Suitability analysis of runoff coefficient (C) in the *kulong* catchment area using the NRECA model and Rational Method

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Abstract. *Kulong* is a basin on the ground's surface formed from mining activities and subsequently inundated by water. The primary water input source to *kulong* originates from rainfall, which generates runoff. One of the recurring issues in *kulong* is the absence of runoff records. The NRECA model is a modeling approach that transforms rainfall data into runoff estimations for *kulong*. Another derived variable from the NRECA model's runoff calculations is the runoff coefficient (C) value. However, the C value generated by the NRECA model's calculations has yet to be verified for its conformity with field conditions. Due to the lack of runoff records, field-based C value computations for *kulong* can be adopted from the Rational Formula-based C calculations. This study employs a quantitative descriptive method to analyze the suitability of the C values within the *kulong* catchment area, utilizing both the NRECA model and the Rational Method. The research is conducted across three *kulong* sites on Bangka Island: *Kulong* PDAM Merawang in Bangka Regency, *Kulong* Spritus in Pangkalpinang City, and *Kulong* Air Kerasak in Central Bangka Regency. Based on the computed C values, it can be concluded that the suitability analysis of the C values within the *kulong* catchment area, utilizing both the NRECA model and the Rational Method, for *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak, falls well within the tolerance limit (α) of < 1%.

Key Words: catchment analysis, hydrological assessment, mining basin dynamics, rainfall-runoff modeling, runoff estimation, water resource management.

Introduction. Bangka Belitung is a region in Indonesia renowned as one of the world's leading tin producers. The local economy is heavily reliant on the mining sector, especially tin extraction. Tin mining activities in Bangka Belitung have significantly contributed to the regional economy. However, these operations often leave behind "*kulong*", which are large pits resulting from the excavations. Local Regulation of Bangka Regency No. 10 of 2002 defines *kulong* as depressions on the ground's surface resulting from mining activities and subsequently filled with water (Local Government of Bangka Regency 2002). Rainfall serves as the primary water source for these *kulong*, generating runoff.

A common challenge associated with *kulong* is the absence of documented runoff data. Lack of runoff data necessitates modeling to estimate runoff from rainfall data. The NRECA model is frequently employed to simulate potential runoff in *kulong*. This model computes runoff based on monthly rainfall, evaporation, soil moisture, and groundwater storage (Ditthakit et al 2021). Effective utilization of the NRECA model assumes no continuous inflow into *kulong* and presupposes that *kulong*'s physical characteristics resemble those of reservoirs (Sabri 2015).

Alternatively, the F.J. Mock model, officially known as the F.J. Mock Hydrological Model, integrates daily rainfall data, evapotranspiration, and specific hydrological watershed attributes (Mediawan et al 2021). This model offers a practical alternative for rapid watershed assessment, as it incorporates hydrological parameters into monitoring and evaluation processes, particularly in data-deficient areas. The selection of a hydrological model depends on various factors, including watershed characteristics, data availability, and anticipated outcomes (Komariah & Matsumoto 2019).

Several research studies have investigated *kulong* runoff using the NRECA model. These studies include research on five *kulong* sites on Bangka Island (Pririzki et al 2022), *kulong* sites in Central Bangka Regency (Sabri & Wijayanto 2019), and *Kulong* PDAM Tirta Bangka (Syah & Sabri 2014).

One study analyzed Kulong Kebintik in Indonesia, determining that the average monthly discharge was 114.7 liters per second. This *kulong* has brackish water quality due to its proximity to the coast and the influence of tides. The utilization analysis of this *kulong's* water employed the Analytical Hierarchy Process (AHP) method. The study found that the best use for the *kulong* water is for fisheries, followed by tourism, and finally as a raw water source (Sabri & Novriyansyah 2023).

Another study employed the NRECA hydrological model to simulate the filling process of a pit lake formed after open-pit coal mining in Kalimantan, Indonesia. This model helped identify the contributions of runoff and groundwater to the pit lake, which is primarily filled by rainwater from the surrounding catchment area and direct rainfall. The results from this hydrological modeling are crucial for planning and managing future pit lakes to ensure their water quality meets environmental standards (Tuheteru et al 2021).

