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A Practical Integrated Workflow for Well Candidate Selection in Mature Oil Fields Using Well Opportunity Index and Delta Potential

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ABSTRACT - Mature oil fields commonly face production decline, increasing water cut, and limited availability of complete static and dynamic reservoir models. Under these conditions, a practical and traceable workflow is necessary to select well candidates for production optimization. This study proposes an integrated workflow combining well opportunity index (WOI), Delta Potential, quadrant analysis, and weighted ranking. The workflow is applied to three producing wells in the G-40 sandstone reservoir of the TM Field, a mature oil field in the South Sumatra Basin, Indonesia. Current oil saturation is estimated using a fractional-flow-based approach and validated by matching calculated and observed oil rates, resulting in Mean Absolute Percentage Error (MAPE) values of approximately 2%, 3%, and 3%. WOI represents reservoir opportunity through flow capacity, movable hydrocarbon pore volume, and remaining pressure support, while Delta Potential quantifies remaining production opportunity. The calculated Delta Potential values are 0.112, 0.103, and 0.042 MMSTB for TM-1, TM-2, and TM-3, respectively. Quadrant analysis places TM-1 and TM-2 in the high-WOI and high-Delta-Potential region; however, TM-2 is treated as a secondary candidate requiring further diagnosis because its WOI is lower than that of TM-1. The final weighted ranking produces the priority order TM-1 > TM-2 > TM-3. These results indicate that the proposed workflow provides a practical and traceable preliminary screening tool for mature-field production optimization under limited data availability.

Keywords: mature oil field, well candidate selection, well opportunity index, delta potential, production optimization.

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1. Introduction

Mature oil fields remain important contributors to hydrocarbon supply, but they commonly experience production decline, increasing water cut, reservoir pressure depletion, and decreasing well productivity. Mature-field development studies have emphasized that remaining reserves, recovery factor, withdrawal rate, facility constraints, and reservoir maturity must be evaluated together to identify production improvement opportunities (Babadagli 2005; Johnson 2003; Sugiantoro 2014). Under these conditions, production optimization becomes increasingly dependent on the ability to identify wells that contain technically attractive remaining potential. In Indonesia, many mature fields show opportunities for production improvement, particularly when remaining reserves are relatively significant, but production withdrawal rates remain low (Sugiantoro 2014). Similar screening concepts have been applied in field redevelopment and enhanced recovery planning, where candidate prioritization considers remaining potential, operational feasibility, and spatial or facility constraints (Cimic 2006; Romli et al., 2021). This condition indicates that production optimization in mature fields should focus not only on increasing production rate, but also on improving the selection of wells or zones with the highest remaining opportunity.

Candidate selection in mature fields is not straightforward because well performance is controlled by both reservoir condition and production behavior. A well may still have remaining recoverable oil, but its deliverability may be limited by low permeability, insufficient pressure support, high water cut, poor production efficiency, or data-quality limitations in water-production measurement (Chetri et al., 2008; Sandau 2008). Conversely, a well with favorable reservoir quality may not be an attractive optimization candidate if its remaining recoverable volume is limited. Therefore, candidate selection should not rely on a single production indicator or a single reservoir property, but should instead integrate reservoir opportunity, remaining production potential, current production contribution, production efficiency, and the relative importance of the selected parameters (Haryanto et al., 2019; Pilcher et al., 2011).

Several approaches have been developed to support production optimization and candidate recognition. Decline curve analysis is widely used to forecast production performance and estimate remaining recovery potential (Arps 1945). Production data-based methods have also been applied to identify underperforming wells and infill opportunities in mature fields, particularly under limited data availability (Jalali et al., 2006; Mattar & Anderson 2003; Mohaghegh et al., 2005). Optimization and allocation studies further show that production improvement requires systematic integration of well-level performance and field-level constraints (Kosmidis et al., 2004). The Heterogeneity Index and Modified Heterogeneity Index have been used to compare well performance, recognize production anomalies, and support candidate screening (Reese 1996; Tan et al., 2010; Salman et al., 2013). In addition, opportunity-index concepts have also been used to support exploitation planning by ranking areas or wells according to their remaining potential (Molina & Rincon 2009). Recent Indonesian studies have emphasized the importance of integrated workflows for matrix acidizing candidate selection, idle well reactivation, and bypassed oil identification by combining production, petrophysical, geological, and diagnostic data (Turnip et al., 2024; Larasati et al., 2026; Prayitno et al., 2026).

Although these methods provide useful screening support, a practical gap remains in integrating reservoir-based opportunity and production-based remaining potential into a traceable well-level decision workflow. Many mature fields lack complete static and dynamic reservoir models, making simulation-based optimization difficult to apply in early-stage screening. In such cases, engineers often rely on commonly available production history, petrophysical summaries, pressure data, and well performance indicators. A practical screening workflow is therefore necessary to combine these data sources into a consistent method for prioritizing well candidates before detailed intervention design, reservoir simulation, or economic evaluation.

This study proposes an integrated well candidate selection workflow that combines Well Opportunity Index (WOI), Delta Potential, quadrant analysis, and weighted ranking. WOI represents reservoir-based opportunity by incorporating flow capacity, movable hydrocarbon pore volume, and remaining pressure support. Delta Potential represents production-based remaining opportunity by comparing estimated ultimate recovery with cumulative oil production. These two indicators are integrated through quadrant analysis to classify candidate priority,

followed by weighted ranking using selected reservoir and production performance parameters. To clarify the distinction between traditional single-indicator screening methods and the proposed integrated workflow, Table 1 summarizes the expected interpretation, likely candidate priority, and main limitation of each screening basis.

Table 1.
Comparison of well screening methods.

