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Evaluation of Water Availability in Batukarut to Fulfill Irrigation Water Needs in Batukarut and Clean Water PDAM Sukabumi City

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Abstract. The condition of water availability in the Batukarut area could be more stable in meeting clean water and irrigation needs, so there is a need for further analysis to fulfill clean water and irrigation needs. This research aims to determine the conditions of water availability, the amount of clean water needed, irrigation needs, and the distribution of water when there is a shortage. The method used to determine water availability is the FJ Mock (1973) method with the water balance principle [1]. The research results show that water availability in Batukarut is 90%; the maximum discharge occurs in February with a value of 231,5 liters per second, and the minimum value occurs in September and October with 87,3 liters per second. PDAM Tirta Bumi Wibawa Sukabumi's clean water requirement is 150 liters per second. Regarding water requirements for irrigation, the maximum requirement occurs in May with a discharge of 414.4 liters per second, while the minimum requirement occurs in November with a value of 0.00 liters per second. The distribution of water needs in February requires clean water of 150 liters per second and irrigation needs of 87.3 liters per second; the distribution of water needs in October requires clean water of 50 liters per second and irrigation needs of 37.3 liters per second.

Keywords: Water availability, PDAM, irrigation, cropping patterns, water balance

INTRODUCTION

Per capita, water availability in many locations worldwide continues to decline. One reason is the increasing proportion of the global population to the amount of water available in many parts of the world. The global population has increased from 2 billion in 1950 to the current population of 7.4 billion for essentially the same water availability [2]. Global per capita water availability has had an inverse relationship, decreasing by a factor greater than three over the recent period [3]. The increasing need of the people of Sukabumi City for clean water, both for daily and agricultural needs, is in line with the growing population density in Sukabumi City in 2021, recorded at 350.803 people [4]. In 2019, PDAM TBW customers were recorded at 21.579, increasing yearly [5].

In research conducted by [6] titled Investigation of the Availability of Surface Water in the South Solok Limestone River for Raw Water Needs. In the last five years, there has been an increase in the number of PDAM customers at the South Solok Regency and in research conducted by [7] with the title "Analysis of Global Planting Management Plans (RTTG) in the Cirasea Irrigation Area, Bandung Regency" Olivvia Sidabutar, and Sophia Dwiratna (2022) stated that the Cirasea Irrigation Area is one of the potential areas as a contributor to rice production which can meet food availability and is the No. 1 producer of quality rice. 1 in Bandung Regency.

PDAM TBW Sukabumi City Resources are unstable and have not yet reached the required normal discharge. Batukarut is a source of raw water that meets the clean water needs of PDAM TBW Sukabumi City, which has yet to meet its average capacity needs [5]. Situ Batukarut has an agricultural area of 366 Ha located in 4 villages: Pasirhalang, Selaawi, Langensari, and Margaluyu [8]. Batukaut is one of the suppliers of clean water needs to

PDAM TBW Sukabumi City with a regular flow of 150 liters/second, whereas, in 2021, the minimum flow condition will occur in March with a flow of 36,5 liters/second or around 24% of the normal flow.

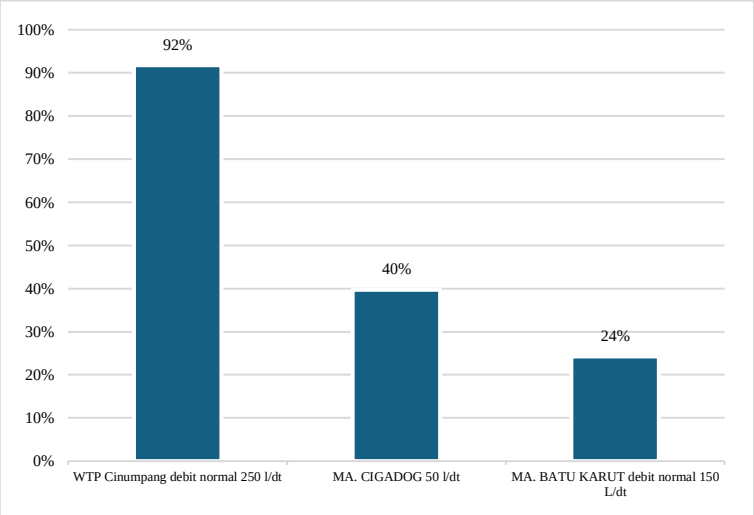


FIGURE 1. Graph of drinking discharge from raw spring water from PDAM Sukabumi City

