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Hydraulic Fracturing Analysis of Low Permeability, Heavy Oil Reservoir Telisa Formation, Bentayan Field

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ABSTRACT

There is no proven economic oil production yet from Bentayan's part of Telisa Layer. However, open hole log from some wells in Bentayan field indicates hydrocarbon presence in TELISA in Bentayan field. GGR study also indicated low value in permeability of Telisa in Bentayan field. Production test in BN-62 indicates oil presence from Telisa with very low influx. To prove the hydrocarbon prospect of Telisa in Bentayan field, operator planned to develop Telisa in BN-62 and BN-21 by conducting hydraulic fracturing using approximately 80,000 lbs of proppant.

Early screen out happened when fracturing both wells. After the job, these two wells could not prove economical hydrocarbon production from Telisa. Both wells only have AOFP of 3 BFPD with lack of hydrocarbon indication.

Evaluation indicated that the cause this failure on the fracturing job may be caused by smaller value of flow efficiency than it was predicted due to the large permeability zones and formation of multiple fractures that caused pad volume and the slurry pumping flow rate to be less to create the expected fracture geometry. Based on rock property map, BN-95 is suggested to be a candidate to prove the prospect of economical hydrocarbon content in from Telisa.

Keywords: well stimulation; hydraulic fracturing; low permeability reservoir; Telisa

I. INTRODUCTION

Bentayan Field is an old oil and gas field that was discovered in 1932 and has been producing until now from Talang Akar Formation (TAF) with OOIP od 152.53 MMSTB, estimated ultimate recovery of 41.46 MMSTB, and cumulative production of 29.71 MMSTB (2020). In 2020 Bentayan field has 108 active producer wells.

Telisa formation is a newly completed formation at Bentayan field. The completed well was BN-62. Based on Figure 1, oil presence in Telisa layer was proven from production test in BN-62 after completed on its Telisa interval. However, the production rate was so insignificant the oil rate was below accepted economical rate and BN-62 had to be suspended for further evaluation. Beside in BN-62, Telisa layer was also found on several other existing wells in Bentayan field based on subsurface data correlation. Telisa formation is also known as major hydrocarbon production formation in other fields using hydraulic fracturing stimulation.

Based on Figure 2, reservoir pressure of Telisa layer in BN-62 is 1197 psi which is relatively high for Bentayan field. Subsurface data correlation also shows that Telisa layer exist on other existing Bentayan wells. Figure 3 shows that BN-62 location is relatively high on the structure of Telisa layer. Based on this information, Telisa layer of Bentayan field was expected to contribute to Bentayan field oil production beside Talang Akar formation layer as new production formation. Telisa layer in Tanjung Laban, an oil field close to Bentayan field has successfully producing oil economically utilizing hydraulic fracturing stimulation method with current recovery factor of 21% from estimated ultimate recovery factor of 33%.