Screening basis	Main parameter	Likely candidate priority	Limitation
Production-only screening	N_p , oil rate, water cut	May identify wells with production anomaly	Does not directly represent reservoir support
Delta Potential only	$EUR - N_p$	TM-1 and TM-2 appear similarly attractive	Does not sufficiently distinguish reservoir deliverability
WOI only	Flow capacity, movable HCPV, pressure support	TM-1 > TM-2 > TM-3	Does not directly quantify remaining production potential
Proposed workflow	WOI + Delta Potential + weighted ranking	TM-1 > TM-2 > TM-3	Requires calibration for larger datasets

The objective of this study is to develop a practical and traceable workflow for selecting well candidates for production optimization in mature oil fields under limited data availability. The workflow is applied to three producing wells completed in the same reservoir interval of a mature oil field. The main contribution of this paper is the integration of reservoir opportunity and remaining production potential into a simple screening framework that can help reduce candidate misclassification and support early-stage production optimization decisions.

2. Methodology

This study develops a practical workflow for well candidate selection by integrating reservoir opportunity and remaining production potential. The workflow consists of six main stages: study data preparation, current oil saturation estimation, Well Opportunity Index calculation, Delta Potential calculation, quadrant-based candidate classification, and final weighted ranking. The proposed workflow is designed for mature fields where complete static and dynamic reservoir models are not available, but production history, petrophysical summaries, well pressure data, and completion information are accessible. Similar integrated screening philosophies have been used in production optimization, inactive-well audit, and well revitalization studies, where multiple indicators are combined to reduce uncertainty in candidate selection (Abdel-Basset et al., 2018; Haryanto et al., 2019; Turnip et al., 2024; Prayitno et al., 2026). The final weighted ranking integrates normalized WOI and normalized Delta Potential using constant weights to determine the final well priority.

2.1 Study data and workflow

The workflow was applied to three producing wells, namely, TM-1, TM-2, and TM-3, completed in the same G-40 reservoir interval of the TM Field. The case study was conducted in the TM Field, a mature oil field in the South Sumatra Basin, Indonesia. The field has been producing since 1974, and the main productive interval evaluated in this study is the G-40 sandstone reservoir. Stratigraphically, the productive reservoir interval is mainly associated with the Air Benakat Formation and is also supported by the Talang Akar Formation as part of the regional petroleum system. The field has reached a mature production stage, as indicated by production decline, increasing water cut, and limited availability of complete static and dynamic reservoir models. For confidentiality reasons, the field and well names are anonymized; however, the general basin setting, reservoir interval, and production characteristics are provided to clarify the geological and operational contexts of the case study. Table 2 summarizes the data availability and sources, while Table 3 tabulates the basic well-level input data used in the WOI and Delta Potential calculations. Because no full reservoir simulation model was available, the evaluation was performed using an integrated analytical screening approach.

The process begins with data collection and quality checking, followed by estimation of current oil saturation using a fractional-flow-based approach. The estimated saturation is then used to calculate the movable hydrocarbon pore volume component of WOI. In parallel, EUR and cumulative production are used to estimate Delta Potential. WOI and Delta Potential are then combined in a quadrant plot to classify well priority. Finally, a weighted ranking is applied to refine the candidate selection by incorporating reservoir and production performance indicators.

A transparent inventory of available and estimated data is required before the workflow is applied. Table 2 summarizes the data used in the study, the source of each dataset, and whether the data were directly available, estimated from production behavior, or assumed from literature.

As shown in Table 2, current oil saturation was not directly measured and was therefore estimated from production data using the fractional-flow approach. Residual oil saturation and endpoint relative-permeability parameters were treated as assumptions based on literature because special core analysis data were not available. The basic numerical inputs used for the well-level calculations are summarized in Table 3.

2.2 Current oil saturation estimation

Current oil saturation is an important input for estimating the remaining movable hydrocarbon volume around each well. In this study, current water saturation was estimated using a fractional-flow-based approach derived from historical production behavior, with the key input values listed in Table 3. The method relates water cut development to changes in water saturation and allows for estimation of current oil saturation when a direct saturation measurement is not available, following the practical use of historical production data for fractional-flow interpretation in Indonesian mature reservoirs (Sitorus et al., 2006).

Table 2.
Data availability and sources used in the study.

Data	Data source or derivation	Availability
Permeability	Petrophysical lumping and pressure build-up interpretation	Available
Net thickness	Petrophysical lumping	Available
Porosity	Petrophysical lumping	Available
Production data	Well-level production history	Available
Current oil saturation	Estimated from production data using fractional-flow analysis	Estimated
Residual oil saturation and endpoint relative permeability	Assumed based on literature due to limited SCAL data	Assumed
Current reservoir pressure	Static Gradient Survey (SGS)	Available
Abandonment pressure	P _{wh} = P _{sep} assumption	Assumed

Table 3.
Basic input data used for WOI and delta potential calculations.

Well	k (mD)	h (ft)	phi	Swc	Soc	Pres (psi)	Pabd (psi)	Np (MMSTB)	EUR (MMSTB)
TM-1	458.00	21.00	0.15	0.55	0.45	721.42	150	0.079	0.191
TM-2	399.00	20.00	0.14	0.58	0.42	708.40	150	0.057	0.160
TM-3	119.19	15.75	0.12	0.61	0.39	709.03	150	0.039	0.081

Note: Sor = 0.27 for all wells. EUR_{trend} refers to the volumetric-trend EUR used consistently in the Delta Potential calculation.

