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Integrated of Static and Dynamic Modeling Workflow for Belimbing Oil Field Development of Talangakar Sandstone Reservoir, South Sumatra Basin

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Integrated of Static and Dynamic Modeling Workflow for Belimbing Oil Field Development of Talangakar Sandstone Reservoir, South Sumatra Basin

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Enhanced Oil Recovery PT Pertamina EP

Abstract

The Belimbing Field S layer is a productive layer of the Upper Talangakar Formation (TRM) with a transition environment, deposited in the syn-rift phase at upper Oligocene to lower Miocene. Belimbing S layer contributes as main production reservoir with 645 bopd (96% watercut). Water injection at Bel-10 wells and Bel-11 wells, at central block, was first performed in October 1997 with 762 bwipd injection rate. The water injection was performed peripherally from flank, with the initial purpose to pressure maintenance, even though the water was injected into the oil zone. There was a significant increase in pressure and oil gain in the monitor wells. With the last RF of 30% indicates that this layer still has a lot of potential to be developed by waterflood method. The BEL-19 injection in the Eastern Block from 2005 to 2015 was success too, indicated by increased of pressure and production at BEL-12, BEL-14 and BEL-27 wells. As an effort to increase production, field development studies were conducted by G&G study and dynamic modeling.

Limitations on number of core data (SCAL and RCA) become obstacles in G&G and Reservoir modeling, so in rock typing, we used core data from the nearest field (Limau Niru). In this method, also performed synthetic data processing curve relative permeability and capillary pressure by evaluating production data. The distribution of acoustic impedance (AI) and waveform is required to know the distribution of Facies and reservoir properties to get a more detailed description and heterogeneity of the reservoir.

From the data above, we obtain rock typing to distribute reservoir property in 3D static and dynamic model. Through the initialization process, history matching and forecast is then processed the best scenario, the waterflood pattern in the form of inverted five spots and primary infill to optimize the oil recovery.

Keywords: static modeling, dynamic modeling, waterflood pattern, secondary recovery, enhanced oil recovery,

1. Introduction

Limau Field is an anticlinorium that elongated in west-east direction and separated by normal faults in a relatively north-south direction. In tectonic terms, Limau Field is located on the Pendopo-Limau Anticlinorium, between Lematang Depression and Limau Graben (Figure 1) which is a depression part of the South Palembang Sub Basin. This Sub Basin together with the Central Palembang Sub Basin and the Jambi Sub Basin were forms a large basin that is called the South Sumatra Basin which is a Tertiary Back Arc Basin located along the west and south sides of the Sunda Land.

Belimbing Fields produce in the Talangakar Formation with productive layers which are oil-producing formations. Oil is produced by layers R3, R4, S, W1, W2, W3, X0, X1, X2 and X3. Currently there are 38 wells in the Belimbing field consisting of 7 production wells, 6 injection wells, 1 abandoned well, and 24 suspended wells with a production of 789 bopd (95% watercut). Coating S contributes the largest production at present with a production of 645 bopd (96%

watercut). Peak production of 7.806 bopd in November 1967 (9% watercut), and the second production peak after injection was reached in August 2010 at 2,521 bopd (95% watercut). Water injection response looks very good in Bel-01 and Bel-06 production wells and overall production from layer S is the biggest contributor to Belimbing Field production. Cumulative water injection for the entire Belimbing field was 124.47 MMBbl with cumulative water injection in the S layer of 107.04 MMBbl. The history of production and injection of the Belimbing Field can be seen in Figure 2.