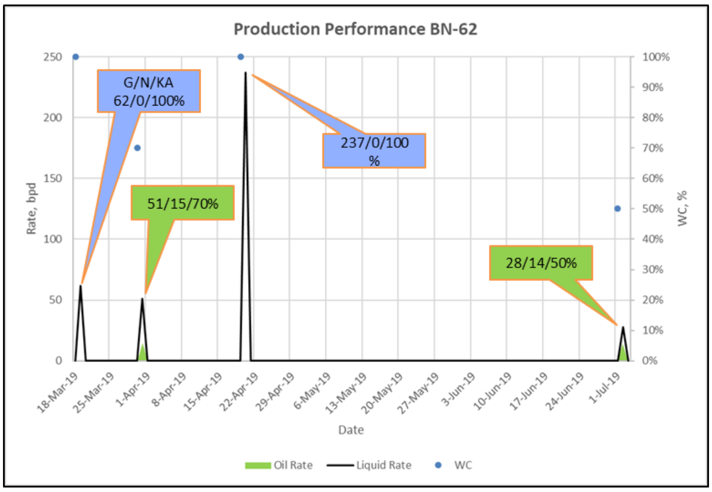

Figure 1. Production Performance of Telisa Layer at BN-62
Source: Pertamina EP

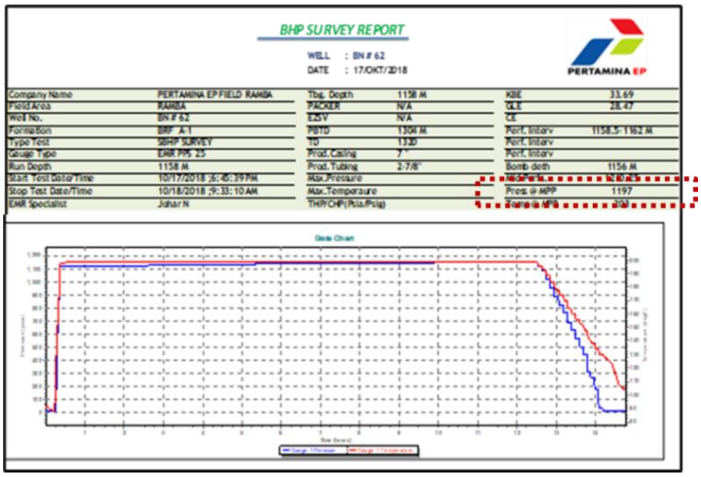

Figure 2. Static Pressure and Temperature Survey of BN-62
Source: Pertamina EP

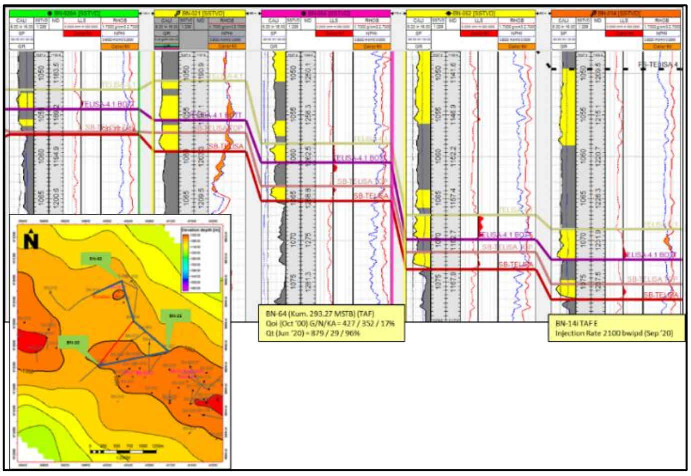

Figure 3. Well Correlation of Telisa Layer at Bentayan
Source: Pertamina EP

II. METHODS

The methodology used on this research can be concluded into several steps, they are: (1) data collection from several sources, (2) hydraulic fracturing design for TELISA layer, (3) feasibility study of hydraulic fracturing project based on frac geometry resulted from design, (4) pre and post hydraulic fracturing job production performance analysis. (5) conclusion and further recommendation related to the development of hydrocarbon prospect in TELISA layer at Bentayan Field. **Figure 4** shows the illustration of the methodology used in this paper.

