Scientific Contributions Oil & Gas, Vol. 47. No. 1, April: 65 - 73

SCIENTIFIC CONTRIBUTIONS OIL AND GAS
Testing Center for Oil and Gas
LEMIGAS

Journal Homepage:http://www.journal.lemigas.esdm.go.id
ISSN: 2089-3361, e-ISSN: 2541-0520

Mature Field and Well Revitalization: Selection of Matrix Acidizing Candidates

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Manuscript received: March 07st, 2023; Revised: March 21st, 2023
Approved: April 05st, 2024; Available online: April 19st, 2024

ABSTRACT - The authors were motivated to conduct this study due to a notable drop in the production of mature fields in Indonesia. This decline in production can be attributed to several factors, including reservoir heterogeneity, resulting in an uneven distribution of fluids and pressure within the reservoir. Well-stimulation techniques such as matrix acidizing can be employed to increase well production. With matrix acidizing, acid is injected into the formation surrounding the wellbore to dissolve minerals and improve permeability, thereby increasing the flow of fluids from the well. Before implementing this method, the well screening process must be conducted to optimize workflow efficiency and ensure that the wells are suitable for matrix acidizing. This paper presents a comprehensive workflow to identify the most qualified candidates for matrix acidizing. The heterogeneity index (HI) concept was used to classify the well's condition and other parameters, such as the well's estimated ultimate recovery (EUR). After obtaining a short list of wells, nodal analysis, well design for matrix acidizing, and potential gain calculation from stimulation results were performed. The study evaluated 24 wells and identified three suitable candidates for matrix acidizing, all showing significant production increases according to the production data. This study proves that using the HI concept for well selection and matrix acidizing stimulation can effectively raise well productivity in Indonesia's mature oil fields.

Keywords: mature field, matrix acidizing, Heterogeneity Index (HI), well selection.

How to cite this article:

Joe Felix Turnip, Amega Yasutra, Fahrizal Maulana, and Sri Dwi Mustaqim, 2024, Mature Field and Well Revitalization: Selection of Matrix Acidizing Candidates, Scientific Contributions Oil and Gas, 47 (1) pp. 65-73. DOI.org/10.29017/SCOG.47.1.1613.

INTRODUCTION

In recent years, the oil and gas industry in Indonesia has experienced a significant shift in focus from exploring new reserves to maximizing the potential of mature fields. These fields, which have been producing for several decades, often experience declining production rates due to factors such as reservoir damage, formation plugging, and decreased permeability (Yulianto, 2017). Due to this condition, research on discovering new methods that can increase the existing production is needed. This is also supported by the government's target to increase national production to 1 million barrels per day. Therefore, all possible methods that can increase production have to be explored. Well stimulation is one of the methods that can increase well production (Ego Syahrial & Hadi Purnomo, 2009). Well stimulation is a technique used to enhance oil or gas flow in a well by dissolving plugging substances or creating new pathways near the wellbore (Economides et al., 1993). One commonly used method of well stimulation is Matrix Acidizing.

A matrix treatment restores permeability by removing damage around the wellbore, thus improving productivity in both sandstone and carbonate reservoirs. Although the acid systems used in sandstone and carbonate differ, the same practices apply to both (Lake & Clegg, 2006).

Selecting appropriate wells is the key to successfully conducting well stimulation using matrix acidizing. In the well-stimulation plan, it is crucial to identify well candidates with good potential for a positive response to stimulation, considering the characteristics of mature fields in Indonesia. One of the methods that can be used to identify well candidates is the Heterogeneity index method (Harami K. et al., 2013).

This study aimed to evaluate the selection of candidates for well stimulation using matrix acidizing in mature fields in Indonesia using the heterogeneity index method and analyze the production performance of wells after implementing well stimulation using matrix acidizing.

