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Integrated Logging, Production, and Geological Analysis for Bypassed Oil Identification in CNA Field, Central Sumatra Basin

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ABSTRACT - The Central Sumatra Basin's CNA Field has been producing hydrocarbons since 1974 and is now considered a mature oil field. The field contains six Long Term Closed (LTC) wells and two Plug and Abandonment wells, providing an opportunity to enhance hydrocarbon recovery by identifying and reactivating residual productive zones. The study is based on two LTC wells, CNA-01 and CNA-03, which are suspected to contain bypassed oil potential. Integrated evaluation of wireline logging data, production history, and geological correlation is performed to identify prospective bypassed oil zones. As a first step in the analysis, resistivity and permeability cut-off values were determined, followed by qualitative log interpretation to identify hydrocarbon-bearing intervals. The identified zones are then confirmed using production test data, structural correlation, and historical production performance. Moreover, Chan's Diagnostic Plot is used to analyze the water production behavior and to identify the dominant water influx mechanism. Results indicated a total of nine potential bypassed oil intervals, with five intervals identified in well CNA-01 and four intervals identified in well CNA-03, within the BKA and BKB sand units. The main factors affecting bypassed oil are reservoir heterogeneity, variation in vertical permeability, channeling and discontinuous sand distribution. The integrated analysis suggests several workover strategies, including additional perforation in uncompleted hydrocarbon-bearing zones, reducing intervals affected by excessive water production, and squeeze cementing to isolate non-productive intervals. The results presented here demonstrate the value of integrated reservoir evaluation in identifying remaining hydrocarbon potential and aiding mature field redevelopment.

Keywords: bypassed oil, log interpretation, chan diagnostic plot, workover optimization, mature field

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INTRODUCTION

Enhancing hydrocarbon recovery remains a key objective in mature field development. Production gains can be achieved through new exploration activities or by optimizing existing reservoirs through comprehensive data re-evaluation. Substantial quantities of hydrocarbons often remain unrecovered in numerous mature fields, attributable to suboptimal displacement processes, reservoir heterogeneity, or operational limitations. Consequently, the re-evaluation of current wells presents a more economical strategy than the drilling of new wells (Rahman et al., 2020).

The Central Sumatra Basin's CNA Field, which commenced oil production in 1974 at an initial rate of about 394 barrels of oil per day, is now classified as a mature field. The objective of this study is to identify possible bypassed oil zones and to recognize the main factors affecting bypassed oil in the CNA-01 and CNA-03 wells. The study also aims to deliver technically justified workover recommendations in support of mature field redevelopment and production optimization.

Numerous wells within this field have undergone production decline, leading to their classification as long term closed (LTC) wells. Notwithstanding their inactivity, these wells may still contain recoverable hydrocarbons resources, a possibility stemming from incomplete reservoir drainage and the presence of bypassed oil accumulations (Bassiouni & Velic 1996). Bypassed oil refers to hydrocarbons that remain trapped in the reservoir during the production process and are not effectively produced. The occurrence of bypassed oil is strongly influenced by reservoir heterogeneity, permeability variation, and production-related problems such as water coning or channeling (Putra et al., 2022). These conditions often lead to uneven sweep efficiency and result in residual oil distribution within certain reservoir zones.

The identification of bypassed oil zones requires an integrated approach combining petrophysical evaluation, production performance analysis, and geological interpretation. Well log analysis plays an important role in determining lithology, porosity distribution, and fluid saturation, particularly in complex or low-resistivity formations (Evdokimova 2013; Al-Shammari et al., 2022). In addition, production data analysis provides insight into reservoir performance and helps identify production anomalies such as early water breakthrough. Chan's Diagnostic Plot and similar diagnostic methods are widely used to evaluate water production. They do this by analyzing the relationship between the water-oil ratio (WOR) and its derivative (WOR'). This approach is effective in identifying the main production mechanisms, such as channeling or coning (Chan 1995; Hassan et al., 2023).

Several studies (Al-Ajmi et al., 2021; Zhang et al., 2021; Wang et al., 2023) have proved the application of petrophysical, geological, and production data integration to identify bypassed oil in mature reservoirs. Nevertheless, existing studies have been largely focused on general reservoir characterization or residual oil evaluation without a comprehensive validation workflow by integrating production tests, structural correlation, historical production performance, and water production diagnostics. In addition, there is limited work on bypassed oil identification specifically in the Bekasap Formation of the Central Sumatra Basin, particularly in inactive or long term closed (LTC) wells, where reservoir uncertainty and production-related issues are more predominant.

This study proposes an integrated workflow that combines the determination of resistivity and permeability cut-off, qualitative log interpretation, production history analysis, structural correlation, and evaluation of Chan's Diagnostic Plot in identifying bypassed oil zones in the CNA Field. In contrast to previous studies that either employed petrophysical interpretation or production analysis alone, this study integrates multiple datasets to enhance the reliability of bypassed oil identification and workover candidate selection.

An application of the proposed workflow identified nine potential bypassed oil intervals in two LTC wells and proposed technically justified workover recommendations, demonstrating the applicability of this workflow for mature field redevelopment in the Central Sumatra Basin. The proposed workflow provides a practical framework for mature field reactivation, particularly in areas with limited subsurface data availability.

METHODOLOGY

The methodological framework of this study is structured around six principal components: preliminary investigation, data preparation, data processing, quantitative data interpretation, qualitative data interpretation, and integrated assessment of bypassed oil.