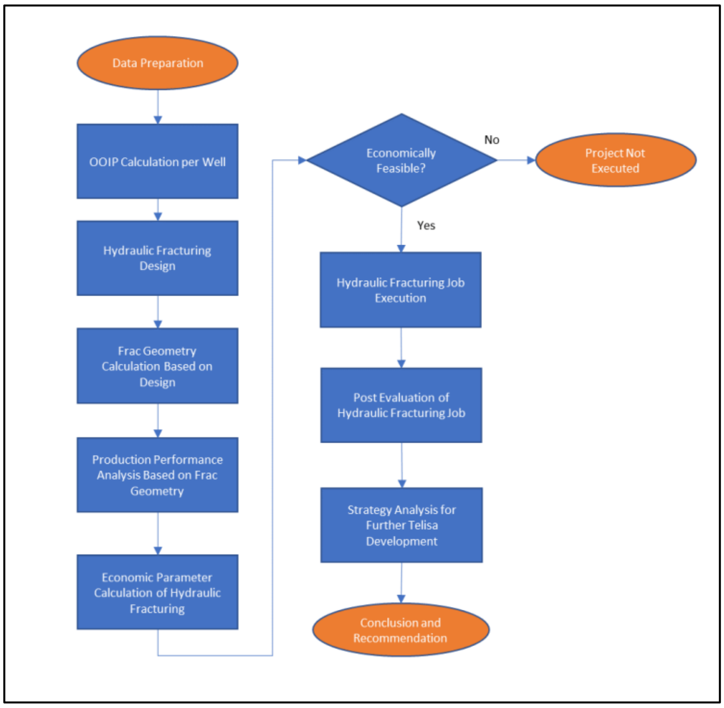

Figure 4. Research Method

III. RESULTS AND DISCUSSION

3.1. Hydrocarbon Volume Estimation

Calculation of of original oil volume estimation (OOIP) was done using volumetric method. Calculation was done based on reservoir parameters of Telisa layer of each well which includes PVT data, bottomhole pressure and temperature, and triple combo log which presented on **Table 1** using **Equation 1.**

Table 1. Input for OOIP Calculation

Properties	BN-62	BN-21
Netpay Thickness (m)	3.63	2.50
Porosity (%)	12.00	13.00
Permeability (mD)	14.00	14.00
Reservoir Pressure	1,197.00	1,197.00
Reservoir Temperature	203.00	203.00
Water Saturation	0.50	0.50
Re (m)	250.00	250.00
Boi (RB/STB)	1,157.00	1,157.00

$$OOIP = \frac{7758 \times A \times h \times \phi \times (1 - S_{wi})}{B_{oi}} \quad (1)$$

From the calculation of oil volume on each well, OOIP of Telisa layer in BN-21 and BN-62 is 1.698.278 STB and 2.554.935 STB respectively.

3.2. Hydraulic Fracturing Design

Hydraulic fracturing design on BN-21 and BN-62 was done using Fracpro a hydraulic fracturing simulator using well mechanical data, petrophysical data, PVT data, and other data related to geomechanics and downhole friction which acquired form breakdown test, step rate test, and mini frac prior main hydraulic fracturing job. Additional input for this simulation related to breakdown test, step rate test and mini frac data are summarized in **Table 2** and **Table 3.**

Table 2. Geo-mechanical Data of BN-21

Parameter	Unit	Value
Stress Gradient	psi/ft	0.76
Young Modulus	pso	1,040,000.00
Toughness	psi.in^0.5	800.00
Poisson Ration		0.276
Leak Off Coefficient	ft/min^0.5	1.923 x 10^-3

Table 3. Geo-mechanical Data of BN-62

Parameter	Unit	Value
Stress Gradient	psi/ft	0.76
Young Modulus	pso	1,010,000.00
Toughness	psi.in^0.5	500.00
Poisson Ration		0.271
Leak Off Coefficient	ft/min^0.5	7.047 x 10^-3

Based on properties of Telisa Layer in BN-21 and BN-62 final design was made to create optimum fracture geometry of both wells from hydraulic fracturing job. For frac job on BN-21, designed pumped proppant mass is 65000 lbs of Bauxlite 20/40 with average pumping pressure of 2500 psi and 16 bpm pump flow rate, while BN-62 will use the same type and amount of proppant with average pumping pressure of 3000 psi and 15 bpm pump flow rate. Designed pumping schedule will be shown in Table 4 and Table 5. From this job design as simulation input, at BN-21 Telisa layer fracture will be created with geometry of xf = 48 m, hf = 37.5 m and wp = 0.328, and FCD of 2.12, while on BN-62 xf = 61.1 m, 23.5 m, wp = 0.375 m, and FCD of 1.391. Analysis was proceeded to calculate estimate production rate with created geometry of each well. From the IPR calculation, the created fracture geometry of both wells resulted in AOFP of 90 BFPD for BN-21 and 127.5 BFPD for BN-62. With the assumption of producing 80% AOFP and 50% water cut, initial oil production rate of BN-21 and BN-62 is 36 BOPD and 51 BFPD respectively.

3.3. Job Economic Analysis

Job economic analysis was done to determine the feasibility of required investment of hydraulic fracturing job of BN-21 and BN-62 to the estimated production. Assumption on several input parameter for this analysis is shown in **Table 4** including initial oil production from previous calculation. Economic analysis on hydraulic fracturing plan on both wells conclude that the jobs were economical with NPV of USD 184,000 and USD 313,000, IRR of 45.8% and 67.4% for BN-21 and BN-62. Calculation was also made to calculate minimum initial oil production rate with NPV > 0 and IRR >=40%. The result, the minimum initial oil production for the plan to be economical is 33 BOPD.