Relative permeability and residual oil saturation assumptions were treated consistently with waterflood remaining-oil concepts and mixed-wet reservoir behavior described in previous studies (Hirasaki 1996). Because water production behavior can strongly affect production interpretation in mature fields, the use of production-derived saturation should be accompanied by careful data checking, particularly when water cut is high (Sandau

2008). Water fractional flow was calculated using Equation 1,

$$f_w = \frac{q_w}{q_o + q_w} \quad (1)$$

where f_w , q_w , and q_o are the water fractional flow, the water production rate, and the oil production rate, respectively. Relative permeability relationships are represented using the Corey-type expressions in Equations 2 and 3,

$$kro = kro_0 \left[\frac{(1-Sw-Sor)}{(1-Swi-Sor)} \right]^\alpha \quad (2)$$

$$krw = krw_0 \left[\frac{(Sw-Swi)}{(1-Swi-Sor)} \right]^\beta \quad (3)$$

where kro , krw , kro_0 , krw_0 , Sw , Swi , and Sor are oil and water relative permeability, endpoint relative permeabilities, water saturation, is initial water saturation, and residual oil saturation, respectively. while α and β are Corey exponents. The estimated oil rate was matched against observed historical oil production to validate the saturation model. The validation error was calculated using the Mean Absolute Percentage Error (MAPE) in Equation 4,

$$MAPE = (1/n) \sum \left| \frac{(q_{o_{obs,i}} - q_{o_{cal,i}})}{q_{o_{obs,i}}} \right| \times 100\% \quad (4)$$

where $q_{o_{obs}}$, $q_{o_{cal}}$, and n is the observed oil rate, the calculated oil rate, and the number of production data points, respectively. The calibrated current oil saturation was then used as input for the WOI calculation. Equation 1-4 follow the fractional-flow-based production interpretation approach adapted from Sitorus et al. (2006), with Corey-type relative permeability assumptions supported by Hirasaki (1996).

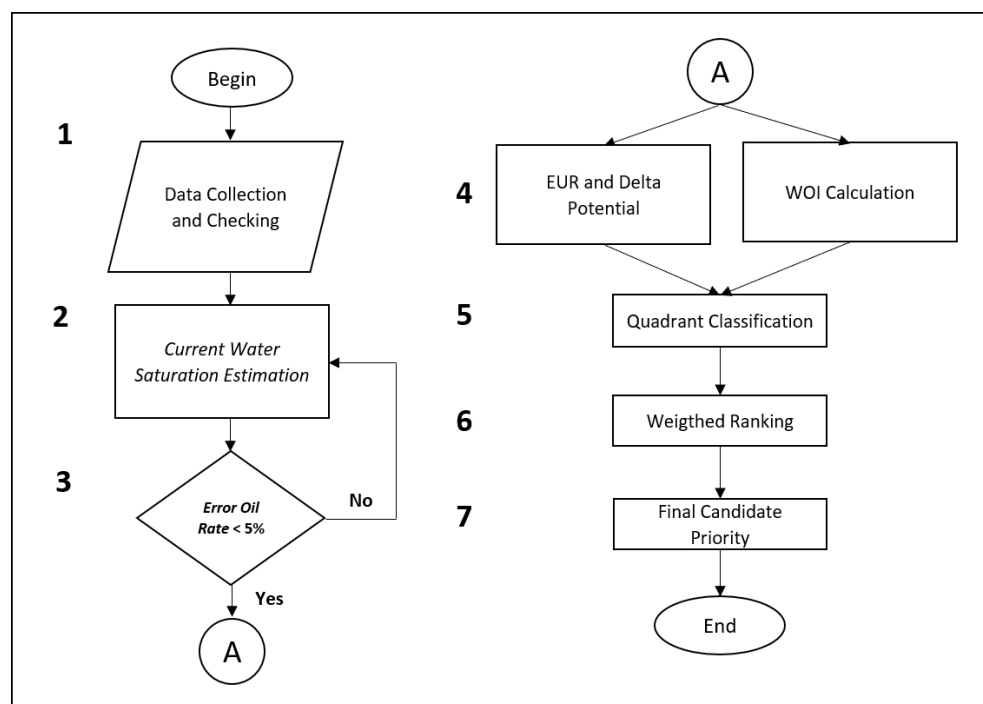


Figure 1.

Proposed integrated workflow for well candidate selection using WOI, delta potential, quadrant analysis, and weighted ranking.

2.3 Well opportunity index calculation

Well Opportunity Index was used to represent the reservoir-based opportunity of each well. The index integrates three main reservoir components: flow capacity, movable hydrocarbon pore volume, and remaining pressure support. These components were selected because a candidate well should have not only remaining oil, but also sufficient flow capacity and pressure support to produce it. WOI and its components were calculated using Equations 5 through 8,

$$WOI = (I_{kh} \times I_{HCPV} \times I_p)^{1/3} \quad (5)$$

$$I_{kh} = k \times h \quad (6)$$

$$I_{HCPV} = (S_{o,current} - S_{or}) \times \phi \times h \quad (7)$$

$$I_p = P_{res,current} - P_{abd} \quad (8)$$

The geometric mean was used to avoid domination by a single component and to ensure that a well with a poor value in one critical component receives a lower opportunity score. Equations 5 through 8 were adapted from the opportunity-index formulation of Molina and Rincon (2009), where WOI is the Well Opportunity Index, I_{kh} is the flow-capacity index, I_{HCPV} is the movable hydrocarbon pore volume index, and I_p is the remaining pressure support index. The variables k , h , ϕ , $S_{o,current}$, S_{or} , $P_{res,current}$, and P_{abd} represent permeability, net pay thickness, porosity, current oil saturation, residual oil saturation, current reservoir pressure, and abandonment pressure, respectively.

2.4 Delta potential calculation

Delta Potential was used to quantify the remaining production opportunity of each well. It represents the difference between estimated ultimate recovery and cumulative oil production. This study reviewed three EUR approaches: volumetric calculation, decline curve analysis, and reciprocal analysis. Decline curve analysis extrapolates the production-rate decline trend, whereas reciprocal analysis estimates reserve from a reciprocal-rate relationship. The EUR values used for Delta Potential were taken from the volumetric trend, as this basis is more consistent with the reservoir-opportunity components used in WOI and reduces uncertainty caused by scattered production trends. Delta Potential (DP) was calculated using Equation 9,

$$DP = EUR - N_p \quad (9)$$

where DP , EUR and N_p are the remaining production potential, the estimated ultimate recovery, and the cumulative oil production, respectively. A high Delta Potential indicates that a well still has a relatively large remaining production opportunity. However, Delta Potential alone does not guarantee that the well is technically attractive, as the well may still have limited flow capacity or insufficient pressure support. Therefore, Delta Potential was integrated with WOI to provide a more balanced candidate screening process. Equation 9 was defined in this study to represent the remaining production opportunity as the difference between EUR and cumulative oil production.

