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Optimization of Well Work Strategy at Angsana Field Using Monte Carlo Simulation

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Abstract:

Angsana Field, one of the major oil and gas fields in Indonesia that is operated by PT TerraNova, has received a national production target from the Ministry of Energy and Mineral Resources to produce up to 108 thousand Barrels Oil Per Day (BOPD) Annual Average (AA) in 2025. This production target proves ambitious, given that the base production from the Angsana Field is only expected to reach around 100 thousand BOPD AA. To bridge the gap of 8 thousand BOPD AA, TerraNova intends to implement a comprehensive production optimization strategy, focused on well work. In the oil and gas industry, the potential oil gain from the well work strategies is usually evaluated using a deterministic approach via reservoir simulation model. However, this method has its own disadvantage of not fully reflecting the complexity of the actual implementation and uncertainty from subsurface aspect. In this study, the integration of deterministic analysis and Monte Carlo simulation are used to provide a more robust analysis on the potential oil gains from well work strategies. Operations management aspect is also considered to create a realistic strategy that aligns with the company's objective. The results from the analysis indicate that the 8 thousand BOPD AA gap is highly likely to be achieved by prioritizing Type-C well work technology early in the second quarter 2025.

Keywords: *Production Optimization, Monte Carlo Simulation, Well Work Strategies, Well Work Technology*

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1. Introduction

According to the United Nations Department of Economic and Social Affairs (2024), Indonesia, the fourth most populous nation in the world, is populated by 280 million. This dense population, according to Muzayanah et al. (2022), correlates positively with the overall energy consumption, where a 1% increase in the population density translates to an additional 0.36% of energy consumption. This condition, however, creates a challenging situation for Indonesia, especially from an energy security aspect.

Since 2004, Indonesia has transitioned into a net oil importer. The gap between its oil supply and demand continues to get wider each year due to the natural decline from the existing field and the increasing population. By 2023, according to the Energy

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Institute (2024), the oil shortage in Indonesia has reached 966 thousand BOPD. This condition forces the Indonesia's government to allocate a huge amount of budget each year to fulfill domestic oil demand. According to Sri Mulyani, Minister of Finance of the Republic of Indonesia (2023), the overall state budget in 2023 was around US$ 204 billion, whereas according to Statista (2024), Indonesia had spent US$ 36 billion (around 18% of the state budget) to import oil and gas in that same year. Knowing the significance of energy security to improve Indonesia's fiscal healthiness, the Ministry of Energy and Mineral Resources has set an ambitious target to increase national oil production to 630 thousand BOPD in 2025 through an aggressive exploration well work activities, and recovery of idle wells (Setiawan, 2024).

The Angsana Field, operated by TerraNova under Production Sharing Contract (PSC) agreement, is one of the major oil and gas fields in Indonesia that is expected to support this target. In 2025, TerraNova is expected by the government to produce 108 thousand BOPD AA. This production target proves to be a challenge for TerraNova, given that the base production in 2025 is expected to only reach 100 thousand BOPD AA. The ability to achieve this target is further complicated by technological challenges and subsurface uncertainties. To bridge the 8 thousand BOPD AA gap, TerraNova intends to implement a comprehensive production optimization strategy from a series of well work activities.

Historically, there are four different well work technologies that have been proven to enhance field production. These technologies are known as:

1. Type-A, uses a mechanical method to improve the productivity of the oil-producing zone.
2. Type-B, uses a chemical reaction to improve the productivity of the oil-producing zone.
3. Type-C, uses a mechanical method to isolate non-productive reservoir intervals.
4. Type-D, uses a chemical reaction to isolate non-productive reservoir intervals.

In addition to the well work technologies that provide an oil uplift, other technologies such as those that support the integrity and reliability of the overall operations are also considered important. These technologies are known as:

1. Type-E, uses a chemical to protect the downhole equipment from corrosion.
2. Type-F, uses a sonar to collect reservoir-related parameters.
3. Type-G, uses mechanical methods to rectify minor integrity issues in the production wells.
4. Type-H, uses mechanical methods to improve the injectivity of the water and gas injection well.

This study aims to find the most optimal well work strategy that has the highest probability of delivering 8 thousand BOPD AA. In this case, the combination of deterministic analysis and Monte Carlo simulation are used to provide a more robust analysis, as relying solely on the typical deterministic model using reservoir simulation has its own limitation of not considering the operation complexity and subsurface uncertainties. For the evaluation, both well work technologies that are used to enhance production and maintain operations reliability are considered as part of the well work strategy.

2. Theoretical Background

Rational Decision Making: According to Heracleous (1994), the rational decision-making process is a way in which decisions should be made. It involves a strictly defined sequences that starts from problem identifications. Once the problem has been clearly identified, the potential alternative courses of actions are defined. After that, they go through an objective evaluation process before the best alternative is being implemented and monitored. If the result of the implementation is unsatisfactory, then the process of rational decision-making will be repeated as necessary.

Monte Carlo Simulation: While deterministic models are typically useful for assessing the potential oil gain from the well work strategy, it has a limitation in capturing uncertainties, especially if there are many possible outcomes. Monte Carlo simulation on the other hand, is designed to bridge the relationship between probability and the value for parameters. According to Kok (2006), Monte Carlo simulation starts with a calculation model where each input parameter must be described by a probability distribution. Once the input parameters have been prepared, the calculation model is run numerous times using different sets of randomly generated inputs to provide meaningful insights for a wide range of problems.

