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Successfull Pilot Waterflood to Determine Connectivity of Reservoir Sand in W3 Layer North Niru Structure Limau Field

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Successful Pilot Waterflood to Determine connectivity of Reservoir Sand in W3 Layer North Niru Structure Limau Field

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Abstract

North Niru Structure is located in the working area of PT. PERTAMINA EP ASSET 2, which is in the south Sumatera province, was found in 2006 with the first well is NR-01, starting October 2006 production by natural flow with initial oil production is 678 BOPD with 0% watercut, it has a good permeability with a range value of 200-500 md, and viscosity 0.94 cp, initial pressure 1698 Psi and saturation pressure 1580 psi.

After the discovery of the NR-01 well, massive drilling was performed on the northern Niru structure, peak production layer W3 north Niru is 5,573 bopd in June 2010. Production by pleatau obtained until the year 2013 and then decline production significantly, its happened because reservoir pressure is only 835 psi below bubble point pressure. previously W3 Niru structure has not been inject by water, this is because there is little uniqueness, although the value of good permeability and pressure is low but the injectivity test showed the results of low injectivity rate.

Hydraulic fracturing stimulation of 2 injection wells resulted in a very large injection rate of about 7,000 Bwpd with wellhead pressure only 100 psi, after injection lasted for 2 months there was a significant increase in the watercut of the monitor well, by 2017 pilot waterflood with peripheral pattern with previous data, pilot waterflood planning with peripheral pattern there are 4 injection wells and 8 production wells. For this pilot will not do hydraulic fracturing to increase well injectivity and do different things with hydrofluoric acid over displace Stimulation, the result got good injectivity 1500 bwpd with 200 psi well head pressure. surveillance monitoring was performed on both production and injection wells and one monitor well showed good results with a increase in DFL and a decrease in watercut in less than 2 months.

this paper will describe the steps that have been done from the evaluation of production data, selection of injection well criteria and how to monitor the survillance until the success of the pilot waterflood.

Keywords: Pilot Waterflood.

1. Introduction

North Niru Structure is located in the working area of PT. PERTAMINA EP ASSET 2, located in the south Sumatera province, was found in 2006 with the first well is NR-01, starting October 2006 production by natural flow with initial oil production is 678 BOPD with 0% watercut, it has a good permeability with a range value of 200-500 md, and viscosity 0.94 cp, initial pressure 1698 Psi and saturation pressure 1580 psi.

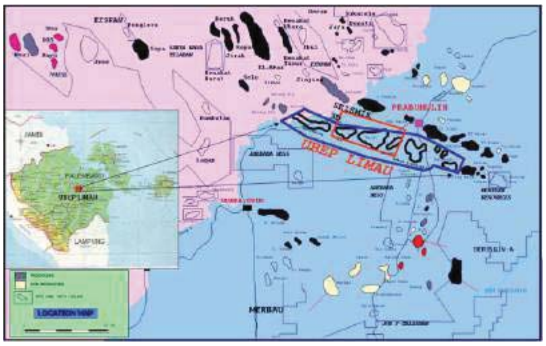


figure 1.1 Location Niru Structure in South Sumatera

After the discovery of the NR-01 well, massive drilling was performed on the northern Niru structure, peak production layer W3 north Niru is 5,573 bopd in June 2010. Production by pleatau obtained until the year 2013 and then decline production significantly, its happened because reservoir pressure is only 835 psi below bubble point pressure.

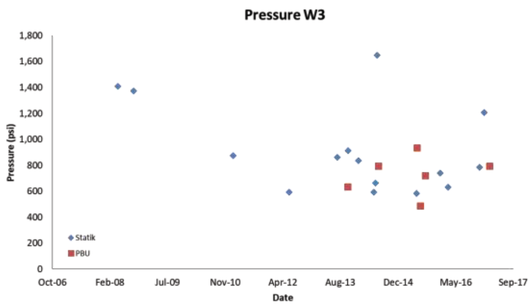


figure 1.2 Pressure History Niru Structure

previously W3 Niru structure has not been inject by water, this is because there is little uniqueness, although the value of good permeability and pressure is low but the injectivity test showed the results of low injectivity rate.

In 2014 there is a pilot waterflood plan with Hydraulic fracturing stimulation of 2 injection wells resulted in a very large injection rate of about 7,000 Bwpd with wellhead pressure only 100 psi, after injection lasted for 2 months there was a significant increase in the watercut of the monitor well.