2.5 Quadrant-based candidate classification

WOI and Delta Potential were combined in a quadrant analysis to classify candidate wells. WOI represents reservoir opportunity, while Delta Potential represents remaining production opportunity. This two-indicator classification follows the broader logic of opportunity-index analysis, heterogeneity-based performance comparison, and production-potential ranking, where wells or areas are screened according to both reservoir quality and production response (Molina & Rincon 2009; Tan et al., 2010; Salman et al., 2013; Pilcher et al., 2011). The average values of WOI and Delta Potential were employed as reference thresholds, as calculated using Equations 10 and 11

$$WOI_{avg} = (1/n) \sum WOI_i \quad (10)$$

$$\Delta Potential_{avg} = (1/n) \sum \Delta Potential_i \quad (11)$$

Equations 10 and 11 were defined in this study as average-based screening thresholds for quadrant classification. Wells located in the high-WOI and high-Delta-Potential region were classified as primary candidates because they combine favorable reservoir opportunity with significant remaining production potential. Wells with high WOI but low Delta Potential were considered technically good but with limited remaining production opportunity. Wells with low WOI but high Delta Potential require further diagnosis because the remaining oil potential may be constrained by poor deliverability or pressure support. Wells with low WOI and low Delta Potential were considered lower-priority candidates.

2.6 Weighted ranking

After quadrant-based classification, a weighted ranking was applied to refine the final well priority. This step was included because quadrant analysis can identify the candidate category, but it does not fully quantify the relative priority among wells. Weighted and multi-criteria screening approaches have been applied in mature-field redevelopment, inactive-well audit, and production optimization workflows to improve transparency in candidate selection (Cimic 2006; Haryanto et al., 2019; Abdel-Basset et al., 2018). The weighted ranking in this study was developed using well potential parameters that represent both reservoir performance and production performance.

In this study, the final ranking uses two normalized indicators: WOI as the reservoir-performance indicator and Delta Potential as the remaining-production-potential indicator. This revision avoids using the production-maturity ratio Np/EUR as a positive contribution to the score, as a higher Np/EUR indicates a more depleted well and less remaining potential. For the base case, constant weights were assigned to all wells, with $wI = 0.5$ for normalized WOI and $wD = 0.5$ for normalized Delta Potential. Equal weights were selected because the proposed workflow is intended as a preliminary screening tool that assigns balanced importance to reservoir opportunity and remaining production potential. The normalized indicators and final ranking factor were calculated using Equations 12 through 14,

$$WOI_i^* = \frac{WOI_i}{\max(WOI_i)} \quad (12)$$

$$DP_i^* = \frac{DP_i}{\max(DP_i)} \quad (13)$$

$$FRF_i = wI WOI_i^* + wD DP_i^* \quad (14)$$

where FRF_i , wI , and wD are the final ranking factor for well i , the constant weight assigned to normalized WOI, and the constant weight assigned to normalized Delta Potential, respectively. The base-case weights satisfy $wI + wD = 1$. The final priority was determined based on the highest FRF value. Sensitivity analysis was then performed by varying the weights to test whether the ranking order remained stable. Equations 12 through 14 were defined in this study to normalize the WOI and Delta Potential indicators and calculate the final ranking factor using constant weights.

3. Result and discussion

The proposed workflow was applied to three producing wells, namely, TM-1, TM-2, and TM-3, completed in the G-40 reservoir interval of the TM Field. The evaluation was conducted with limited data availability, without a complete static or dynamic reservoir model. Therefore, the analysis relied on production history, petrophysical lumping, pressure survey data, and analytical production performance interpretation. The results are presented in five stages: current oil saturation estimation, Well Opportunity Index calculation, Delta Potential calculation, quadrant-based candidate classification, and final weighted ranking. This structure follows the workflow

developed in this study and allows the contribution of each parameter to be evaluated before the final candidate priority is determined.

3.1 Current oil saturation estimation

Current oil saturation was estimated using a fractional-flow-based approach derived from historical production behavior. This step is important because the movable hydrocarbon pore volume component of well opportunity index depends on the estimated current oil saturation. The saturation model was validated by matching calculated oil rates against observed historical oil rates.

The history matching results produced mean absolute percentage error (MAPE) values of approximately 2% for TM-1, 3% for TM-2, and 3% for TM-3. These values are below the 5% matching criterion used in this study, indicating that the estimated saturation trends are acceptable for the subsequent WOI calculation.

Table 4.
Summary of oil-rate matching results.

Well	Reservoir	Matching parameter	MaPe
TM-1	G-40	Calculated oil rate vs observed oil rate	2%
TM-2	G-40	Calculated oil rate vs observed oil rate	3%
TM-3	G-40	Calculated oil rate vs observed oil rate	3%