Another variable derived from the NRECA model's runoff calculations is the runoff coefficient (C) value. The C signifies the ratio of peak runoff to rainfall intensity (Asdak 2014). The catchment area's features significantly influence the runoff volume flowing into the *kulong* basin, a factor driven by the C (Kordana-Obuch et al 2023). In the book "Pengelolaan Sumber Daya Kulong" Sabri presents the computation of the *kulong* C value within the NRECA model by comparing runoff outcomes with rainfall intensity (Sabri 2015). Additionally, to characterize the *kulong* catchment area, the Rational Method Table (Chow et al 1988) can be utilized to determine the land type and the purpose of the *kulong* catchment area.

The reliability of *kulong* C value computations within the NRECA model raises concerns regarding their conformity with real-world conditions. Consequently, an assessment of conformity with field-calculated C values becomes imperative (Sabri 2015). Given the absence of flow data in *kulong*, field-derived C values are determined based on the Rational Method's C value table, reflecting actual land cover conditions (Hill 2002) within the *kulong* catchment area. This method's foundation lies in the Rational Method Table (Chow et al 1988), as utilized by Sabri (2015). Furthermore, the Rational Method is one of the oldest formulas frequently utilized by governmental bodies for runoff analysis (Burra et al 2021), particularly on Bangka Island.

Considering the context above, this study assesses the conformity of C values (Machado et al 2022) within the *kulong* catchment area, employing the NRECA model and the Rational Method.

Material and Method. This study utilized a quantitative descriptive approach to analyze C values within the *Kulong* catchment area, employing the NRECA model and the Rational Method. The investigation was conducted at three *kulong* sites on Bangka Island: *Kulong* PDAM Merawang in Bangka Regency, *Kulong* Spritus in Pangkalpinang City, and *Kulong* Air Kerasak in Central Bangka Regency. The research's geographical locations can be visualized in Figure 1.

The research incorporates both primary and secondary data sources. Primary data includes field observations of vegetation types in the *kulong* area, GPS measurements of *Kulong* coordinates, and technical information gathered through field interviews. Secondary data consists of five years (2016-2020) of climate data from the Meteorology, Climatology, and Geophysics Agency (Badan Meteorologi, Klimatologi, dan Geofisika or BMKG) Depati Amir Station in Pangkalpinang, administrative maps of the Bangka region from Watershed Management Agency (Balai Pengelolaan Daerah Aliran Sungai or BPDAS)

Baturusa Cerucuk Pangkalpinang, periodic satellite images from Google Earth, and Digital Elevation Model (DEM) data from USGS.

Figure 1. Research site locations (source: processed, 2023).

The methodology of the study involves several stages. It begins with collecting and processing both primary and secondary data, followed by analyses of *kulong* characteristics, *kulong* hydrology, land use, and slope analysis of the *kulong* catchment area. It also includes calculating C values using the NRECA model and the Rational Method, along with assessing the consistency between C values derived from the NRECA model and the Rational Method. The final stages of the research involve making decisions and providing recommendations based on the findings.

Analysis of kulong characteristics. The analysis aims to pinpoint the unique features of each *kulong*. Key factors examined include coordinates, types of vegetation, and technical details about the *kulong*. For more detailed insights into *kulong*'s traits, refer to Sabri (2015) and Sabri et al (2020).

Analysis of kulong hydrology. This involves studying rainfall using the algebraic mean method and evaluating evapotranspiration using the Penman-Monteith method, modified and refined by FAO in 1990 (Allen et al 1998). Data covering five years (2016-2020) were sourced from the BMKG Depati Amir Station in Pangkalpinang.

Analysis of land use and slope in the kulong catchment area. The analysis of land use entails interpreting maps covering five years (2016-2020) from digitized images in Google Earth to determine land cover conditions in the *kulong* catchment area. Land use types were classified, and their areas were calculated using ArcGIS 10.1 software. Slope analysis utilized Digital Elevation Model (DEM) data processed with ArcGIS 10.1 software.