So, there is a need for further research related to water availability to meet the agricultural and clean water needs of PDAM TBW Sukabumi City based on priorities in Batukarut. This research aims to determine the availability of water in Batukarut and the need for water supplied by Batukarut. When there is a shortage, clean and irrigation water needs are distributed based on priority needs in Batukarut. Priority needs in Batukarut Based on interview results; irrigation needs are prioritized because the agricultural sector is one of the main livelihoods in the Batukarut area.

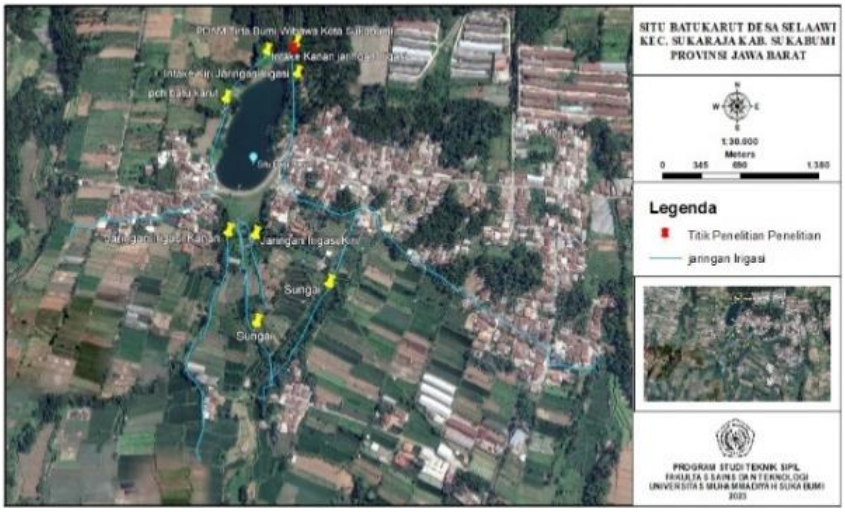


FIGURE 2. Conditions of the study location.

METHOD

River discharge in this study was used to determine water availability using the FJ Mock method with the water balance concept.

$$P = Ea + \Delta GS + TRO \quad (1)$$

[1]

With increment GS, GSAs precipitation or rain, Ea is the actual evapotranspiration, GS is the change in groundwater storage, and TRO is the total runoff.

Penman method in Evapotranspiration analysis. The following equation is used.

$$E = \frac{AH+0,27D}{A+0,27} \quad (2)$$

$$H = R(1-r)(0,18+0,55\,S) - B\left(0,56-0,092\sqrt{e_d}\right)(0,10+0,9S) \quad (3)$$

$$D = 0,35(e_a - e_d)(K+0,01w) \quad (4)$$

With H is energy budget, D is heat for evapotranspiration, Ais the slope of the vapor pressure curve mmHg/F ^{0}, Bis black body radiation (mmH_2 O)/day, ande_a is the saturated water vapor pressure in mmHg.

