International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 9 (September, 2024), PP 244-253

Water Balance Study of Komering Sub-Watershed, East OKU Regency

Setiya Budi AF[1]; Achmad Syarifudin[2]
[1]*Post Graduate of Civil Engineering, Faculty of Engineering*
[2]*Professor of Civil Engineering, Faculty of Engineering*
Bina University, Palembang, Indonesia
Corresponding Author: achmad.syarifudin@binadarma.ac.id

Abstract
This study was conducted to obtain the groundwater potential in the Komering River Sub-Watershed, East OKU Regency and to calculate the water balance in the Komering River Sub-Watershed in East OKU Regency. The data analyzed included rainfall data and frequency analysis to obtain the IDF curve and the amount of surface flow discharge with the formula Qt = 0.2778 C I A and water balance analysis.
The results of the study produced the potential of groundwater or the volume of water that seeps into the soil or infiltration (R) of 20,305.7 m^3/month with a rainfall value of 0.2357 m/month and a run-off coefficient value of 0.45 which occurred in the Komering Sub-Catchment Area, East OKU Regency and the water balance with the availability of water in January to October in 2023 is still a surplus (excess) of water) only for November and December there is a shortage (deficit) of water due to the transition from the dry season to the rainy season.

***Keywords**: Groundwater potensial, IDF-Curve, Discharge, waterbalance*

Date of Submission: 08-09-2024 Date of Acceptance: 24-09-2024

I. INTRODUCTION

OKU TIMUR Regency is geographically located at 103o 40’– 104o 33’ East Longitude and 3o 45’– 4o 55’ South Latitude. In accordance with Law Number 37 of 2003, the area of Ogan Komering Ulu Timur Regency (OKU TIMUR) is 3,370 km², where most of the area is lowland and tends to be flat except in the Martapura District and its surroundings which tend to be hilly. (OKUT in figures, 2022) Topographically, the OKU TIMUR Regency area can be classified into flat areas (Peneplain Zone), undulating (Piedmont Zone), and some are hilly areas that have varying elevations, namely between 42 meters to the highest elevation reaching 87 meters above sea level (asl) and slope gradients varying between 0-2% and 2-15%. Flat areas are found in Belitang District and Buay Madang District, while hilly areas are found in part of Martapura District. (OKUT in figures, 2022)

The physiography of OKU TIMUR district is part of the Barisan Mountains Zone and the Basin Zone. The Barisan Mountains Zone is characterized by a landscape of volcanic cones, mountains and undulating hills formed by intrusive rocks of andesitic-granite composition, pyroclastic and Tertiary sedimentary rocks; while the Basin Zone is characterized by a landscape of low and gentle undulating plains which are mostly formed by river alluvial deposits; in some places there are Tertiary sedimentary rocks and local swamp deposits and reef limestone. (Satria Jaya Priatna et al., 2011)

In OKUT district, the Komering River flows in the southern part of Sumatra Island which has a tropical rainforest climate. The average temperature per year is around 24 °C. The hottest month is October, with an average temperature of 26 °C, and the coldest is January, around 22 °C. The average annual rainfall is 2902 mm. The month with the highest rainfall is November, with an average of 435 mm, and the lowest is August, with an average of 83 mm. The Komering Sub-DAS is one of the nine Musi Sub-DAS and is located in the southern part of the island of Sumatra, which has an area of 915,375.820 ha. (OKUT in figures, 2022)