Analysis of C value calculation using the NRECA model. The NRECA (National Rural Electric Cooperative Association) model, developed by Norman H. Crawford (USA) in 1985, operates on a water balance equation that considers inflow, outflow, and storage (Hadisusanto 2010). This model, often used in hydrological studies, considers components such as direct precipitation, runoff, groundwater inflow, evaporation, and groundwater outflow to simulate the water balance in a watershed or specific water body (Tuheteru et al 2021):

$$\text{Runoff} = \text{Rainfall} - \text{Evapotranspiration} + \text{Storage change} \quad (1)$$

The NRECA model is designed with a simple framework, relying on two main inputs: monthly rainfall data and monthly potential evapotranspiration (Soewarno 2015). It breaks down monthly flow into direct runoff and base flow. Storage is segmented into moisture storage and groundwater storage. Storage change is calculated as the difference between ending and starting storage. Moisture storage is influenced by rainfall, evaporation, and excess moisture, contributing to direct runoff as well as groundwater inflow. Groundwater storage is impacted by incoming groundwater and outflow (Fritz 1984; Soewarno 2015; Senjaya et al 2023). The structural diagram of the NRECA model is depicted in Figure 2.

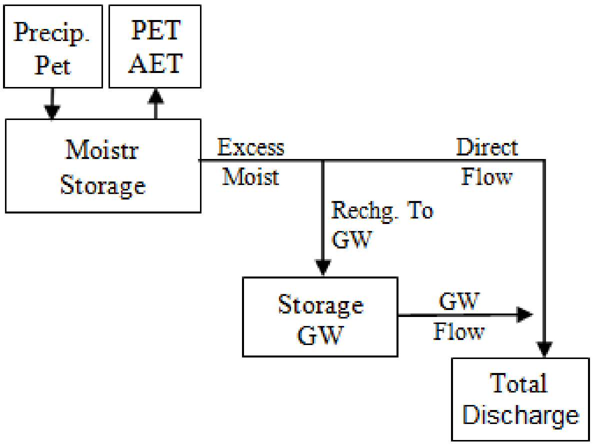

Figure 2. Structural diagram of the NRECA model: PET = potential evapotranspiration; AET = actual evapotranspiration; GW = groundwater (source: Fritz 1984).

Calculation of the C value in the NRECA model for the *kulong* catchment area, as explained in the book "Pengelolaan Sumber Daya Kulong" (Sabri 2015), is determined by the ratio of total runoff to total rainfall, as illustrated in equation 2 below:

Runoff coefficient (C) = Total runoff / Total rainfall (2)

Moreover, to evaluate the land cover conditions within the *kulong* catchment area, the C values calculated from the NRECA model can be compared with those presented in Table 1, which are derived from the Rational Method as documented by Chow et al (1988).

Table 1

Runoff coefficient (C) values using the rational method

Character of surface	*Return period (years)*						
	2	5	10	25	50	100	500
Developed areas							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover more than 50% of the total area)							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the total area)							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover largest than 75% of the total area)							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							

Undeveloped areas							
Cultivated land							
Flat, 0-2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/woodlands							
Flat, 0-2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2-7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Source: Chow et al (1988).

Analysis of rational method runoff coefficient (C) calculation*.* The Rational Method stands as one of the earliest and most widely recognized empirical formulas in hydrology. Renowned for its simplicity (Brotowiryatmo 2000), it remains a cornerstone in estimating runoff.

In cases where a drainage area exhibits heterogeneity, characterized by diverse land use types, the associated C values will vary accordingly. Consequently, the drainage area undergoes subdivision into sub-drainage areas (Ai) delineated by land use types (Ci). The determination of the C value employs an approach reliant on the land characteristics outlined in Table 2.

Table 2

Runoff coefficient (C) values

Drainage area condition	*C value range*
Business	
Urban areas	0.70-0.95
Suburban areas	0.50-0.70
Residential	
Single houses	0.30-0.50
Multi-unit, detached	0.40-0.60
Multi-unit, attached	0.60-0.75
Settlements	0.25-0.40
Apartments	0.50-0.70
Industrial	
Light industry areas	0.50-0.80
Heavy industry areas	0.60-0.90
Roofs	0.75-0.95
Grass yards	
Sandy, flat (2%)	0.05-0.10
Sandy, average (2-7%)	0.10-0.15
Sandy, steep (7%)	0.15-0.20
Heavy, flat (2%)	0.13-0.17
Heavy, average (2-7%)	0.18-0.22
Heavy, steep (7%)	0.25-0.35
Railway yards	0.10-0.35
Playground areas	0.20-0.35
Parks, cemeteries	0.10-0.25
Forest	
Flat (0-5%)	0.10-0.40
Undulating (5-10%)	0.25-0.50
Hilly (10-30%)	0.30-0.60

Source: Brotowiryatmo (2000).