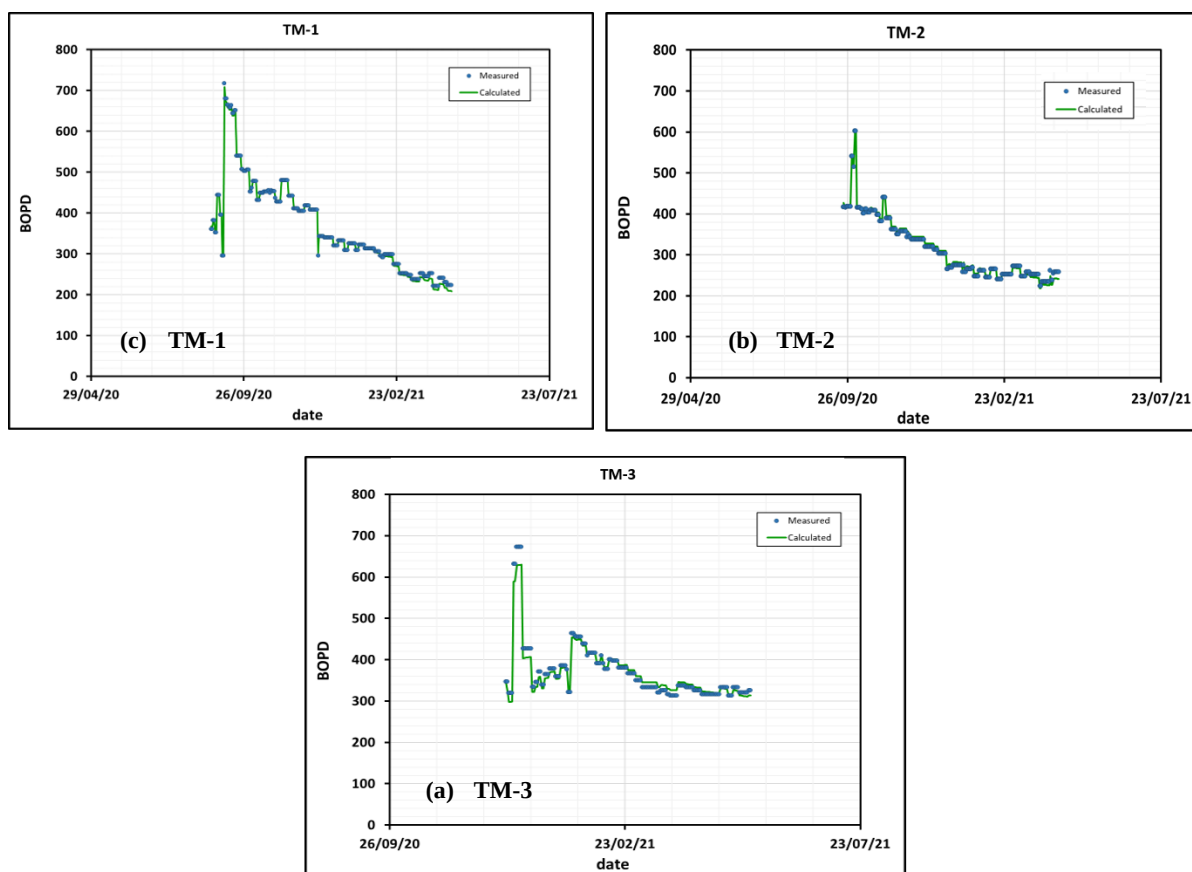


Figure 2.

History matching of observed and calculated oil rates for (a) TM-1, (b) TM-2, and (c) TM-3.

The matching results show MAPE values of approximately 2%, 3%, and 3%, respectively, indicating acceptable agreement for current saturation estimation.

The low matching errors indicate that the fractional-flow-based approach can reasonably infer saturation behavior from production data. This is particularly useful in mature fields where direct saturation measurements or full reservoir simulation models are not always available. The calibrated saturation profile was then used to estimate the movable hydrocarbon pore volume component in WOI calculation.

3.2 Well opportunity index results

Well opportunity Index was calculated using three reservoir components: flow capacity, movable hydrocarbon pore volume, and remaining pressure support. The calculated components and final WOI values are summarized in Table 5.

Table 5.
Well opportunity index components and final values.

Well	Reservoir	I _{kh}	I _{HCPV}	I _p	WOI
TM-1	G-40	9618.00	0.58	571.42	147.19
TM-2	G-40	7980.00	0.42	558.40	123.38
TM-3	G-40	1877.24	0.23	559.03	62.08

TM-1 has the highest WOI value of 147.19, indicating the strongest reservoir-based opportunity among the three wells. This result is supported by its high flow capacity, highest movable hydrocarbon pore volume, and favorable remaining pressure support. TM-2 shows a moderate WOI value of 123.38, while TM-3 has the lowest WOI value of 62.08.

The WOI result shows that reservoir opportunity cannot be evaluated using a single parameter. Although the remaining pressure support values are relatively close among the three wells, the differences in flow capacity and movable hydrocarbon pore volume significantly affect the final WOI. Therefore, integrating these components through a geometric mean provides a more balanced reservoir-opportunity indicator than evaluating permeability, thickness, saturation, or pressure separately.

3.3 Delta potential results

Delta Potential was calculated to quantify the remaining production opportunity of each well. In this study, EUR values were based on volumetric trend analysis. The term “volumetric trend” refers to the EUR basis selected from the volumetric calculation and its well-level trend with WOI, while decline curve and reciprocal analyses were used as supporting comparisons. This approach was selected to maintain consistency with the reservoir-based WOI evaluation and to reduce uncertainty from scattered production trends in decline or reciprocal analysis. The calculated EUR, cumulative oil production, and Delta Potential values are summarized in Table 6.

Table 6.
EUR, cumulative oil production, and Delta Potential.

Well	Reservoir	EUR (MMSTB)	N _p (MMSTB)	Delta potential (MMSTB)
TM-1	G-40	0.191	0.079	0.112
TM-2	G-40	0.160	0.057	0.103
TM-3	G-40	0.081	0.039	0.042

TM-1 has the highest Delta Potential, with 0.112 MMSTB of remaining production opportunity. TM-2 follows closely with 0.103 MMSTB, while TM-3 has a significantly lower Delta Potential of 0.042 MMSTB. This indicates that TM-1 and TM-2 retain larger remaining production opportunities compared with TM-3.

However, Delta Potential alone is not sufficient for candidate selection. A well may still have remaining recoverable oil, but its production improvement may be constrained by low flow capacity, limited movable hydrocarbon pore volume, or insufficient pressure support. Therefore, Delta Potential was integrated with WOI to obtain a more balanced screening decision.

3.4 Quadrant-based candidate classification

WOI and Delta Potential were plotted in a two-dimensional screening space to integrate reservoir-based opportunity and remaining production opportunity. WOI was used as the reservoir-opportunity axis, while Delta Potential was used as the production-opportunity axis.