Data Binning: As this research heavily involves Monte Carlo simulation in it, statistical knowledge becomes crucial. One such knowledge is data clustering method known as data binning. According to Deckert and Kummerfeld (2022), data binning is a pre-processing step in data analysis, where continuous numeric variables are converted into discrete variables. The bin size in data binning comes with various ranges. Some have equal widths on the measurement scale, some contain equal numbers of samples, while the more complex unsupervised methods classify the data into groups based on patterns and similarity.

Production Sharing Contract (PSC): To attract foreign investors in the oil and gas sectors, Indonesia has been using PSC scheme for many years. It starts with the government granting the rights for the oil company to explore a specified area. Initially, the oil company bears the financial risks from exploration, development, and production. However, once the production phase starts, the oil company is allowed to use the profit from producing oil to recover the capital and operating expenditures. The remaining profit will then be split between the government and the oil company, where the percentage of profit share will depend on the International crude price (Lundin Group, 2019).

3. Methodology

This research addresses a business problem of evaluating the most optimal well work strategy to resolve a production gap between the expected base production from the Angsana Field with the production target set by the Ministry of Energy and Mineral Resources. The primary data source comes from secondary data, where internal company database focuses on historical well work activities is leveraged for the evaluation purpose. The data analysis technique employs not only the common deterministic method, but also the probabilistic model such as Monte Carlo simulation to find the most optimal well work strategy that can deliver the highest production uplift. The combination of these two methods provide a more robust and realistic solution, giving clarity to the decision-makers to make sound business decisions.

4. Empirical Findings/Result

Evaluating the Potential Well Work Technologies for Angsana Field

One of the most important steps in evaluating well work strategy is to first understand the potential oil gain from each of the well work technology. As the reservoir conditions change over time, the required well work technologies will also evolve. This assessment is usually done annually by a multi-disciplinary team in a workshop known as "Wellbore Utility Review", which evaluates the wellbore integrity aspect, the potential opportunities for production enhancement, and the economic viability for the upcoming year. The result from the assessment is summarized in Table 1.

Table 1. Summarized result of the Wellbore Utility Review

Well work category	Technology type	Number of potential activities in 2025	Estimated activity duration (days)	Estimated gross cost (US$ M)
Production enhancement activities	Type-A	10	3 – 5	0.1 – 0.5
	Type-B	28	<3	<0.1
	Type-C	3	>15	>1.0
	Type-D	13	>15	>1.0
Non-production enhancement activities	Type-E	23	3 – 5	0.1 – 0.5
	Type-F	7	3 – 5	<0.1
	Type-G	4	3 – 5	<0.1
	Type-H	12	3 – 5	0.1 -0.5

Evaluating the Potential Oil Gain from Well Work Technologies

Typically, in the industry, the potential oil gain from the well work strategies is evaluated using a deterministic approach via reservoir simulation model. While this method is practical, it has its own disadvantage of not fully reflecting the complexity of the actual implementation and the uncertainty from subsurface aspect. This drawback, most often than not, leads to significant differences between model predictions and the actual benefit realization post well work activity. Because of that, a stochastic analysis, in this case Monte Carlo simulation, is employed in the evaluation to predict the range of potential oil gains from well work strategies by leveraging historical results.

To perform the Monte Carlo simulation, the first and most crucial step is to have reliable input parameters described in probability distribution form. These input parameters include the potential oil gain from each of the production enhancement technologies (e.g. Type-A, Type-B, Type-C, and Type-D) and their benefit sustainment duration. To ensure the reliability of the data, three years' worth of historical well work activities from 2022 until 2025 are thoroughly analyzed. Those data consist of 32 Type-A, 15 Type-B, 11 Type-C, and 4 Type-D. The oil gain and benefit sustainment duration for each of the activity is then estimated using deterministic analysis via a mathematical mode. These estimates are subsequently grouped and clustered into several class ranges to be converted into probability distribution forms for Monte Carlo's input data. The deterministic analysis results from the production enhancement technologies are summarized in Figure 1 and 2.