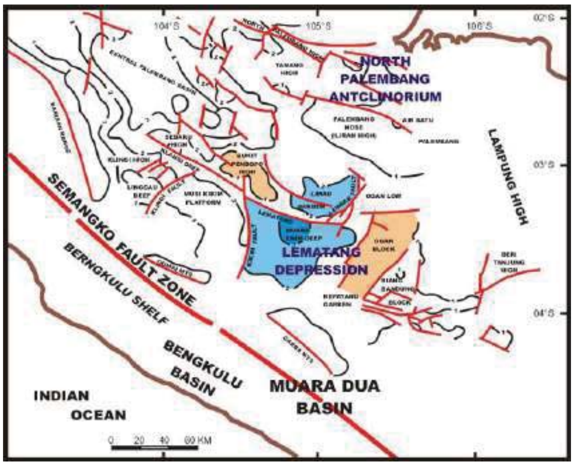


Figure 1. Lematang Depression and Limau Graben

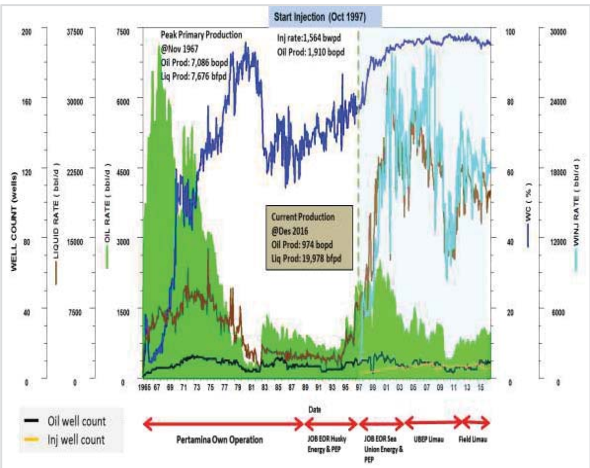


Figure 2. Production and Injection History of Belimbing Field

2. Sub-Surface Modelling

2.1. Geological Modelling

In geological modeling, the results of geophysical, geological and petrophysical analysis are compiled becomes a comprehensive subsurface geological model, these data including:

1. Well Marker (Correlation)
2. Horizon, in depth domain
3. Fault, in depth domain
4. Petrophysical calculation, containing: Vshale, Porositas, Net to gross (NTG) dan water saturation (SW)
5. Cut off analysis
6. Fluid Contact

Generally, geological modeling can be categorized into two steps, there are: structural modeling and property modeling. Structural modeling is processes to create a geometric model of subsurface geological conditions. Property modeling is processes to create the subsurface properties models such as Vshale, porosity, permeability, NTG and SW which were quantitatively calculated in petrophysical calculations. Generally, modeling workflows can be illustrated by the workflow in Figure 3.

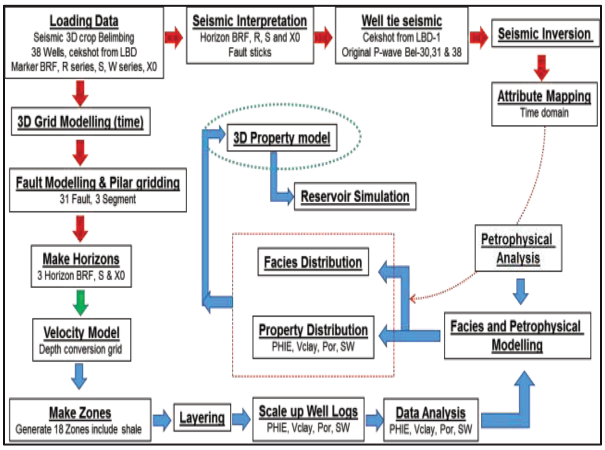


Figure 3. Workflow of Geological Modeling Belimbing Field

2.1.1. *Structural Modeling*

Structural modeling can be defined as subsurface geological geometry models that compose the results from interpretation of seismic data (horizon and fault). The stages of making a geological structure model, generally, start from making a horizon model in a time model, time-depth conversion, zoning, layering and up-scaling. After QC was done on the time domain, it was continued modeling to time-deep conversion of the horizon time domain model into the horizon depth domain (Figure 4). After changing to depth domain, then proceed with making zones and layering between the zones. After the layering process, the QC structure model was carried out by looking at the histogram data with the results scale as shown in Figure 5. From the histogram it could be concluded that the quality of structural model is classified as good because scale-up result has a difference of 5% to the overall raw data.

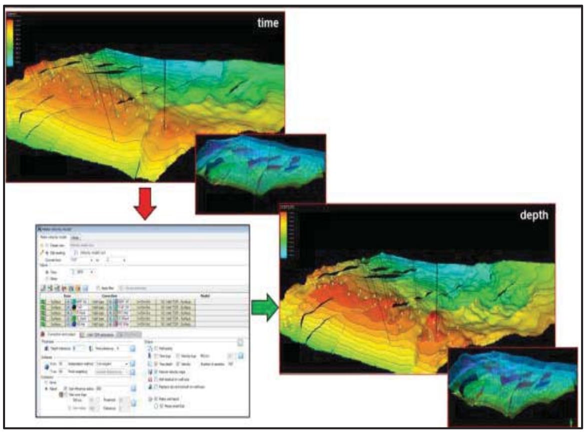


Figure 4. Time-depth Convertion

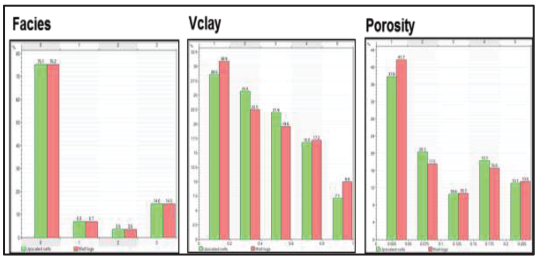


Figure 5. Upscale properties to QC the structural model

2.1.2. Properties Modeling

Properties modeling can be defined as interior modeling of geological models that have been built on structural modeling. This property modeling ware include Model Facies, Porosity, Vshale, Permability, and Water Saturation Modeling.

