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Qualitative and Quantitative Analysis of Water Coning and Breakthrough Time Prediction on ZNC Field

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ABSTRACT

Given the current public need for oil and gas as a primary energy, all oil and gas companies need to increase production to meet this demand. One of the things companies usually do to achieve this is to evaluate and analyze the productivity of each well. Of course, production decreases from time to time, so the company must try to increase its production. One of the reasons for the decline in oil production from the ZNC-1 well in the ZNC Field is the production of excessive water content. There are several factors that cause excessive water content in oil wells, and this is called water coning. The method used to determine the occurrence of the water cone problem requires qualitative and quantitative analysis. In using qualitative analysis, two analyzes were carried out, including an analysis of the production history of the well and an analysis of the Chan Diagnostic Plot showing bottom-water coning problems with late-time channeling. Meanwhile, based on the quantitative results, the critical flow rate of the ZNC-1 well calculated using the Bornazel and Jeanson method is 167 STB/D. With these results, the value of the critical flow discharge is greater than the actual discharge, which is 291.3 STB/D. Thus it can be ascertained that there has been water coning in the ZNC-1 well. After that, the breakthrough time obtained by the Bournazel and Jeanson method was 361.3 days.

Keywords: bornazel and jeason method, breakthrough time, critical flow rate, water coning,

I. INTRODUCTION

In the oil and gas field, production is certain to decline. Data from the BP Statistics Review 2020 shows that Indonesia's oil and gas production has dropped significantly since 1998 until now, indicating production problems in the oil and gas sector. One of the production problems in the oil and gas field is the reduced recovery factor caused by water production. One problem which is caused by the production of water caused by the actual flow rate, which is higher than the critical flow rate, which is called water coning. In his book, Rukmana writes that the formation of a water cone is an event that results in water production due to the pressure gradient of the flowing well compared to the gravitational gradient of the liquid. As a result, water forms a cone-like shape and rises towards the perforation to a certain extent. Water moves periodically because it takes a long time for water to penetrate the oil zone to reach the perforations.

The ZNC-1 well is a production well that has been producing since 2019. This well is a vertical well that produces oil. Based on production history, it appears that the ZNC-1 well has experienced a significant increase in water production. If a well produces more water than oil or gas, it will have an impact on a company's losses both from an operational and economic perspective.

II. METHODS

The research to be carried out will begin with data collection that has indications of water coning problems. There are steps that need to be carried out. First, provide some data wells that are in the field. Then do a historical analysis of production from the well. Then look at the significant increase in water cuts that have occurred in production history. After a significant increase in the water cut, it is necessary to identify the problems with water production that occur in a well by using a diagnostic plot made by K.S Chan. First of all, data preparation is necessary. Next, do a qualitative analysis by looking at the production history of the well and analyzing the causes of water coning using the Chan Diagnostic Plot.

According to Chan, Chan's Diagnostic Plot is a method used to determine the mechanism of excessive water production in production wells. This method connects the log-log plots of Water Oil Ratio or can be called WOR and Water Oil Ratio Derivative or can be called WOR' with time. Production problems that usually occur in reservoirs are Coning and Channeling. There is a difference between water coning and water channeling. Coning is caused by a vertical pressure gradient near the wellbore. Meanwhile, channeling is a heterogeneous reservoir that can cause large permeability flows (Rukmana, 2011). The WOR & WOR' plots show that the characteristics of the reservoir near the well, both vertical and horizontal, play an important role in the formation of the WOR & WOR' curve of the well (Al Otaibietal., 2019).