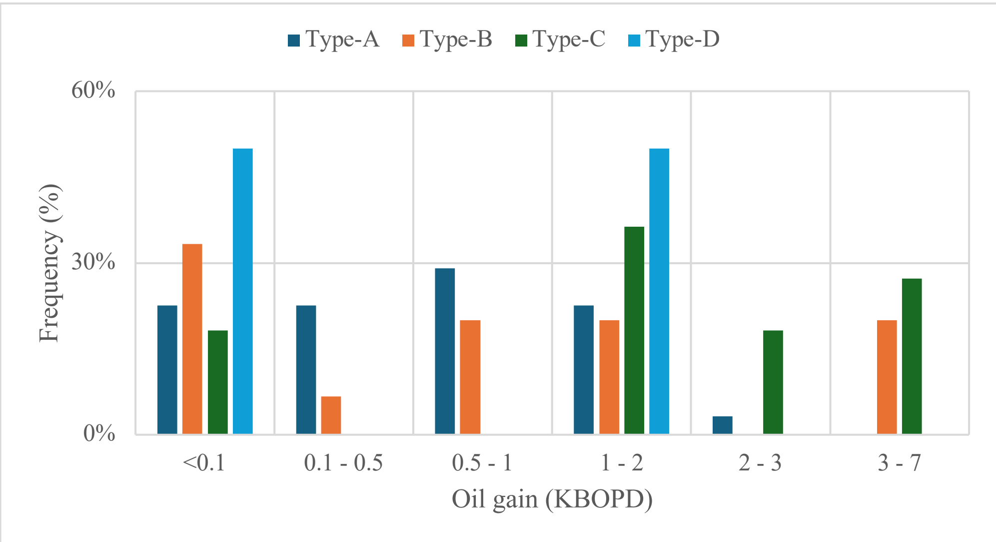

Figure 1. Potential oil gain from production enhancement technologies

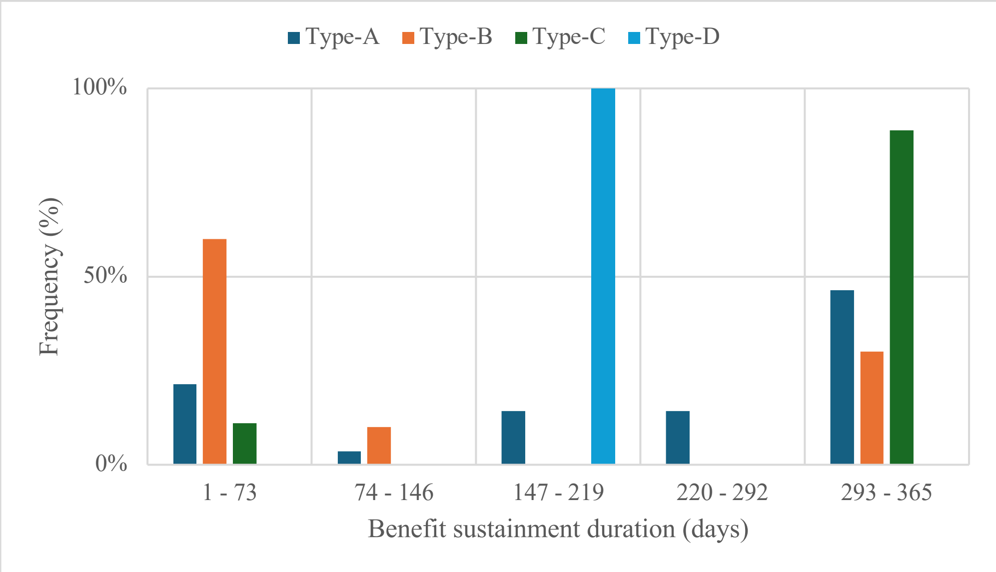

Figure 2. Benefit sustainment duration from production enhancement technologies

The analysis result of the oil gain and benefit sustainment duration from Type-A, Type-B, Type-C, and Type-D technologies are summarized in Table 2 to provide a clear comparison of the pros and cons of each technology.

Table 2. Comparison of the production enhancement technologies

Parameters	Type-A	Type-B	Type-C	Type-D
Oil gain	Moderate	Moderate	Very high	High
Chance of success	Moderate	Low	High	Low
Activity duration	Short	Very short	Long	Long
Cost	Low	Very low	Very high	Very high

Evaluating the Potential Oil Gain from Base Well work Strategy

During the development of this research, some of the well work activities in the first quarter of 2025 have been performed, which contributed to approximately 3.8 KBOPD AA uplift. This leaves 4.2 KBOPD of production gap that needs to be addressed in the second quarter onward.

In estimating the potential oil gain from the second quarter onward, having a thorough understanding of the operation timeline from the well work strategy becomes crucial, as the benefit from the well work activities is the function of time. The earlier the benefit is realized, the higher the oil gain will be. Figure 3 illustrates the operation timeline from the base well work strategy on second quarter onward.