Actual evapotranspiration uses the following equation.

$$E_a = E_p - \Delta E \quad (5)$$

$$\Delta E = E_p\left(\frac{m}{20}\right)(18-n) \quad (6)$$

The equation used to determine water surplus is as follows.

$$WS = (P - E\_a) + SS \quad (7)$$

Soil moisture storage (soil moisture storage) is abbreviated as SMS. The following are the equations used in the Mock method:

$$SMS = ISMS + (P - E_a) \quad (8)$$

The equation used to determine the infiltration value is as follows:

$$\text{Infiltasi (i)} = WS \times if \quad (9)$$

Several things can influence the value of groundwater storage, namely, infiltration when determining the value of groundwater storage. The equation used is as follows.

$$GS = \{0,5 \times (1+K) \times i\} + \{K \times Gsom\} \quad (10)$$

Changes in groundwater storage affect the formation of river base flow (base flow) BF. The following equation is used to determine the base flow value.

$$BF = i - \Delta GS \quad (11)$$

With BFis the base flow of the river, (base flow), I is infiltration, and ΔGS is changes in groundwater storage. The equation is used to calculate direct runoff.

$$DRO = WS - i \quad (12)$$

Total runoff (TRO) is the base flow, direct runoff, and storm runoff. The following equation is used.

$$TRO = BF + DRO + SRO \quad (13)$$

A reliable debit is a debit that is likely to be equal to or exceed the desired debit. The probability determined in this analysis is Q90%. The equation used to determine the probability value is as follows.

$$p = \frac{m}{n} \times 100\% \quad (14)$$

Water demand is the amount used for various purposes or community activities in the region. In the case of this research, two needs must be met: the clean water needs of PDAM Tirta Bumi Wibawa Sukabumi City and the water needs for irrigation.

Irrigation Needs

Determining the amount of irrigation water needed is influenced by the land area, planting pattern, actual evapotranspiration, effective rainfall, type of planting, and efficiency of irrigation channels. The following equation is used.

$$NFR = ETc + P + WLR - Re \quad (15)$$

Land preparation in this research used the method developed by Van de Goor and Zijlsha (1968) [9]. The following equation is used.

$$IR = Me^k/(e^k - 1) \quad (16)$$

$$M = Eo + P \quad (17)$$

$$K=M.T/S \quad (18)$$

With IR is the need for irrigation water at the rice field level (mm/day), M is the need for water to replace water losses that occur due to evaporation and percolation in saturated rice fields, Eois the evaporation of open water taken 1,7 Eto during land preparation (mm/day), Pis the percolation (mm/day), Tis the land preparation period (days) and Sis the water requirement, for soil saturation plus a water layer of 50 mm.

Consumptive use is the amount of water plants use for the photosynthesis process and the plant. The following equation is used.

$$ETc = Kc.ETo \quad (19)$$

The effective rainfall is set at $R_{80,}$ which means rainfall smaller than R_{80} has a 20% chance of occurring. The following equation is used.

$$fri = \frac{fai}{n} \quad (20)$$

The rainfall for rice plants is 70% of the semi-monthly rainfall from 80% rainfall, while the effective rainfall for secondary crops is 50% of the 80% rainfall. The following equation is used to determine effective rainfall.

$$\text{Re Paddy} = \frac{R_{80} \times 0,7}{\text{Observation period}} \quad (21)$$

$$\text{Re palawija} = \frac{R_{80} \times 0,5}{\text{Observation period}} \quad (22)$$

Where Reis the effective rainfall (mm/day), and s is d R_{80} is, the rainfall with an 80% probability of occurrence.

Clean Water Needs

The water requirement determined in Sukabumi City is 100-125 l/o/h. This is because Sukabumi City is a medium-sized city with a population of 100.000-500.000 000 [9] [10]. In this study, the amount of clean water needed is set at 150 liters/second, the amount of discharge expected from Batukarut so that needs can be met typically.

RESULTS AND DISCUSSION

Climate change will likely cause increases in temperature and changes in rainfall patterns, potentially impacting water resources [11]. The rainfall data is obtained from the Cisadea-Cibareno SDA Center, West Java, in this hydrological analysis. The regional rainfall used is the rainfall at the Batukarut point because the nearest rain measuring station point cannot represent the rainfall in the Batukarut area, or the data needs to be representative. Rainfall will be shown in the following image.