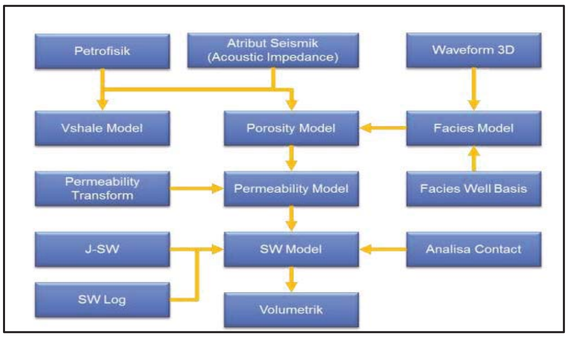


Figure 6. Properties Modeling Workflow

2.1.2.1. Facies Modeling

Facies model was constructed from well data (electrofacies analysis) which was distributed using waveform attributes of 3D Seismic with the Truncated Gaussian Simulation method/TGS. Comparison between waveform on seismic, Facies model of waveform and Facies from Well Basis was describe by map in Figure 7.

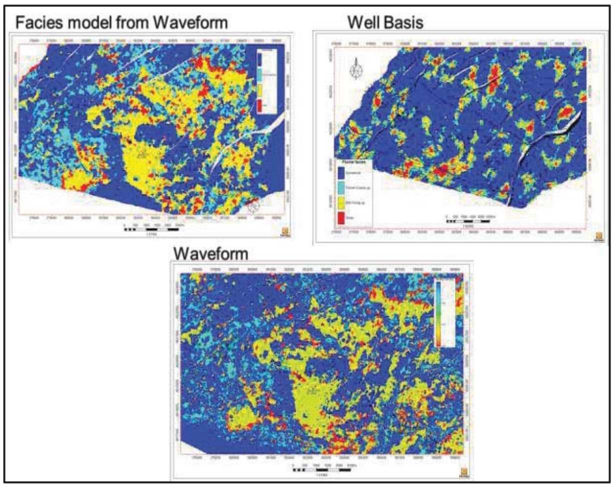


Figure 7. Comparation between waveform of 3D Seismic, facies model from that seismic atribute and Facies model from Well Basis

2.1.2.2. Porosity Modeling

Porosity modeling was created by using well data with helping by trends from accoustic impedance (AI) seismic attributes that are conditioned to facies and using variogram results from data analysis. The results of porosity modeling along with AI and facies can be seen in Figure 8 while variogram and histogram (as QC) are shown in Figure 9. The results of the comparison of the histogram data, upscale and models show the differences that occur from 5%.

2.1.2.3. Vclay modeling

Vclay modeling was also carried out by using well data with helped by trends from AI seismic attributes that are conditioned on facies and combine that with variogram data analysis results. The results of porosity modeling along with AI and facies can be seen in Figure 10. While the variogram and histogram (as QC) are shown in Figure 11. The comparison results of the histogram data, upscale and models show the differences that occur from 5%.

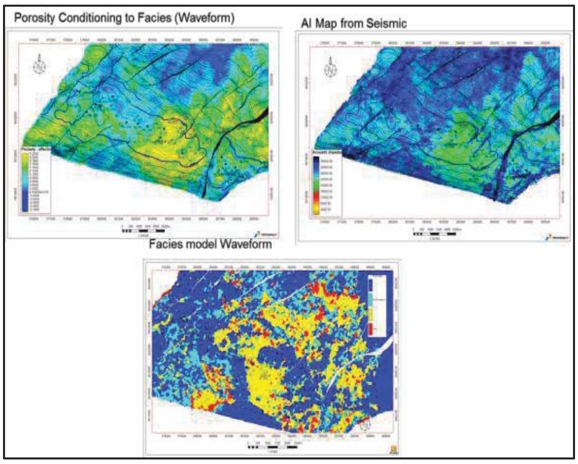


Figure 8. Porosity, AI, and Facies Model

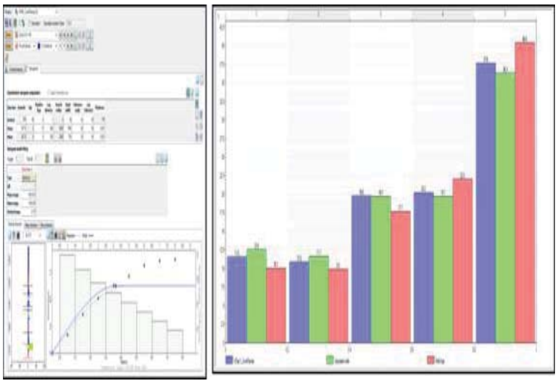


Figure 9. Variogram and Histogram of the properties modelling result.

