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# Analyze of Water Injection Performance Surveillance in "ATHENA" Field

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**Abstract**

To measure the success of waterflood activities, we need evaluation and analysis. To support evaluation and analysis need to be done assessment of well connectivity to the response of injection wells, performance wells with Hall-plot and Voidage Replacement Ratio and calculate water breakthrough time with method Buckley-Leverett whether according to the actual field. To examine these required supporting data such as field history, production and injection history, fluid level measurement data. The results of the study showed the well ATH-43 less response (poor response) and the well ATH-37 and ATH-33 gave good response (good response) and gain oil obtained by 8,196 barrels. The hall-plot evaluation showed that the well ATH-04 had no formation/normal damage, and the results of the VRR showed the VRR < 1. The results of the calculation of water breakthrough time calculations with actual show the well experiencing breakthrough earlier than the calculation (Premature breakthrough).

## INTRODUCTION

The key success of water injection project is the planning and implementation of monitoring at the wells. Previously, Buckley Leverett's equations helped in understanding improvement average water saturation in the sweeping area and the time it takes to perform the injection (Nidiarti et al., 2018; Thomas et al., 2015; Yang, 2009). This study aims to analyze Buckley Leverett's equations to actual and evaluate the performance of water injection projects with several analyze such as Well connectivity, Hall plot, and Voidage Replacement Ratio.

The analysis and evaluation used in this study are as follows:

### 1. Well Connectivity

At the waterflood pilot stage, the connectivity of wells is analyzed by conducting a tracer test. While at the full-scale stage, connectivity analysis is carried out by analyzing the plot of oil production rate, liquid production, water content, and injection rate. From the production and injection plots can be seen how well production responds well to water injection from injection wells (Mursyidah et al., 2020; Terrado et al., 2007).

### 2. Hall Plot

The main purpose of this method is to determine the performance of the injection and the problems that may occur in the injection well. To evaluate, we need data injection rate and pressure at a certain time. Once the Hall-Plot curve plot is obtained, it can be estimated the next procedure can be done or workover (Andalucia et al., 2016; Hamdi, 2015; Hariyadi & Aribowo, 2013; Iqbal et al., 2017). The equation of this method obtained:

$$i_w = A(P_{inj} - P_{avg}) \quad (1)$$

### 3. Voidage Replacement Ratio (VRR)

This method is used to determine the pressure response due to injection, helping to determine strategies in optimizing production and knowing the performance of injection. If the value of VRR<1 means that the

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injection rate is not optimal and must be improved for production optimization. If VRR>1 then the injection rate is optimal enough (Alida & Juliansyah, 2016). The equation of this method obtained:

$$VRR = \frac{Injected\ Reservoir\ Volumes}{Produces\ Reservoir\ Volumes} \quad (2)$$

### 4. Buckley-Leverett

To calculates recovery by estimating fluid saturation in linear systems as a function of distance and frontal advance equations to evaluate the velocity of water saturation in invaded zones. The assumption of linear flow and homogenous single layer in Buckley-Leverret theory is considered to be widespread area of sweep efficiencies (acreage and vertical sweep efficiencies) is 100% (Thomas et al., 2015). Fractional flow equation obtained:

$$f_w = \frac{1}{1+\left(\frac{\mu_w}{\mu_o}\right)ae^{bs_w}} \quad (3)$$

## METHOD

The methodologies used in this research are (1) Collecting and reviewing data, both field history, reservoir data, daily production data, daily injection data, and fluid levels, (2) Conducting well connectivity analysis by creating and viewing well performance graphs based on both production rate and injection rate, to find out how well production responds to injection performed, (3) Perform calculation and analyze Hall-Plot based on cumulative pressure and cumulative injection volume , in order to know the performance of the injection and possible problems that arise, (4) Perform calculations and analyze Voidage Replacement Ratio (VRR) to evaluate the effectiveness of injection performed, (5) Perform breakthrough time calculations with Buckley-Leveret method, using SCAL (special core analysis) data and reservoir properties. This is to compare the results of the calculation with the actual that occurred in the field.