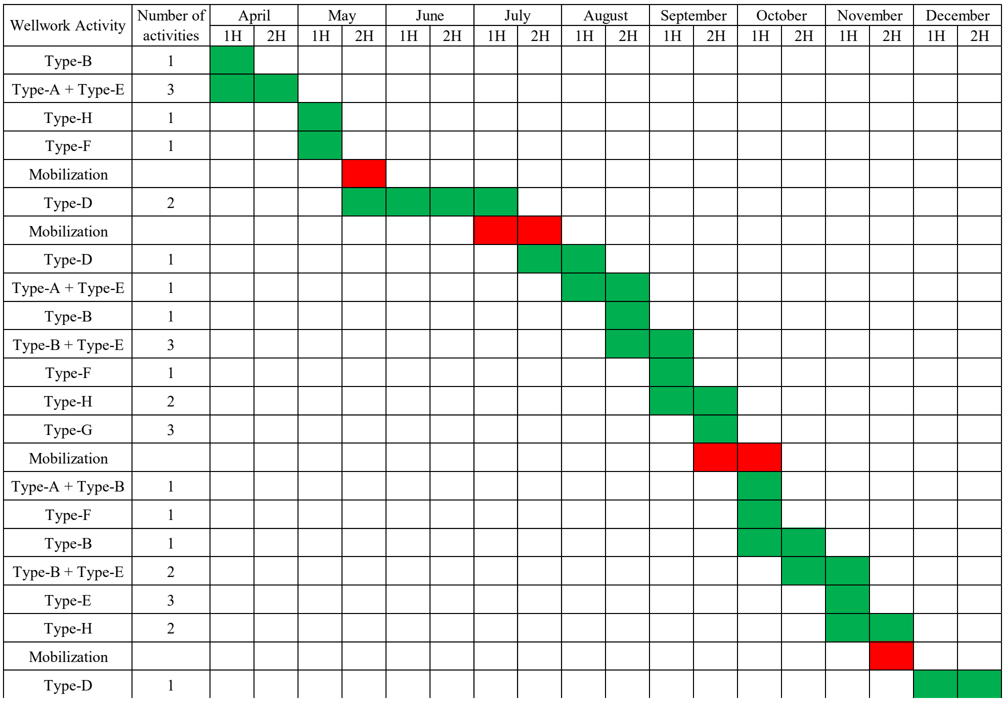

Figure 3. Operation timeline from the base well work strategy

The potential oil benefit from the base well work strategy is then estimated using Monte Carlo simulation. It involves randomizing oil gain and the benefit sustainment duration for production enhancement technologies. To ensure reliable results, the Monte Carlo simulation is run for 10,000 iterations, representing the 10,000 possible outcomes from the base well work strategy. Figure 4 illustrates the potential oil gain after 10,000 iterations

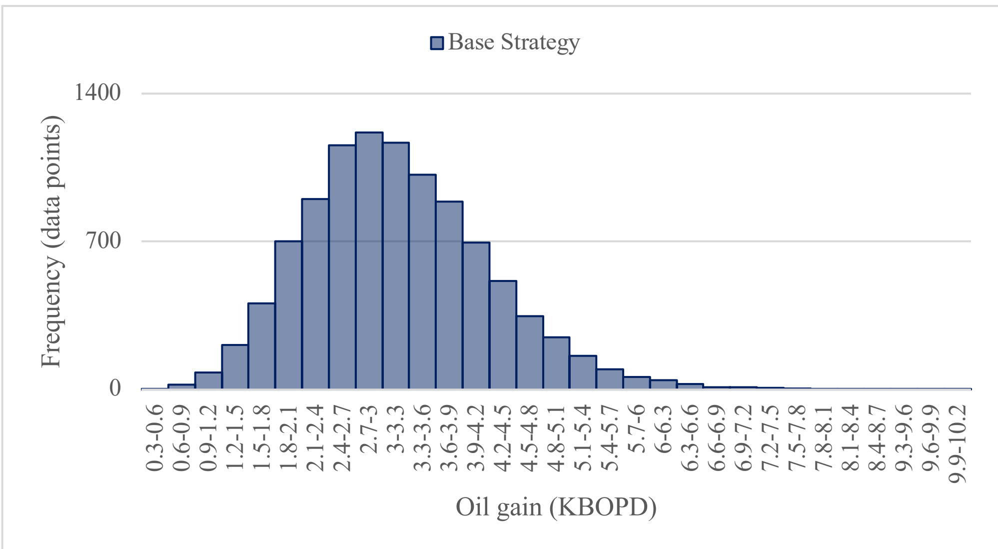

Figure 4. Potential oil gain from the base well work strategy

Defining the Sensitivity Scenarios

The well work technologies can be classified into two main categories: (1) production enhancement technologies, which contribute to the production increase, and (2) non-production enhancement technologies, which focus on maintaining reliability and integrity of the operations. Among these two categories, the non-production enhancement technologies are usually more rigid and considered a higher priority due to their critical role in ensuring the long-term operational integrity and reliability. In 2025, several non-production enhancement technologies have been identified as high priorities by TerraNova. These activities are:

1. Type-E technology: A minimum of 12 activities must be conducted in 2025 to maintain the integrity of production wells from corrosion and erosion.
2. Type-F technology: A minimum of 3 activities on different well pad are required to collect reservoir data for simulation purposes.
3. Type-G technology: 3 activities must be performed to address minor integrity issues in production wells.
4. Type-H technology: 5 activities must be performed to manage reservoir pressure effectively.

To maximize the oil gain from the well work strategy, it is essential to minimize the frequency of mobilizations across well pads, as each mobilization can take up to 2 weeks on its own. Additionally, prioritizing the most beneficial well work activities (e.g. those with high oil gain and strong likelihood of success) helps to maximize the production by accelerating the gain. However, determining the most optimal well work strategy becomes more complex due to varying oil gains, probability of success, and durations associated with the production enhancement technologies. As such, to streamline the evaluation process, three sensitivity scenarios (Scenario 1, 2, and 3) focusing on the production enhancement technologies are developed:

1. Scenario 1 prioritizes the implementation of Type-D technology on each well pad
2. Scenario 2 prioritizes the implementation of Type-A and Type-B technologies on each well pad.
3. Scenario 3 prioritizes the implementation of Type-C technology on each well pad.

In analyzing the modified well work strategy that will be discussed in the next three sections, the operational sequences for the production enhancement technologies will follow the prioritization from Scenario 1, 2, and 3. All the requirements from the non-production enhancement technologies will also be integrated into each of the well work strategy sensitivity. In addition to that, the sequences have been set accordingly to minimize the mobilization frequency from each well pad to maximize the potential oil gain.

Analysis of Scenario 1

The modified well work strategy and the potential oil gain for Scenario 1 are presented in Figure 5 and 6. The analysis indicates that prioritizing Type-D implementation on each well pad provides minimal to no oil gain compared to the base well work strategy.