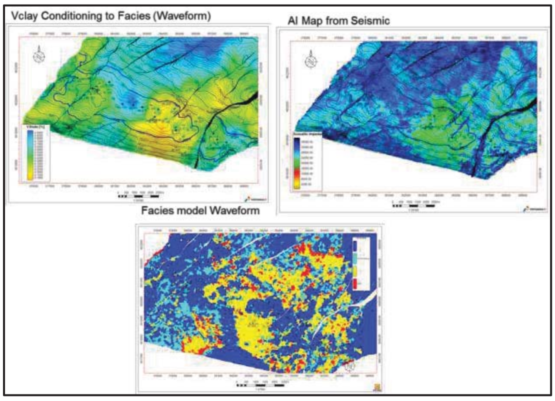


Figure 10. Vclay, AI, dan Facies Model

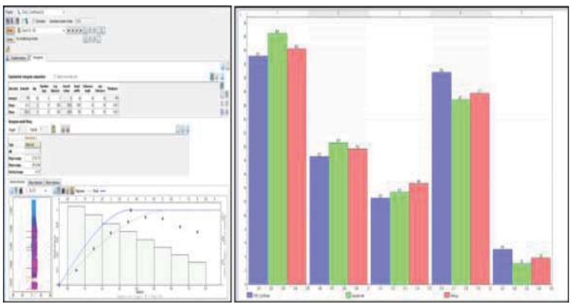


Figure 11. Variogram and Histogram from Facies Model.

2.1.2.4. Permeability Modeling

Permeability was distributed by using the transform equation (Figure 13) from the Bel-33A well routine core analysis.

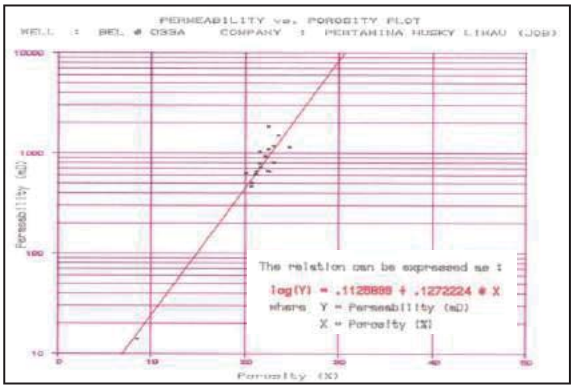


Figure 12. Crossplot between permeability and porosity

2.1.2.5. Water Saturation Modeling

Water saturation modeling was carried out with three diffusion options with each flow as follows:

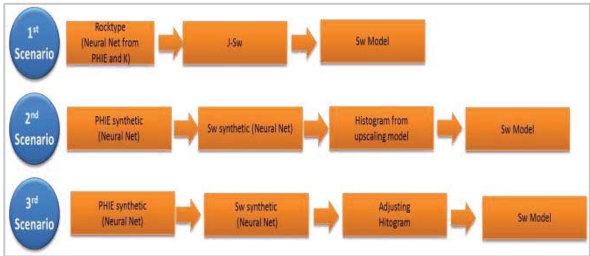


Figure 13. SW Modeling Workflow

Options 2 and 3 were distributed using log data, while Option-3 was distributed using core data from Niru Field with rocktyping using neural networks. Rocktyping using neural network method was necessary because the number of core data was limited. The results of this rocktype could be used to split Kro and Krw based on limited core data. The results of this analysis can be seen in the following graph.

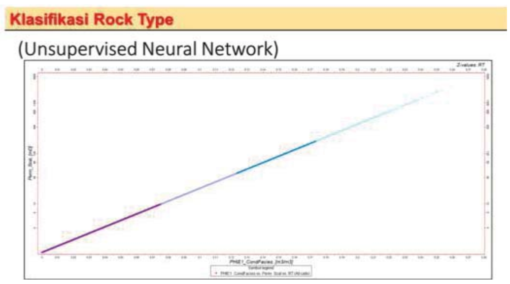


Figure 14. Rock typing using Neural Network

2.1.3. *Volumetric Calculation*

From the results of modeling Porosity, Vshale and Saturation, volumetric calculations of the three SW options could be done as follows:

Table 1. OOIP calculation results are based on SW modeling options

Lapisan	STOIIP (Option-1)[*10^3 STB]	STOIIP (Option-2)[*10^3 STB]	STOIIP (Option-3)[*10^3 STB]
R3	45,074	20,330	21,753
R4	14,822	6,556	7,015
S	115,542	104,848	104,339
W1	280	54	58
W2	4,998	1,677	1,794
W3	21,843	45,777	48,921
X0	16,151	18,753	20,066
Total	218,710	197,995	204,006

2.2. *Dynamic Modeling*

Several data that used in the dynamic modeling process is fluid analysis, production-injection history, static pressure survey, and core analysis.