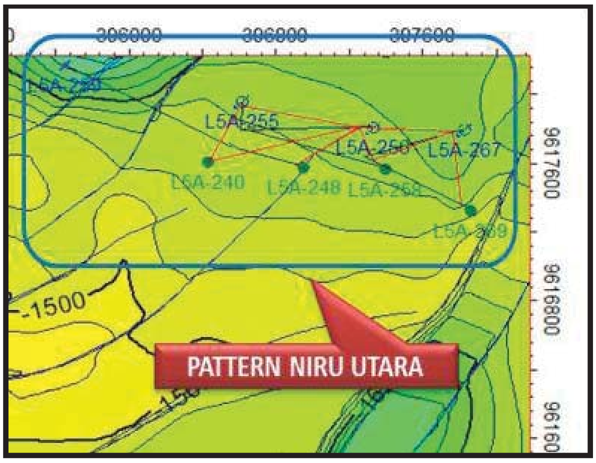


figure 1.3 Pattern Waterflood in Niru Structure

2. Basic Theory

Waterflooding is the most widelt used fluid injection process in the world today. It has been recognized since 1880 that injecting water into oil-bearing formation has the potential to improve oil recovery. However, waterflooding did not experience fieldwide application until 1930s when several injection project were initiated, and it was not until the early 1950s that the current boom in waterflood began. Waterflooding is responsible for significant fraction of the oil currently produced in the World.

Many complex and sophisticated enhanced recovery processes have been developed through the years in an effort to recover the enormous oil reserves left behind by inefficient primary recovery mechanisms. Many of these processes have the potential to recover more oil than waterflooding in a particular reservoir. Howerver, no process has been discovered which enjoys the widespread applicability of waterflooding. The primary reasons why waterflooding is the most successful and most widely used oil recovery process are:

- General availability of water
- Low cost relative to other injection fluids
- Ease of injecting water into a formation
- High efficiency with which water displaces oil

The purpose of these notes is to discuss the reservoir engineering aspects of waterflooding. It is intended that the reader will gain a better understanding of the processes by which water displaces oil from a reservoir and, in particular, will gain the ability to calculate the expected recovery performance of a waterflood project.

2.1 Waterflooding Versus Pressure Maintenance

Maximum combined primary and secondary oil recovery occurs when waterflooding is initiated at the or near the initial bubble point pressure. When water injection commences at a time in the life of a reservoir when the reservoir pressure is at a high level, the injection is frequently referred to as a pressure maintenance project. On the other hand, if water injection commences at a time when reservoir pressure has declined to a low level due to primary depletion, the injection process is usually referred to as a waterflood. In both instances, the injected water displaces oil and is a dynamic displacement process. Nevertheless, there are important differeneces in the displacement process when water displaces oil at high reservoir pressure compared to the displacement process which occurs in depleted low pressure reservoir.

Unit displacement efficiency is how water displaces oil from a porous and permeable reservoir rock on a microscopic scale. This is the level of analysis that is applied when water-/oil-flow measurements are made on small core-plug samples in a laboratory. Calculations for determining how well waterflooding will work on a reservoir scale must include the effects of geology, gravity, and geometry (vertical, areal, and well-spacing/-pattern arrangement). The formula for overall waterflood oil-recovery efficiency ER might be simply stated as the product of three independent terms:

$$E_R = E_D E_I E_A, \quad \text{......(1)}$$

where

ED = the unit-displacement efficiency,

EI = the vertical-displacement efficiency, and

EA = the areal-displacement efficiency. Of course, assuming independence of these three factors is not valid for real oil reservoirs.

There is a one step before decided full scale waterflood which one needs to be done, this is a pilot waterflood. Pilot waterflood is a same as a fullscale waterflood but in the small scale. We pick the best pattern that will success.

3. Methodology

The most important aspect of evaluating a field waterflooding project is understanding the reservoir rocks. This understanding begins with knowing the depositional environment at the pore and reservoir levels and possibly also several levels in between. Second, the diagenetic history of the reservoir rocks must be ascertained. Then, the structure and faulting of the reservoir must be determined to understand the interconnectivities among the various parts of the reservoir, particularly the injector/producer connectivity. Finally, the water/oil/rock characteristics need to be understood because they control wettability, residual oil saturation to waterflooding, and the oil relative permeability at higher water saturations. Because of these needs, there always should be a developmental geologist on the waterflood-evaluation team.

All oil reservoirs are heterogeneous rock formations. The primary geological consideration in waterflooding evaluation is to determine the nature and degree of heterogeneities that exist in a particular oil field. Reservoir heterogeneities can take many forms, including

- Shale, anhydrite, or other impermeable layers that partly or completely separate the porous and permeable reservoir layers.
- Interbedded hydrocarbon-bearing layers that have significantly different rock qualities—sandstones or carbonates.
- Varying continuity, interconnection, and areal extent of porous and permeable layers throughout the reservoir.
- Directional permeability trends that are caused by the depositional environment or by diagenetic changes.
- Fracture trends that developed because of regional tectonic stresses on the rock and the effects of burial and uplift on the particular rock layer.
- Fault trends that affect the connection of one part of an oil reservoir to adjacent areas, either because they are flow barriers or because they are open conduits that allow unlimited flow along the fault plane.