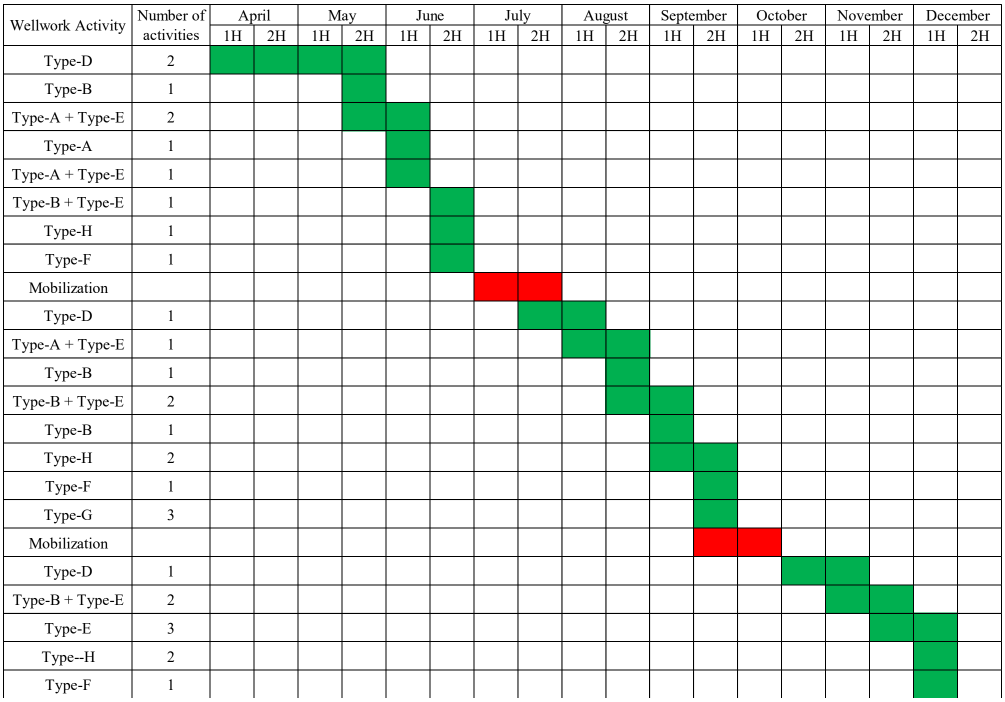

Figure 5. Operation timeline from the Scenario 1 well work strategy

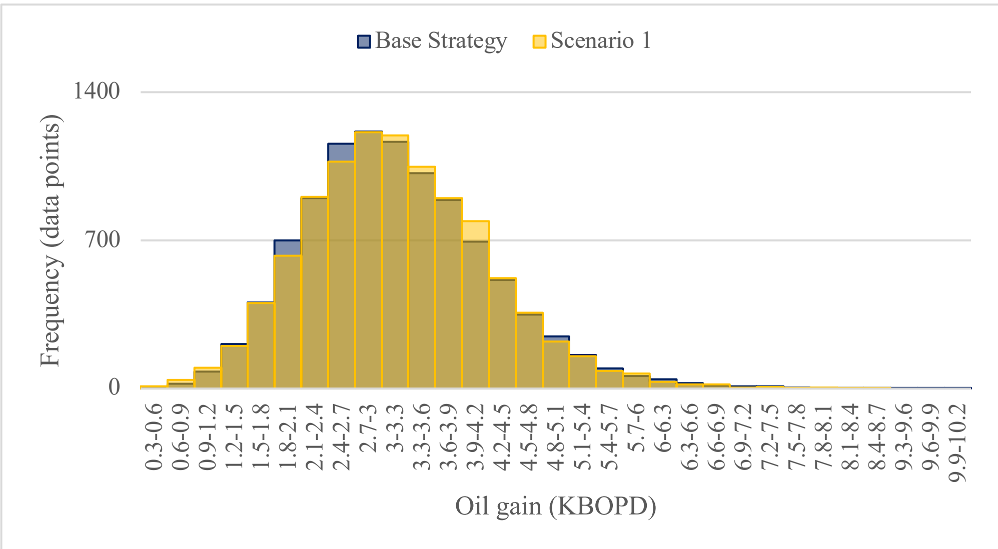

Figure 6. Potential oil gain from Scenario 1 well work strategy

Analysis of Scenario 2

The modified well work strategy and the potential oil gain for Scenario 2 are presented in Figure 7 and 8. The analysis indicates that prioritizing Type-A and/or Type-B implementation on each well pad also provides minimal to no oil gain, similar with Scenario 1.