2.2.1. *Rock Characteristic*

Routine Core Analysis (RCA) and Special Core analysis (SCAL) are needed in the dynamic modeling process to determine rock typing which also determines the number of oil in place and the saturation distribution. Due to the absence of special core analysis (SCAL) data, the method used is the relative permeability curve reconstruction using Niru L5A-240 well core data from the W3 layer Niru field because it is considered to be in the same depositional environment. The workflow process of reconstruction the relative permeability curve shown in Figure 16.

Capillary pressure uses data from the Niru L5A-240 to reconstruct Belimbing capillary pressure by following the prediction of capillary pressure equation from the SPE 127078 paper.

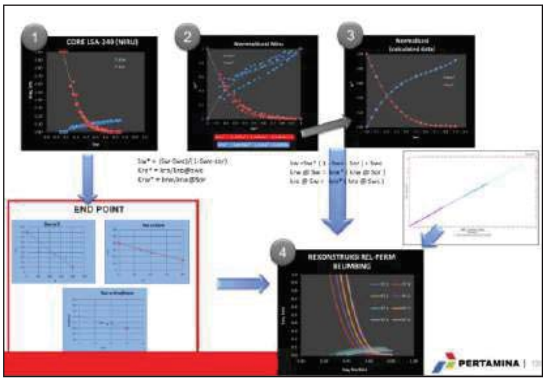


Figure 15. Rock typing using Neural Network

Origin rock typing that has been predetermined, then normalization and denormalization are carried out so as to produce a Pc-Sw and J-function curve per rock type as shown in figure below.

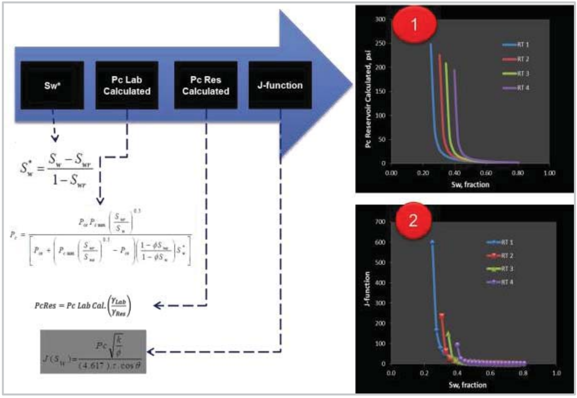


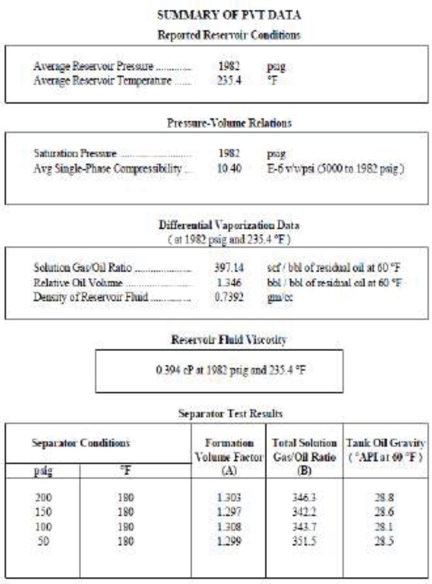
Figure 16. Workflow of Capillary Pressure

Table 1. Summary of Water saturation for each J-function type

Summary					
	ka (md)	ϕ	Swc	Sor	Equation
RT 1	670	0.2	0.249	0.244	$Sw = 0.9389*J\text{-}funct^{-0.243}$
RT 2	107	0.17	0.305	0.209	$Sw = 0.7823*J\text{-}funct^{0.211}$
RT 3	30	0.1	0.345	0.184	$Sw = 0.7412*J\text{-}funct^{-0.192}$
RT 4	8	0.06	0.398	0.151	$Sw= 0.7159*J\text{-}funct^{-0.169}$

2.2.2. *Fluid Properties*

Fluid analysis was obtained from BEL-006 layer, the fluid properties can be seen in Figure below.