Table 1. Description of Reservoir Properties (Source: PT. PEP Archived)

| Reservoir Properties | Value |
|---|---|
| Pi | 1249 psi |
| *Oil Gravity* | 37 API |
| Bo | 01.08 bbl/STB |
| Bw | 1.02 bbl/STB |
| H | 20 ft2 |
| A | 16404.2 ft2 |
| Porosity | 20% |
| Iw | 750 BWPD |
| Distance | 250 meter |
| Visc. Oil | 0,5875 cp |
| Visc. Water | 0,29 cp |
| Dip angle | 15 |
| Swc | 20% |
| Swi | 25% |
| Sor | 20% |
| Recovery Factor (RF) | 29% |
| Water Injection Project started | 2008 |
| Total Wells | 70 |
| Drive Mechanism | Solution Gas Drive and Water Drive (weak) |

## RESULT AND DISCUSSION

The results of evaluates and analyzes the waterflood activities, including analysis of well connectivity, hall-plot analysis, Voidage Replacement Ratio analysis, and calculation of water breakthrough time with Buckley-Leveret are shown below.

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**Wells Connectivity Analysis**

Figure 1 is a correlation of field well log data "ATHENA" which shows there are three layers that are the target of water injection activities, namely layers SAND- 24AB.1, SAND- 24AB.2 and SAND-24CD and known types of reservoir rocks are sandstone. The results of connectivity analysis showed that two ATH- 33 and ATH-37 have good connectivity. This can be seen from the connectivity graph of each well in the Figure 2.

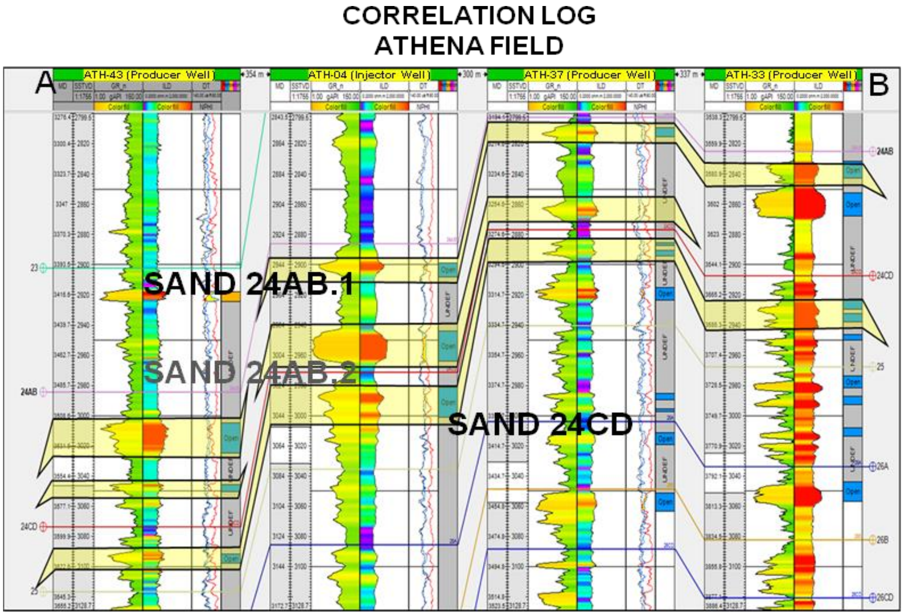


Figure 1. Well Log Data of ATH-43, ATH-4, ATH-37, and ATH-33 (Source: Archive of PT. PEP, 2020)