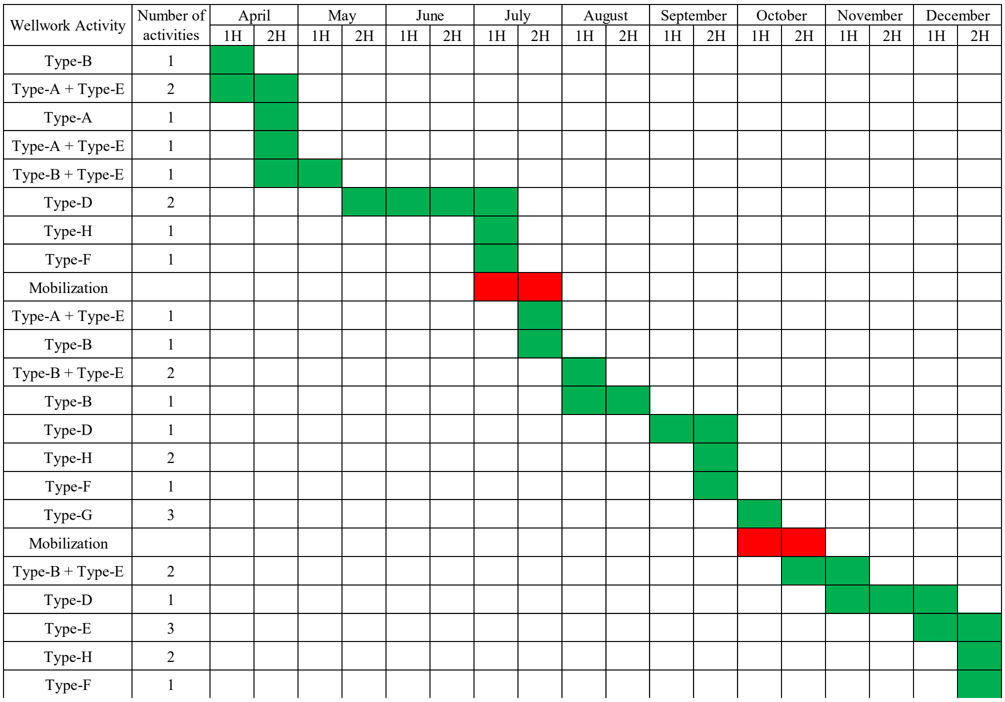

Figure 7. Operation timeline from the Scenario 2 well work strategy

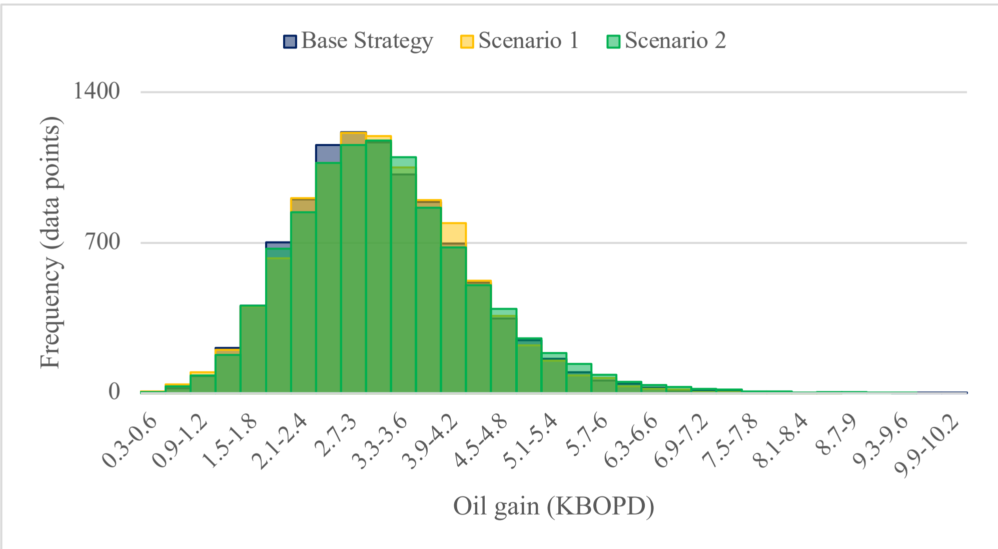

Figure 8. Potential oil gain from Scenario 2 well work strategy

Analysis of Scenario 3

The modified well work strategy and the potential oil gain for Scenario 3 are presented in Figure 9 and 10. The analysis indicates that prioritizing Type-C implementation early in the second quarter 2025 provides the highest possible oil gain to close the production gap required to achieve the target set by the Ministry of Energy and Mineral Resources.