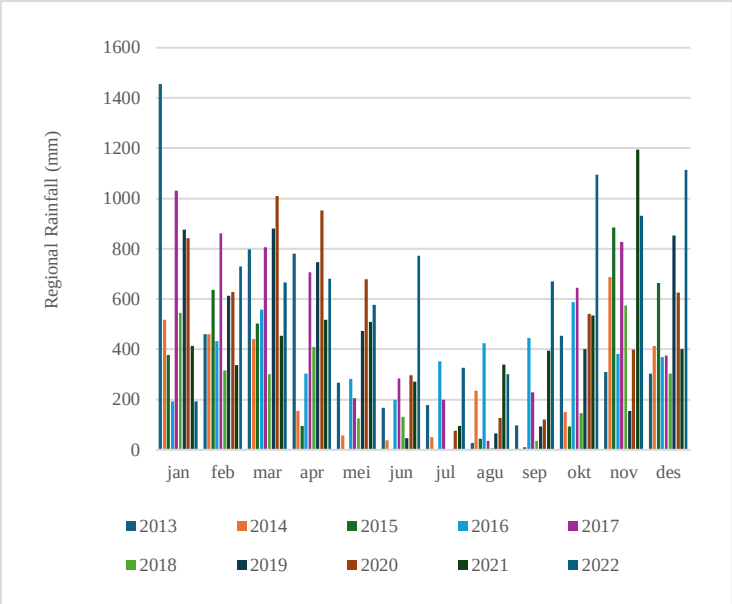
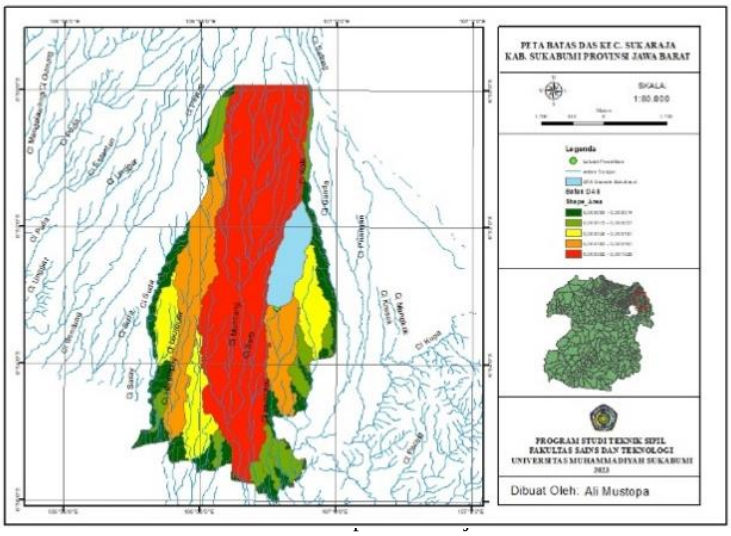


FIGURE 3. Batukarut rainfall graph
(Source: Cisadea-Cibareno SDA Center, 2023)

The climate data obtained from the NASA website, namely Power.larc.nasa.gov, has data for the last ten years.

The catchment area was calculated using the digitization method with the Arcmap 10.8 rock application. The following watershed map is shown in Figure 4.



In determining water availability, water availability analysis is carried out using the F. J. Mock method with the water balance concept.

The soil surface proportion (m) is determined to be 30%, the moisture capacity or SMC is determined to be 200mm, the infiltration coefficient value is determined to be 0,85, the value of the recency constant is 0,85, and the percentage factor is determined to be 0,1.

Calculate the average monthly debit using the FJ Mock method, namely the arrangement of columns and rows. This debit calculation is carried out each month in one year of observation. An example of the discharge calculation described is in the first two weeks of January 2013. The following is the river discharge obtained using the F. J Mock method.

