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

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Abstract. The Belimbing Field S layer is a layer of the Upper Talangakar Formation (TRM) with a transition precipitation environment deposited in the syn-rift phase with the upper Oligocene lifetime up to the lower Miocene productively producing oil. This is a sandstone layer that contributes the largest production current with 645 bopd production (96% watercut) of OOIP 107 MMBBL. Water injection at Bel-10 wells and Bel-11 wells was first performed in October 1997 with an injection rate of 762 bwipd. The water injection is performed peripherally from the north flank of the star fruit structure (Central Belimbing block) with the initial goal of pressure maintenance even though the water is injected into the oil zone in the S layer. There is a significant increase in pressure and oil gain in the monitor wells in the injection area. 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 detected by success with increased pressure and increased production at BEL-12, BEL-14 and BEL-27 wells. As an effort to increase production, field development studies were conducted for GnG study and dynamic modelling. Limitations on the number of core data (SCAL and RCA) become obstacles in G & G and Reservoir modeling, so in determining rock typing used core data from the nearest field (LimauNiru) is L5A-240 well. In this method also performed synthetic data processing curve relative permeability and capillary pressure by evaluating production data. The distribution of artificial intelligent (AI) and wavefom is required to know the distribution of Facies and reservoir properties so as 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 recovery of oil recovery.

1. Introduction
Belimbing Fields produce in the Talangakar Formation with productive layers which are oil-producing formations [1][2]. 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.

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 such as Well Marker (Correlation), horizon, fault, petrophysical calculation, cut off analysis, and fluid contact. Generally, geological modeling can be categorized into two steps, there are: structural modeling and property modelling [3][4]. 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 1 (B).

![Figure 1. (A). Production and Injection History of Belimbing Field, (B) Workflow of Geological Modeling Belimbing Field](image)

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 2). 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, thus 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 2. Time-depth Conversion](image)
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.

2.1.3 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 4.

![Figure 3. (A) Properties Modeling Workflow (B) SW Modeling Workflow.](image)

2.1.4 Porosity Modeling

Porosity modeling was created by using well data with helping by trends from acoustic 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 5 (A).

2.1.5 Vclaymodeling

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 5 (B).

2.1.6 Permeability Modeling

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

2.1.7 Water Saturation Modeling

Water saturation modeling was carried out with three diffusion options with each flow as can be seen in Figure 4 (B). 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 5](image1.jpg)

**Figure 5.** (A) Porosity, AI, and Facies Model, (B) Vclay, AI, and Facies Model

![Figure 6](image2.jpg)

**Figure 6.** Crossplot permeability-porosity

### 2.1.8 Volumetric Calculation

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

| 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

#### 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. 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 7. (A) Rock typing using Neural Network, (B) Workflow of Capillary Pressure

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 8.

2.2.2 Fluid Properties

Fluid analysis was obtained from BEL-006 layer, oil viscosity about 0.394 cp at bubble pressure 1982 cp with 28 °API.

2.2.3 Initialization

The comparison of OOIP between the simulation results and the new geological model.

Table 2. Initialization in place

| BLOCK | 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%  |

2.2.4 History Matching

There are some of uncertainty analysis combination is used in history matching process. Some of history matching parameters, such as: hydrocarbon distribution, compressibility, well productivity index, aquifer support, and transmissibility. History matching is done on liquid rate, oil rate, water rate and pressure history, the results shown in the Figure 8 (A-C).

Figure 8. (A) History matching eastern block, (B) History matching middle block, (C) History matching western block

3 Result and Discussion

3.1 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 9 (A). 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 analyzed 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 9 (B). The existing production and injection activities in this area show a good relationship in some part. The other parts of this area are unswept 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 irregular water flood pattern, and well placement strategy.

Figure 9. (A) Development scenario Map, (B) VRR, Observed Static Pressure, and FIFO Eastern Belimbing S Layer

3.2 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.

3.3 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.

3.4 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.

3.5 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 Belimbing 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.

![Figure 10. Nine ideal pattern map (a), Seven inverted irregular pattern (b), Five inverted irregular pattern (c), OPU current map (d)](image)

**Table 3. Incremental recovery**

| No. | Scenario       | Total Pemboran | OOIP (MMSTB) | Current 2017 | Forecast to end of PSC (2035) | Incremental to Basecase |
|-----|----------------|----------------|--------------|--------------|-------------------------------|-------------------------|
| 0   | BC             | -              | 85.3         | 30           | 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                    |

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.

![Figure 11. Production forecast](image)
4 Conclusions
The following conclusions may be made: 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%. Based 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. Neural network and reconstruction SCAL data from another field with the same depositional system can be used to generate rock region distribution in static and dynamic model.

References
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