Based on the combined WOI and Delta Potential evaluation, TM-1 is identified as the strongest primary candidate for production optimization. This well combines the highest WOI and the highest Delta Potential, indicating that it has both favorable reservoir conditions and the largest remaining production opportunity among the evaluated wells.

TM-2 is classified as a secondary candidate. Although TM-2 has a Delta Potential value close to TM-1, its WOI is lower. This suggests that the remaining production opportunity in TM-2 may require further diagnostic evaluation to confirm whether it can be effectively produced. A possible follow-up evaluation may include a wellbore condition review, a production-system diagnosis, and an intervention feasibility assessment.

TM-3 is classified as a lower-priority candidate because it has both the lowest WOI and the smallest Delta Potential. This result indicates that TM-3 has limited reservoir-based opportunity and limited remaining production potential compared with TM-1 and TM-2.

The quadrant analysis demonstrates the value of integrating reservoir and production indicators. If candidate selection were based only on Delta Potential, TM-1 and TM-2 may appear similarly attractive. However, the WOI result shows that TM-1 has stronger reservoir support. Conversely, using WOI alone would not fully capture the remaining production opportunity. Therefore, combining both indicators reduces the risk of selecting wells based only on reservoir quality or remaining volume.

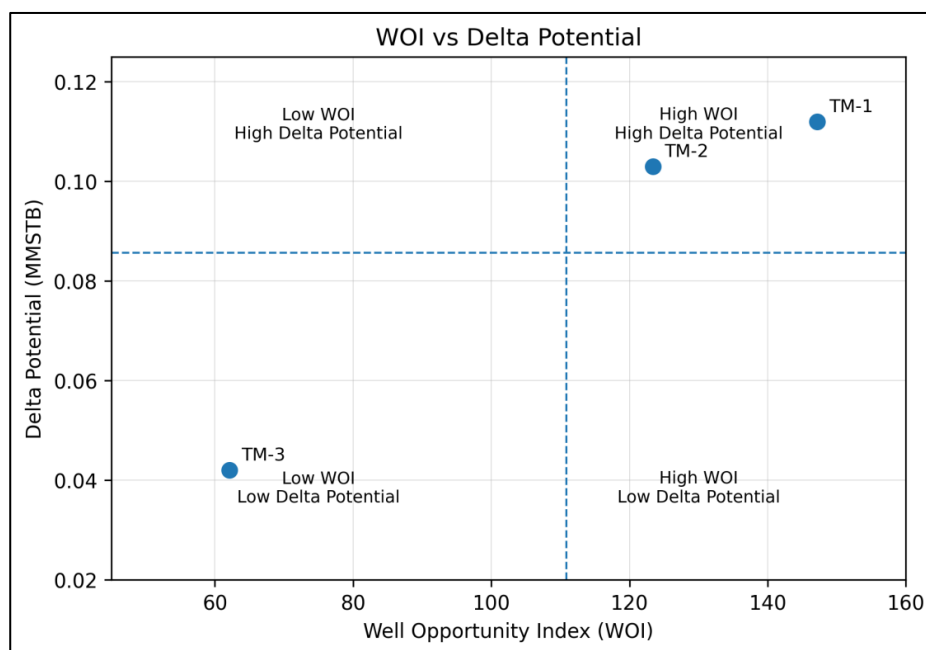


Figure 3.

Quadrant classification of well candidates based on WOI and Delta Potential.

The dashed vertical and horizontal lines indicate the average WOI and average Delta Potential thresholds, respectively.

3.5 Weighted ranking results

After quadrant-based classification, weighted ranking was applied to quantify the final well priority. The revised ranking used normalized WOI as the reservoir performance indicator and normalized Delta Potential as the remaining production potential indicator. Constant equal weights were applied to all wells in the base case. This formulation avoids assigning a positive score to the production-maturity ratio Np/EUR, as a higher Np/EUR indicates that a larger fraction of the estimated recovery has already been produced and therefore implies less remaining potential.

Table 7.
Final well candidate ranking based on constant weighted parameters.

Well	Reservoir	WOI	DP	WOI*	DP*	wI	wD	FRF
TM-1	G-40	147.19	0.112	1.00	1.00	0.50	0.50	1.00
TM-2	G-40	123.38	0.103	0.84	0.92	0.50	0.50	0.88
TM-3	G-40	62.08	0.042	0.42	0.38	0.50	0.50	0.40

The weighted ranking confirms that TM-1 is the highest-priority candidate, with a base-case final ranking factor of 1.00. In Table 7, DP denotes Delta Potential, while WOI* and DP* denote normalized values. TM-2 ranks second with a final ranking factor of 0.88, while TM-3 ranks lowest with a final ranking factor of 0.40. The final priority order is therefore TM-1 > TM-2 > TM-3.

This ranking is consistent with the quadrant-based screening. TM-1 is consistently identified as the strongest candidate because it combines the highest reservoir opportunity, the largest Delta Potential, and the highest final ranking factor. TM-2 remains a secondary candidate because it lies in the high-WOI and high-Delta-Potential region but has lower reservoir opportunity than TM-1. TM-3 is less attractive for short-term production optimization because both its reservoir and production-potential indicators are limited.

A simple sensitivity analysis was performed by varying the relative importance of reservoir opportunity and remaining production potential. The base-case, reservoir-dominant, and production-dominant weighting scenarios all produced the same priority order: TM-1 > TM-2 > TM-3.

The sensitivity results show that TM-2 has FRF values between 0.86 and 0.90, while TM-3 remains much lower, with FRF values between 0.39 and 0.41. This indicates that the ranking is robust for the evaluated three-well case, although further calibration is needed for larger well populations and different reservoir settings.

3.6 Discussion

The results show that the proposed integrated workflow provides a more balanced framework for well candidate selection in mature fields. WOI represents reservoir-based opportunity by combining flow capacity, movable hydrocarbon pore volume, and remaining pressure support. Delta Potential represents remaining production opportunity by comparing EUR and cumulative oil production. The weighted ranking then refines candidate priority by incorporating reservoir and production performance into a quantitative final score using constant and transparent weights.