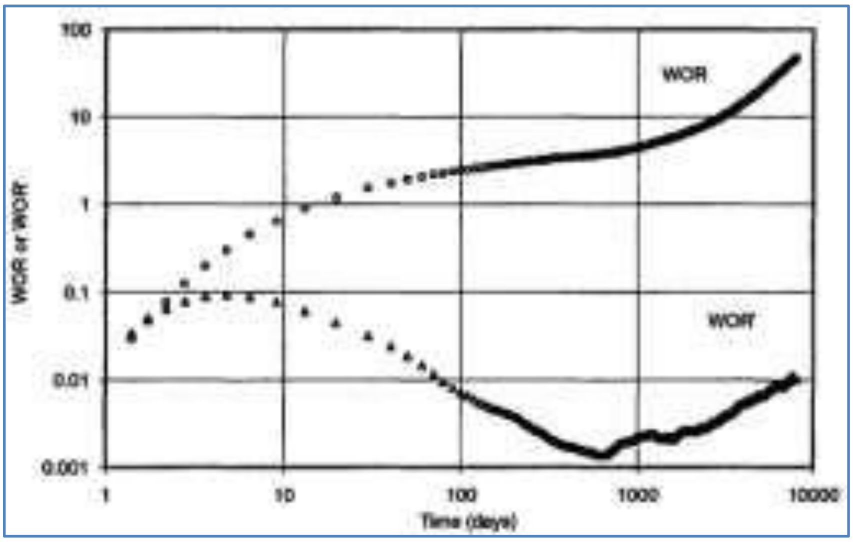

Figure 1. ***Bottom-water Coning with Late Time Channeling Behavior*** **(Chan, 1995)**

Based on Figure 1, it depicts the diagnostic plot between WOR (Water Oil Ratio) and WOR derivatives versus time. The diagnostic plot shows the WOR derivative has a positive slope value which tends to be constant for channeling and a negative slope value which changes for coning. The derivative WOR trend for channeling behavior that occurs at the end of water coning is shown in Figure 1. The plot results also show a positive slope value.

The critical production rate is the rate at which the pressure gradient flowing down the well causes water (or gas) to flow into the well. At a critical level, the cone that is formed will be stable but is in the position of the latest breakthrough (Ahmed, 2019). Critical flow rate calculation is done by using the following equation:

$$q_c = \frac{0.0071\ (k\ h)(\rho_w - \rho_o)(h\ h_c)}{\mu_o B_o} \qquad (1)$$

Critical flow rate calculations often show low flow rates, which, for economic reasons, are usually not applicable to production wells. Therefore, if a well is producing above its critical level, water will break through the water-oil boundary to form a cone after a certain period of time. This is what is called Breakthrough Time or tBT (Ahmed, 2019).

Bournazel and Jeanson found that the breakthrough time they calculated was usually smaller than that calculated by Sobocinski and Cornelius. Therefore they modified the Sobocinski and Cornelius equations. The changes made are to make the td equation as a function of Z to replace the "breakthrough" (td)BT vs Z curve of Sobocinski and Cornelius. and set alpha=0.7 for all M values in the interval 0.14 to 7.3.

The equation for determining breakthrough time with the Bournazel and Jeanson methods is as follows:

Dimensionless Cone Hight

$$Z = 0.492\ x\ 10^{-4}\,\frac{(\rho_w - \rho_o)\ kh\ h(h - h_p)}{\mu_o B_o q_o} \qquad (2)$$

Dimensionless Time to Breaktrough

$$(tD)\ BT\ = \frac{Z}{3 - (0.7xZ)} \qquad (3)$$

Actual Breakthrough Time

$$tBT = \frac{\mu_o\ h\ \emptyset\ (tD)BT}{0.00137\ (\rho_w - \rho_o)K\ h\ (1 + M^{0.7})} \qquad (4)$$

III. RESULTS AND DISCUSSION

Given that each well has a different production history, an analysis of production history is necessary to determine whether the well has experienced a significant increase in the water cut. This process is the first step in detecting the appearance of a water cone. Based on the data, the ZNC-1 well is a vertical oil well. Sumur ZNC-1 started production on December 1, 2019 with an initial production value of 241 BFPD or 190 BOPD.