Table 4. Input Parameter Assumption for Job Economic Analysis

			BN-21	BN-62
		Units	Value	Value
Investasi		$(000)	301	301
	Capital	$(000)	0	0
	Non Capital	$(000)	301	301
Opex				
	Oil	US$/bbl	25	25
	Gas	US$/mmbtu	-	-
Asummsi				
	Production forecast			
	Qoi	Bopd	36	51
	Qgi	mmscfd	0	0
	Decline	%/years	20.00%	20.00%
	Prod. Life	Years	5	5
	Prices			
	Oil Price	US $/bbl	50	50
	Gas Price	US $/MMBTU		

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Table 5. Output for Job Economic Analysis

				BN-21	BN-62
	Total Gross Revenue		US $ (000)	2,092.72	2,964.69
1	Opex & Depresiasi		US $ (000)	1,347.76	1,783.74
2	Contractor Take		US $ (000)	297.98	472.38
3	Government Take		US $ (000)	*446.98*	*708.57*
	NPV (DF 9.22%)		US $ (000)	**184.56**	**313.25**
	IRR		%	**45.8**	**67.4**
	POT		Years	**1.01**	**0.86**
	PI		US$ / US$	**1.61**	**2.04**

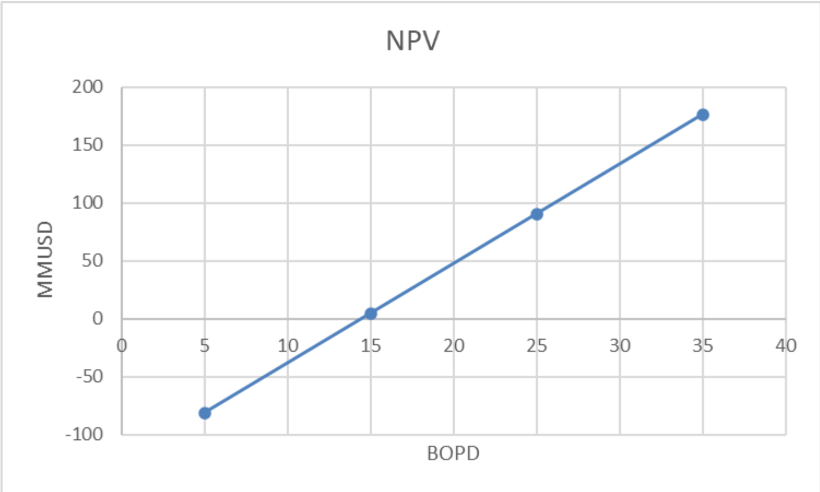

Figure 5. Sensitivity Analysis on NPV

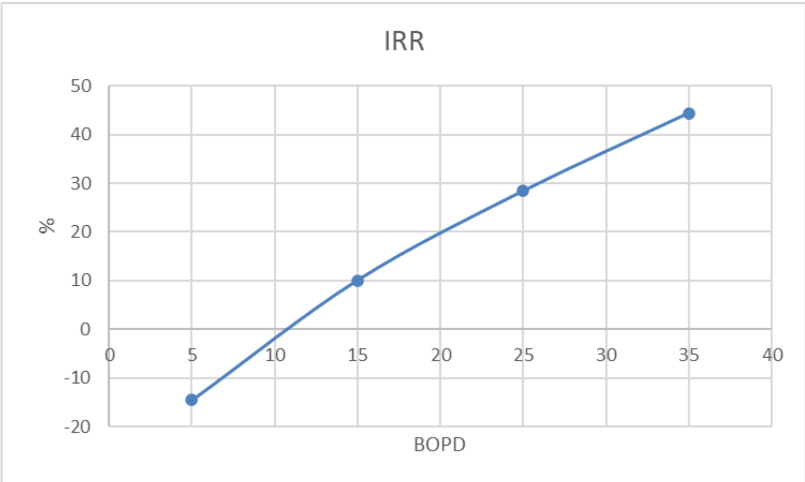

Figure 6. Sensitivity Analysis on IRR

3.4. Post Job Evaluation

Actual execution of hydraulic fracturing BN-21 and BN-62 were not going as planned. Early screen out happened when pumping slurry and proppant to both wells. Total pumped proppant mass to BN-21 was only 36,200 lbs while BN-62 was only 52,451 lbs from design which is 65,000 lbs. Hydraulic fracturing simulation was re-run to estimate fracture geometry from actual job execution report. Based on BN-21 actual fracturing job execution parameter as input, the geometry of created half-length is 35 m, fracture height 27.8 m, average frac width 0.208 m, and FCD 4.43. While for BN-62: half-length 49.5 m, fracture height 27.2 m, average frac width 0.348 m, and FCD 2.029.

Evaluation was also conducted to determine the cause of the early screen out event on both wells. From the evaluation the most possible cause of the event is due to the actual value of flow efficiency (FE) for both wells are smaller than predicted, this may happen due to the reservoir permeability higher than estimated one or multiple fracture formation during the job. The lower FE value than predicted causes not enough % volume pad and pump rate designed could not create expected initial fracture geometry. Based on the post job evaluation, there are several recommendations to increase success probability of fracturing formation with similar characteristic as Telisa Layer in Bentayan Structure, they are:

- Prior to the planning of hydraulic fracturing, it is better to prove the existence of hydrocarbon in targeted interval using RST log or swab job after perforation.
- Increasing the accuracy of fluid efficiency (FE) or choosing lowest FE value as worst-case scenario if there are more than one value from multiple value estimation methods.
- Anticipating low FE value by increasing % volume PAD on design phase, increasing gell loading capacity, and increasing pumping flow rate.
- Increasing time duration between PPG pumping stages and limiting proppant concentration to 6 PPG max on pumping schedule design.
- Decreasing near wellbore friction by using larger shape charge size for perforation and increasing sand slug mass during early pumping stages on fracturing job.
- Pumping solvent during early stages of fracturing job to increase oil mobility in reservoir especially on heavy oil cases.

3.5. Post Job Production Performance

Production performance analysis after the fracturing job was executed showed that both BN-21 and BN-62 had poor influx with 100% water cut from Telisa layer and failed to show economical production from Telisa layer in Bentayan structure.

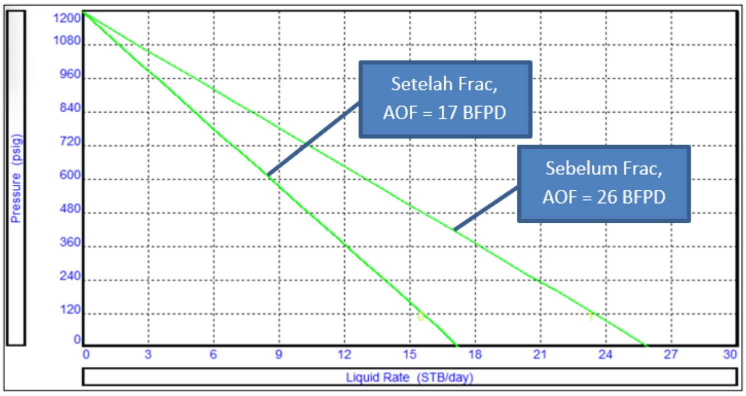

Figure 7. IPR BN-21 Prior and Post Fracturing Job

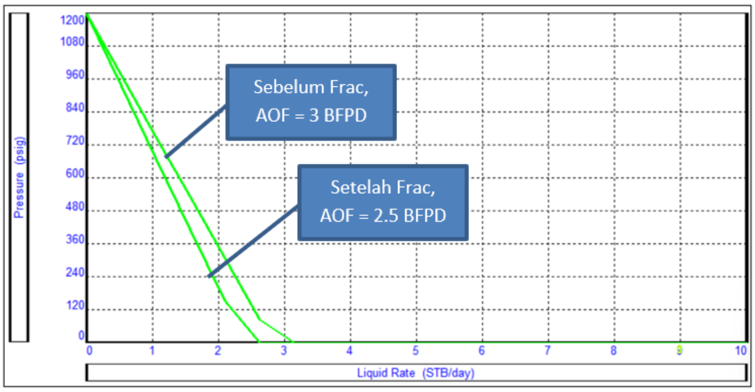

Figure 8. IPR BN-62 Prior and Post Fracturing Job

3.6. Further Development Strategy of Hydrocarbon Prospect in Telisa Layer, Bentayan Field

The effort to prove economical oil production from Telisa layer in Bentayan through the completion and hydraulic fracturing was not yet succeeded. The next step in terms of further development strategy of Telisa layer is still to prove economical oil production from this layer. This is done by looking for another well candidate having better reservoir