Preliminary investigation

The first step, called a preliminary inquiry, involves a thorough review of existing research on bypassed oil, poor reservoir performance, squeeze cementing methods, and related topics. The following analysis is based on a thorough review of various sources, including textbooks, academic journals, conference proceedings, and technical reports. This approach helps to build a strong theoretical foundation for the following discussion. The first step in data preparation is to gather and organize all relevant datasets, which is crucial for the upcoming analysis. This study uses geological data, wireline logging data, and production history data to evaluate reservoir characteristics and production results. The fundamental methodology involves data processing and integration, utilizing a multimodal approach that integrates petrophysical evaluation, production appraisal, and geological interpretation. Potential hydrocarbon zones are identified through both quantitative and qualitative methodologies. Numerical methods establish cut-off values, whereas descriptive assessments of well logs reveal potentially productive intervals. Subsequently, the presence of bypassed oil is validated within the specified area. Identifying bypassed oil requires analyzing production and petrophysical data. Chan's Diagnostic Plot is widely used to evaluate water production behavior and identify dominant water influx mechanisms, such as channeling and coning, which are critical for optimizing oil recovery in bypassed oil zones.

The integrated workflow used in this study is shown in Figure 1. The workflow begins with data gathering and processing. Then, there is the quantitative estimation of resistivity and permeability cut-off values. The identified reservoir intervals are then qualitatively interpreted through log interpretation and integrated with production history, well test data, and geological correlation. The integrated datasets are subsequently used to verify potential by-passed oil zones before developing appropriate work-over recommendations.

Data preparation

The first phase is to gather and structure all relevant datasets. In this study, different data are used to evaluate the reservoir. The dataset includes production data, such as well production rates, production history, production test results, and swab test data, used to evaluate reservoir performance and confirm hydrocarbon productivity. Geological data, including structural correlations and core data (e.g. water saturation) are also included to assess reservoir continuity, and position of reservoir intervals with respect to the current oil-water contact (COWC). Furthermore, logging data such as lithology, porosity, permeability, and resistivity information are used to identify reservoir characteristics and hydrocarbon intervals. The combined datasets allow for a complete reservoir evaluation and form the basis for the identification and validation of bypassed oil.

Data processing

All data sets are processed and merged after data collection to ensure uniformity in petrophysical, production, and geological interpretations. At this stage, the logging data, production history, well test data and geological correlation data are integrated and standardized based on reservoir interval correlations and depth

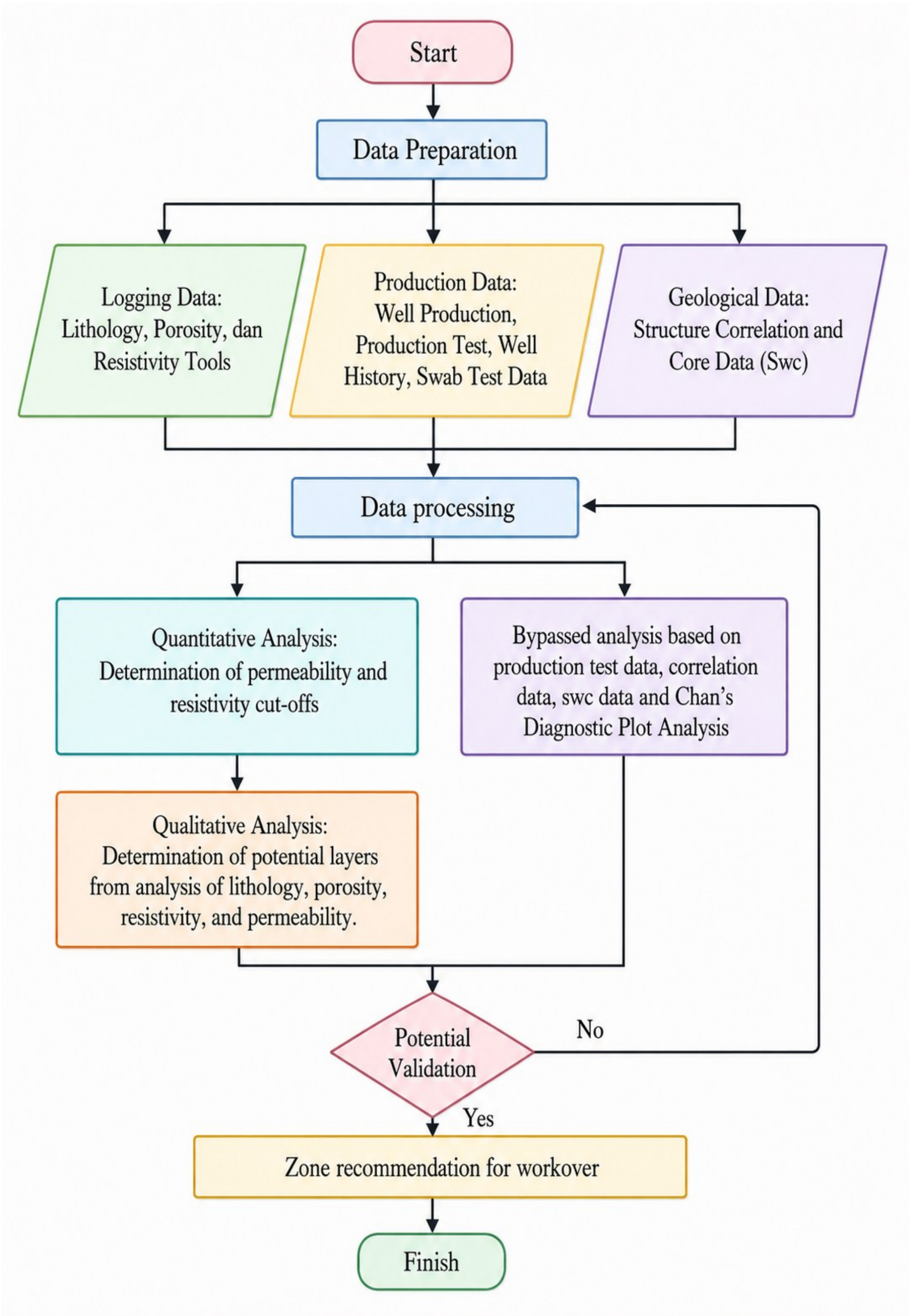

Figure 1. Integrated Workflow for Bypassed Oil Identification and Validation in the CNA Field.

matching. Production data are compared to geological correlations to assess reservoir continuity and the position of each interval relative to the current oil–water contact (COWC). The aim of this stage is to provide reliable input data for further quantitative and qualitative analysis and to allow identification and validation of potential bypassed oil zones.