This integrated structure is important because mature-field candidate selection is often biased when only a single data type is used. Production-based indicators can identify wells with remaining volume or abnormal behavior, but they may not fully explain whether the reservoir has sufficient deliverability or pressure support. Reservoir-based indicators can identify wells with favorable subsurface properties, but they may not fully indicate whether the well has meaningful remaining recoverable potential. The proposed workflow bridges this gap by combining both perspectives in a sequential decision process.

The field case also demonstrates the practical value of the workflow under limited data conditions. The analysis was conducted using three wells in the same reservoir interval without a complete static or dynamic reservoir model. This condition is common in mature-field evaluation, where engineers must often make early screening decisions using production history, petrophysical summaries, and pressure survey data. Compared with conventional HI or MHI approaches, which primarily evaluate relative production behavior or anomaly position, the proposed workflow adds reservoir opportunity through WOI and remaining production opportunity through Delta Potential. Compared with opportunity-index screening alone, the workflow also adds production-based remaining-potential evaluation and a final ranking step. Therefore, the method can serve as a preliminary screening tool before detailed well diagnosis, intervention design, reservoir simulation, or economic evaluation.

The workflow should not be interpreted as a replacement for detailed reservoir and economic evaluation. The results are based on a limited number of wells within a single reservoir interval, and the weighting factors may need further calibration when applied to larger datasets or different reservoir settings. Sensitivity analysis using different WOI and Delta Potential weights did not change the ranking order in this case. For quadrant thresholds, the use of average values placed TM-1 and TM-2 in the high-WOI and high-Delta-Potential region, while a more conservative median-based threshold places TM-2 near the decision boundary. This supports the interpretation of TM-2 as a secondary candidate requiring further diagnosis. Nevertheless, the consistency among WOI, Delta Potential, quadrant classification, and weighted ranking indicates that the method can help reduce candidate-selection uncertainty and provide a transparent basis for prioritizing mature-field production optimization opportunities.

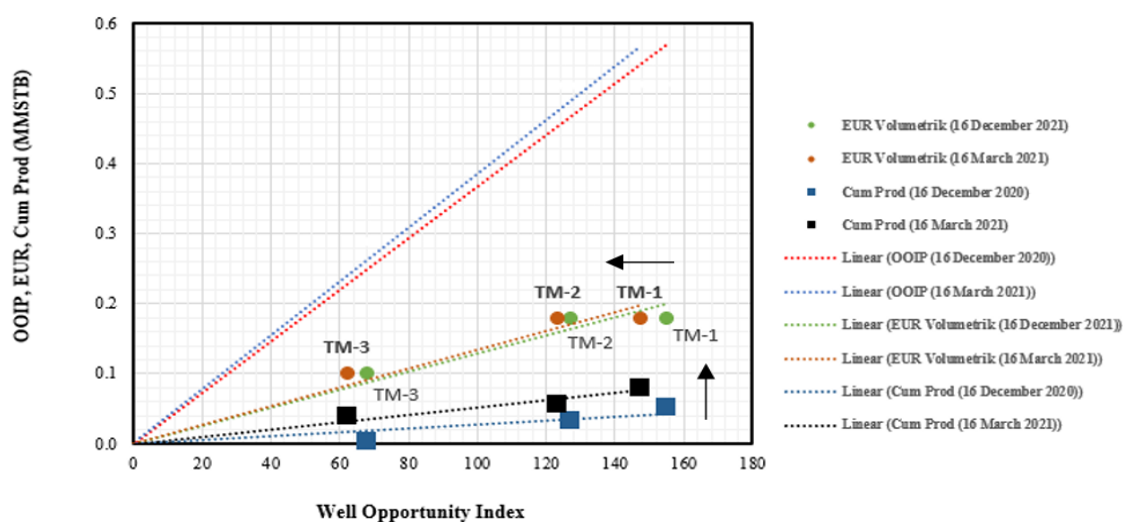


Figure 4.

Validation of the proposed method using historical production data from 16 December 2020 and 16 March 2021. The arrows indicate directional changes in WOI and cumulative production with production time.

The comparison with traditional screening approaches indicates that different single-parameter methods may lead to incomplete candidate interpretation. A production-only screening may identify wells with production anomalies, but it does not directly describe reservoir support. A Delta-Potential-only approach makes TM-1 and TM-2 appear similarly attractive because both wells have relatively high remaining production opportunity. A WOI-only approach gives the order TM-1 > TM-2 > TM-3, but it does not explicitly quantify the remaining production volume. By integrating WOI and Delta Potential through weighted ranking, the proposed workflow preserves the same overall priority order while providing a clearer technical explanation: TM-1 is the primary candidate, TM-2 is a secondary candidate requiring further diagnosis, and TM-3 is a lower-priority candidate.

The proposed method was further validated by comparing its application to historical production datasets on 16 December 2020 and 16 March 2021. As shown in Figure 4, longer production duration tends to increase cumulative oil production while reducing oil saturation, reservoir pressure, Delta Potential, and WOI. This

behavior is reflected by the leftward shift of WOI with production time and the upward shift of cumulative oil production. The validation confirms that the proposed workflow remains consistent with reservoir depletion behavior and continues to identify TM-1 as the strongest candidate, while TM-2 remains a secondary candidate and TM-3 remains a lower-priority candidate.

4. Conclusion

This study developed a practical integrated workflow for well candidate selection in mature oil fields by combining Well Opportunity Index, Delta Potential, quadrant analysis, and weighted ranking. The workflow was designed for data-limited mature fields where complete static and dynamic reservoir models are not available, but production history, petrophysical summaries, pressure data, and completion information can be used to support early-stage candidate screening.

The application to three wells in the G-40 reservoir interval showed that the fractional-flow-based current saturation estimation provided acceptable oil-rate matching results, with MAPE values of approximately 2% for TM-1, 3% for TM-2, and 3% for TM-3. These results indicate that production history can be used to infer current saturation behavior for screening purposes when direct saturation measurement is limited.