METHODOLOGY

Well Selection

Abdel-Basset et al. (2018) have previously laid out the complete workflow for production optimization through well selection. Our study delved deeper into the Heterogeneity Index method for selecting potential well candidates. Since there are numerous wells to consider, a screening process was required to identify the most promising ones. Moreover, careful selection for matrix acidizing is pivotal to stimulate the chosen wells.

To identify suitable candidates for matrix acidizing in Field "A", the Heterogeneity Index of existing wells was analyzed. The selection process involved assessing the cumulative production of oil and water from each well within the field. Candidates were selected based on low Heterogeneity Index values for both oil and water, ensuring that the chosen wells had low oil and water production to prevent any potential production challenges down the line (Salim et al., 2019).

After identifying potential oil wells using the Heterogeneity Index method, the candidates were narrowed down by analyzing their Estimated Ultimate Recovery (EUR) through the use of Decline Curve Analysis (DCA) and reciprocal methods. This process helped select wells with the highest oil reserves in comparison to other wells.

Evaluation Well Performance

Once the suitable candidates for well stimulation with matrix acidizing had been identified, a performance evaluation of the wells was conducted. This evaluation is crucial for comparing the pre-acidizing performance with the post-acidizing performance. The evaluation involved creating an Inflow Performance Relationship (IPR) assessment and utilizing Soekarno's (1986) IPR model. The average production data of the wells prior to their inactivity served as the basis for the evaluation.

Matrix Acidizing Design

Once the appropriate well candidates for well stimulation had been identified, a matrix acidizing design was created for each selected well. The design of the acidizing process was based on the unique characteristics of each well. The type of reservoir rock has a significant impact on the matrix acidizing design. For instance, the design will differ based on whether the well has carbonate or sandstone rock characteristics.

In order to ensure optimal results, it is imperative to perform a solubility examination on the acid prior to implementation. This evaluation ascertained the complete solubility of the sample to be introduced during the matrix acidizing procedure. The specific actions involved in the solubility test are outlined below:

- Grind the sandstone sample into fine particles.
- Place 1 to 3 grams of the sample in a 250 mL glass beaker.
- While under the fume hood, cover the sample with an organic solvent and let it settle.
- Carefully pour off the solvent. Weigh approximately one gram of the sample and add it to the glass beaker.
- Let the sample remain in the solution for at least 1 hour at the test temperature.
- Filter insoluble materials using pre-weighed

filter paper and dry in an oven at 105°C.

- Cool the sample in a desiccator and weigh it.

To determine the total solubility of a sample in acid, a solubility test can be conducted. This information is crucial in the design of a matrix acidizing treatment for each well, ensuring effective dissolution of formation damage and improved well productivity.

If all the necessary steps have been completed, the percentage of solubility can be calculated to determine if the acid is suitable for use in matrix acidizing. The following equation can be used to calculate the % solubility:

$$\% \textbf{ Solubility} = \frac{\text{sample Wieght } - \textit{insoluble} \text{ weight}}{\text{sample weight}} \textbf{ x 100\%} \qquad (1)$$

The design of the acidizing matrix is influenced by the well's schematic and the volume employed. This design involves determining the additives utilized and the volume of each component. The selection of additives is divided into two categories: pre-flush and main acid for matrix acidizing. The pre-flush acid serves to effectively clean the well's components of impurities, ensuring proper implementation of the matrix acidizing process.

The matrix acidizing design in this study was developed using design standards that are often used in companies where the research was carried out. The same treatment was given to all the existing wells because they were still in the same reservoir.

Evaluation Result of Matrix Acidizing

Once matrix acidizing had been complete, well performance was assessed and compared to its performance prior to stimulation. Utilizing Pudjo Soekarno's IPR, we can observe the well's performance before and after acidizing. Wiggins' Future IPR was employed to assess the well's performance post treatment, measuring the pressure of the current reservoir and analyzing the desired skin sensitivity for the results of the acidizing process. By running the matrix acidizing through various skin sensitivity tests, we can determine the effectiveness of the treatment and whether or not the stimulation process was successful. Ultimately, the results of the well's performance indicated if it was a suitable candidate for stimulation.