Quantitative data interpretation

Quantitative analysis is used to determine reservoir cut-off parameters, especially permeability and resistivity cut-off values. These parameters are important for distinguishing hydrocarbon-bearing zones from non-productive intervals and are the basis for the next stages of interpretation. The resistivity cut-off values were determined by correlating the average resistivity values of previously perforated intervals with historical oil production rates and production test results. This comparison indicated that resistivities of productive intervals in the BKA and BKB sand units were generally greater than 4 ohm-m, whereas those in the BKC sand unit were greater than 6 ohm-m. Thus, these values were used as minimum resistivity thresholds for the indication of hydrocarbons. The permeability cut-off value was determined based on permeability data, sidewall core data, and production performance. Intervals with permeability values > 70 mD had generally better flow capacity and hydrocarbon productivity.

Reservoir were classified into high quality reservoir (HQR) and low quality reservoir (LQR) categories based on permeability threshold, where the interval with permeability value > 70 mD is classified as HQR and the interval with permeability value < 70 mD is classified as LQR as commonly used in previous studies (Yuni et al., 2007).

Qualitative data interpretation

The interpretation of well log data is performed to characterize the reservoir including lithology, porosity distribution, and existence of fluids. This approach detects intervals where log signatures indicate the presence of hydrocarbons. Log interpretation was conducted using Gamma Ray, Deep Induction, Density and Neutron logs, augmented with permeability and sidewall core data. Potential hydrocarbon-bearing intervals were identified where the resistivity and permeability values were above the predetermined cut-off values and where the log responses were suitable for hydrocarbon saturation. Log-based interpretation is very beneficial in finding potential zones in heterogeneous reservoirs (Evdokimova, 2013; Al-Shammari et al., 2022). The identified intervals were subsequently validated using production data and geological correlation to assess their potential as bypassed oil zone.

Integrated assessment of bypassed oil

Further evaluation of potential areas includes geological correlation, production data analysis, and water saturation data examination. Bypassed oil zones were validated by integrating qualitative log analysis, production test data, swab test results, structural correlation, and the position of each interval relative to the current oil-water contact (COWC). The intervals identified from log interpretation were first screened against the resistivity and permeability cut-offs previously established. These intervals were then compared to production test and swab test results to confirm hydrocarbon productivity. Geological correlation was used to assess the reservoir continuity, and the intervals were found to be above the interpreted COWC. Potential bypassed oil zones were defined as zones with favorable petrophysical properties, hydrocarbon productivity and structural position. Analysis of water production patterns using the Diagnostic Plot of Chan further helps to identify the dominant flow mechanisms that lead to the reduction in oil recovery. This approach allows for the identification of dominant production mechanisms like channeling and coning, which are important factors in bypassed oil occurrence (Chan 1995; Kumar et al., 2022). The validated zones were then utilized as the basis for appropriate workover recommendations.

RESULT AND DISCUSSION

Bypassed zone determination at wells CNA-01 and CNA-03 is generally divided into three main stages: such as cut-off determination, qualitative analysis, and zone validation. Analysis of the cause of bypassed oil in wells CNA-01 and CNA-03 was conducted by analyzing Chan's diagnostic plot. This section presents the results of the petrophysical, production, and geological analysis and then discusses their implications on the bypassed oil occurrence and the workover candidate selection in the CNA Field.

Cut-off determination

The first step in identifying potential bypassed zone is the determination of resistivity and permeability cut-off values. Quantitative analysis was conducted to establish the limit of resistivity value between water and oil, and the limit of rock permeability value that is able to drain oil. A resistivity cut-off is useful to distinguish the resistivity value of water from that of hydrocarbon. Cutoff determination is done by making a scatter plot between resistivity (mean) vs. Qo and validated with the results of petrophysical analysis and production data. Tabulation of the average resistivity value and oil flow rate at each perforation in the CNA field can be seen in Table 1, and the results of the scatter plot graph can be seen in Figure 2. The identical procedure is employed to ascertain the cut-off permeability. Following the investigation, the cut-off resistivity values obtained for the CNA field sand units BKA and BKB are 4 ohm-m, while the BKC sand unit exhibits a value of 6 ohm-m. The cut-off permeability value for the Bekasap layer (BKA, BKB, and BKC) is determined to be 70 mD.