The structure of the reservoir and how it affects waterflood performance is another geological consideration. Structure creates dipping beds that dip at various angles. The interplay between the bed angle, gravity, and the oil/brine density difference at reservoir conditions significantly affects the relative vertical and horizontal flow behaviors. Structural considerations also can include whether the oil column has an underlying aquifer or an overlying gas cap, either of which can significantly affect the likelihood of successfully waterflooding the oil column.

Geologists and geophysicists must assess such geological and structural aspects of a reservoir. Geologists use cores and routine-core-analysis data to develop an understanding of the depositional environment and post-depositional diagenesis and to characterize the reservoir's internal architecture. Using seismic data, geophysicists can discern the major faults, as well as trends in rock quality, since cores and well logs are essentially pin pricks into the overall reservoir.

The technical team that is evaluating and monitoring waterflood performance should include a geologist and a geophysicist. Including a geostatistician on the technical team, as well, will help to ensure that the geoscientists' reservoir description is properly translated into engineering calculations, whether those are simpler calculations or are detailed numerical reservoir simulations.

For a waterflood, the reservoir description must be developed on the scale that is required for the quantitative evaluation. A variety of approaches can be used. The "flow unit" is a concept that frequently is used by geologists and that would be useful to engineers. "A flow unit is a volume of the total reservoir rock within which geological and petrophysical properties that affect fluid flow are internally consistent and predictably different from properties of other rock volumes .

The process of evaluating a reservoir's geology begins when the reservoir is discovered and is placed on primary production. After a waterflood has been initiated, the production- and injection-well data provide additional insight into the internal characteristics of the rock volume that is being flooded. In fact, the waterflood production-well data (the water and oil rates as a function of time) are critical because they are the first data that relate directly to the interwell connectivity within the reservoir and that validate or cause modification of the geoscientists' concepts of the various levels of reservoir heterogeneities.

During a waterflood, tracers can be injected to track which injector/producer pairs are well connected and which are poorly connected. Other monitoring techniques include the use of specially drilled observation wells and 4D-seismic interpretations to track the directionality and shape of the higher-pressure water-swept reservoir areas that are centered on the injection wells.

4. Case Study

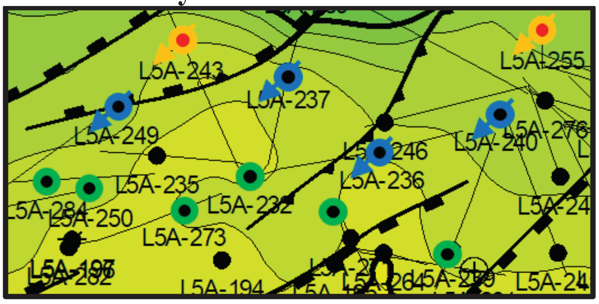


Figure 4.1 Pilot Waterflood Niru Structure

Niru Structure have 51 wells, it helpful to build a good geological model, to run this pilot we did a workover 4 injection well and use 8 eksisting production wells. In the first pilot injection the injection well injected almost 4000 bwpd and the result is a early water breaktrough, therefore in this pilot we limited the injection rate with 1500 bwpd every injection well. The first problem in here is a low injectivity rate, the pilot injection before did a hydraulic fracturing to get a rate in injection well. In this pilot we didn't do hydraulic fracturing besides it is quite expensive it is makes early water breaktrough. So we did a Hidrofloric Acid.

Sandstone reservoir is mainly composed of quartz and aluminosilicates (such as feldspars). Migration of these particles (fines) into the pores of the near-wellbore area can reduce production and they will not dissolve in strong acids such as hydrochloric acid, but will dissolve in hydrofluoric acid (HF).

Although highly corrosive, HF is classified as a weak acid due to its low ionization in water and it is very toxic. HF, or more usually HF-releasing chemicals such as ammonium bifluoride (NH_4HF_2), is used for sandstone matrix acidizing, combined with hydrochloric (HCl) or organic acids. An aqueous HF/HCl blend is often called a "mud acid". A preflush and overflush of an ammonium salt is often used to remove incompatible ions such as Na^+, K^+, and Ca^{2+} that could form insoluble fluorosilicate salts (e.g., Na_2SiF_6) with HF. Generally, the max HF concentration in the fluid package is 3% due to the concern of deconsolidation of near wellbore sandstone formation[6]. HCl/HF ratios usually vary from 4:1 to 9:1.

In sandstone acidizing, one has to be particularly careful of reprecipitation of reaction products, which could cause new formation damage[7]. They occur mostly if the well is shut-in for a long period of time. The basic chemistry is HF reacts first with aluminosilicates to form fluorosilicates, which react further with clays to form insoluble sodium or potassium flurosilicates. Prevention methods include: 1)overflush with dilute HCl or NH_4Cl to push the solution deeper into the formation 2)use delayed acid formulations that generate HF slowly 3) buffered acid system that allow for a deeper penetration. CaF_2 and AlF_3 can also precipitate in the spent acid.