One of the serious problems that hit several urban and rural areas in Indonesia is flooding. The flood is not purely due to natural factors alone, but rather due to uncontrolled changes in land use without considering the sustainability of the river basin from upstream to downstream. The part that must be considered in flood control is not only surface flow, but also runoff. The rate and volume of runoff are influenced by the distribution and intensity of rainfall throughout the watershed. (Achmad Syarifudin, 2018) In hydrology, rainfall is an important input component where the analysis of rainfall data in the review of hydrological planning aspects is used as an approach in estimating the amount of flood discharge that occurs in a watershed. The approach to estimating flood discharge that occurs from rainfall data is carried out if the watershed in question is not equipped with an Automatic Water Level Recorder (AWLR) water measuring instrument. To obtain the amount of rainfall that can be considered as the actual depth of rainfall that occurs throughout the watershed, a number of rainfall stations are needed that can represent the amount of rainfall in the watershed. (Achmad Syarifudin, 2017) In addition to rainfall data, surface runoff is an important factor in the transport system of various materials that will be carried into river flow. If the intensity of rainfall exceeds the infiltration rate, excess water begins to accumulate as surface reserves. If the surface reserve capacity is exceeded, surface runoff begins as a thin layer flow. Surface runoff is the part of the runoff that passes over the land surface towards the river channel (Seyhan 1990).

In high intensity rain, the total volume of surface runoff will be greater than in low intensity even though the total rainfall received is the same. Topographic forms such as land slope will affect surface runoff. Watersheds with high slopes will produce greater surface runoff. The presence of vegetation can increase the amount of water retained on the surface, thereby reducing the rate of surface runoff. (Achmad Syarifudin, 2018).

For this reason, research is needed that will discuss the amount of discharge that occurs in the Komering River Sub-Watershed and the water balance in 2023.

II. MATERIAL AND METHODS

This research will be conducted in the Komering Sub Watershed or river basin in East OKU district as shown in Figure 1.

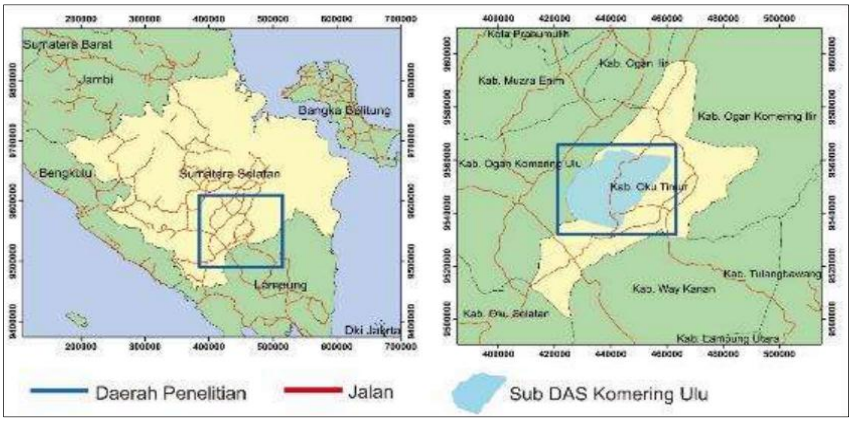

Figure 1: Administrative location of research area

2.1. Research Methods

In this study, the general sequence of stages or flow of activities to be carried out are as follows:

1) Literature Review

Using references from books, literature, or articles as references or guidelines whose truth can be accounted for in data analysis.

2) Data Collection

Data collection, data selection and data compilation are carried out.

3) Data Processing and Analysis

From the data that has been obtained, data processing is carried out. The results of the calculations are analyzed.

4) Conclusion

All stages of activities carried out in this study can be seen in table 1.

2.2. Data Collection

The data used is secondary data. Secondary data is data obtained in a finished form, has been collected and processed by other parties. The data includes:

a) Hourly rainfall data

This data is used to determine the intensity of rainfall. The data used is rainfall data based on the recording of rainfall data from the local BMG Station.

b) Geometric data of Komering River

In the form of cross section data with distances between cross sections taken from PUPR & Spatial Planning of East OKU Regency.