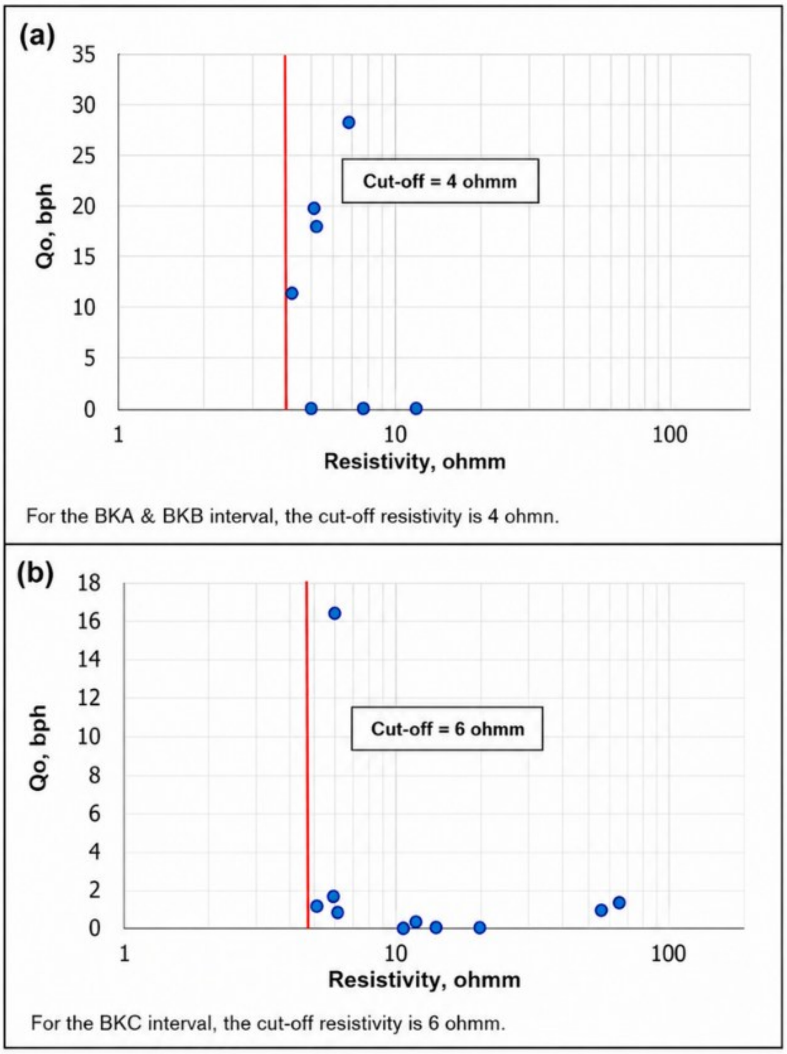

Figure 2. Determination of resistivity cut-off values for the Bekasap Formation. This illustrates the resistivity cut-off determination for the Bekasap Formation. The productive intervals in the BKA and BKB sand units indicate a resistivity cut-off of 4 ohmm, whereas the productive intervals in the BKC sand unit indicate a resistivity cut-off of 6 ohmm.

Table 1. Tabulation of mean resistivity and Qo values of the BK formation

Unit sand	Well	Perforation(ft)		Resistivity	Qo (bpd)
		Top	Bottom	Mean	
BKA	CNA-01	2940	2950	5.8	20.16
BKA	CNA-03	2984	2996	4.7	12
BKA	CNA-03	3014	3027	7.5	29
BKA	CNA-06	2914	2916	5.7	18.225
BKA	CNA-06	2916	2934	5.2	0.282
BKA	CNA-06	2936	2943	7.6	0.192
BKA	CNA-05	2949	2954	11.9	0.12
BKB	CNA-06	2982	2996	7.3	0.282
BKC	CNA-01	3064	3068	6.2	16
BKC	CNA-01	3076	3083	10.3	0.9
BKC	CNA-03	3136	3140	11.3	0
BKC	CNA-05	3053	3056	13	0.3
BKC	CNA-05	3056	3062	51.6	0.5
BKC	CNA-05	3065	3075	58.8	0.6
BKC	CNA-06	3052	3055	18.9	0.99
BKC2	CNA-05	3131	3138	8.8	0.672
BKC2	CNA-06	3148	3164	6.5	0
BKC3	CNA-05	3154	3158	13.5	1.47

Qualitative analysis

Qualitative analysis was performed to assess the effectiveness of identifying sand units with potential as bypassed zones. This analysis was performed subsequent to acquiring the resistivity and permeability cut-off values. A qualitative analysis was performed by examining well-log responses to identify prospective hydrocarbon-bearing intervals. The interpretation incorporated Gamma Ray Log, Deep Induction Log, Density Log, Neutron Log, supported by permeability and sidewall core data. Zones with permeability values over the threshold of 70 mD are classified as high quality Reservoirs (HQR), whereas those with permeability values below this threshold are classified as low quality reservoirs (LQR) (Yuni et al., 2007; Evdokimova 2013).

A qualitative log analysis was performed to identify the bypassed zone by examining the curve deflection of the CNA-01 well within the interval of 2933-3181 ft and the CNA-03 well within the interval of 2984-3140 ft, namely in the Bekasap layer (BKA, BKB, and BKC). These intervals are located within the Bekasap Formation, where historical production data confirm the presence of hydrocarbons. The tabulation of prospective zones at wells CNA-01 and CNA-03, derived from a qualitative review of chart logs, is presented in Table 2 and 3.

From the qualitative log interpretation, five potential bypassed oil intervals were identified for well CNA-01 and four potential bypassed oil intervals for well CNA-03. These intervals meet the defined resistivity and permeability cut-off criteria and are supported by historical production data.

Zone validation

Production data

The qualitative study of the CNA-01 and CNA-03 wells identified seven perforated zones, which were subsequently corroborated by production data and tests presented in Table 4. Validation of production data and tests conducted reveal that the seven produced zones still exhibit residual oil, categorizing them as bypassed zones.

Table 2. Hydrocarbon prospect zone well CNA-01

Unit Sand	Interval	Status	Resis (ohmm)	Perm (mD)	Reservoir quality
BKA	2933-2950	Existing	5.1812	646.4493	HQR
	2959-2966	New	4.5463	51.3674	LQR
BKB	2995-3011	New	5.6333	108.0324	HQR
BKC	3063-3068	Existing	4.8719	26.8971	LQR
	3070-3084	Existing	8.4589	79.8598	HQR
	3086-3101	Existing	6.5659	183.4852	HQR

Table 3. Hydrocarbon prospect zone well CNA-03

Unit Sand	Interval	Status	Resis (ohmm)	Perm (mD)	Reservoir Quality
BKA	2984 – 2996	Existing	4.5669	128.802	HQR
	2998 - 3005	New	3.7613	89.7171	HQR
	3014 – 3030	Existing	6.87	865.553	HQR
BKC	3134-3140	Existing	11.1323	309.380	HQR

Table 4. Production test of wells CNA-01 & CNA-03

Well	Perforation		Status	Swab test	Prod test
	Top	Bot			
CNA-01	2940	2950	Open	11.44bph/50%	119.43/11.6/90%
	3064	3068	Open	31.5bph/100%	3.27/0.319/90%
	3076	3083	Open	(C)33bph/100%	37.16/3.63/90%
	3086	3090	Open	(C)33bph/100%	12.14/1.18/90%
CNA-03	2984	2996	Open	20bph/40%	-
	3014	3027	Open	24.3bph/20%	-
	3136	3140	Isolate	0bph/100%	-

Structure correlation

Structural correlation from the CNA domain helps validate bypassed zones in both current and proposed unperforated zones. The supplied correlation data includes resistivity, permeability, perforation status, SWC data, depth by TVD and MD, geological variances, and, most importantly, the well's location. Utilizing correlation and production data, we can assess the position of the current oil-water contact (COWC) to identify zones that still contain movable hydrocarbons. Not all of them are designated as bypassed zones, as certain areas, upon analysis, are already below the present oil-water contact (COWC) and have consequently been inundated with water. The structural correlation of the Bekasap Formation is seen in Figure 3. Following validation with test data and correlation, the bypassed zones in wells CNA-01 and CNA-03 are presented in Table 5.