Figure 2. Graph of ZNC-1 Well Production History

Based on Figure 2, it can be seen that the production history of the ZNC-1 well shows an increase in fluid production by 23 BFPD from 170 BFPD to 193 BFPD. This is due to a change in bean size from 3.5 inches to 5 inches. Furthermore, there was also an increase in fluid production of 76 BOPD from 261 BFPD to 337 BFPD. This was also caused by a change in bean size from 5 inches to 7 inches. Furthermore, there was also an increase in fluid production by 43 BFPD from 391 BFPD to 434 BOPD. This was also caused by a change in bean size from 7 inches to 9 inches. From this increase, it can be seen that the water cut experienced a significant increase of 5.23% from 0.4% to 5.63%. The significant increase in WC indicates the occurrence of water coning. To prove again the occurrence of water coning in the ZNC-1 well, it is necessary to analyze Chan's Diagnostic Plot.

After analyzing the history of production from the ZNC-1 well, it was confirmed that there had been a significant increase in WC. Next, it is necessary to know the causes of the increase in toilets. For this reason, we need to know the cause of water coning in the ZNC-1 well, by conducting a Chan's Diagnostic Plot analysis by plotting a graph between the Water Oil Ratio (WOR) and the Water Oil Ratio derivative versus time in the ZNC-1 well. The plot results will show whether the ZNC-1 well is experiencing water coning or channeling.

Based on the calculation results of the WOR and WOR derivative values from the production data, a WOR and WOR derivative plot was carried out to see the graphical results, and after that, the graphical results of the ZNC-1 well were matched with the Chan's Diagnostic Plot simulation results, so that the behavior of water problems can be identified.

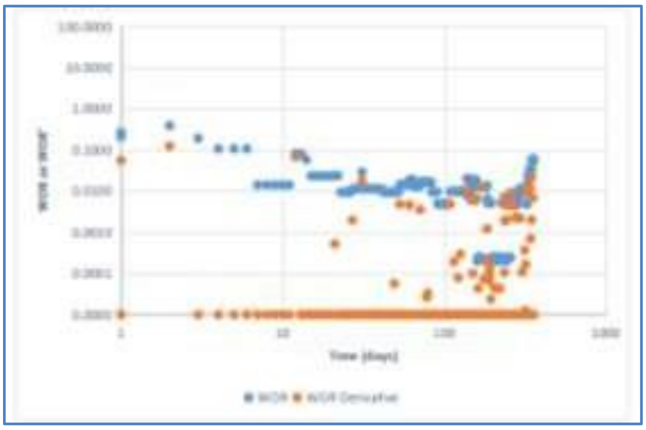

Figure 3. ***Diagnostic Plot*** **ZNC Field**

Figure 3 shows that the ZNC-1 well has a WOR which tends to show a positive slope while the derivative WOR shows a negative slope at the beginning and at the end of the period shows a positive slope. After being compared with several of Chan's Diagnostic Plot models such as Chan's model, it can be seen the similarities between the slope of the WOR and the WOR derivative. From these similarities, it can be shown that the ZNC-1 well indicates the occurrence of bottom-water coning with late-time channeling problems.

Qualitative analysis is not enough to know that a well is experiencing water coning. For that, it is necessary to know the critical flow rate. Calculation of the critical flow rate needs to be done to determine the maximum flow rate in the well so that it does not experience water coning. The critical flow rate will be compared with the actual flow rate to confirm that water coning has occurred. If the production flow rate is much greater than the critical flow rate, an indication of a drastic increase in the water cut and the Chan plot shows water coning, it can be confirmed that water coning has occurred in a well. For this reason, there is a method that can be used to calculate the critical flow rate in vertical wells, namely using one of the methods, namely the Bournazel and Jeanson methods

Table 1. Calculation Data of Critical Flow Rate of Well ZNC

Parameter	Simbol	Value	Unit
Oil Zone Thickness	Ho	147.637	ft
Permeability	kh	100	mD
Oil Viscosity	μ_o	0.8	cp
Water Density	ρ_w	0.99	gr/cc
Oil Density	ρ_o	0.88	gr/cc
Formation Volume Factor	B_o	0.972	bbl/STB
Perforation Bottom Distance and WOC	h_c	147.637	ft

The critical flow rate using the Bournazel and Jeanson method can be calculated by referring to Equation (1) with the data in Table (1). From the results of the calculations above, it shows that the results of calculating the estimated critical flow rate with several methods, it was found that the Bournazel and Jeanson Methods have a value of 167 STB/D. The results of the calculation of this critical flow rate when compared with the actual production flow rate of 291.3 STB/D, it can be seen that the actual production figure is much higher than the point flow rate so it is confirmed that water coning will occur.

