity water channel where the water moves laterally towards the well. Chan, therefore, classifies this behavior as channeling. [9]

Diagnostic plots derivative method

Using Water/oil ratio (WOR) diagnostic plots prepared by Chan (1995). A set of diagnostic plots is generated by conducting a series of systematic water-control numerical simulation studies using a black oil simulator. This three-dimensional, three-phase simulator is capable of modeling the performance of reservoir flow under different drive mechanisms and waterflood schemes. According to this method, a log-log plot of WOR versus time will show different behavior for the varying mechanisms. Log-log plots of WOR time derivatives versus time are said to be capable of differentiating whether a production well is experiencing water coning, channeling due to high-permeability layers, or normal with high water cut. The Derivative method can be considered as the most appropriate methodology for identifying the source of the water production problems.

Therefore this method is considered as a unique technique and has been proposed as an easy, fast, and inexpensive method to identify excessive water and gas production mechanisms. The water problem is diagnosed with the help of table (1). [10] [11]

Table 1: Behavior of the WOR and WOR'

WOR Slop	***WOR'* Slop**	**Reason for Water Production**
positive	positive	Channeling
positive	Negative	Coning
Positive linear slope	horizontal line	water/oil contact rising

Methodology

In this project several steps were performed to reach the main objectives, these steps start with the understanding main concept of the water sources in oil and gas reservoirs and the used approaches to identify these sources, and finally processing the raw measured production data to be suitable for the project objectives and where it can be summarized as follows:

- Collecting the required data from several wells in the reservoir for this study that includes the water production rate and oil production rate.
- Define the wells with bad water production by using the analytical approach in MS Excel.
- Identify the water source by using the diagnostic WOR approach and compare the results with the textbook behavior to define the water source.
- Discussing and recommending the practical solutions for the identified water source

Case Study

A122 oil field was discovered in 1959 by the well A1. It is located along the eastern flank of the Sirte Basin. A122 covers an area of 166,000 acres. The area is subdivided reservoir-wise into three main reservoirs: A, M & F based on the oil PVT properties and pressure/production performance. These three reservoirs share a common aquifer and have an original field average oil/water contact at 10250'

SS. A122 development to date includes 166 wells six of which drilled as appraisal wells were abandoned. The field location can be shown in figure (6).

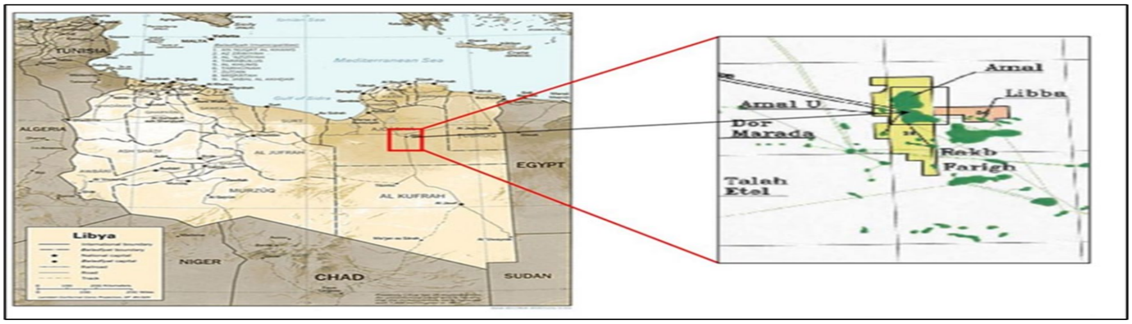

Figure 6: Location map for A122

Results and Discussions

The provided production history for wells (A18, A-30, A-20, A-90, A-97) was used to calculate the water cut, to identify the excessive water production issue, and further to calculate the WOR and the WOR' to identify the cause of the issue.

Well A-18

As it can be seen in figure (11) increasing trend for water production can be indicated from the water cut behavior to reach about 60%.

The diagnostic plot as shown in figure (7) indicates a decreasing trend in the WOR' after 3000 to 6000 days (about from eight years to sixteen years from the start of well production). This was interpreted as bottom water drive coning through the well completion. After 6000 to 7000 days (about from sixteen to twenty years from the start of well production) within a general upward trend on the WOR' which can be interpreted as channeling.