The cumulative runoff coefficient for all assessed drainage areas is derived through a composite runoff coefficient, expressed by equation 3:

$$C_{composite} = \frac{\sum_{i=1}^{n} C_i . A_i}{\sum_{i=1}^{n} A_i} \quad (3)$$

where: $C_{composite}$ = average surface runoff coefficient;
C_i = surface runoff coefficient for land cover type i;
A_i = area of land cover type;
n = number of land cover types.

***Assessing consistency in runoff coefficient (C) values*.** The examination of consistency in C values aims to gauge how closely the calculated C values from the NRECA model align with those derived from the Rational Method within the *kulong* catchment area. This assessment is conducted through relative error analysis.

Relative error analysis is a method used to determine the percentage difference between modeled values and actual values by calculating the percentage discrepancy between the predicted and observed outcomes (Soewarno 2015). The formula to ascertain relative error is as follows:

$$Kr = \frac{Xa - Xb}{Xa} x\, 100 \quad (4)$$

where: K_r = relative error (%);
X_a = actual value;
X_b = modeled value.

When evaluating conformity between two variables or methods, the acceptable threshold for testing errors is often expressed as α = 0.01 (indicating a 1% probability of error), α = 0.05 (indicating a 5% probability of error), and α = 0.10 (indicating a 10% probability of error) (Diekhoff 1992).

Results and Discussion

***Analysis of kulong characteristics*.** To assess *kulong's* characteristics, various software tools like Google Earth Pro, Global Mapper, and ArcGIS 10.1 were employed. The categorization of these characteristics followed the framework outlined by Sabri et al (2020). Table 3 displays the findings from the analysis of *Kulong* attributes at the designated research sites.

Table 3

Characteristics of catchment areas in the research locations

No.	*Catchment area characteristics*		*Kulong PDAM Merawang*	*Kulong Spritus*	*Kulong Air Kerasak*
1	Location of kulong	Location	Dwi Makmur village, Merawang, Bangka Regency	Governor's Office Complex, Pangkalpinang city	Dul, Pangkalan Baru, Bangka Tengah Regency
		Coordinates	S 1°57′11.10″ – E 106°6′35.62″	S 2°9′39.96″ – E 106°9′37.70″	S 2°10′3.84″ – E 106°8′39.22″
2	Area of kulong	Surface area	5.84 ha	2.65 ha	2.71 ha
		Volume	183,843.93 m^3	25,662.072 m^3	21,823.058 m^3
		Catchment area size	21.44 ha	11.91 ha	22.68 ha
3	Age of kulong		> 100 years	> 70 years	> 70 years
4	Vegetation in kulong		Scrub, acacia plants, oil palm plantations, wild grass, forest	Gelam trees, scrub, aquatic plants	Oil palm plantations, gelam trees, scrub, forest

Source: Sabri et al (2020).

Table 3 presents distinctive features of *kulong* characteristics at various research locations, each exhibiting unique attributes shaped by its formation site and the surrounding natural landscape within the catchment area.

Analysis of kulong characteristics. Rainfall and climatological data retrieved from the BMKG Depati Amir Station in Kota Pangkalpinang are formatted on a daily basis. Daily rainfall records spanning five years (2016-2020) were aggregated into monthly data. Figure 3 illustrates the average monthly rainfall from 2016 to 2020 using the Arithmetic Mean Method. As depicted in Figure 3, the peak monthly rainfall was observed in February at 323.20 mm, while the lowest occurred in August at 85.44 mm.