Furthermore, it can take into account the Breakthrough Time. This is intended to estimate when water coning has occurred. The calculation of Breakthrough Time on the ZNC-1 well is as follows

Table 2. Breakthrough Time Calculation Data for ZNC-1 Well

Parameter	Symbol	Value	Unit
Oil Zone Thickness	Ho	147.637	ft
Perforation Thickness	h_p	16.404	ft
Actual Flow Rate	qT	291.3	STB
Permeability	kh	100	mD
Porosity	ϕ	0.093	
Oil Viscosity	μ_o	0.8	Cp
Water Density	ρ_w	0.99	gr/cc
Oil Density	ρ_o	0.88	gr/cc
Formation Volume Factor	Bo	0.972	bbl/STB
Mobility Ratio	M	4.5	

Breakthrough Time calculated using the Bournazel and Jeanson method can be calculated by referring to Equations (2), (3) and (4) with the data in Table (2). Based on the calculation results of the estimated Breakthrough Time, it was found that the Bournazel and Jeanson method has a Breakthrough Time value of 361.3 days. The results of the sensitivity analysis of the effect of flow rate on breakthrough time can be seen in Figure 4.

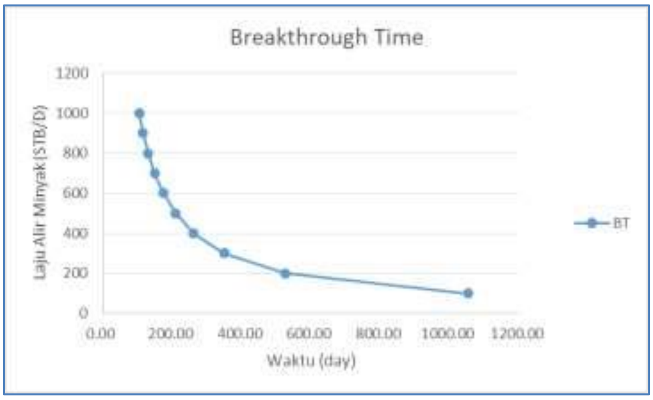

Figure 4. Breakthrough Time

Based on Figure 4, shows the condition when the flow rate is greater than the breakthrough time will be faster and vice versa, if the flow rate is smaller than the penetration time will be slower. Thus, the production flow rate of a well is very influential on the acceleration of water production in oil wells which will affect the increase in the water cut of a well.

IV. CONCLUSION

Based on the results of the discussion above, it can be concluded that based on the results of a qualitative analysis using production history analysis and diagnostic plots, it is indicated ZNC-1 well-experienced water coning. From this increase, it can be seen that the water cut experienced a significant increase of 5.23% from 0.4% to 5.63%. The significant increase in WC indicates the occurrence of water coning. To prove again the occurrence of water coning in the ZNC-1 well, it is necessary to analyze Chan's Diagnostic Plot.

Based on Chan Diagnostic that the ZNC-1 well has a WOR which tends to show a positive slope while the WOR derivative shows a negative slope in the early period and at the end of the period shows a positive slope. After being compared with several of Chan's Diagnostic Plot models such as Chan's model, it can be seen the similarities between the slope of the WOR and the WOR derivative. From these similarities, it can be shown that the ZNC-1 well indicates the occurrence of bottom-water coning with late-time channeling problems.

Based on the calculation results, the critical flow rate obtained by the Bournazel and Jeanson method is 167 STB/D. Once it is known that the ZNC-1 well is experiencing water coning, it can be estimated that the breakthrough time with the Bournazel and Jeanson Method is 361.3 days.

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