Chan's diagnostic plot

Upon validation with production test data and structural correlation, it was determined that the bypassed zones of wells CNA-01 and CNA-03 were exclusively present in the BKA and BKC layers; consequently, further analysis is required on

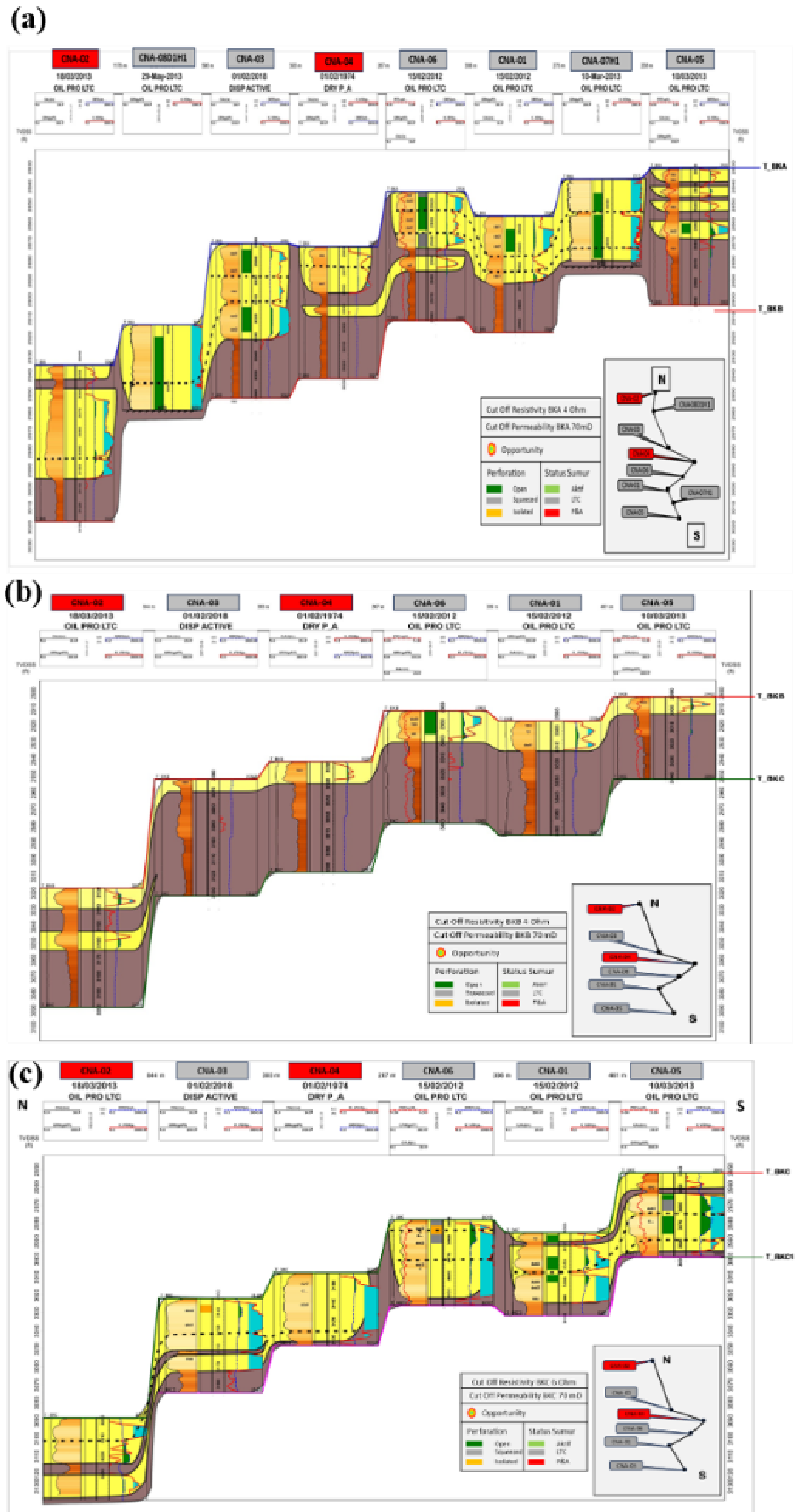

Figure 3. Structure correlation of bekasap formation. Structural correlation of the (a) BKA; (b) BKB; and (c) BKC, sand units in the CNA Field shows several potential bypassed oil intervals identified through integrated petrophysical, geological, and production data analysis. Bypassed oil opportunities in the BKA unit are associated with incompletely drained reservoir sections, while those in the BKB unit are related to reservoir continuity and existing completion configurations. In the BKC unit, potential bypassed oil intervals are mainly associated with isolated reservoir compartments. Overall, reservoir heterogeneity, incomplete drainage, and production-related factors contribute to the occurrence of bypassed oil within the Bekasap Formation.

these layers to ascertain any prior production issues. According to Figures 4 and 5, wells CNA -01 and CNA-03 exhibit an increase in water production, suggesting the possible presence of bypassed oil. Therefore, Chan's Diagnostic Plot (Chan 1995) was evaluated to identify the source of excessive water production. The study of Chan's Diagnostic Plot involves graphing WOR and its derivative (WOR) against cumulative production time. Figure 6 displays the results of the water diagnostic plot for Well CNA-01, sand unit BKA CAN-01, and Well CNA-03. According to Chan's Diagnostic Plot, well CNA-01 exhibits a near-wellbore water channeling issue (Figure 6), where as well CNA-03 demonstrates Multilayer Channeling with Production Variations in sand unit