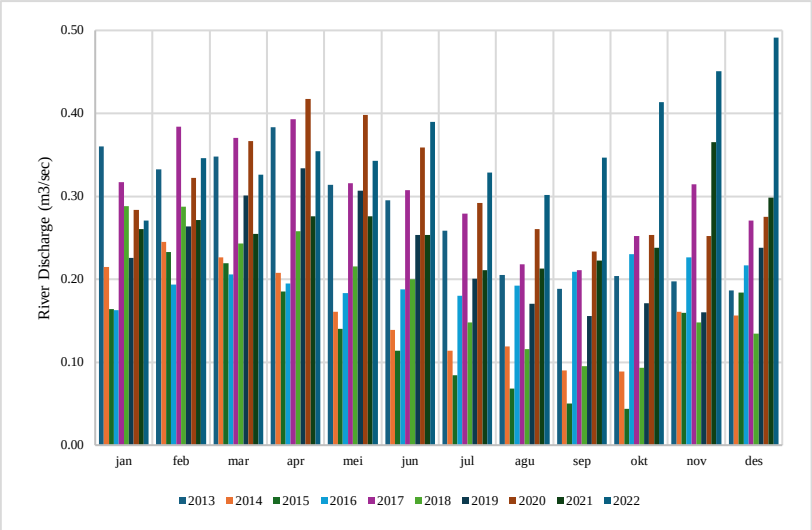


FIGURE 5. Batukarut River Flow Discharge

An average debit graph is created based on the monthly debit each year. The average monthly discharge of Batukarut is as follows.

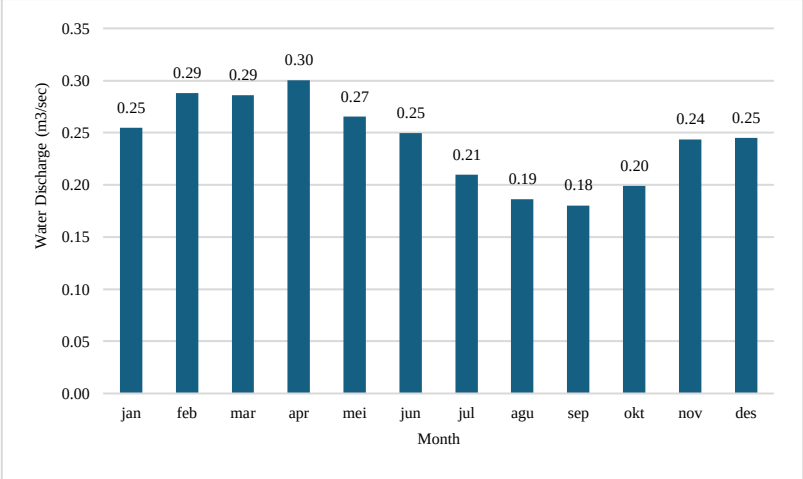


FIGURE 6. Average discharge of limestone

Based on this graph, the maximum average discharge value occurs in April with a 0,3 m 3 /second value, and the minimum average value occurs in September with 0.18 m ^{3} /second.

After obtaining the river discharge, the mainstay discharge can be determined. The mainstay debit used is Q 90%. The following is a reliable debit using a 90% probability.