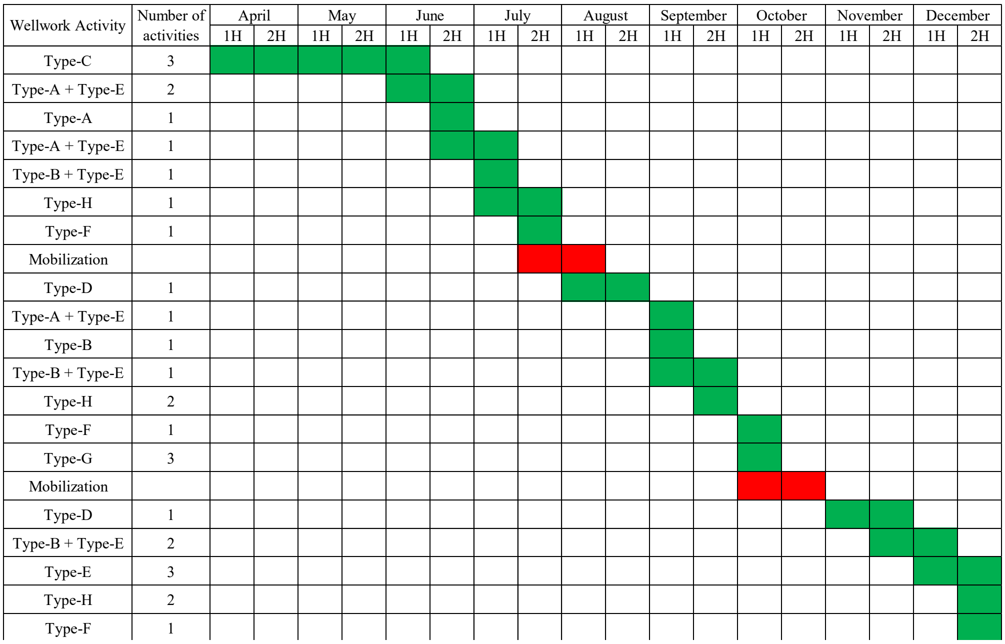

Figure 9. Operation timeline from the Scenario 3 well work strategy

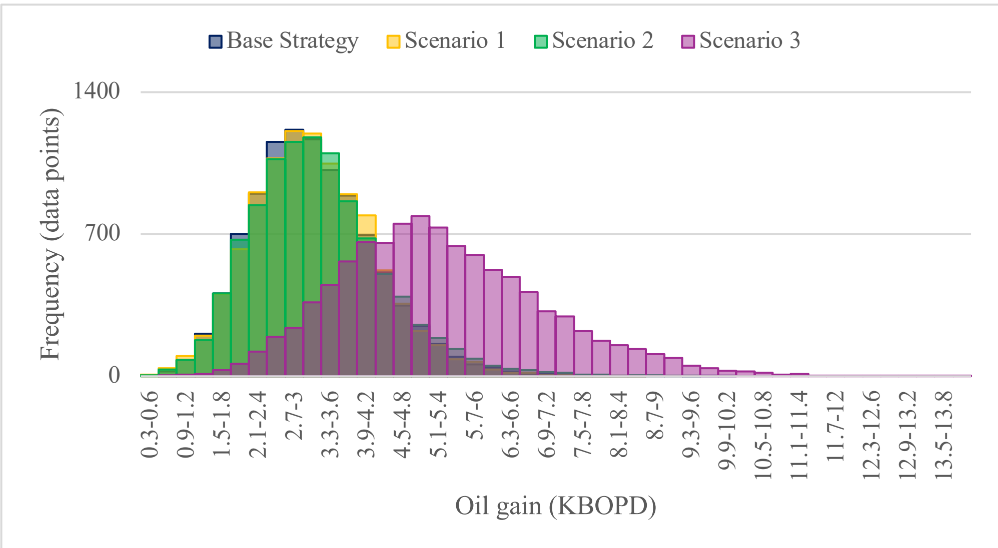

Figure 10. Potential oil gain from Scenario 3 well work strategy

Economic Evaluation

To assess the viability of the well work strategy, an economic evaluation was performed using PSC scheme by assuming an international oil price of $75/BBL.

Some of the key inputs in the economic evaluation are the total cost and expected oil gain from each well work strategy, which is summarized in Table 3.

Table 3. Summary of oil gain from each of the well work strategy

Scenario	Total well work cost ($M)	Realized oil gain from 1Q25 (KBOPD AA)	Expected oil gain 2Q – 4Q25 (KBOPD AA)	Total full year expected oil gain (KBOPD AA)
Base strategy	31.5	3.8	3.2	7.0
Scenario 1	30.9		3.2	7.0
Scenario 2	31.6		3.3	7.1
Scenario 3	34.4		5.3	9.1

The economic evaluation in the PSC scheme follows several steps that has been governed under the PSC agreement to determine the profit share between the contractors (TerraNova as the operator and Pertamina as the non-operating partner) and government. For this research purpose, the PSC structure is assumed to follow the typical split between the contractors and government as shown in Figure 11.

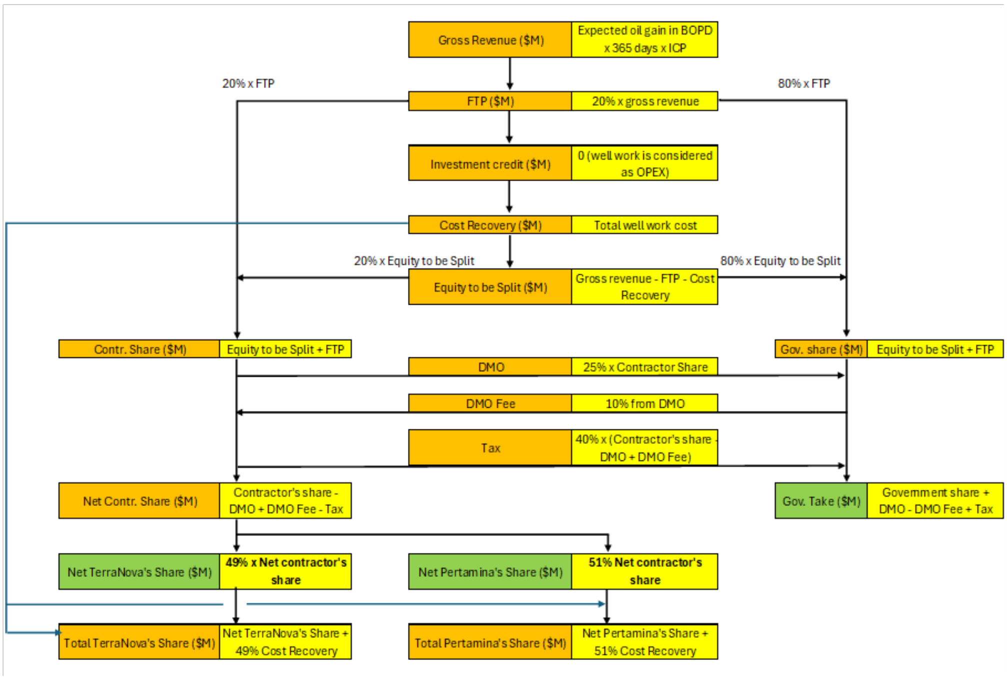

Figure 11. PSC economic structure for the Angsana Field

From the economic evaluation, although the well work cost on Scenario 3 is 10% higher than the other scenarios, the resulting net profit for TerraNova still outmatches the other cases ($9.8M vs $7.3M) due to its high oil gain. Now, to further strengthen the evaluation, a sensitivity analysis was performed by (1) varying the international oil price to represent the volatile global market, and (2) increasing the well work cost to represent the cost overrun. The result, which is summarized in Table 4 and 5, shows that:

1. The economics from Scenario 3 is still far superior than the other cases.
2. TerraNova's net profit is more sensitive with volatile oil price rather than the well work cost itself.

Table 4. Sensitivity analysis on various international oil price.

Oil price	TerraNova's net profit ($M)			
	Base strategy	Scenario 1	Scenario 2	Scenario 3
Oil price -20%: $60/bbl	5.5	5.6	5.6	7.5
Oil price -10%: $67.5/bbl	6.4	6.4	6.5	8.6
Reference oil price: $75/bbl	7.3	7.3	7.4	9.8
Oil price + 10%: $82.5/bbl	8.1	8.2	8.2	10.9
Oil price +20%: $90/bbl	9.0	9.0	9.1	12.1

Table 5. Sensitivity analysis on various international oil price.

Oil price	TerraNova's net profit ($M), assuming oil price at $60/bbl			
	Base strategy	Scenario 1	Scenario 2	Scenario 3
Reference well work cost	5.5	5.6	5.6	7.5
Well work cost +10%	5.4	5.4	5.4	7.4
Well work cost +20%	5.2	5.3	5.3	7.2

5. Discussion

Out of all the 3 scenarios in the modified well work strategy, Scenario 3 provides the highest oil gain to close the required gap to the production target of 108 KBOPD AA. This finding supports the objective of identifying the most optimal well work strategy to maximize production.

1. In Scenario 1, even though Type-D technology has the potential to provide a high oil gain, its effectiveness is hindered by a high degree of uncertainty due to limited data points available. Furthermore, the extended well work duration for Type-D means that no additional oil gain can be realized throughout the Type-D job, resulting in opportunity losses and making this scenario less favourable in maximizing oil production.
2. In Scenario 2, even though Type-A and Type-B technologies have a higher probability of success compared to Type-D, the potential oil gain that can be

realized from these activities are less superior than Type-D and Type-C. In addition to that, Type-A and Type-B are only effective when executed in active production wells, which requires temporarily shutting in those wells throughout the execution. This results in production losses that offsets the oil gains and leads to a net zero benefit overall.

3. In Scenario 3, even though Type-C technology takes longer to complete compared to the other production enhancement technologies, its high potential oil gain combined with the strong chance of success outweighs the opportunity loss during the execution period, resulting in the greatest oil gain compared to the other scenarios.

It is worth to highlight that in most of the cases, using Monte Carlo simulation will provide a more superior robustness in the analysis, as it allows result uncertainties to be factored in and provides an easily traceable calculation method, something that deterministic analysis lacks. However, while Monte Carlo simulation helps decision-makers to make a sound business decisions, there are still some pitfalls that need to be carefully considered. One of those pitfalls that is highly correlated with this study is the small data sets available.

In the oil and gas industry, well work jobs can be considered as a high-risk activity due to its high cost and result uncertainties. Because of that, it is common for many oil and gas companies to only have a small amount of well work data points, as the jobs are not performed as frequent. With small data points, the uncertainty in which the model is built will be relatively high and resulted in a higher prediction's uncertainty, aligns with the study from Williamson, Sawaryn, and Morrison (2006). This problem can be clearly seen on the analysis result of Type-D technology, where the probability distribution is only based on 4 historical well work jobs. However, this limitation does not mean that the Monte Carlo simulation should not be used.

As an example, the potential oil gain and benefit sustainment duration from Type-A, Type-B, and Type-C are driven by 32, 15, and 11 data points respectively. At the first glance, this amount of data might be considered small and unrepresentative to be used as the input to the Monte Carlo simulation. However, the actual results from those well work technologies do have the consistencies and are supported by a rigorous mathematical model from reservoir simulation. Because of that, the analysis result from Type-A, Type-B, and Type-C are not baseless and can be used with a relatively high confidence in the Monte Carlo simulation. This highlights the importance of using Monte Carlo simulation in accordance with engineering judgement to make a better decision-making, especially in the absence of sufficient data points, which is a common problem in the oil and gas industry.

6. Conclusions

This study is intended to identify the most optimal well work strategy for TerraNova to maximize the oil gain in 2025. In the evaluation, the combination of deterministic analysis and Monte Carlo simulation are used to provide reliable oil gain projections by considering uncertainties. Based on the analysis and limited data available, it can be concluded that the current well work strategy will most likely gain additional 6 KBOPD AA, leaving a gap of 2 KBOPD to the required production target. To bridge this gap, the base well work strategy needs to be modified using the operational sequences as stated in Scenario 3, where the implementation of Type-C technology early in the second quarter 2025 will provide the highest gain out of all the other scenarios. Future studies can be explored further by continuously expanding the dataset with the recent well work jobs to reduce the uncertainty in the Monte Carlo simulation.

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