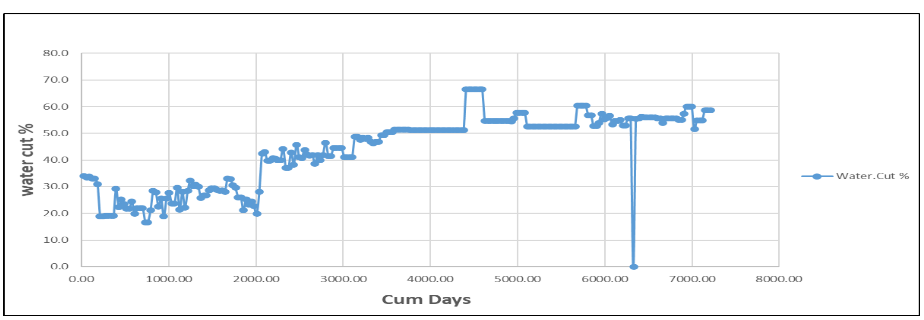

Figure 7: Water cut history for well A18

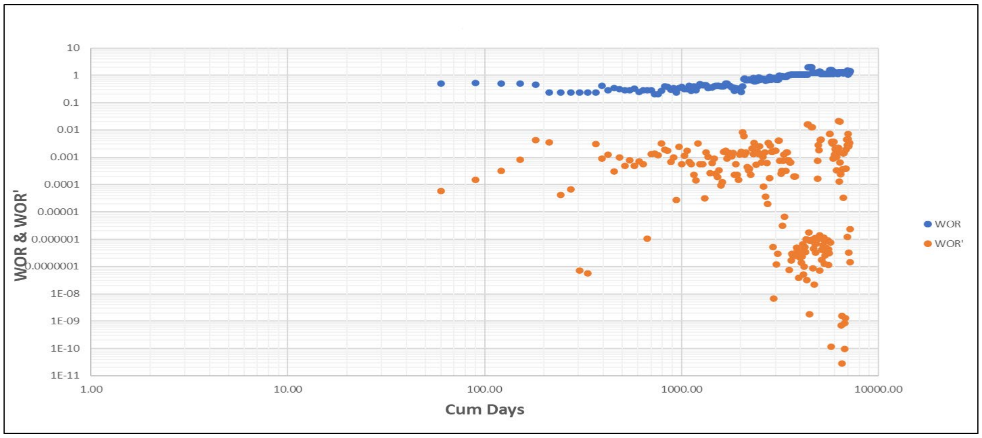

Figure 8: WOR and WOR' for well A18

Well A30

As it can be seen in figure (9) increasing trend for water production can be indicated from the water cut behavior to reach about 65%.

The diagnostic plot as shown in figure (10) indicates a decreasing trend in the WOR' after 10000 to 15000 days (about from twenty-seven years to forty-one years from the start of well production). This was interpreted as bottom water drive coning through the well completion, especially after this long production period. Similar to well A18 later water channeling can be indicated.