SUMMARY OF PVT DATA

Reported Reservoir Conditions

Average Reservoir Pressure .... 1982 psig
Average Reservoir Temperature ...... 235.4 °F

Pressure-Volume Relations

Saturation Pressure .... 1982 psig
Avg Single-Phase Compressibility ... 10.40 E-6 v/v/psi (5000 to 1982 psig)

Differential Vaporization Data
(at 1982 psig and 235.4 °F)

Solution Gas/Oil Ratio .... 397.14 scf / bbl of residual oil at 60 °F
Relative Oil Volume .... 1.346 bbl / bbl of residual oil at 60 °F
Density of Reservoir Fluid .... 0.7392 gm/cc

Reservoir Fluid Viscosity

0.394 cP at 1982 psig and 235.4 °F

Separator Test Results

Separator Conditions		Formation Volume Factor (A)	Total Solution Gas/Oil Ratio (B)	Tank Oil Gravity (°API at 60 °F)
psig	°F			
200	180	1.303	346.3	28.8
150	180	1.297	342.2	28.6
100	180	1.308	343.7	28.1
50	180	1.299	351.5	28.5

Figure 17. PVT data

2.2.3. *Driving Mechanism*

Determination of driving mechanism using the method of Satter, A. and G. C. Thakur plot, which describes the change in pressure of each zone to the cumulative oil production then the trend is compared with the trend of the data trend.

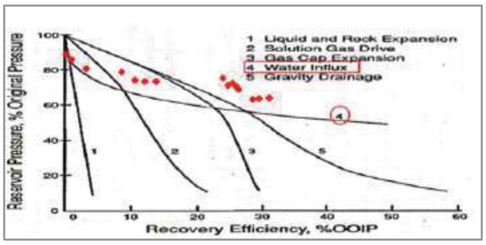


Figure 18. Satter, A. and G. C. Thakur plot

2.2.4. Initialization

From the simulation model, OOIP structure of Belimbing layer S was obtained at 530.62 MMSTB. Figure 21 shown the comparison of OOIP prices between the simulation results and the new geological model.

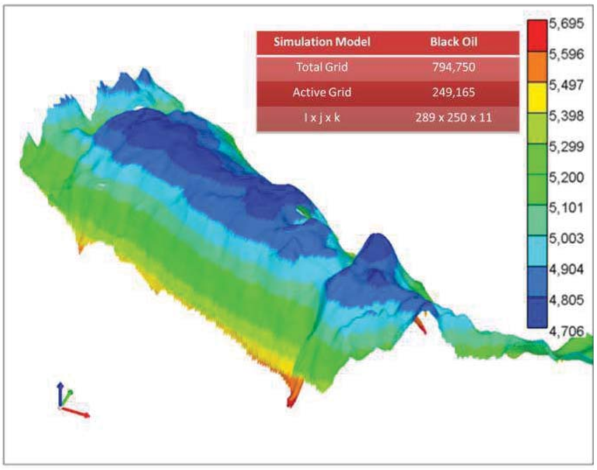


Figure 19. Depth structure 3D model layer S

Table 2. Initialization inplace

BLOCK	STOOIP (MMBBL)			
	RESERVE BOOK 2017	G&G VOLUMETRIC	SIMULATION	DELTA
EASTERN	15.27	17.88	17.88	0%
MIDDLE	57.06	82.23	84.91	4.3%
WESTERN	12.6	4.74	4.74	0%
TOTAL	84.926	104.85	107.62	2.6%

2.2.5. History Matching

There are some of uncertainty analysis combination is used in history matching process. Some of history matching parameters, such as:

a. Hydrocarbon distribution
b. Compressibility
c. Well productivity index
d. Aquifer support
e. Transmisibility

History matching is done on liquid rate, oil rate, water rate and pressure history, the results shown in the Figure 20 – 23.