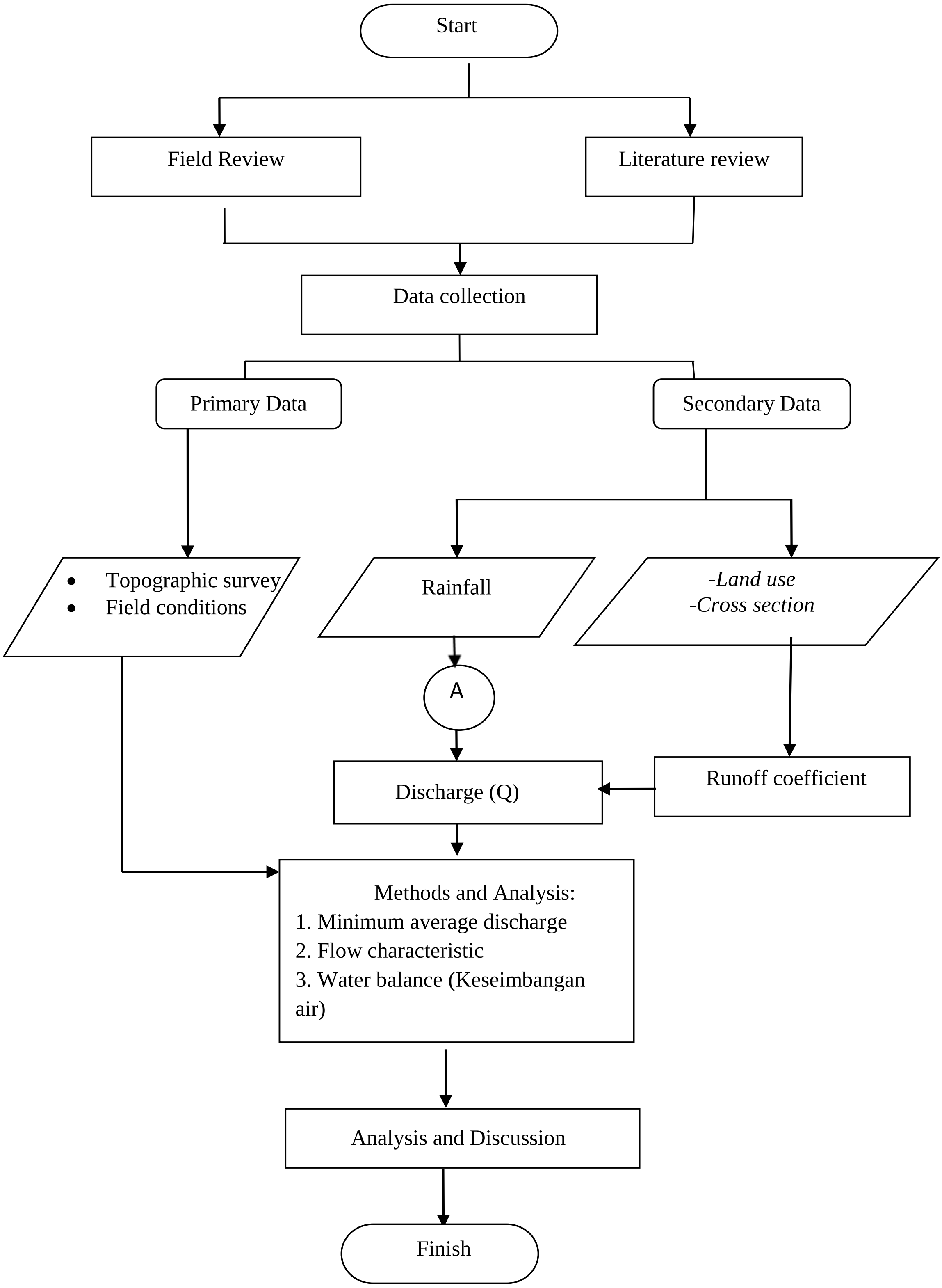

Figure 1: Administrative location of research area

III. RESULTS AND DISCUSSION

3.1. Selection of Return Period

Determination of return period based on the method:

1. Empirical Method

Past event observation data to predict future events with the same magnitude. The probability of extreme events in "N" years will recur in the next "n" years is expressed as:

P (N,n) = n / N + n .... (1)

2. Risk Analysis

The risk of failure of the planned building is a risk analysis expressed in the equation:

R = 1 - 1 - 1/T n .... (2)

with:

R = Probability where Q Qt occurs at least once in n years.