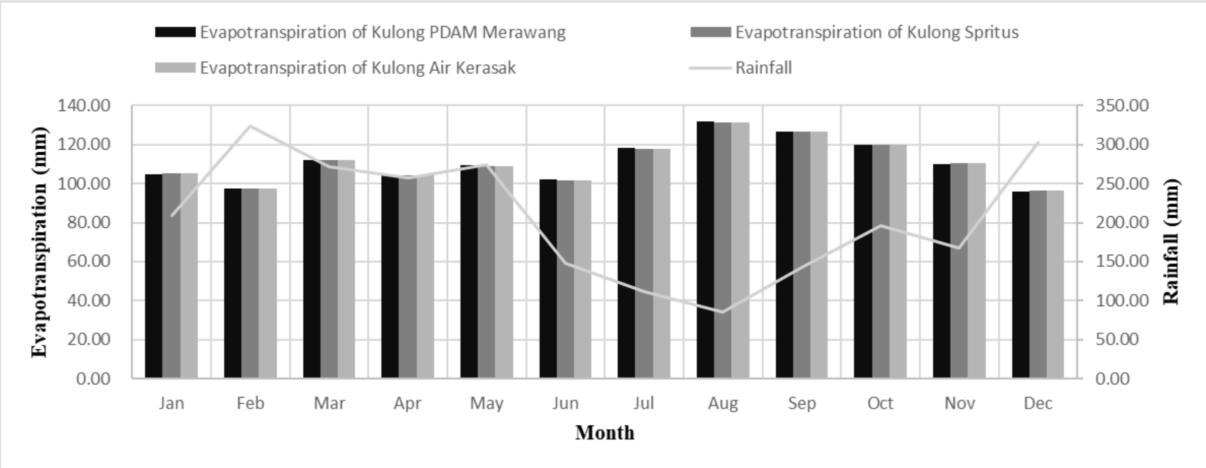

Figure 3. Graph of monthly average rainfall and evapotranspiration from 2016 to 2020 (Source: processed, 2023).

The climatological dataset utilized in this study encompasses air temperature, wind speed, air humidity, and sunshine duration over five years (2016-2020). Table 4 provides a summary of monthly average data for air temperature, wind speed, air humidity, and sunshine duration during this timeframe. Monthly potential evapotranspiration was computed using the Modified Penman Method based on this climatological data. Figure 3 further illustrates the average monthly potential evapotranspiration for each *kulong* from 2016 to 2020.

Table 4

Monthly data for air temperature, wind speed, air humidity, and sunshine duration from 2016 to 2020

Month	*Climatological data*			
	Air temperature (^oC)	*Wind speed (knot)*	*Air humidity (%)*	*Sunshine duration (%)*
January	26.65	2.26	87.44	31.25
February	26.47	2.22	87.69	32.65
March	26.74	1.98	87.23	39.26
April	27.2	1.7	87.01	39.07
May	27.86	2	86.25	46.37
June	27.52	2.28	85.15	46.81
July	27.35	2.9	82.92	56.95
August	27.66	3.36	80.91	58.35
September	27.54	2.92	81.71	52.65
October	27.52	2.16	83.25	42.39
November	27.47	1.82	83.27	41.56
December	26.42	2.02	88.35	23.57

Source: processed, 2023.

From Figure 3, it is evident that potential evapotranspiration varies among *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak. The geographical coordinates of each *Kulong* location influence its potential evapotranspiration values, with higher shortwave solar radiation values significantly impacting evaporation (Pririzki et al 2022).

Additionally, the monthly maximum potential evapotranspiration values for the years 2016 to 2020 for *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak coincide, all occurring in August at 131.80 mm, 131.56 mm, and 131.56 mm, respectively. Conversely, the minimum monthly potential evapotranspiration values for these *Kulong* sites were observed in December, with values of 96.03 mm, 96.23 mm, and 96.23 mm for *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak, respectively.

Analysis of land use and catchment area slope. The land use analysis conducted in this study utilized classification criteria established from class signatures generated by defining sample areas (training areas). The identification of land use classes relied on the interpretation of Google Earth Pro imagery juxtaposed with clear boundaries observed in the field, aligning with the actual conditions at the research sites. From the comprehensive results of the land use classification process, a total of 8 (eight) distinct land use types were delineated across the 3 (three) research locations, as outlined in Table 5. Furthermore, Table 6 presents a summary of the land use distribution within the catchment areas of *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak for the period spanning 2016-2020.

Table 5

Classification of land use categories

Land use	*Satellite image*	*Field image*
A. Water bodies: dark and light tones with fine texture; bluish, green, or brown, with very minimal vegetation.		
	Location: *Kulong* Air Kerasak, Bangka Tengah Regency	
B. Built-up areas: irregular patterns with square, rectangular, or circular shapes; colors include black, red, white, dark, or light. This category includes permanent and non-permanent structures like houses, residential areas, buildings, factories, offices, etc.		
	Location: *Kulong* Air Kerasak, Bangka Tengah Regency	
C. Forest/vegetation: generally irregular shapes with dark and light tones; green in color, with different roughness levels due to uneven tree heights.		
	Location: *Kulong* Spritus, Pangkalpinang City	
D. Paved roads: regular patterns, usually long lines with light grey tones.		
	Location: *Kulong* Air Kerasak, Bangka Tengah Regency	