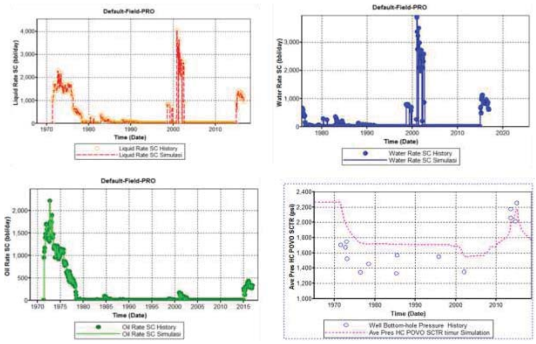


Figure 20. Production and pressure history matching eastern block

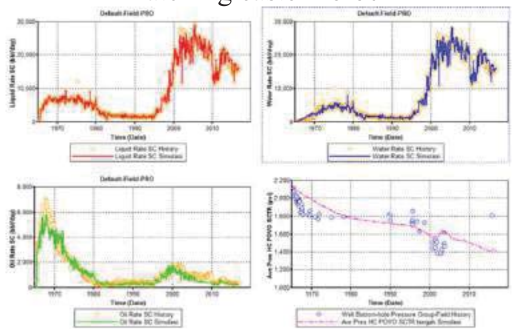


Figure 21. Production and pressure history matching middle block

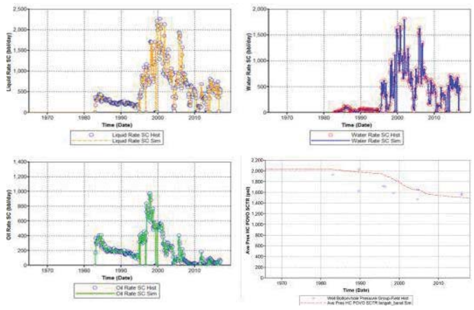


Figure 22. Production and pressure history western block

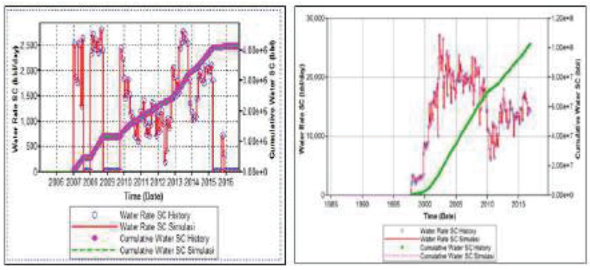


Figure 23. Injection history matching results Middle and Western block layer S

3. Field Developemnt Scenario and Production Forecast

2.3. Field Development Scenario

The strategy to improve recovery in Belimbing Field is by adding primary and waterflood wells in this time phase 1 POFD, details can be seen in Figure 24.

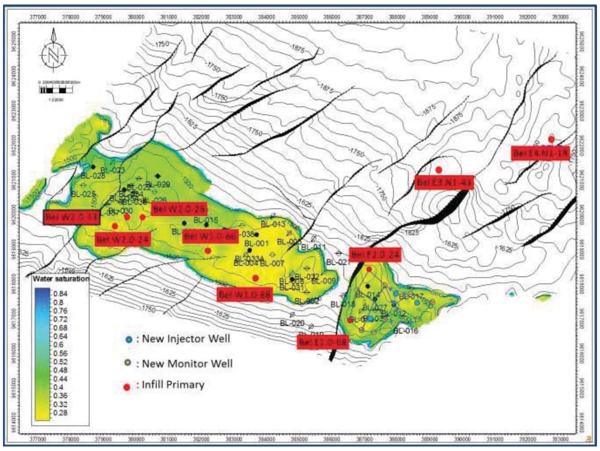


Figure 24. Development scenario of Belimbing Field S layer

Scenario of waterflood development on eastern Belimbing Layer S was determined based on sweep efficiency analysis from existing injector on that area. Sweeping area was analize by observing the low of voidage replacement ratio (VRR) cumulative, static pressure survey, and fluid in fluid out analysis (FIFO). The results of the water sweep efficiency can be seen in the Figure 25.

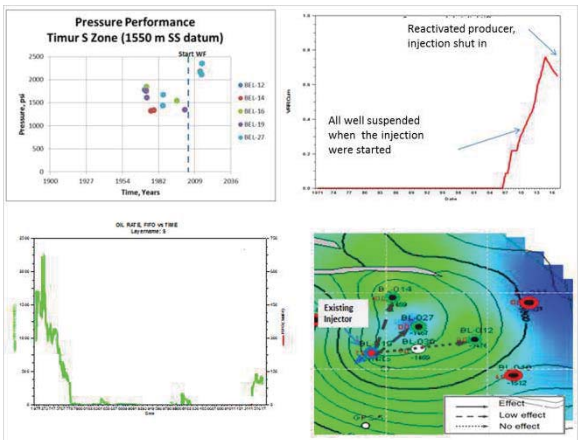


Figure 25. VRR , Observed Static Pressure, and FIFO Eastern Belimbing S Layer

The existing production and injection activities in this area show a good relationship in some part. The other parts of this area are un-swept area. Thus need to be drained.

Numbers of Sensitivity scenario was made to address the best scenario, the stage of building scenario such as:

- Oil per unit (OPU) distribution map and permeability map
- Design and optimization ideal and irregullar waterflood pattern
- Well placement strategy.

First Scenario

Nine ideal patterns with an area of 40 acres are formed to optimize primary and waterflood drainage in the remaining potential area. This concept is to reduce well spacing in waterflood optimization.

Second Scenario

Seven (7) re-patterns are formed by placing the production / injection infill which takes into account the selection of a pretty good property even though the drainage area is not ideal and is quite broad compared to the area of the pattern in the first scenario. The infill of the new wells was adjusted to the position of the existing well with an area that varied from 20 - 120 acres.

Third Scenario

Pattern waterflood 5 re-pattern which uses fewer wells than the second scenario. The infill of the new wells was adjusted to the existing well position and the area of the pattern varied from 40 - 130 acres.