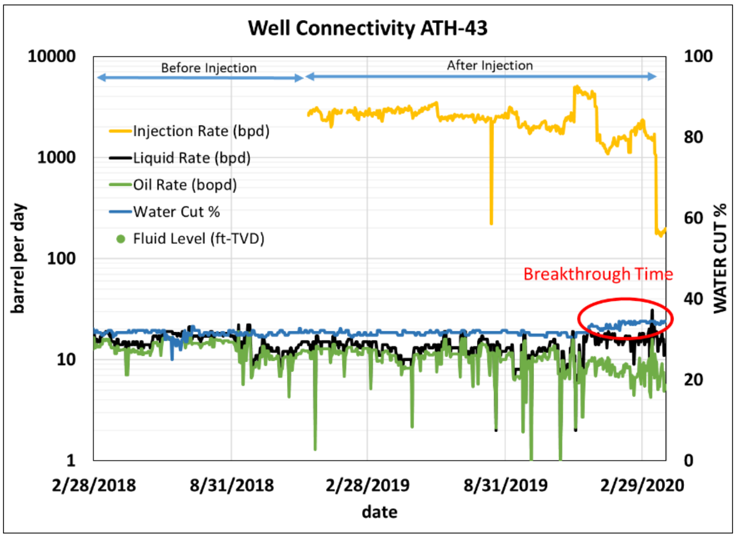


Figure 2. ATH-43 Well Connectivity

The ATH-43 well is down-dip than ATH-4 well, in theory ATH-43 well will breakthrough early because it is quite close with the other two wells. But in the connectivity results showed the response to the injection is poor response, seen when the injection rate was raised water breakthrough also rise up. However, when the injection rate is lowered, the water-cut chart increases. Similarly, fluid level does not show any response, it may cause by the measurement of Sonolog-Data (fluid level) is less accurate, so the increase in water-cut and liquid rate due to optimization of pumps carried out, and the type of pump used is also a factor. This well using Hydraulic Jet Pump (HJP).

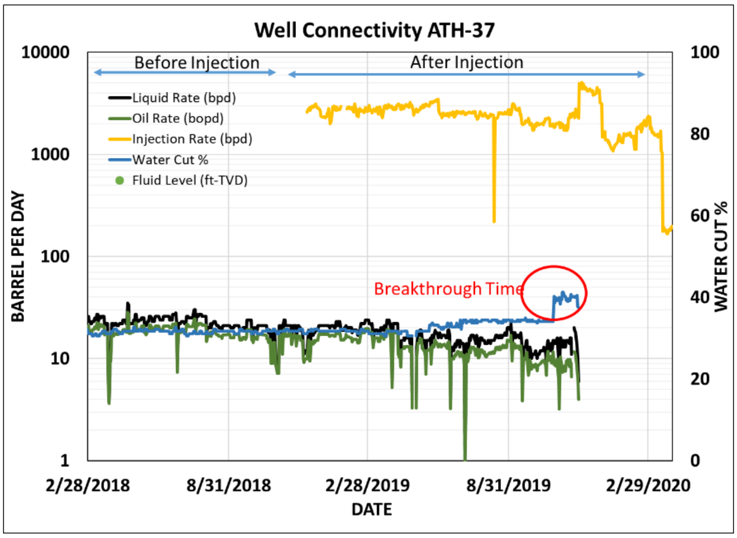


Figure 3. ATH-37 Well Connectivity

The ATH-37 well also showed a fairly good response to the injection, as it shown in Figure 3 when the injection rate was decreasing liquid rate also decreased. The ATH-33 well also showed a fairly good response to the injection (Figure 4). It showed when the injection rate was lowered liquid rate also decreased.

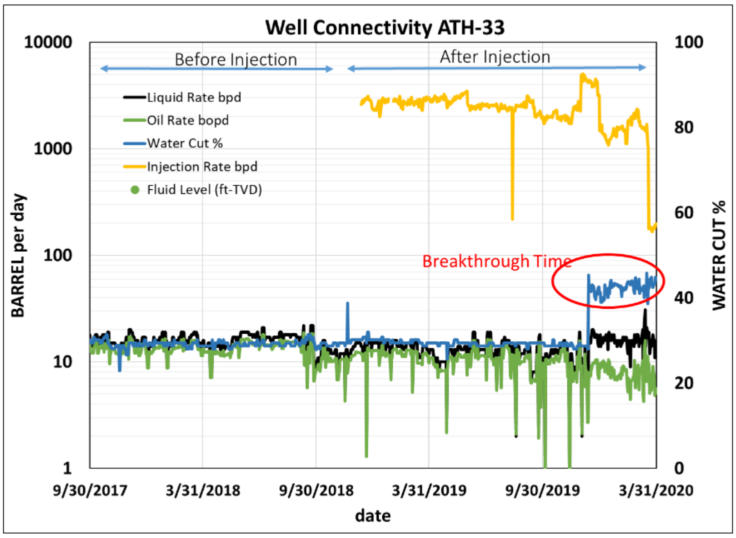


Figure 4. ATH-33 Well Connectivity

### Hall Plot

Figure 5 is the result of calculation of Hall Plot in injection well "ATH- 04". The Hall curve of this plot can be seen that the injection well is in normal condition or there is no formation damage.