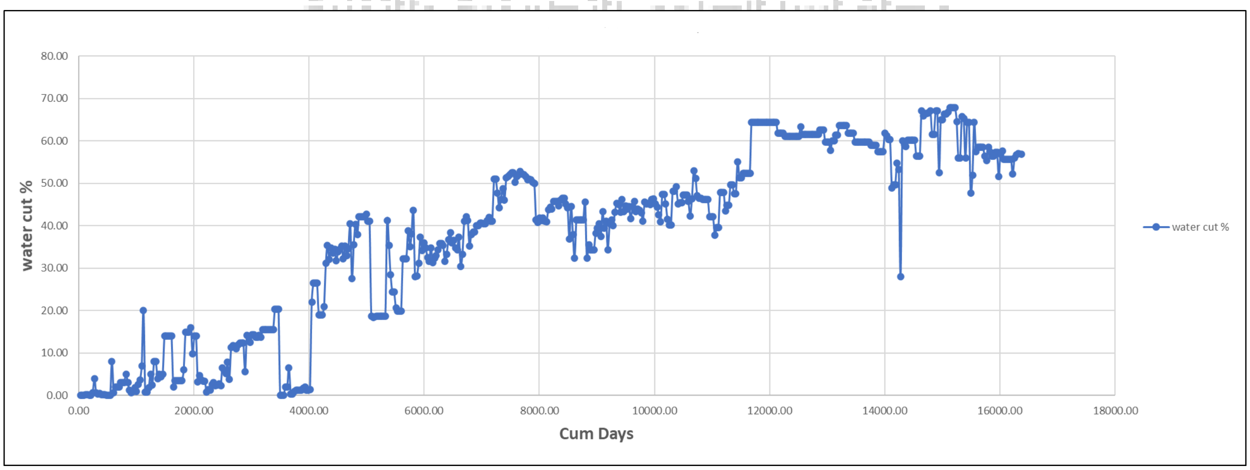

Figure 9: Water cut history for well A30

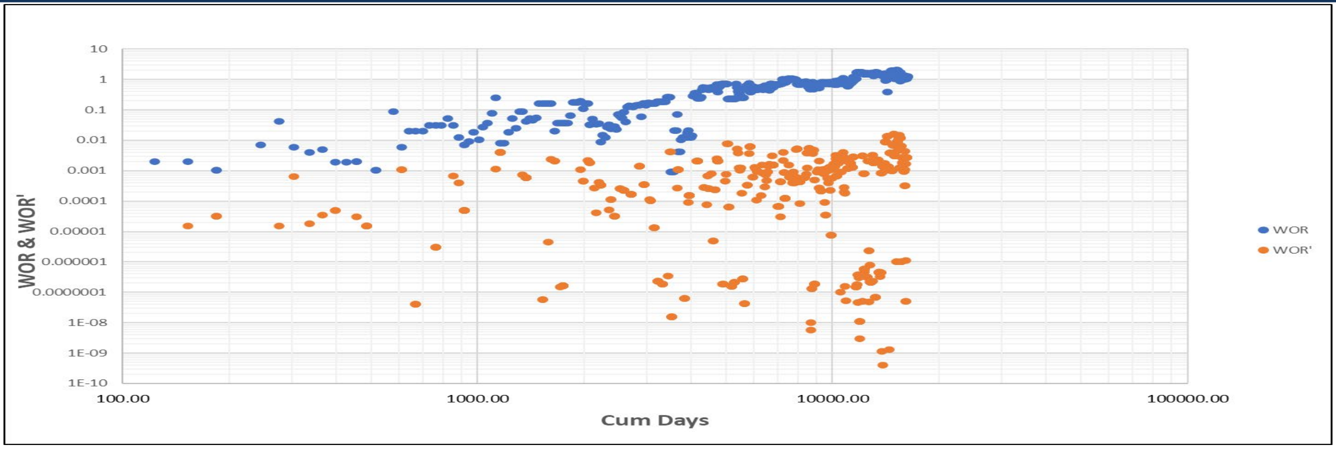

Figure 10: WOR and WOR' for well A30

Well A20

As it can be seen in figure (11) water production start to increase after 3000 days from the start of the production and further increased to reach about 73%.

The diagnostic plot as shown in figure (12) indicates a decreasing trend in the WOR' after 15000 days (about forty-one years from the start of well production). This was interpreted as bottom water drive coning through the well completion.