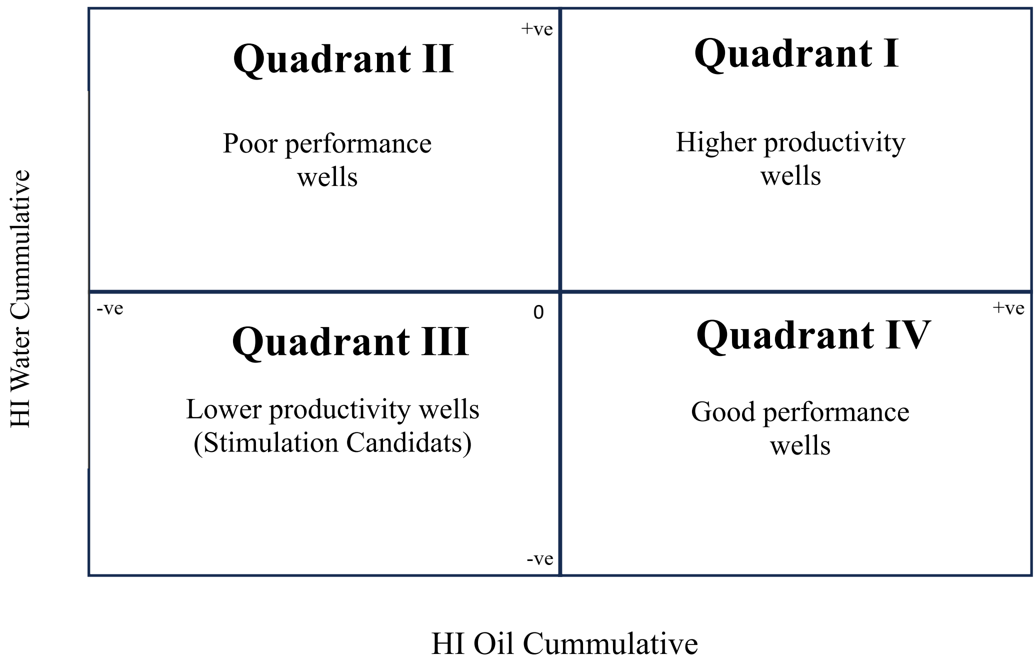

Figure 1
Matrix of heterogenity index

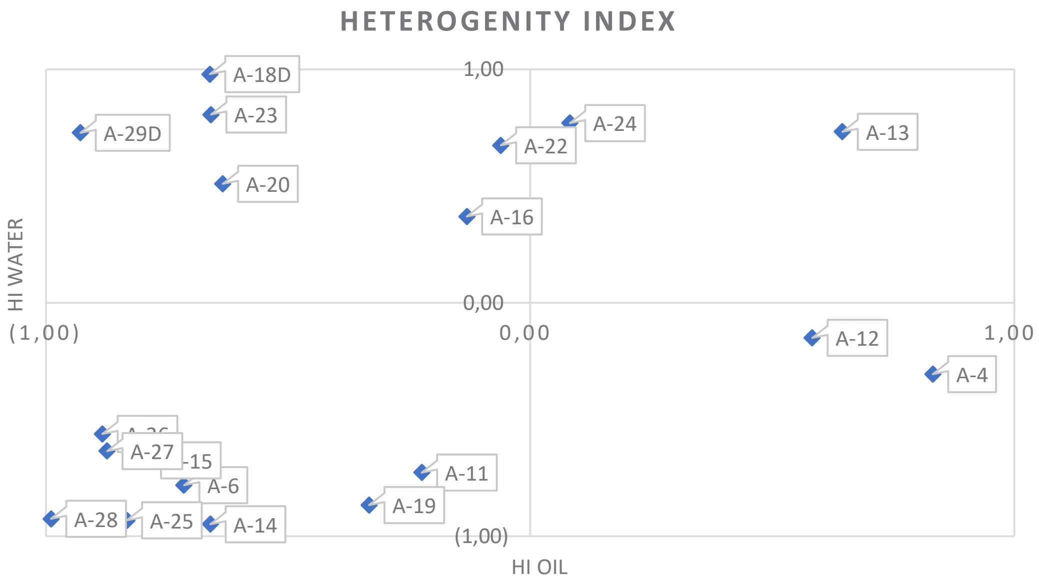

Figure 2
Result of heterogenity index

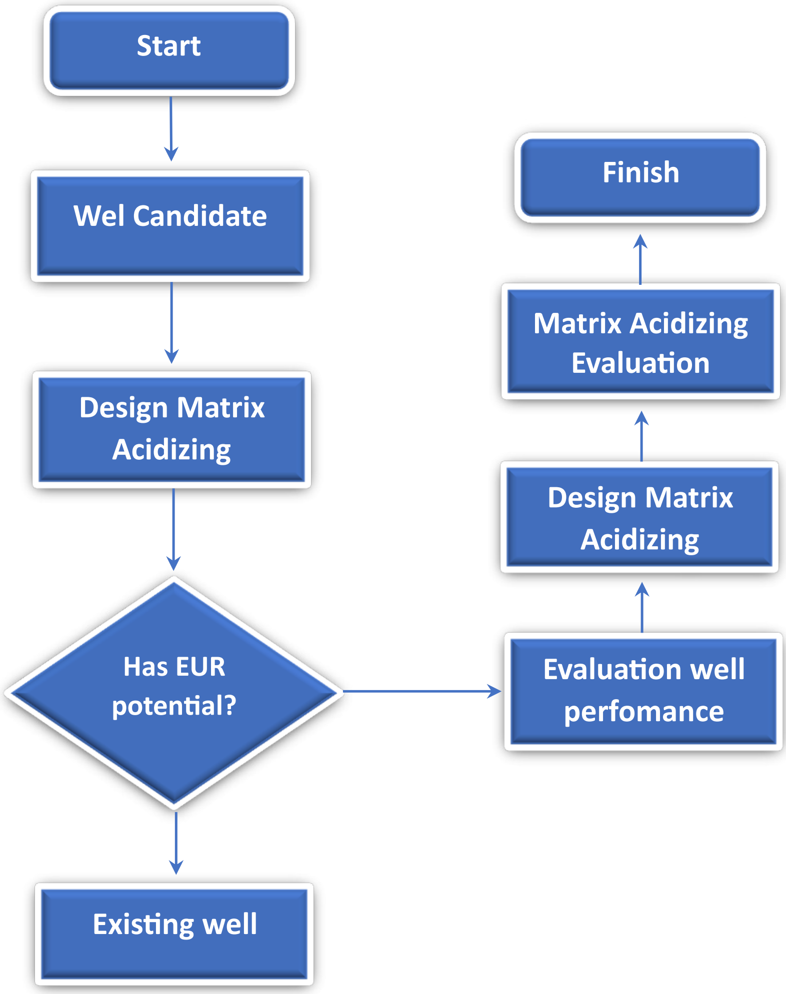

Figure 3
Flowchart of well selection

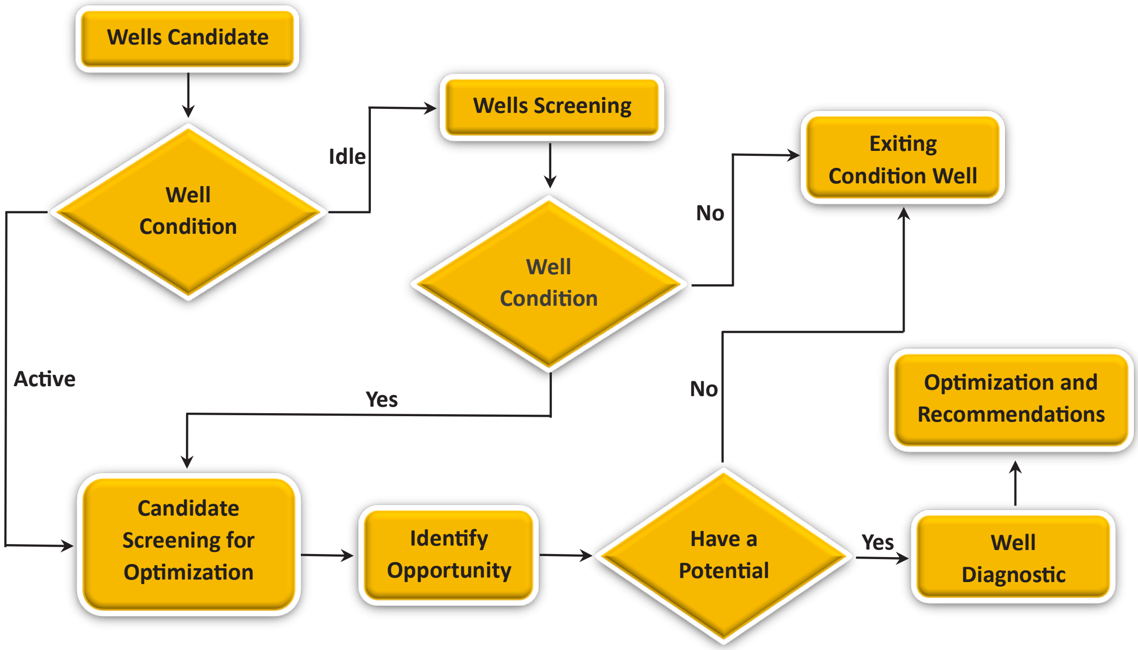

Figure 4
Workflow for screening and optimization (Abdel, M et al 2018)

RESULT NAD DISCUSSION

Well Selection with Heterogeneity Index and EUR

The process for selecting suitable well candidates rely on the Heterogeneity Index of each well. This index indicates the expected levels of oil and water production of a given well in comparison to others within field "A". We identify the most promising candidates as those with low oil and water Heterogeneity Index scores, as this allows for effective well stimulation without excessive water production. A visual representation of the quadrant analysis related to the Heterogeneity Index is included in the diagram below.