### Voidage Replacement Ratio (VRR)

The results showed the value of VRR at the beginning of injection in December 2018 of 0.01 (VRR< 1) that it is necessary to increase the injection rate aimed at more efficient sweep. By the calculation shows the value of VRR is increasing and it is expected that the value of VRR remains worth less than 1 (VRR < 1) so that the oil sweep is more optimal (Figure 6).

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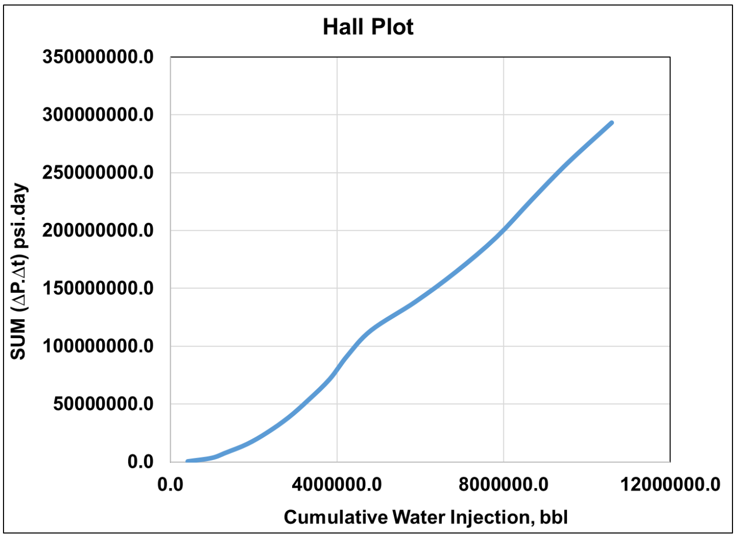


Figure 5. Hall Plot Result

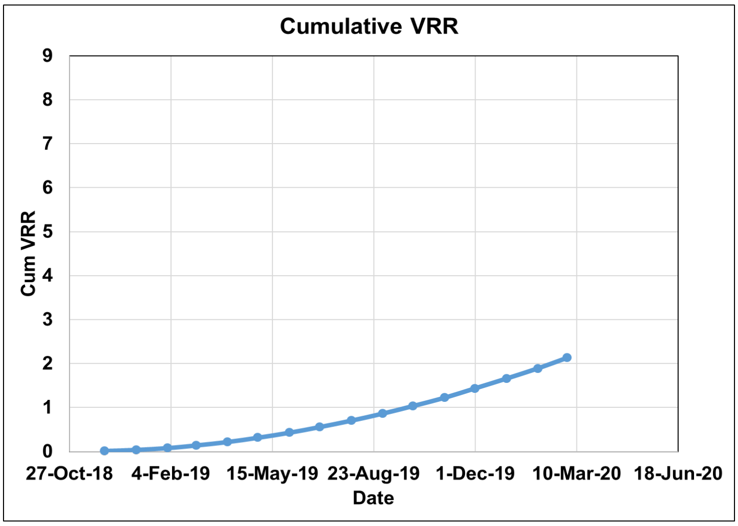


Figure 6. Voidage Replacement Ratio Result

## Buckley Leveret

The initial stage in the calculation of this method plots the ratio value of relative permeability (krw/kro) vs. saturation of water on a semi log scale. From the calculation, obtained the value a =18611 and the value b = -20.39 which is then used in fractional flow calculation. Based on qualitative analysis on fractional flow curve found in Figure 7 obtained results in "ATHENA" field has Swf = 0.5180 and Fw = 0.801 and SwfBT = 0.583. Furthermore, breakthrough time calculation is performed on the well based on each layer. From the calculation of each layer those are Sand-24AB.1, Sand-24AB.2 and Sand-24CD, breakthrough time is obtained as follows:

1. The distance between the ATH-43-layer 24CD with injection wells is 1161.41 ft so that the results of breakthrough time calculations with the Buckley-Leveret method it takes 812.5 days or 2.25 years (Figure 8).
2. The distance between ATH-37 wells and injection wells is 984ft so that the results of breakthrough time calculations with the Buckley-Leveret method it takes 1215.6 days or 3.37 years at layer 24AB.1, while 957 days or 2.61 years at layer 24CD (Figure 9).
3. The distance between ATH-33 wells and injection wells is 38890ft so the result of breakthrough time calculations with the Buckley-Leveret method takes 2025.95days or 5.62 years at 24AB.1 layer, while 1720 days or 4.77 years at 24CD (Figure 10).
4. Table 2 summarizes the result of water breakthrough time for each well.

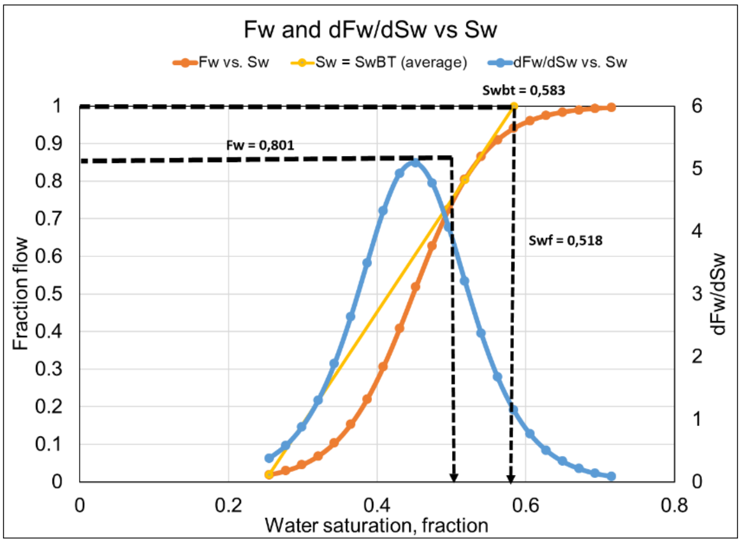


Figure 7. Fractional flow plot

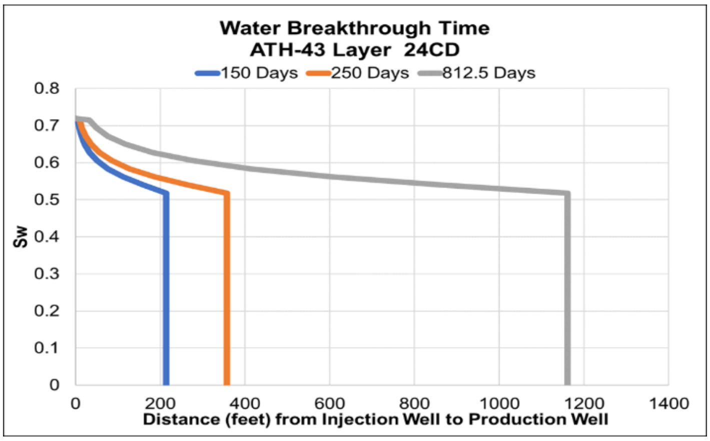


Figure 8. Water Breakthrough Time ATH-43 Layer 24 CD

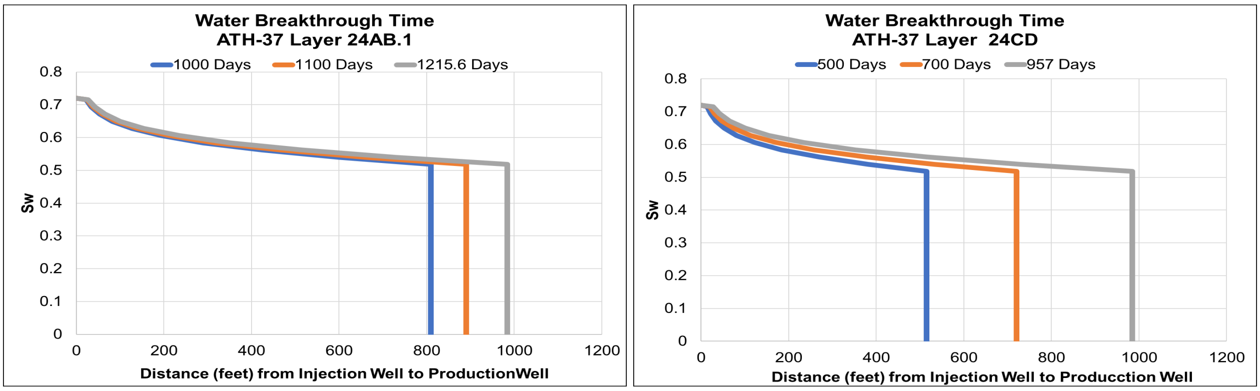


Figure 9. Water Breakthrough Time ATH-37 Layer 24AB.1 and Layer 24 CD

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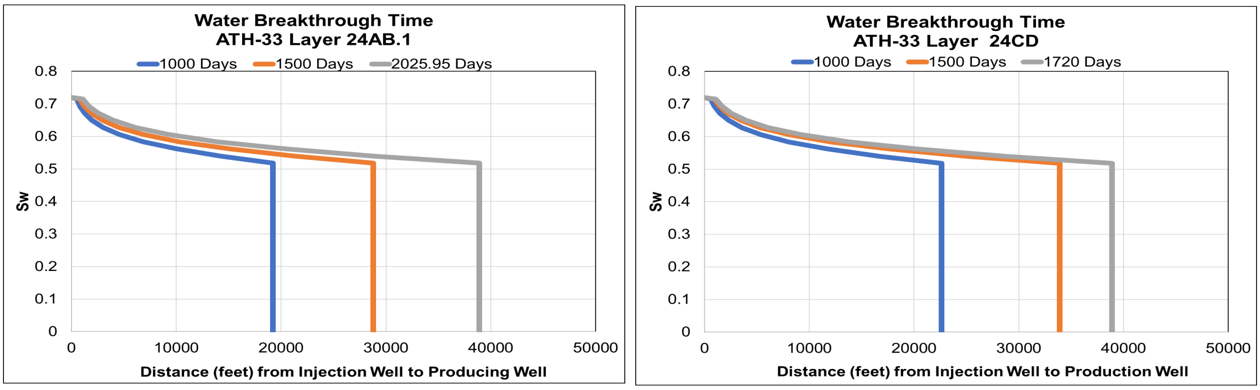