E. Plantation: regular pattern with star-shaped canopy, representing oil palm trees, dark green.	 Location: *Kulong* PDAM Merawang, Bangka Regency
F. Mining: irregular shapes and colors match the soil-water puddles due to mining activities.	 Location: *Kulong* PDAM Merawang, Bangka Regency
G. Agriculture: generally orderly shapes with bright green tones. Neat roughness pattern due to plant layout.	 Location: *Kulong* PDAM Merawang, Bangka Regency
H. Open/empty land: indistinct and irregular shapes are due to openness and unclear use; heterogeneous tones match soil colors due to the removed top cover.	 Location: *Kulong* PDAM Merawang, Bangka Regency

The slope analysis reveals the steepness of the terrain resulting from variations in elevation between two points, typically measured in percentages or degrees. In this research, the slope of the land within the catchment areas was determined by processing Digital Elevation Model (DEM) data using ArcGIS 10.1 software. The breakdown of area classifications for slope classes in the catchment areas of *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak is provided in Table 7.

Table 7

Recapitulation of slope area within *kulong* catchment areas in the research locations

Slope gradient	*Slope area (ha)*		
	Kulong PDAM Merawang	*Kulong Spritus*	*Kulong Air Kerasak*
Flat (0-8%)	13.247	8.707	17.121
Gentle (8-15%)	5.823	2.433	5.283
Moderate (15-25%)	2.304	0.590	0.224
Steep (25-45%)	0.066	0.177	0.054
Very steep (45%)	-	-	0.002

Land use and slope gradient are key factors that impact the speed and quantity of surface runoff within the *Kulong* catchment area. Vegetation cover plays a significant role in decreasing potential surface runoff by facilitating water absorption into the soil. Conversely, areas with flat terrain tend to produce less surface runoff compared to those with steeper slopes.

Table 6

Recapitulation of land use area within *kulong* catchment area at research locations

Land use	*Land use area (ha)*														
	2016			*2017*			*2018*			*2019*			*2020*		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Water bodies	0.379	0.104	1.409	2.331	0.132	1.409	1.038	0.263	1.146	1.038	0.275	0.958	1.894	0.275	0.796
Built-up areas	0.276	8.471	2.043	0.32	8.657	2.043	0.411	7.141	2.539	0.411	7.662	2.665	0.471	7.903	2.689
Forest/vegetation	10.869	1.271	14.909	9.016	1.27	14.909	8.079	1.27	14.648	8.079	1.27	13.545	8.142	1.27	16.382
Paved roads	0.125	0	0.457	0.125	0	0.457	0.124	0.023	0.485	0.124	0.702	0.738	0.311	0.804	0.738
Plantation	3.143	-	-	3.191	-	-	3.165	-	-	3.165	-	-	3.197	-	-
Mining	3.56	2.061	0.711	3.405	1.848	0.711	4.863	3.21	1.123	4.863	1.998	0.872	4.676	1.654	0.298
Agriculture	0.363	-	-	1.129	-	-	1.155	-	-	1.155	-	-	0.284	-	-
Open/empty	2.726	0.104	3.155	1.922	0.132	3.155	2.605	0.263	2.742	2.605	0.275	3.907	2.464	0.275	1.781

Note: 1 = *Kulong* PDAM Merawang; 2 = *Kulong* Spritus; 3 = *Kulong* Air Kerasak. Source: processed, 2023.

NRECA model analysis. The determination of the C coefficient in the NRECA model for the *Kulong* catchment area relies on hydrological analysis data spanning five years (2016-2020). Key parameters inputted into the NRECA Model include monthly rainfall data and monthly potential evapotranspiration (Soewarno 2015). Furthermore, certain parameters within the NRECA model, such as initial moisture storage (IMS), groundwater storage (IGWS), surface soil characteristic coefficient (P1), and subsurface soil coefficient (P2), are optimized using the solver tool in Microsoft Excel to derive optimal values. Table 8 presents the average value of the total run off obtained from the NRECA Model.