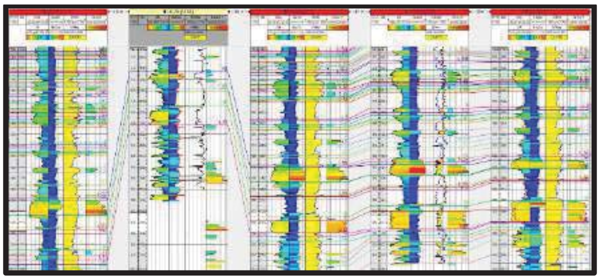


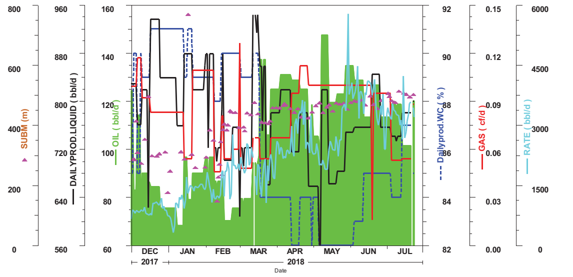
Figure 4.2 well log correlation

After injection, surveillance monitoring is applied to production and injection wells. Using acoustic well sounder to get a dynamic fluid level and submerge, take a well head pressure using pressure gauge and production/ injection rate in gathering stastion.

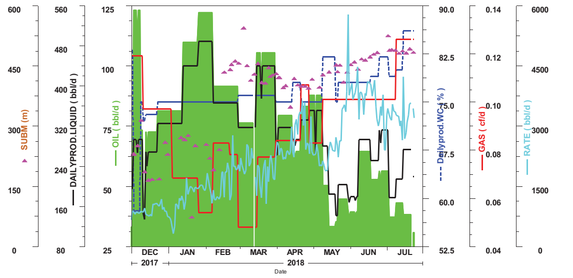
5. Result and Discussion

the target in the pilot waterflood this time is to get connectivity between production wells and injection, to find out there is a connection between injection wells and production is one of them is the increase in submerge without a decrease in the production rate of the well.

Two months after the injection finally the respond in production well achieved, looked from dynamic fluid level increase with increase production gross.



the submerge increase in February, two months after start injection well in pilot pattern.



And second well have a similar submerge parameter with same two months response. With that data we can say there is a connectivity between production and injection well.

6. Conclusion

Pilot waterflood is the first step before doing a fullscale waterflood, the most important point in pilot waterflood is to get connectivity from the injection well to the production well. on pilot waterflood usually use tracer test to get connectivity, but this paper shows that even without tracer can get connectivity with good surveillance monitoring. important parameters during surveillance monitoring is the increase in pressure on the production well, but this is difficult because it needs to turn off the well which causes production to drop, so it is necessary to find an alternative there is well bottom hole flowing pressure (Pwf) which can be equated with dynamic fluid level.

7. Recommendation

the best result to know a connectivity between injection and production well use a tracer test, so we recommendation to do the tracer test in Niru Structure.

8. Acknowledgement

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List of Tables

Tabel 1.PVT Summary

Summary PVT		
Average Reservoir Pressure	1698	psig
Average Reservoir Temperature	226	°F
Saturation Pressure	1580	psig
Avg Single-Phase Compressibility	7.65	E-6 v/v/psi (5000 to 1580 psig)
Solution Gas/Oil Ratio	337	scf / bbl of residual oil at 60 °F
Relative Oil Volume	1.221	bbl / bbl of residual oil at 60 °F
Density of Reservoir Fluid	0.8	gm/cc
Viscosity at 1580 psig and 226 °F	0.94	cp

Tabel 1.Summary Relative Permeability

Summary Water-Oil Relative Permeability Data							
Well	**Sample Number**	**Ka (mD)**	**Por.(frac.)**	**Swc (frac.)**	**Krw@Sor**	**Kro@Swc**	**Sor (frac.)**
216	226	318.0	0.206	0.242	0.420	0.631	0.212
	232	335.0	0.204	0.236	0.424	0.565	0.168
	233	89.0	0.154	0.426	0.585	0.372	0.225
217		419.0	0.196	0.210	0.485	0.472	0.242
		436.0	0.181	0.201	0.741	0.521	0.256
		954.0	0.214	0.173	0.615	0.475	0.291
236	1	179.0	0.218	0.290	0.134	1.000	0.330
	2	1672.3	0.268	0.134	0.430	1.000	0.408
	3	1673.8	0.209	0.168	0.411	1.000	0.398