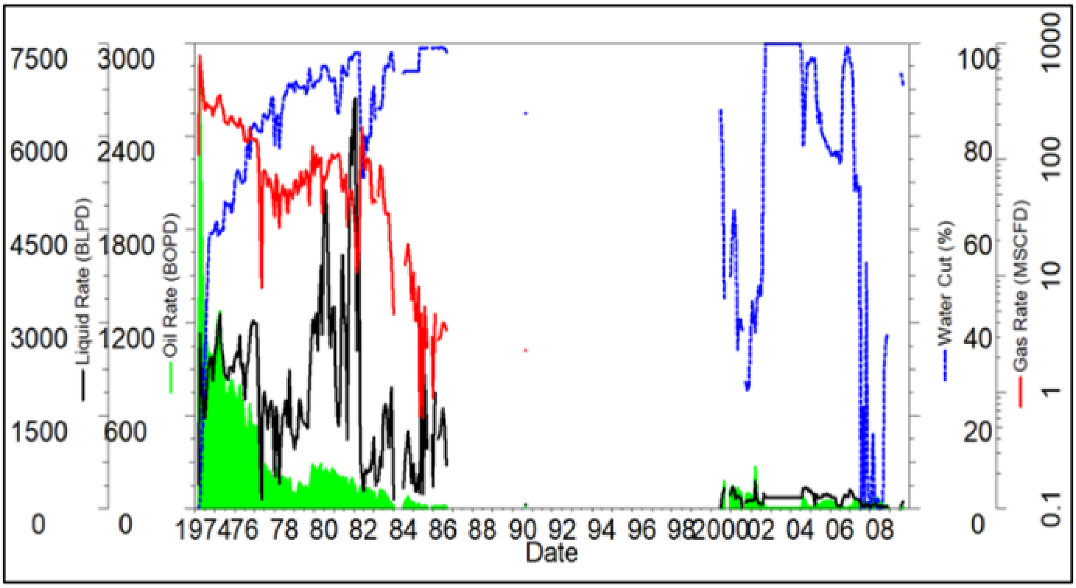

Figure 4. Production performance of well CNA-01. The well has seen a decline in oil production and an increase in water cut, indicating reservoir depletion and potential water production problems during its operational history.

Table 5. Tabulation of bypassed oil zones after validation

Well	Unit Sand	Interval (ft)	Status	Perm (mD)	Oil Rate
CNA-01	BKA	2933-2950	Existing	6.464.493	11.6
	BKA	2959-2966	Usulan	513.674	-
	BKC	3063-3068	Existing	268.971	0.319
	BKC	3070-3084	Existing	798.598	3.63
	BKC	3086-3101	Existing	1.834.852	1.18
CNA-03	BKA	2984 – 2996	Existing	1.288.019	12
	BKA	2998-3005	Usulan	897.171	-
	BKA	3014 – 3030	Existing	8.655.527	19.4
	BKC	3134-3140	Existing	3.093.792	-

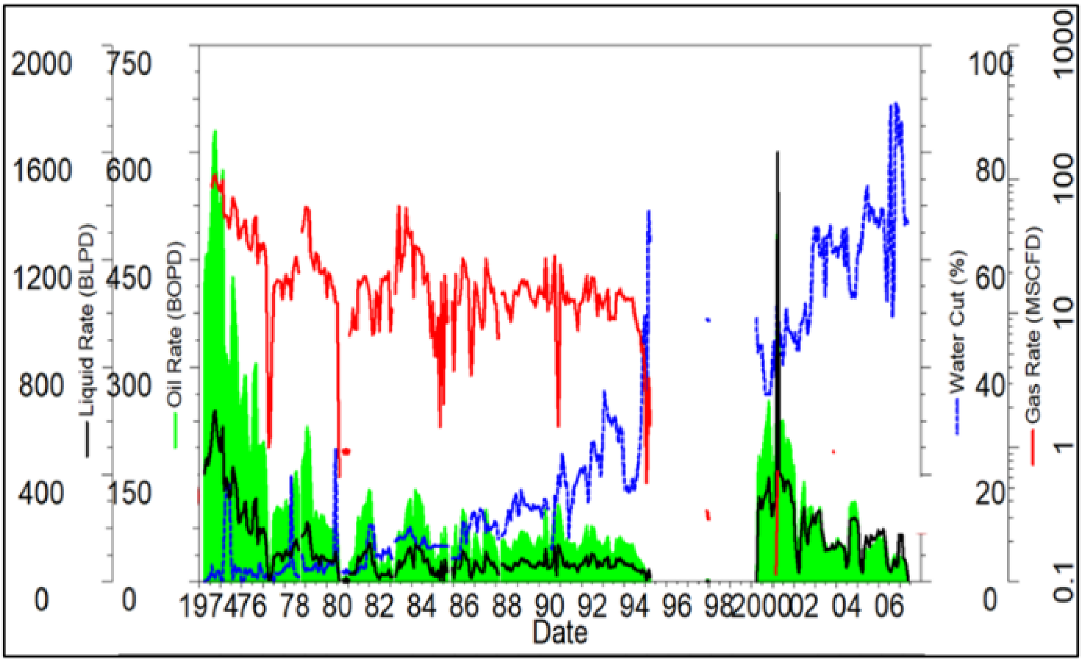

Figure 5. Production performance of well CNA-03. The production history shows a decreasing oil rate and increasing water cut, indicating a decline in reservoir performance and the potential for remaining hydrocarbons in the undepleted reservoir zones.