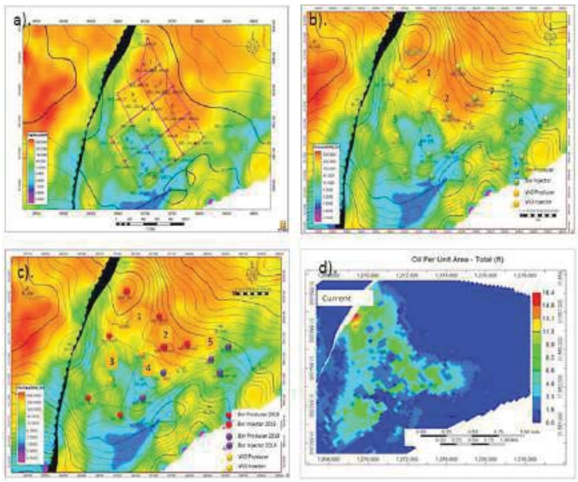


Figure 26. Nine ideal pattern map (a), Seven inverted irregular pattern (b), Five inverted irregular pattern (c), OPU current map (d)

2.4. *Production Forecast*

The results of the three scenarios that have been run provide different incremental values from the basecase, as shown in the table below. It can be seen that the increasing number of wells (Scenario 1) does not provide a significant cumulative gain compared to the number of wells in the second scenario but is still higher than the scenario-3. The following shows the development of S layer starfruit scenarios in the eastern segment with the assumption that there is no sensitivity to increase the number of drilling in the middle and west segments.

The cumulative production and incremental forecast results for each scenario have been tabulated in Table 3. Where it is seen that Scenario 1 has a higher incremental basecase when compared to Scenarios 2 and 3 at the end of the contract, year 2035.

Table 3. Incremental recovery of full segement Belimbing S layer

No.	Skenario	Total Pemboran	OOIP (MMSTB)	Current 2017		Forecast to end of PSC (2035)		Incremental to Basecase	
				NP (MMSTB)	RF (%)	NP (MMSTB)	RF (%)	NP (MMSTB)	RF (%)
0	BC	-	85.3	30	35%	30.96	36.30		
1	BC + 24 ID + 9 DI	33				40.10	47.01	9.14	10.72
2	BC + 17 ID + 4 DI	21				39.82	46.68	8.86	10.38
3	BC + 15 ID + 4 DI	19				39.39	46.18	8.43	9.88

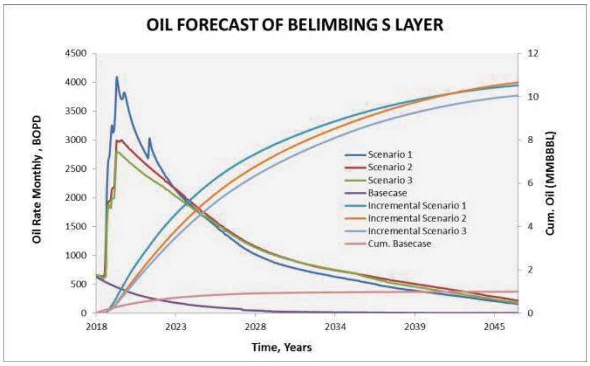


Figure 27. Production forecast

Based on technical and economic analysis the second scenario was chosen as the best scenario that will be applied in Belimbing development planning Phase-1.With an estimated investment cost of 103.83 MMUS$, this project will give additional oil of 8.86 MMBO, and IRR 30.66%. Summary of economic analysis can be seen in the Table 4 below.

Table 4. Summary of Economic Analysis

Parameter		Basecase	1st Scenario	2nd Scenario	3rd Scenario
Incremental Oil	MMBO	0.96	9.14	8.86	8.43
Oil Price	US$/BBL	65	65	65	65
Gross Rev	MMUS$	62.09	594.01	575.84	547.87
Investasi	MMUS$	0	146.65	103.83	98.11
Operating Cost	MMUS$	15.12	136.12	122.34	116.77
IRR	%	#NUM	27.24%	30.66%	28.92%
NPV @11.7%	MMUS$	11.6	35.15	41.74	38.21
POT	Year	0	4.35	3.87	3.99

4. Conclusion

The following conclusions may be made:

a. Static Model using various methods, begun from structural model until volumetric, has done and could be concluded that the Talangakar Formation has a good potential for oil production. It has ranges about 197 MMSTB until 218 MMSTB Oil in Place.

b. Base on dynamic model result, the remaining oil in the eastern blocks could be produced by waterflood method and the other area could be produced by primary recovery.

c. The best scenario, according to oil cumulative and economic calculation, is the second scenario. It will give us 8.86 MMSTB with IRR of 30.66%.

5. Acknowledgement

The authors would like to acknowledge Enhanced Oil Recovery of Pertamina EP.

6. References

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