The Well Opportunity Index calculation identified TM-1 as the well with the highest reservoir-based opportunity, with a WOI value of 147.19, followed by TM-2 with 123.38 and TM-3 with 62.08. Delta Potential analysis also showed that TM-1 had the largest remaining production opportunity at 0.112 MMSTB, followed by TM-2 at 0.103 MMSTB and TM-3 at 0.042 MMSTB. The combination of these two indicators through quadrant analysis consistently placed TM-1 as the primary candidate for production optimization.

The final weighted ranking confirmed the priority order of TM-1 > TM-2 > TM-3, with base-case final ranking factors of 1.00, 0.88, and 0.40, respectively. Sensitivity analysis using reservoir-dominant and production-dominant weighting scenarios did not change the priority order. This consistency between WOI, Delta Potential, quadrant classification, and weighted ranking demonstrates that the proposed workflow can provide a transparent and traceable basis for preliminary well candidate selection in mature fields.

Compared with traditional single-indicator screening, the proposed workflow provides a more complete interpretation of candidate priority. Delta Potential alone may place TM-1 and TM-2 as similarly attractive candidates, whereas WOI helps distinguish the stronger reservoir support of TM-1. The integrated ranking therefore reduces the risk of selecting a well based only on remaining production volume or reservoir quality.

The workflow should be interpreted as a screening tool rather than a substitute for detailed reservoir simulation, well diagnosis, intervention design, or economic evaluation. Because this case study covers only three wells in a single reservoir interval, further application to larger well populations and different reservoir settings is recommended to calibrate the weighting factors, test alternative quadrant thresholds, and evaluate the robustness of the method under broader mature-field conditions.

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6. Declarations

6.1 Author contributions

Adam Muhammad contributed to the original thesis work, data collection, production data processing, current saturation estimation, Well Opportunity Index calculation, Delta Potential analysis, quadrant classification, weighted ranking, and initial technical analysis. Amega Yasutra contributed to research conceptualization, methodology refinement, manuscript development, technical validation and supervision, reservoir engineering interpretation, validation of the proposed workflow, data interpretation, and review, editing, and preparation of the final manuscript for publication. All authors have read and approved the final manuscript.

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6.3 Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

6.4 The use of AI/AI-assisted technologies

During the preparation of this manuscript, AI-assisted technology was used to support language refinement and editorial improvement. The authors reviewed, verified, and edited the manuscript content and take full responsibility for the final version of the paper.

7. Glossary of terms and symbols

Terms & Symbols	Definition	Unit
Abandonment pressure	Minimum assumed pressure limit used as the abandonment condition in the pressure-support calculation.	psi
DP	Delta Potential; remaining production opportunity calculated as EUR minus cumulative oil production.	MMSTB
DP*	Normalized Delta Potential used in the final ranking factor calculation.	Dimensionless
DP _{avg}	Average Delta Potential used as the horizontal threshold in quadrant classification.	MMSTB
Delta Potential	Remaining production opportunity calculated as the difference between EUR and cumulative oil production.	MMSTB
EUR	Estimated Ultimate Recovery; estimated total recoverable oil volume for each well.	MMSTB
FRF	Final ranking factor used to determine well candidate priority.	Dimensionless
fw	Water fractional flow.	Fraction
G-40	Reservoir interval evaluated in the case study.	—
h	Net pay thickness.	ft
HCPV	Hydrocarbon pore volume.	ft or volume-related index
I _{HCPV}	Movable hydrocarbon pore volume index, calculated from current movable oil saturation, porosity, and net pay thickness.	ft
I _{kh}	Flow capacity index, calculated from permeability multiplied by net pay thickness.	mD-ft

Terms & Symbols	Definition	Unit
I_{oppor}	Opportunity index; equivalent term used for WOI in the calculation workflow.	Composite index
I_p	Remaining pressure support index, calculated from current reservoir pressure minus abandonment pressure.	psi
k	Permeability.	mD
k_{ro}	Oil relative permeability.	Fraction
k_{ro0}	Oil endpoint relative permeability.	Fraction
k_{rw}	Water relative permeability.	Fraction
k_{rw0}	Water endpoint relative permeability.	Fraction
MAPE	Mean Absolute Percentage Error between calculated and observed oil rates.	%
n	Number of data points or number of wells, depending on the equation context.	Dimensionless
N_p	Cumulative oil production.	MMSTB
P_{abd}	Abandonment pressure.	psi
$P_{\text{res,current}}$	Current reservoir pressure.	psi
q_o	Oil production rate.	STB/day
$q_{o,cal}$	Calculated oil production rate.	STB/day
$q_{o,obs}$	Observed oil production rate.	STB/day
q_w	Water production rate.	STB/day
$S_{o,current}$	Current oil saturation.	Fraction
S_{or}	Residual oil saturation.	Fraction
S_w	Water saturation.	Fraction
S_{wc}	Current water saturation.	Fraction
S_{wi}	Initial water saturation.	Fraction
SCAL	Special core analysis.	—
SGS	Static Gradient Survey used to estimate current reservoir pressure.	—
TM Field	Anonymized mature oil field used as the case study.	—
WOI	Well Opportunity Index; an integrated reservoir-opportunity indicator calculated from flow capacity, movable hydrocarbon pore volume, and remaining pressure support.	Composite index
WOI*	Normalized Well Opportunity Index used in the final ranking factor calculation.	Dimensionless
WOI_{avg}	Average WOI used as the vertical threshold in quadrant classification.	Composite index
w_D	Constant weighting factor assigned to normalized Delta Potential.	Dimensionless
w_I	Constant weighting factor assigned to normalized WOI.	Dimensionless
α	Corey exponent for oil relative permeability.	Dimensionless
β	Corey exponent for water relative permeability.	Dimensionless
ϕ	Porosity.	Fraction

8. References

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