The IPR calculation involves analyzing cumulative production from the beginning of production until the well becomes idle. To determine the daily production of each well, we compare it to the cumulative average of all wells in Field A. The final cumulative was taken on the date when all wells were idle, and the results were used to generate a graph showing the distribution of HI, which is included in the picture.

Next, we reduce the well candidates by examining the EUR of the well, which was calculated using the DCA and reciprocal methods. These methods are necessary due to the decrease in production in Field A resulting from reservoir conditions, rather than changes in production facilities. Following the calculation, we recommend carrying out matrix acidizing on three wells: A6, A14, and A19. These wells had rates of 187 BFPD, 399 BFPD, and 292 BFPD, respectively, all obtained from the average well production.

The performance of the three selected wells were then evaluated, making it possible to compare the results before and after matrix acidizing treatment was conducted. The results of the IPR of the 3 wells can be seen in Figure 5, 6, and 7 respectively.

Matrix Acidizing Design Solubility Test

Solubility test is an acid solubility test to determine the total solubility of acid samples in a 15% HCl system and a 12:3% HCl:HF system using gravimetric methods, with acidic conditions at a test temperature of 190 ºF. In matrix acidizing, a minimum % of acid solubility of at least 20% is required. The sample used in this test was 1 gram sample vs. 100 ml of acid used to ensure that the acid was more than enough to dissolve the sample. From the calculation results, an average result of 24.96% for 15% HCl and 15.35% for 12:3 HCl:HF resulted in a total solubility of 40.31%. Thus, the acid to be used had sufficient % solubility for matrix acidizing to run effectively.