3.2. Hydrology

Considering the availability of hydrometric data is not yet available properly, rainfall data is used as the basis for hydrological calculations. The rainfall data used is rainfall data recorded by several stations in the planning area and has quite long data, namely from 2011 to 2021 and the average rainfall value is taken from the maximum monthly rainfall data.

For the planned rainfall estimate, frequency analysis is used by reviewing the commonly used distribution:

1. Planned Rain Estimate

a. For Return Periods above 1 year

The planned rainfall estimate is carried out by analyzing the frequency of the annual maximum rainfall data (annual series). There are several distributions in statistics and those commonly used in frequency analysis are 4 (four) types, namely:

1). Normal
2). Gumbel type I
3). Log normal 2 parameters
4). Pearson type III log

Each distribution has its own statistical properties. By calculating the statistical parameters of the analyzed data series, it can be estimated which distribution is appropriate for the data series. The statistical parameters in question are as follows:

$$X = \frac{\Sigma xi}{n} \quad \text{..} \quad (3)$$

$$S = \sqrt{\frac{(xi - xr)^2}{(n-1)}} \quad \text{..} \quad (4)$$

$$Cs = \frac{n}{(n-1)(n-2)S^3} \sum (xi - xr)3 \quad \text{..} \quad (5)$$

$$Ck = \frac{n}{(n-1)(n-2)(n-3)S^4} \sum (xi - xr)4 \quad \text{..} \quad (6)$$

with:

xr = Mean value
S = Standard deviation
Cs = Skewness coefficient
Ck = Curtosis coefficient
xi = rainfall data
n = amount of data

The typical statistical properties of each distribution can be explained as follows:

1). Normal Distribution: Cs = O
Typical characteristics: Cs = 0

Probability P (x-S) = 15.87%
P (x) = 50.00%
P(x+s) = 84.14%

The possibility of a variable in the interval x – S and X + S = 68.27% and in the interval X – 2S and X + 2S = 95.44%.

2). Log normal distribution (2 parameters)
Characteristics: Cs = 3 Cv
Cs is always positive
Probability line equation: x(t) = x + K
With x(t) = rainfall depth with recurrence period t (years) K = Frequency factor

3). Gumbel distribution type I
Characteristics: Cs = 1.3960 cv and Ck = 5.4002
Probability line equation:

$$X(t) = x + \frac{\sigma}{\sigma n}(y - yn) \quad \text{...} \quad (7)$$

with: Y = reduced variated
yn and n = Mean value and standard deviation of reduced variated.

4). Pearson Log Distribution type III
The statistical data does not approach the characteristics of the three previous distributions.
The rainfall data is transformed into its natural logarithm value so that the xi values change to ln xi. Then the average value, standard deviation and skewness coefficient are calculated as follows:

$$\overline{ln \frac{\sum_{i=1}^{n} ln\, xi}{n}} \quad \text{...} \quad (8)$$

$$S = \sqrt{\frac{\sum_{i=1}^{n}(ln\, xi - \overline{ln}\quad x)^2}{(n-1)}} \quad \text{...} \quad (9)$$

$$Cs = \frac{n}{(n-1)(n-2)S^3}\sum_{i=1}^{n}(\ln xi - \overline{\ln}\, x)^3 \quad \text{...} \quad (10)$$

Probability line equation:

$$\ln x(t) = \overline{\ln}\, x + K\, S \quad \text{..} \quad (11)$$

K is the frequency factor. based on the Cs value calculated in equation 11, the depth of rainfall with a return period of t years is obtained by finding the antilogarithm of the ln (t) value.

To find out whether the existing data is in accordance with the selected theoretical distribution, a goodness of fit test is carried out using the Smirnov Kolmogorov and chi-square tests.

a. For Return Period Less than 1 year

The estimated planned rainfall with a return period of less than 1 year cannot be done using the frequency analysis above. Determining the depth of rainfall with a probability of being equaled or exceeded one or more times in a year can be done using the approach below.

1. The length of the rainfall data series is determined (for example n years).
2. Data in each year is broken down from large to small.
3. In each year, the data is taken (k + 1) largest data, where k is the number of events equaled or exceeded in the desired year. So that during n years n x (k + 1) data are obtained.
4. This new data series is sorted from large to small.
5. Rainfall with a probability of being equaled or exceeded k times in a year is data in the order (n x k + 10).