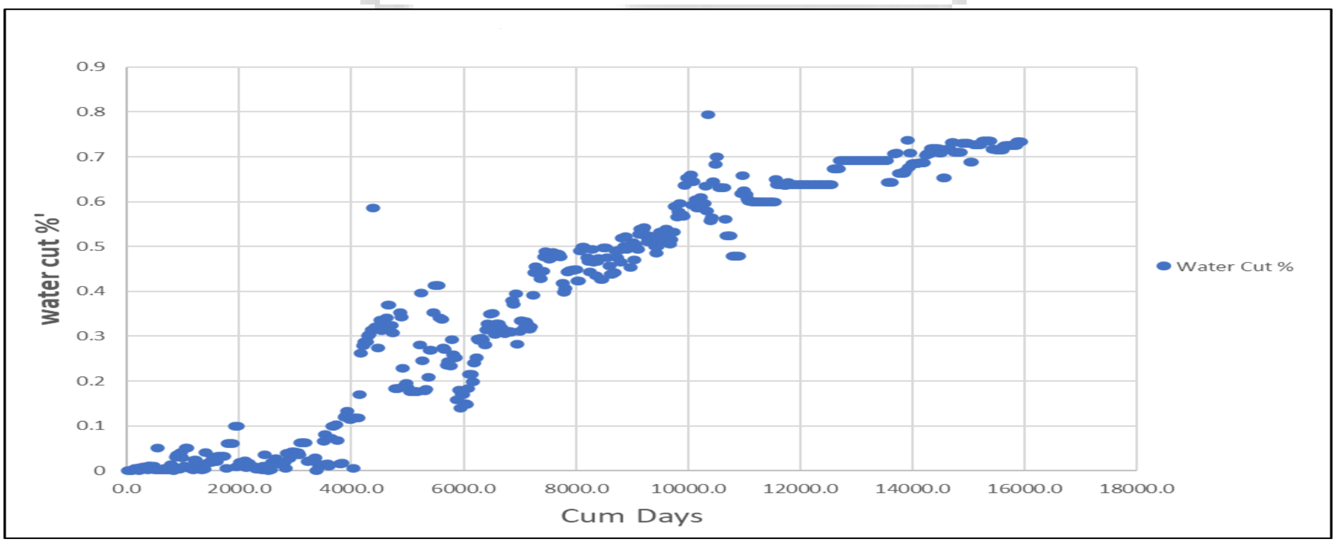

Figure 11 :Water cut history for well A20

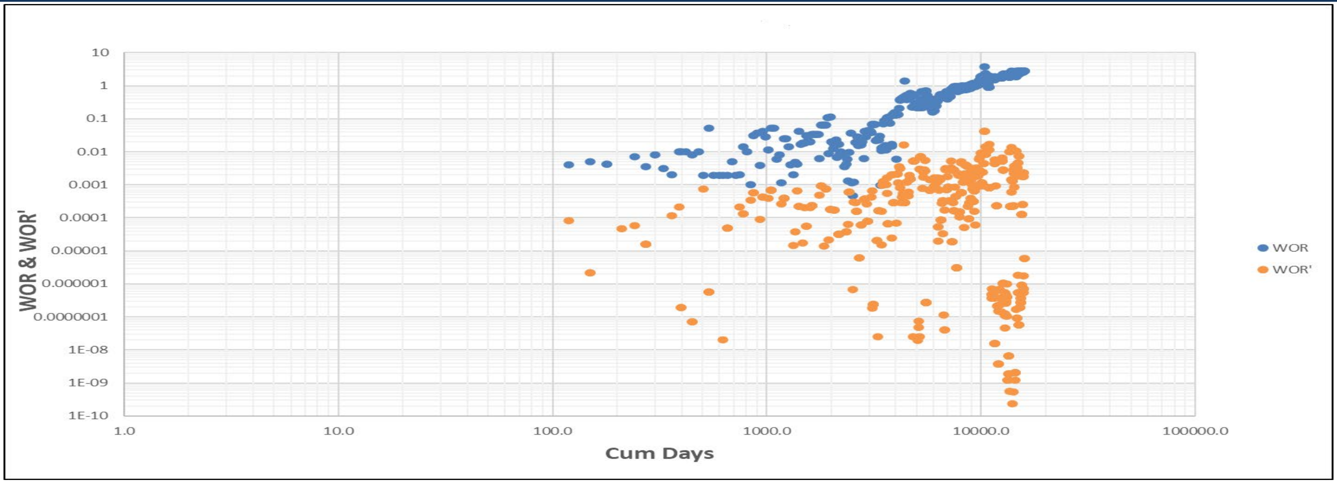

Figure 12: WOR and WOR' for well A20

Well A90

As it can be seen in figure (13) no excessive water production problem can be indicated from the water cut behavior which tends to remain around 2.5% with several spikes.

No clear behavior can be indicated from the diagnostic plot as shown in figure (14). This also supports the observation from the water cut behavior, which was interpreted as bottom water drive coning through the well completion.