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properties based on reservoir property map which includes permeability, porosity, and water saturation. From the analysis BN-95 should be better candidate for proving hydrocarbon prospect in Telisa layer

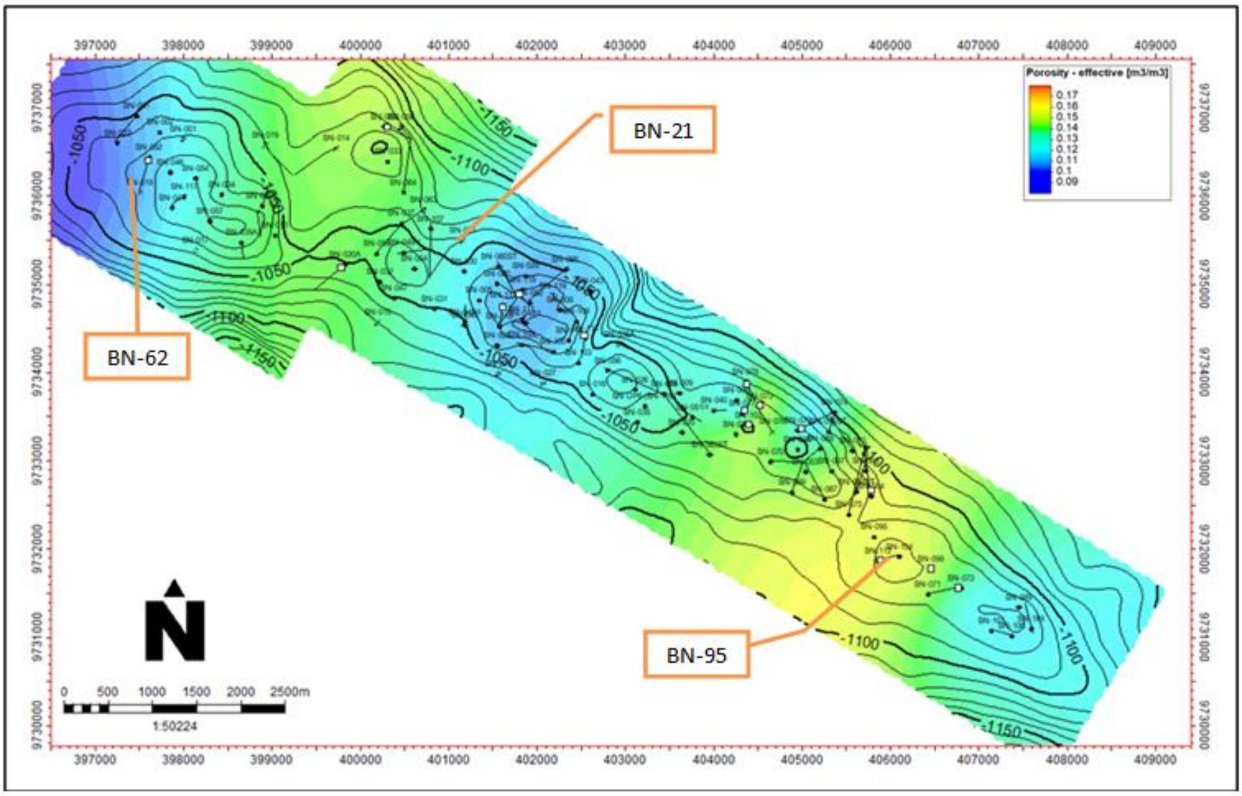

Figure 8. Porosity Map of Telisa Layer
Source : Pertamina EP

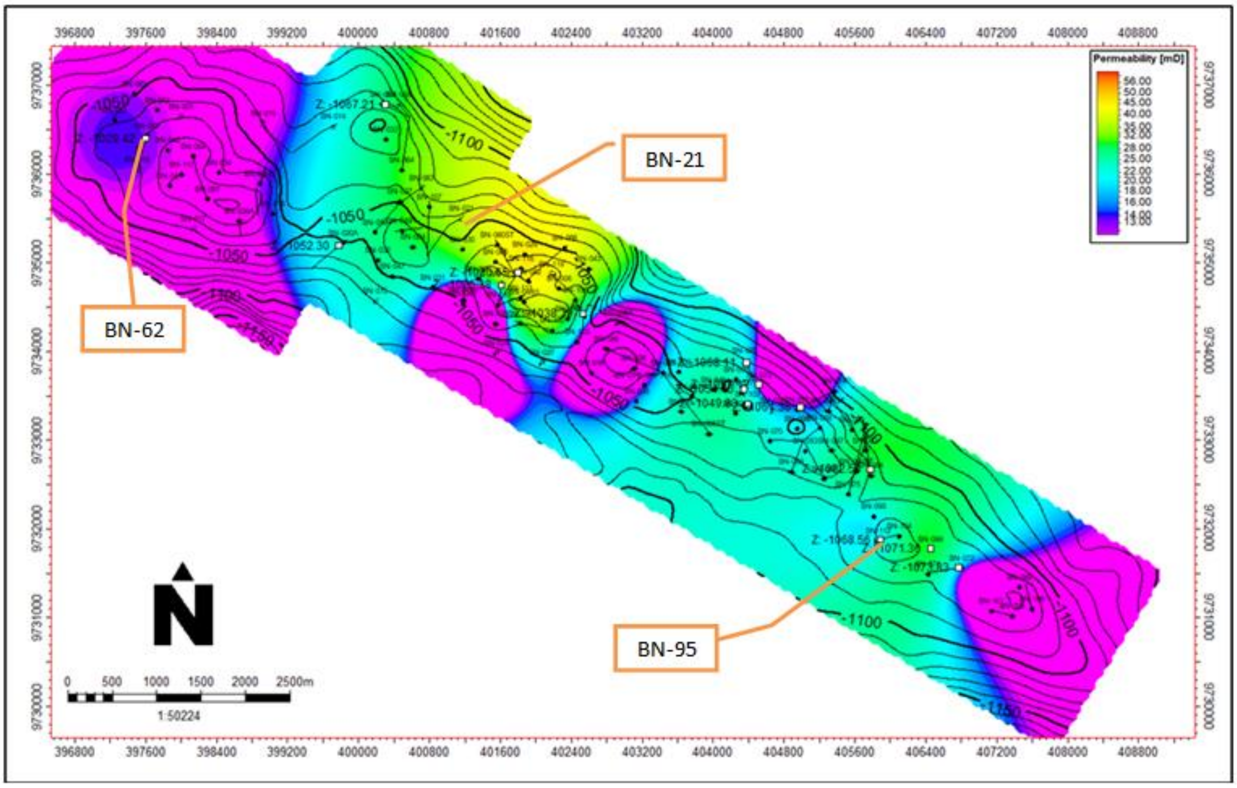

Figure 9. Permeability Map of Telisa Layer
Source : Pertamina EP

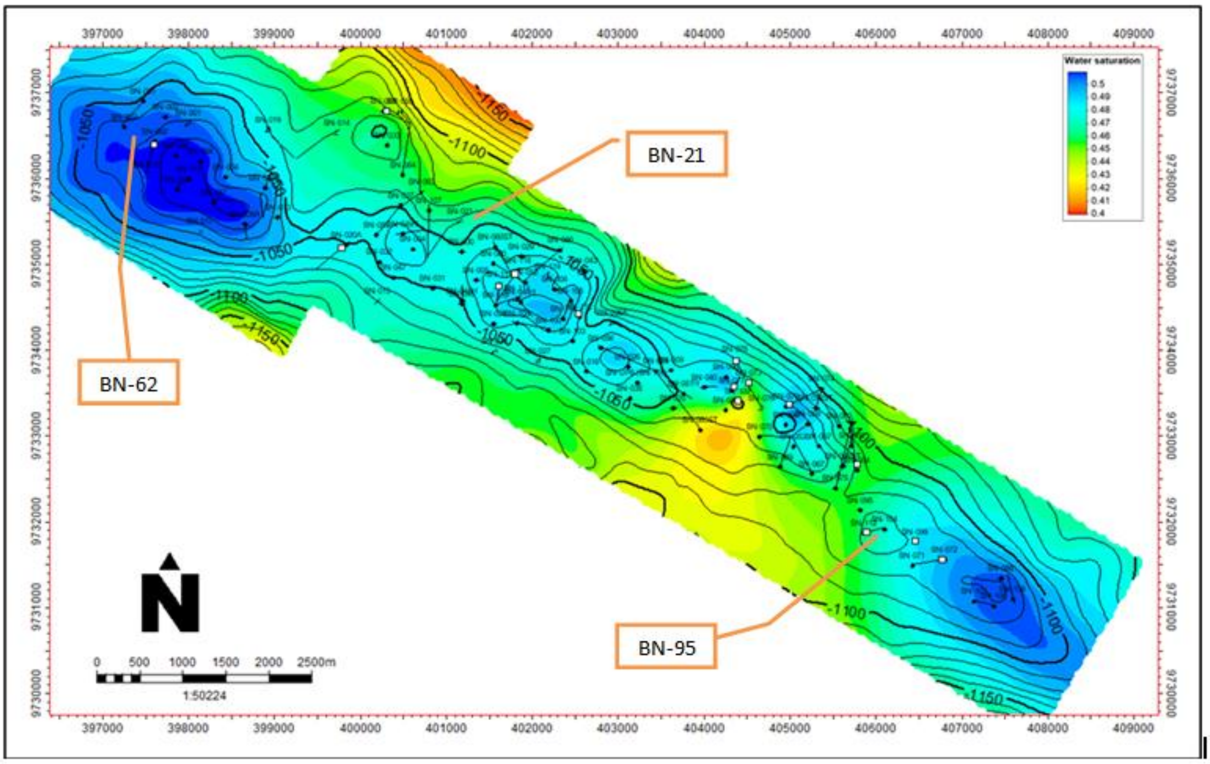

Figure 9. Water Saturation Map of Telisa Layer
Source : Pertamina EP

IV. CONCLUSION

4.1. Conclusions

From this paper, there are several conclusions regarding the development strategy on hydrocarbon prospect in Bentayan part of Telisa layer.

1. Based on initial design and evaluation, hydraulic fracturing job of BN-21 and BN-62 result in positive economic indicators and the job were feasible to be executed with NPV of USD 184,000 and USD 313,000 with IRR of 45.8% and 67.4% for BN-21 and BN-62 respectively. However, the actual production after the fracturing job was not proven economical.