Table 1: Analysis of Design Rain Analysis Results

Return Period (T)	Design Rainfall Frequency Analysis (mm)			
	Normal	Log Normal	Log Pearson Type III	Gumbel
5	188.601	139.711	237.467	193.508

10	205.512	153.019	274.053	221.775
25	221.655	166.901	331.270	257.487
50	235.107	179.428	382.308	283.980
100	245.869	190.123	441.209	310.281

Source: Analysis results, 2024

Based on the results of the rainfall frequency analysis, the ones that meet the design rainfall are based on Log Normal distribution with return periods of 5, 10, 25, 50 and 100 years respectively.

Table 2: Design Rainfall

Return Period (T)	YT	R_{24}
5	2.145	139.711
10	2.185	153.019
25	2.222	166.901
50	2.254	179.428
100	2.279	190.123

By using the Mononobe formula and design rainfall with Log Normal Distribution, the rainfall intensity is obtained as in table 3.

Table 3: Rainfall intensity with various return periods

T (Year)	R_{24} (mm)	I (mm/jam)
5	114	45,0343
10	155	60,9973
25	182	71,8987
50	212	83,5867
100	218	86,1431

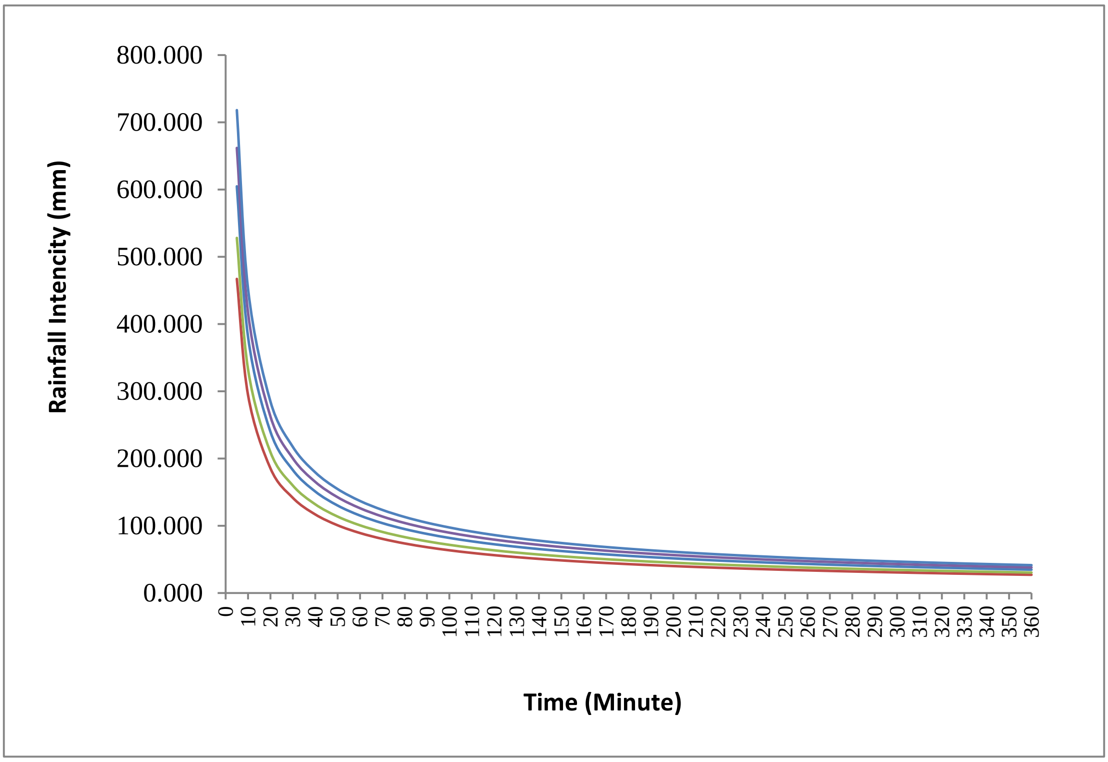

Figure 4: ***Intencity Duration Frequency*** **(IDF) Curve**

3.3. Channel Hydraulic Analysis

Qp = 0.2778 C I A

with:

Qp = Peak discharge (m3/sec)

C = Run off coefficient

I = Rain intensity with duration equal to flood concentration time (mm/hour)

A = catchment area (km2)

Q_{10} = 0.2778. 0.85. (60.9973 mm/hour) . (2.2341 km2)

Q_{10} = 32.18 m3/sec

3.4. Water Balance Analysis

The equation that can be used to calculate the water balance is as follows:

Qavailability - Qneeds = Δs

with:

$Q_{availability}$ = groundwater availability debit

Q_{needs} = groundwater requirement debit

To find out the amount of water that seeps into the soil is determined by calculating the groundwater potential with an empirical approach with the equation from Ffolliot (1980):

R = (P-ET). Ai. (1-Cro)

with:

R = Volume of water that seeps into the soil (m^3)

P = Rainfall (mm)

ET = Evapotranspiration (mm/year)

Ai = Land Area (m^2)

Cro = Surface runoff coefficient (Coefficient Run-off)

This water balance calculation has a scope limit, namely only in unconfined aquifers.

In Figure 2. below will illustrate that the calculation of incoming water (recharge) is infiltration from rainwater and irrigation water, while during the dry season the incoming infiltration only comes from irrigation water, then the calculation of the outgoing water is obtained by calculating evapotranspiration and water discharge taken by industries that have SIPA permits (Groundwater Extraction/Use Permit) and the assumption of groundwater extraction by the OKUT district community which has not been served by PDAM.

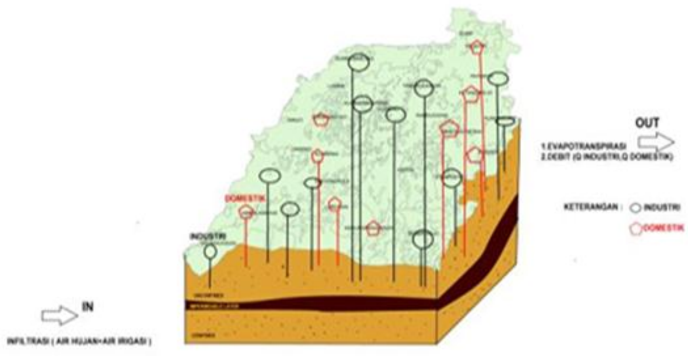

Figure 5: Illustration of Water Balance Calculation

Table 4: Average rainfall/month calculation

Month	Average rainfall/month (mm)
January	235,7
February	182,4
March	251,9
April	127,6

May	144,8
June	60,0
July	124,7
August	116,1
September	229,0
October	118,1
November	421,4
December	587,5
Total (mm/year)	2599,2

Table 4. above shows that the dry season occurs from June to October. Meanwhile, the calculation of the average temperature was obtained from 2021 to 2023, so that the average temperature value was 22.81ºC.

Furthermore, to obtain the runoff coefficient. The runoff coefficient used is the area of rice fields, dry fields, forests, buildings and yards and other lands. In table 4 below there is a combined Cro calculation.

Table 5: Combined Cro calculation

No	Type of Land Use	Cro Value	Area (A)	Cro.A	∑ (Cro.A)/A_{total}
1	Ricefield	0,5	35.148	17.574	
2	Buildings and Yards	0,65	68.582	44.578,3	
3	Moor	0,54	18.486	9.982,44	
4	Forest	0,5	73.657	36.828,5	
5	Others	0,35	2.971	1.039,85	
	Amount		198.844	110.003,1	0,553

3.5. Calculation in January

P = 235.7 mm/year = 0.2357 m/month

PET = 876 mm/month = 0.00876 m/month

Ai = 198,844

Cro = 1 - 0.55 = 0.45

3.6. Calculation of water balance

Volume of water that seeps into the soil or infiltration (R):

R(rainwater) = (P-ET)*Ai*(1-Cro)

= (0.2357 m/month - 0.00877 m/month) * 198,844 m2 * (0.45)

= 20,305.7 m3/month

Likewise for February to December as in the following table 6.