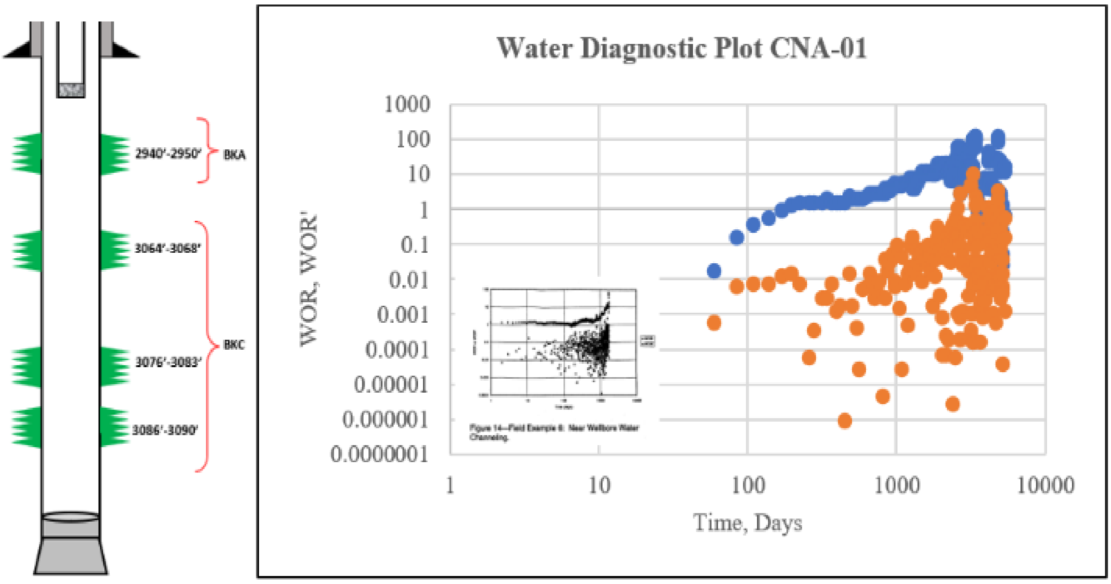

Figure 6. Chan's diagnostic of well CNA-01. The trend of WOR and WOR' indicates the presence of abnormal water production behavior, suggesting that channeling is a contributing factor to the occurrence of bypassed oil in the well.

BKA (Figure 8). Due to the CNA-01 well's simultaneous production from both the BKA and BKC sand units, it is essential to study each sand unit to identify the source of the water-production mechanism that arises. The analytical outcome of the BKA sand unit in the CNA-01 well (Figure 7) indicates Normal Displacement with Elevated Water-Oil Ratio, resulting in Near Wellbore Water Channeling production issues within the BKC layer of the CNA-01 well.

Workover recommendation

Once the quantitative and qualitative analyses and validation have been performed it is possible to provide recommendations on bypassed zones and their causes for wells CNA-01 and CNA-03. Not all

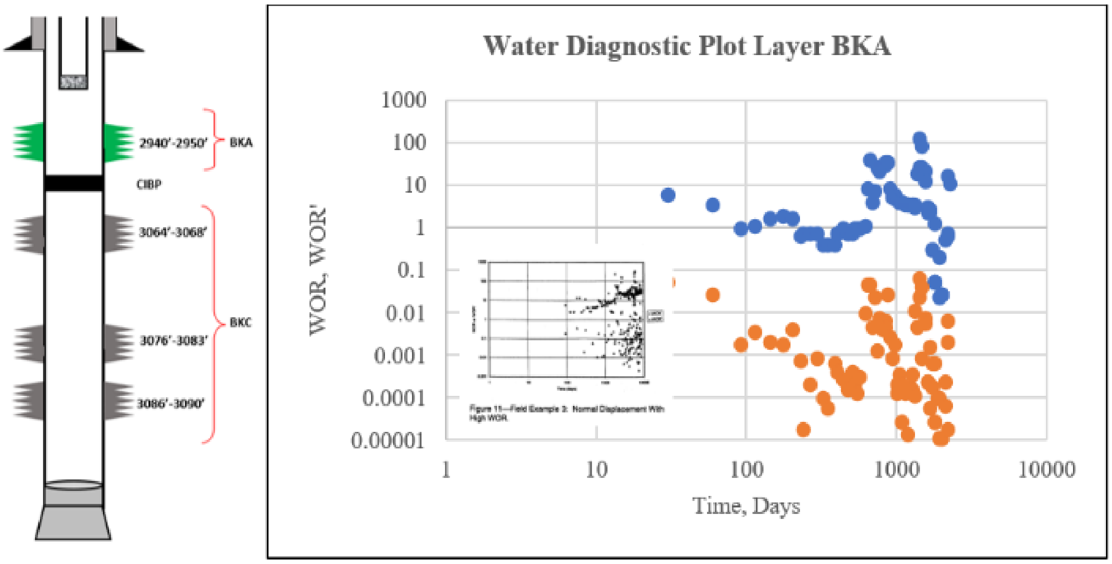

Figure 7. Chan's diagnostic of well CNA-01 BKA layer. The production response indicates water production behavior associated with channeling, which may reduce sweep efficiency and leave hydrocarbons trapped within the reservoir.