Acid and Additive Design

The design of matrix acidizing should be tailored to the characteristics of the reservoir in the well. In general, matrix acidizing is distinguished for carbonate and sandstone. The main difference between the two types of rocks is the characteristics and interaction of rocks with acids to be injected. This case study involved sandstone reservoir rocks. The acid design for sandstone will use a mixture of HCl and HF because sandstone is easier to decay if exposed to acid. So, the use of a mixture of HCl and HF is intended to prevent the reservoir from being damaged.

Before HCl-HF injection, HC pre-flush was first performed to dissolve carbonate minerals in the reservoir and to overcome low pH conditions in the reservoir. In addition, a pre-flush was also done to eliminate impurities in the wellbore. Then, in performing acid design, the first thing to be accomplished was to determine the volume of acid required to stimulate the well. We can see this from the Well Schematic by looking at the perforation of the well. The volume of the pre-flush wellbore was also determined. The targeted penetration for this pre-flush was as deep as 2ft. The calculation of the pre-flush volume uses the formula:

$$v = \theta \pi {r_w}^2 \emptyset S_{wirr} \quad (2)$$

The acid volume for the pre-flush was 683 gal. After that, the main acid volume was calculated using the same formula with a targeted penetration depth of 5 ft. The result of the acid volume for the pre-flush was 3690 gal.

The standard treatment for sandstone reservoirs is 3 wt% HF, 12 wt% HCl, by applying 15 wt% HCl for pre-flush. The use of HF maximum 3 wt% aims to reduce the impact of damage due to acid. The procedure commonly uses acid with a concentration of 32-34%.

The explanation of additives used in matrix acidizing is as follows:

- CI (Corrosive Inhibitor) is useful for slowing down the corrosion process in tubular due to contact with acid. Loading Corrosion Inhibitor is influenced by temperature, acid concentration, type of tubular material, and protection time.
- Iron Control Agent is useful for contracting from casing or tubing and also iron minerals in wells. Iron Control Agent is divided into 2 functions, namely Iron Reducing Agent and Iron Chelating Agent. Iron reducing converts Fe3+ into Fe2+, where Fe3+ precipitates at low pH (pH +/-2, or acidic conditions). Iron Chelating Agent acts as a complexion, so Fe2 + remains in a complex bond and does not turn into loose iron.
- Clay Stabilizer serves to prevent Clay Migration.
- Non-Emulsifier is part of Surfactant which functions to break emulsions.
- US (Universal Solvent) is part of Surfactant, which works by lowering the surface tension between 2 phases of fluid.
- ABF (Ammonium Bi-Fluoride) or AF – (Ammonium Fluoride) is a chemical that will generate HF (Hydrofluoric Acid) after reacting with HCL.

Evaluation of Results

The Future IPR of the wells was analyzed using the Wiggins method (1994). Future IPR will see the performance of wells with pressure conditions from the reservoir in which depletion has occurred. It can be seen in the figure, that over the production time, the reservoir pressure will continue to deplete. To overcome this, the reservoir pressure can be increased again by injecting water as done in the A37 reservoir layer to make pressure trend graph increase.

After making the acid design, the results of well stimulation were seen by sensitizing the target skin to be obtained. Matrix acidizing will improve the permeability of the well, thus decreasing the skin from the well (Tobing, 2013). Matrix acidizing itself usually decreases skin from the well approaching 0 because it only dissolves the materials in the reservoir. The injection carried out in the matrix acidizing is also regulated with pressure below the parting pressure formation to prevent any fractures.

In this case study, each well to which Matrix Acidizing was to be applied was targeted to have skin 0, -0.05, and -0.1. The results of the calculations can be seen in the appendix to Table 1.