Table 6: Results of ∆s calculation in 2023

No	Month	R (m^3/det)	Q_{10} (m^3/det)	∆s
1	January	20.305,65	32.178,39566	11.872,75
2	February	15.500,59	32.178,39566	16.677,81

3	March	21.674,69	32.178,39566	10.503,71
4	April	10.632,88	32.178,39566	21.545,52
5	May	12.171,94	32.178,39566	20.006,46
6	June	4.584,05	32.178,39566	27.594,35
7	July	10.310,76	32.178,39566	21.867,64
8	August	9.594,919	32.178,39566	22.583,48
9	September	19.706,14	32.178,39566	12.472,26
10	October	9.773,879	32.178,39566	22.404,52
11	November	36.886,26	32.178,39566	-4.707,86
12	December	51.739,9	32.178,39566	-19.561,50

Description:

R = Water requirement (m3/sec)

Q = Water availability (m3/sec)

Δs = Different reservoirs (m3/sec)

It can be seen from the table above that the availability of water is still surplus or can meet the needs for irrigation, PDAM and other needs. As can be seen in the following graph.

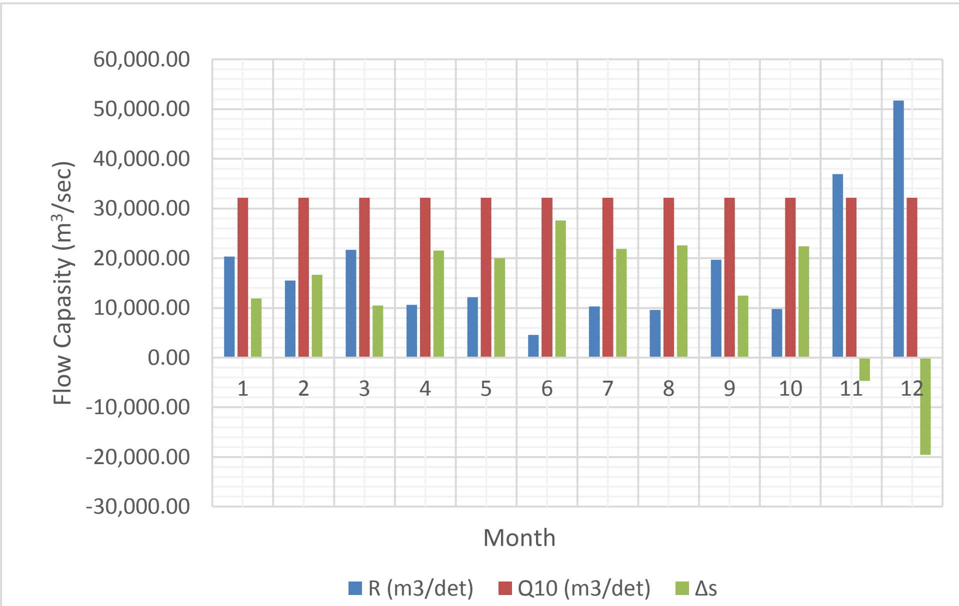

Figure 6: Graph of water availability in the Komering Sub-watershed in 2023

In Figure 6 above, it can be explained that the availability of water from January to October is still surplus, but for November and December 2023 there is a water shortage (deficit) due to the transition from the dry season to the rainy season.

IV. CONCLUSION

This study produced the following conclusions:

1. The potential of groundwater or the volume of water that seeps into the soil or infiltration (R) is 20,305.7 m^3/month with a rainfall value of 0.2357 m/month and a run-off coefficient value of 0.45 which occurs in the Komering Sub-watershed, East OKU Regency.

2. The water balance with water availability from January to October in 2023 is still a surplus (excess) of water) only for November and December there is a water deficit due to the transition from the dry season to the rainy season.

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