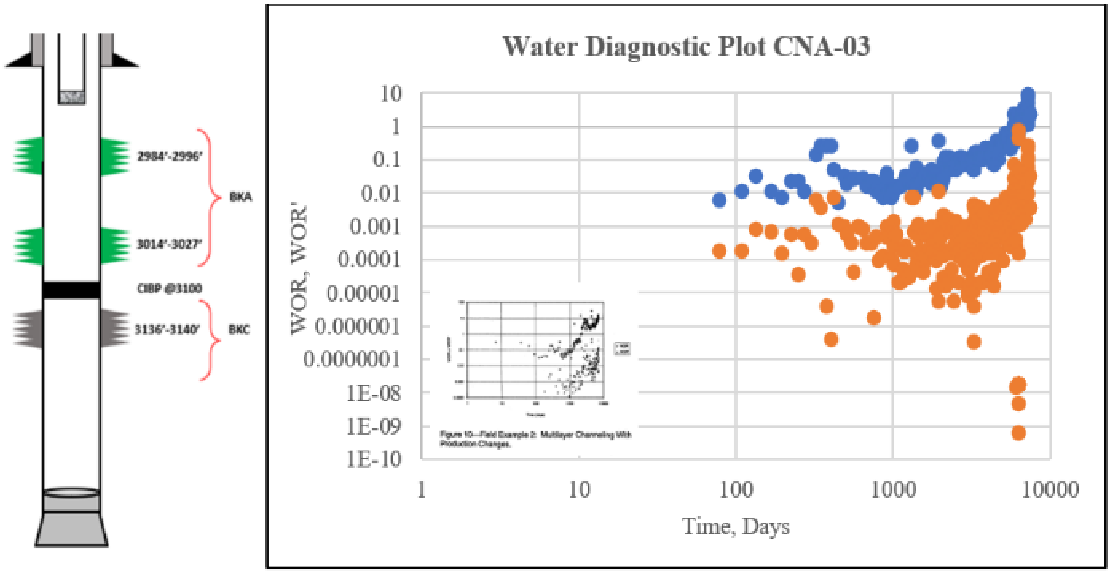

Figure 8. Chan's diagnostic of well CNA-03 BKA layer. The WOR and WOR' trends indicate channeling as the dominant water production mechanism, suggesting reduced sweep efficiency and the potential presence of bypassed oil within the reservoir. Chan's diagnostic plot shows that channeling is the primary water production process in various intervals. Channeling shows that the water flows preferentially along the high-permeability channels, thereby reducing the sweep efficiency and leaving parts of the reservoir unswept. Consequently, hydrocarbon accumulations might be confined in intervals that are not efficiently contacted by the production process.

bypassed oil zones are suitable for production, as the production rate and water cut in that interval have to be considered. The most suitable workover strategy for each interval is selected considering the reservoir quality, production history, completion status, and water production behavior. Uncompleted areas with favorable petrophysical properties and hydrocarbon indications are candidates for additional perforation, while intervals suffering from excessive water production may require work such as interval shut-off or squeeze cementing to improve production efficiency. Table 6 presents classification of bypassed oil zones and the corresponding workover recommendations based on production history and problems faced in the wells CNA-01 and CNA-03.

Table 6. Workover zone recommendation

Well	Job	Interval	Perm (mD)	Resis (ohmm)	Swc	Resrvoir Quality
CNA-01	Shortening & Perforation	2933-2945	90.6	5	Dot1/3	LQR
	Perforation	2959-2966	51.4	4.6	Dot1	LQR
	Squeeze Cementing	3064-3068	50	4.7	Tr	LQR
	Shortening & Perforation	3072-3077	163	8.9	Dot3	LQR
	Squeeze Cementing	3086-3090	183.5	12.7	Dot3	LQR
CNA-03	Reopen	2984-2996	128.8	4.6	Dot1	HQR
	Perforation	2998-3005	89.7	3.8	Nso	HQR
	Shortening	3014-3027	1294.5	7.5	Dot2	HQR
	Reopen & Perforation	3134-3140	179.7	9.9	Dot2	HQR

CONCLUSION

Based on the results and discussion, five potential bypassed oil zones are identified in well CNA-01 at depths of 2933–2950 ft, 2959–2966 ft, 3064–3068 ft, 3070–3084 ft, and 3086–3090 ft. In well CNA-03, four potential bypassed oil zones are identified at depths of 2984–2996 ft, 2998–3005 ft, 3014–3030 ft, and 3134–3140 ft. These intervals are identified through integrated well-log analysis supported by resistivity and permeability cut-off evaluations, production data, well test results, and sidewall core information.

Integrated petrophysical analysis, structural correlation, and Chan’s Diagnostic Plot evaluation indicate that reservoir heterogeneity, vertical permeability variations, channeling, and laterally discontinuous sand bodies are the main factors contributing to bypassed oil occurrence in the studied wells. Variations in permeability distribution cause uneven fluid flow and sweep efficiency, allowing hydrocarbons to remain trapped within less permeable reservoir sections. These findings are consistent with observations reported in mature reservoirs where vertical permeability contrasts contribute to incomplete reservoir drainage (Putra et al., 2022).

The results support several workover strategies, including squeeze cementing to isolate non-productive intervals, interval shut-off of high-water-cut zones while retaining residual oil potential, and additional perforation of newly identified hydrocarbon-bearing intervals. These recommendations provide practical opportunities to optimize production and support mature field redevelopment in the CNA Field.

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DECLARATIONS

Author contribution

Karina Larasati contributed to data collection, petrophysical evaluation, production analysis, production data evaluation, interpretation of results, and manuscript preparation. Dimas Suryo Wicaksono contributed to research conceptualization,methodology development, supervision, manuscript review, and editing. Dedi Kristanto contributed to reservoir engineering analysis, technical guidance, and manuscript review. Hariyadi contributed to geological interpretation and structural correlation analysis. Rahajeng Suryo Rahmadhini contributed to Chan's Diagnostic Plot analysis, and technical discussion. Carin Nova Azzaria contributed to data validation, field information verification, and manuscript review. All authors have read and approved the final version of the manuscript.

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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.

The use of AI or AI-assisted technologies

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GLOSSARY OF TERMS AND SYMBOLS

Terms & Symbol	Definition	Unit
WOR	Water–Oil Ratio	
WOR'	Derivative of Water–Oil Ratio	
WC	Water Cut	%
Rt	True Formation Resistivity	ohm·m
φ	Porosity	fraction
k	Permeability	mD
GR	Gamma Ray Log	API
ILD	Deep Induction Log	ohm·m
RHOB	Density Log	g/cc
NPHI	Neutron Porosity Log	fraction
COWC	Current Oil–Water Contact	ft
HQR	High Quality Reservoir	
LQR	Low Quality Reservoir	
LTC	Long Term Closed Well	

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