Table 8

NRECA model total run off values

Kulong name	*Total run off (mm)*				
	2016	*2017*	*2018*	*2019*	*2020*
PDAM Merawang	111.267	110.726	70.719	69.166	81.509
Spritus	96.270	107.249	69.985	68.835	81.737
Air Kerasak	87.009	106.540	69.735	68.691	81.851

The runoff coefficient (c) value is obtained using equation 2. Table 9 presents the calculated annual average C coefficient values obtained from the NRECA Model.

Table 9

NRECA model coefficient values (C)

C value		*Kulong PDAM Merawang*	*Kulong Spritus*	*Kulong Air Kerasak*
CAnnual	2016	0.446	0.294	0.313
	2017	0.429	0.410	0.404
	2018	0.332	0.316	0.309
	2019	0.260	0.254	0.249
	2020	0.319	0.313	0.309
C5-Year average		0.3571	0.3173	0.3169

Furthermore, to analyze the land cover conditions of the *kulong* catchment area, the results of the NRECA model C coefficient calculation can be plotted against the table of Chow et al (1988), as presented in Table 1. The analysis results show that the catchment area of *Kulong* PDAM Merawang in Kabupaten Bangka is categorized as an average gradient of 2-7%, with a fair condition of land cover (grass cover on 50 to 75% of the area), with a C value of 0.36. The catchment area of *Kulong* Spritus in Kota Pangkalpinang is also categorized as an average gradient of 2-7%, with good land cover condition (grass cover larger than 75% of the area), with a C value of 0.32. Similarly, the catchment area of *Kulong* Air Kerasak in Kabupaten Bangka Tengah is categorized as an average gradient of 2-7%, with good land cover condition (grass cover larger than 75% of the area), also having a C value of 0.32.

Rational method*.* Calculating the C coefficient using the Rational Method for the *Kulong* catchment area is carried out using Equation 3. The C coefficient in the Rational Method can be calculated by first determining the runoff coefficients for each land use condition within the *Kulong* catchment area. Based on Table 2, the runoff coefficients for each land use type within the *Kulong* catchment area are specified and presented in Table 10.

Table 10 provides the C coefficient values for the land use within the *kulong* catchment Table 10 provides the C coefficient values for various land uses within the *kulong* catchment area. These values reflect the conditions of the area influenced by land use and slope gradient. For a detailed analysis, Table 8 provides the conditions under which these coefficients are applied. The results of the land use analysis over a 5-year period (2016-2020) involve multiplying the respective land use areas by the C values specified in Table 10, according to the conditions outlined in Table 8. The summarized results of the annual average C coefficient calculations using the Rational Method are presented in Table 11.

Table 10

Runoff coefficient (C) values for the Rational Method based on land use

Land use	*C*
Water bodies	0.05
Built-up areas	0.75
Forest/vegetation	0.25
Paved roads	0.75
Plantation	0.40
Mining	0.75
Agriculture	0.10
Open/empty land	0.20

Source: processed, 2023.

Table 11

Runoff coefficient (C) values using the Rational Method

C value		*PDAM Kulong Merawang*	*Kulong Spritus*	*Kulong Air Kerasak*
Annual $C_{composite}$	2016	0.352	0.299	0.301
	2017	0.328	0.301	0.301
	2018	0.374	0.302	0.325
	2019	0.374	0.336	0.327
	2020	0.374	0.342	0.321
C5-year average		0.3605	0.3159	0.3153

Source: processed, 2023.

Based on Table 11, the summarized values of the Rational Method's C coefficient calculations over five years (2016-2020) are as follows: *Kulong* PDAM Merawang 0.3605, *Kulong* Spritus 0.3159, and *Kulong* Air Kerasak 0.3153. These C values can be interpreted to mean that 36.05% of the rainfall in the *Kulong* PDAM Merawang catchment area, 31.59% in the *Kulong* Spritus catchment area, and 31.53% in the *Kulong* Air Kerasak catchment area will become surface runoff. At the same time, the rest will infiltrate into the soil.

Suitability analysis of runoff coefficient (C). The suitability analysis of the C values for the *Kulong* catchment area using the NRECA Model and the Rational Method is performed to assess the compatibility level of the C values obtained from these two methods. This analysis involves a test of relative errors based on Equation 4.

The C values used in the Rational Method are adopted as the variable Xa, representing the true value. This is due to the absence of recorded flow/runoff data needed to calculate field runoff coefficients, leading to the use of the Rational Method's C values. In the book of Sabri (2015), to assess land cover conditions in the *kulong* catchment area, the table from Chow et al (1988) is used, which contains Rational runoff coefficient values based on the study year. Therefore, the Rational Method's C values are established as the Xa variable for relative error calculation between the two methods. The results of the suitability analysis of C values using the NRECA model and the Rational Method with relative error testing can be seen in Table 12.