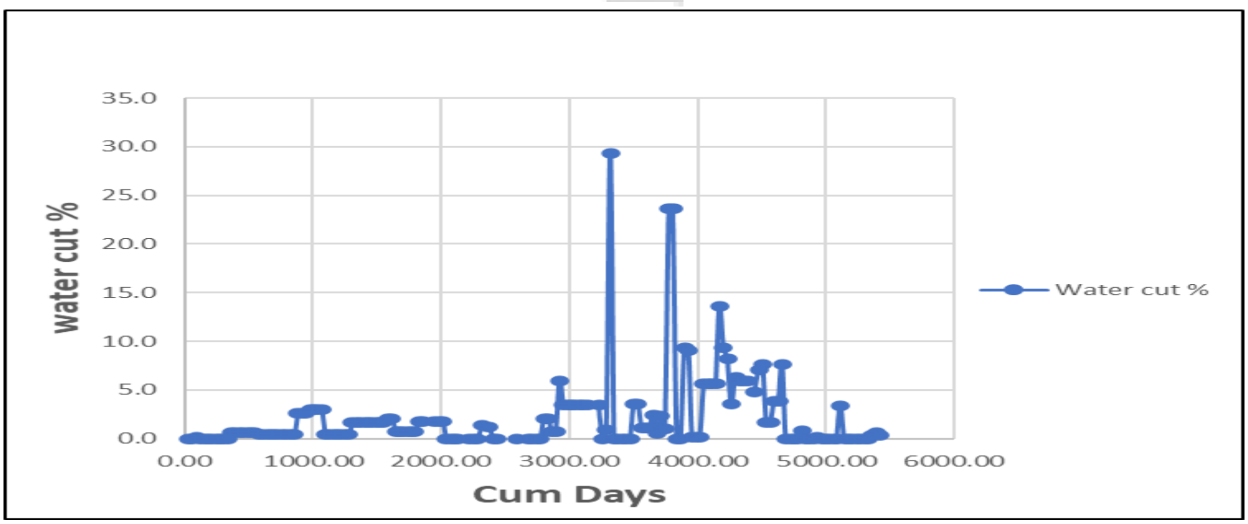

Figure 13: Water cut history for well A90

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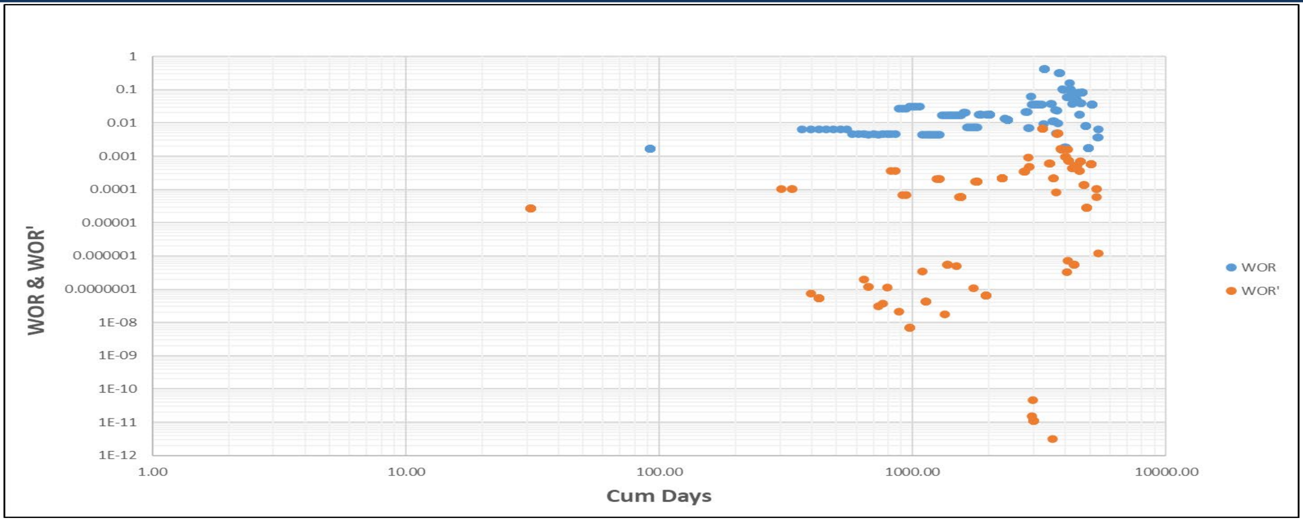

Figure 14: WOR and WOR' for well A90

Well A97

As it can be seen in figure (15) the water production is almost constant along the production period to be around 30%.

The diagnostic plot as shown in figure (16) indicates a decreasing trend in the WOR' after 2000 to 4000 days (about from five years and six months to around eleven years from the start of well production). However, the behavior might not be conclusive as the water cut behavior does not indicate any increase, and further investigations are needed.