Figure 10. Water Breakthrough Time ATH-33 Layer 24AB.1 and Layer 24 CD

Table 2. Water Breakthrough Time Result

| Well | Layer | Breakhtrough time (Buckley Leverett) | Breakthrough time actual | Oil Gain (Bbls) |
|---|---|---|---|---|
| ATH-43 | 24CD | 2 years | 1 years (after) | 8,189 |
| ATH-37 | 24AB.1 | 3 years | 0.83 years (after) | 8,253 |
| | 24CD | 2 years | | |
| ATH-33 | 24AB.1 | 5 years | 1 years | 8148 |
| | 24CD | 4 years | | |

## CONCLUSION

From the discussion that has been described before, it can be concluded as follows:

1. Results of connectivity analysis on ATH-43 (poor response) wells, ATH-37 wells (good response) and ATH-33 (good response) with oil gain of 8.19 barrels
2. In Hall analysis the plot shows the ATH-04 well is normal or there is no formation damage. Analysis of Voidage replacement ratio (VRR) shows the value (VRR< 1) so it is necessary to optimize the injection,

Comparison of water breakthrough time calculation results with Buckley-Leveret method to actual in the field shows the result that breakthrough occurred early (premature) and also due to Buckley Leveret's equation assumes for homogeneous reservoir whereas in actual is heterogeneous.

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