Furthermore, to analyze the level of compatibility between the methods, the researchers categorized the suitability criteria with allowable tolerance limits in Table 13.

Table 12

Results of suitability analysis for runoff coefficient (C) using NRECA model and rational method with relative error testing

Kulong name	*NRECA model*	*Rational method*	*Relative error (%)*
PDAM Merawang	0.3571	0.3605	0.943
Spritus	0.3173	0.3159	0.443
Air Kerasak	0.3169	0.3153	0.507

Source: processed, 2023.

Table 13

Suitability levels between methods

Tolerance limit (ɑ)	*Description*
< 1%	Highly suitable
1-5%	Suitable
5-10%	Less suitable
> 10%	Not suitable

Source: processed, 2023.

Based on Table 13, the results of the suitability analysis for the C values in the *kulong* catchment area using the NRECA Model and the Rational Method are categorized as highly suitable. This is because the relative error test results between the NRECA model and the Rational Method for each *kulong* (*Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak) in Table 11 exhibit only slight differences within the tolerance limit (ɑ) of < 1%.

Furthermore, the researcher also analyzed the compatibility of the land cover conditions obtained from the calculated C values using the NRECA Model plotted against Chow et al's (1988) Table with the Rational Method's C values. The analysis indicates that the NRECA Model's C value for *Kulong* PDAM Merawang, when plotted against Chow et al's (1988) Table with a 5-year return period, corresponds to surface flow characteristics in the form of an area with an average gradient of 2-7% and a fair condition land surface (grass cover between 50% and 75% of the area) with a value of 0.36. This is in line with the land use conditions of the *Kulong* PDAM Merawang catchment area in 2020 based on the Rational Method, where the land cover consisted of vegetation covering an area between 50% - 75%, and the catchment area had an average slope gradient of 0-8%.

Similarly, the catchment area of *Kulong* Spritus has surface flow characteristics of an area with an average gradient of 2-7% and a good-condition land surface (grass cover larger than 75% of the area). This corresponds to the Rational Method's results for the *Kulong* Spritus catchment area in 2020, where the land cover consisted of vegetation covering more than 75% of the area, and the catchment area was flat with an average slope gradient of 0-8%.

Likewise, the catchment area of *Kulong* Air Kerasak has surface flow characteristics of an area with an average gradient of 2-7% and a good condition land surface (grass cover larger than 75% of the area). This is consistent with the Rational Method's results for the *Kulong* Air Kerasak catchment area in 2020, where the land cover consisted of vegetation covering more than 75% of the area, and the catchment area was flat with an average slope gradient of 0-8%.

The consistency of the runoff coefficient (C) values and land cover conditions within the *Kulong* catchment area using the NRECA Model and the Rational Method implies that both methods can be equally utilized as references for calculating the C values within the *Kulong* catchment area. Consequently, for *Kulong* areas lacking flow data records, the NRECA Model can be relied upon for calculating several essential variables, including the runoff coefficient (C), using simple input data such as rainfall and evapotranspiration.

Conclusions. Based on the conducted calculations, the runoff coefficient (C) values obtained from the calculations using the NRECA Model and the Rational Method for *Kulong* PDAM Merawang are 0.3571 and 0.3605, for *Kulong* Spritus are 0.3171 and 0.3159, and for *Kulong* Air Kerasak are 0.3169 and 0.3153. The analysis results of the relative error testing indicate that the compatibility of the runoff coefficient (C) values in the *Kulong* catchment area using the Rational Method and the NRECA Model for *Kulong* PDAM Merawang, *Kulong* Spritus, and *Kulong* Air Kerasak are categorized as highly suitable within the tolerance limit (ɑ) of <1%.

Recommendations. The high consistency in the runoff coefficient (C) calculations between the NRECA Model and the Rational Method suggests that these methods can be used interchangeably and may provide insights for further research to choose the method that simplifies variable calculations in *Kulong* studies.

Furthermore, this study is particularly effective for situations where there is no continuous inflow into the *Kulong*; however, for *Kulong* areas with inflow, other methods for calculating the runoff coefficient (C) are recommended.

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