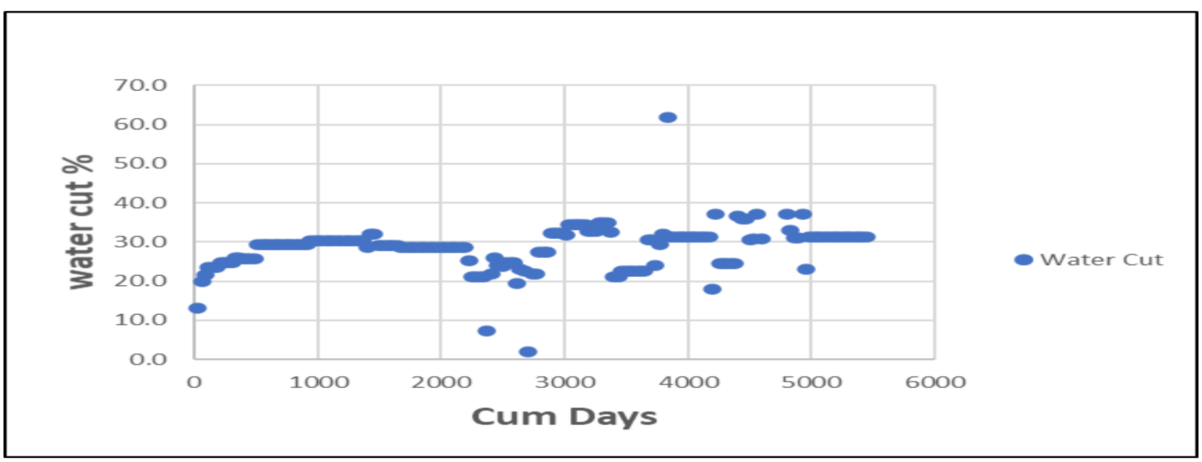

Figure 15: Water cut history for well A97

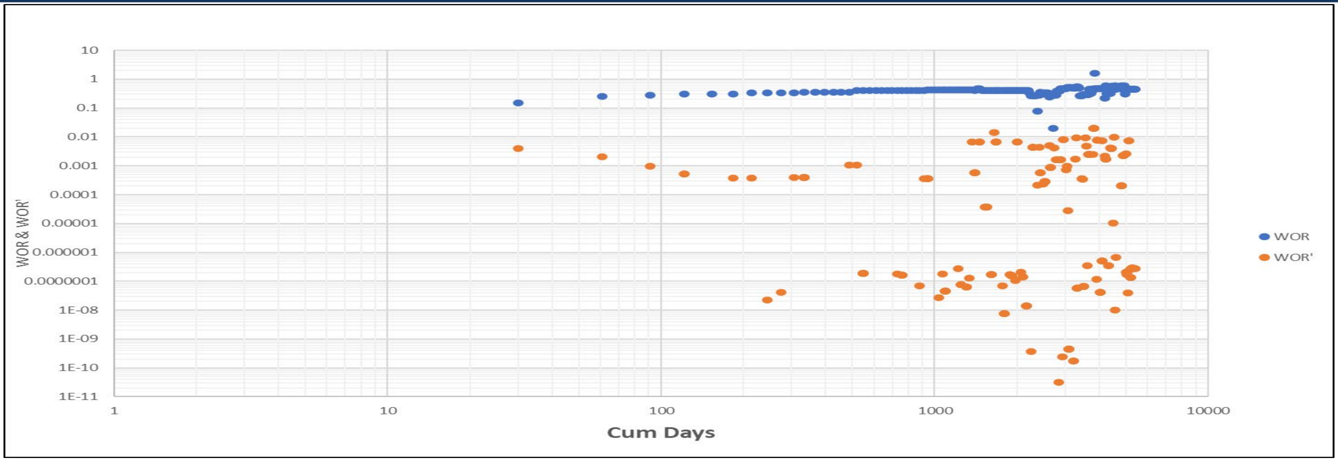

Figure 16: WOR and WOR' for well A97

Conclusion

Excess water production not only reduces oil production rates but also demands expensive and time-consuming water management activities, ranging from oil wells and oil field treatment to environmental issues for wastewater disposal.

It is critical to first identify the cause of the problem in order to successfully address the excess water production issue. The derivative approach offers a lot of benefits in this study since it uses a methodology that may be utilized to rapidly diagnose and assess water production processes.

four wells out of the five wells included in this study from the Amal field have indicated excessive water production due to the bottom water coning which can be related to the high production rates. Further analysis and investigation by borehole measurements are needed to define the location of the perforation that contributes to the excessive water production and the potential treatment in this stage.

Recommendations

A cement squeeze job should be conducted for the perforation intervals that exhibit a highly water-saturated profile and the production casings should be tested to evaluate their condition and confirm any potential leak experience. This can be done by reviewing the Cement Bond Log (CBL) and Variable Density Log (VDL) data. Also Polymer treatment is one of the preferred water shut-off techniques to be applied, as it can reduce the mobility of water production and help avoid or delay the onset of viscous fingering issues.

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