From the evaluation results of the three wells, it can be seen that all the wells showed significant production increase. Thus, it can be concluded that the matrix acidizing carried out was successful and the selected wells were the right candidates for matrix acidizing. In addition, matrix acidizing significantly increased production from wells which had formation

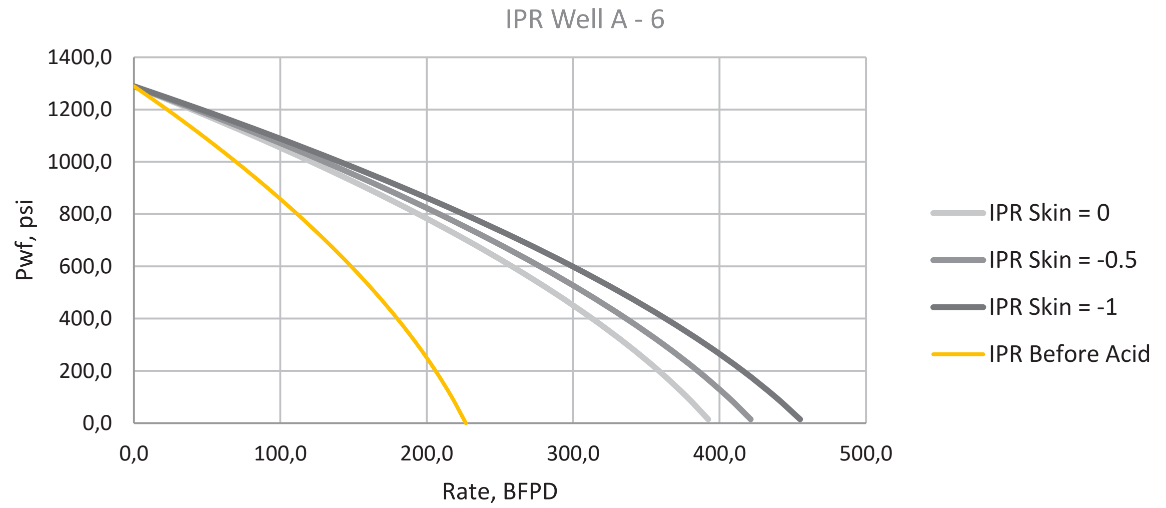

Figure 5
IPR for well A6

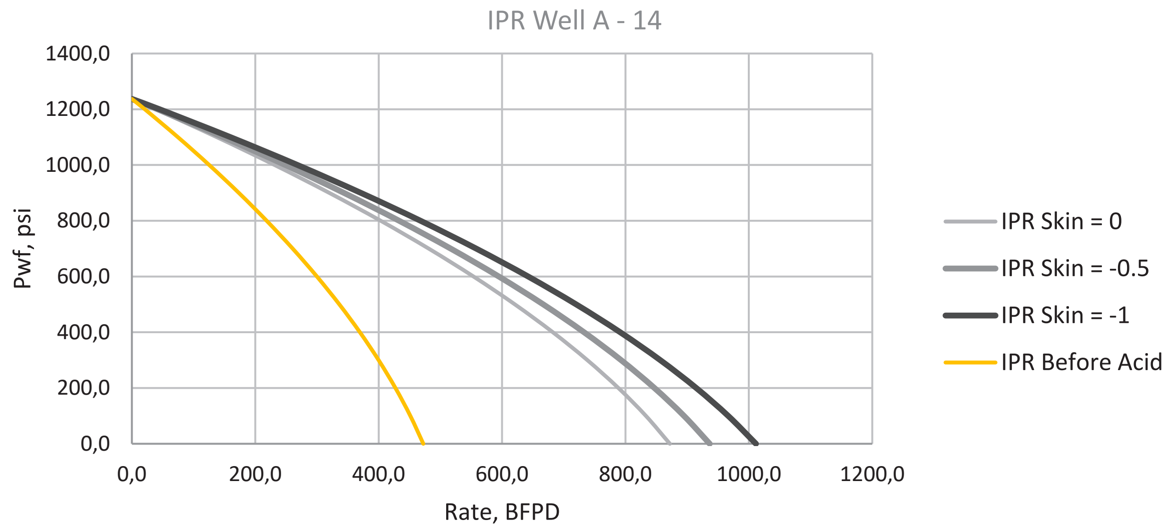

Figure 6
IPR for well A14

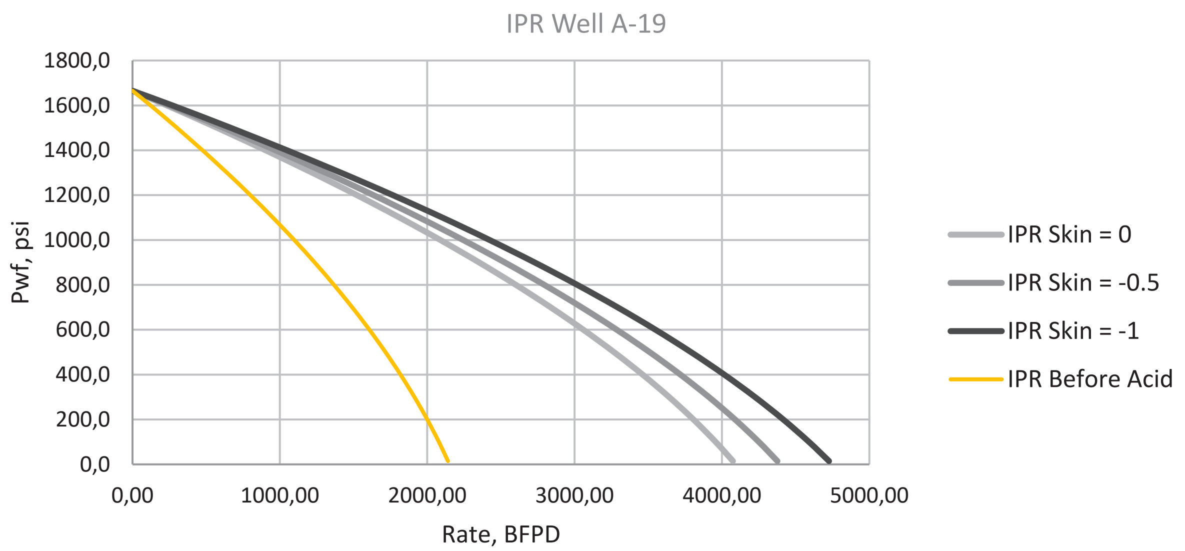

Figure 7
IPR for well A19

Table 1
Result of matrix acidizing

skin	Well (BFPD)		
	A-6	**A-14**	**A-19**
0	306	744	497
-0.5	328	799	534
-1	355	863	577

damage.

CONCLUSION

Based on the results of the research on the selection of matrix acidizing candidates using the Heterogeneity Index, some conclusions can be drawn as follows.

Selection of matrix acidizing candidates is one of the important steps in determining the success of matrix acidizing. In this case study, the selection of well candidates using the Heterogeneity Index method could significantly reduce the number of candidates from 24 wells to 3 wells, namely A6, A14, and A19.

Matrix Acidizing as a well stimulation method can be used to repair damaged wells by dissolving mineral components in the well so as to improve the permeability in the reservoir, thus decreasing the skin of the well approaching 0. Based on the evaluation results of the wells to which matrix acidizing treatment had been applied, the flow rates for A6, A14, and A19 wells were 354 BFPD, 862 BFPD, and 576 BFPD, respectively.

ACKNOWLEDGEMENT

First and foremost, the writers would like to thank Allah, the Almighty God for all the blessings and strengths that have been given, so the writers could complete this study. Also, the authors present the greatest gratitude to families and the academic community of Petroleum Engineering Department Bandung Institute of Technology.

Thank you to Baker Hughes' Mr. Nathanel for taking the time to discuss Acidizing with us.

GLOSSARY OF TERMS

Symbol	Definition	Unit
q_i	Initial production rate	bbl/day
q_t	Production rate at *t* time	bbl/day
Q	Cumulative production at certain time	bbl
Q_f	Cumulative production at final condition	bbl
t	Time since start of production	day
S_w	Water saturation	Fraction
K_{rw}	Water relative permeability	Fraction
K_{row}	Oil-water relative permeability	Fraction
P_{cow}	Oil-water capillary pressure	psi

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