2. The root cause of early screen out on job on both well may be the value of flow efficiency (FE) which lower than estimated FE value which become the input of job design.
3. The actual job of hydraulic fracturing on both well has not yet been able to prove economical oil production from Telisa layer in Bentayan.

The next step of further development strategy of Telisa Bentayan hydrocarbon prospect is to look for well candidate that has better Telisa properties.

4.2. Recommendations

Based on evaluation from this research, there are several recommendations that hopefully would improve the success probability of hydraulic fracturing jobs of Telisa layer at Bentayan or formations those have similar characteristics, they are:

1. Prior hydraulic fracturing execution, it is better to increase the probability of hydrocarbon existence on target formation by running RST log or swab job.
2. Improve the estimation accuracy of fluid efficiency (FE) or using lowest FE value if there are several values from multiple calculation.
3. Anticipating low FE value by increasing the % volume of PAD volume, improving gel loading capacity, and increasing pumping rate.
4. Increasing time period between PPG stages so the pumping schedule become less aggressive and limiting proppant concentration to 6 PPG maximum.

5. Reducing near wellbore friction by using larger diameter shape charge on perforation stages and increasing the amount of sand slug at the early stage of hydraulic fracturing job.
6. Considering pumping solvent before hydraulic fracturing job to increase oil mobility in reservoir especially on heavy oil cases.
7. Based on evaluation on property maps of Bentayan's Telisa layer, it is indicated that next potential existing well candidate for similar job is BN-95.

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