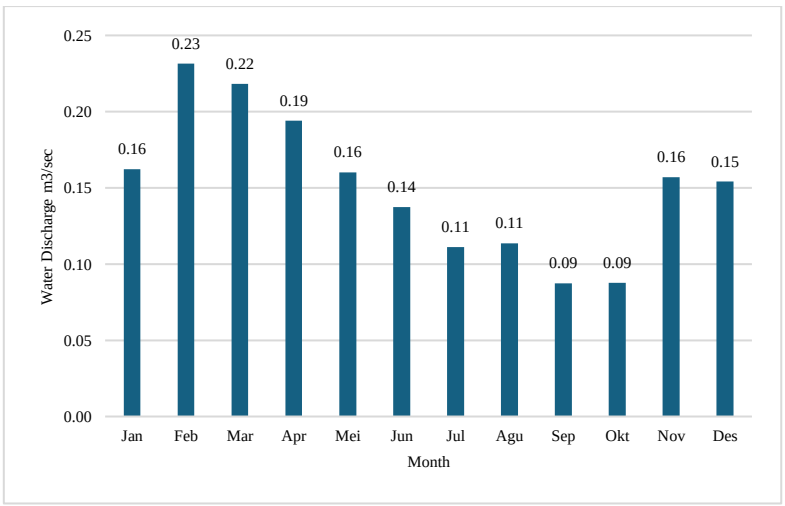


FIGURE 7. Q mainstay discharge 90%

Based on this graph, the maximum discharge value occurred in February with a value of 0,23 m^3/second, and the minimum value occurred in September and October with 0,09 m^3/second.

The area irrigated in the first planting season for rice is 200 Ha, Batukarut; the value obtained is then multiplied by the specified area.

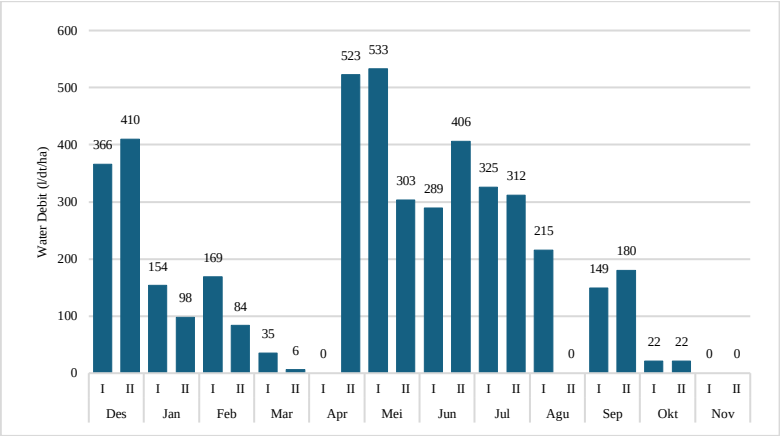


FIGURE 8. Graph of irrigation needs

Based on calculations using the global planting planning method, it is known that the maximum value of water requirements occurs in May in the first period with a value of 533 L/s, while the minimum value of irrigation water requirements occurs during the harvest and drying period, namely April, August and November.

In the case of Batukarut, in meeting irrigation needs, the Batukarut dam helped some, but the dam did not help others. The irrigation area assisted by the dam is 60,32 Ha, and the irrigation area assisted by the dam is 139,68 Ha.

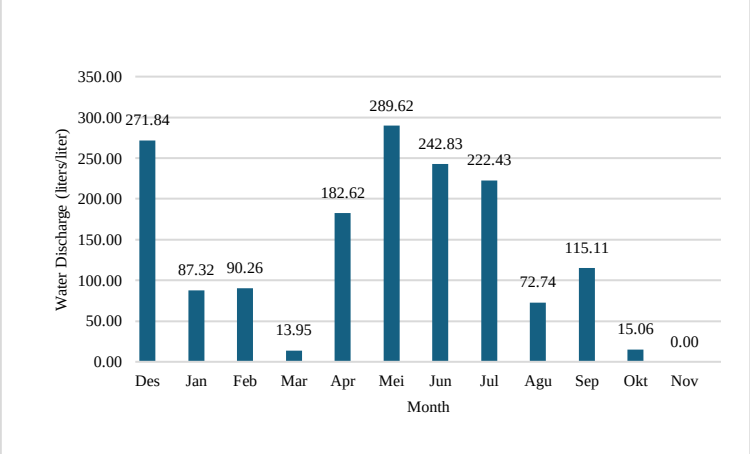


FIGURE 9. Graph of irrigation needs for 139,68 Ha

Based on this graph, the maximum value occurred in May with a value of 289,62 liters/second, while the minimum occurred in November with 0.00 liters/second.

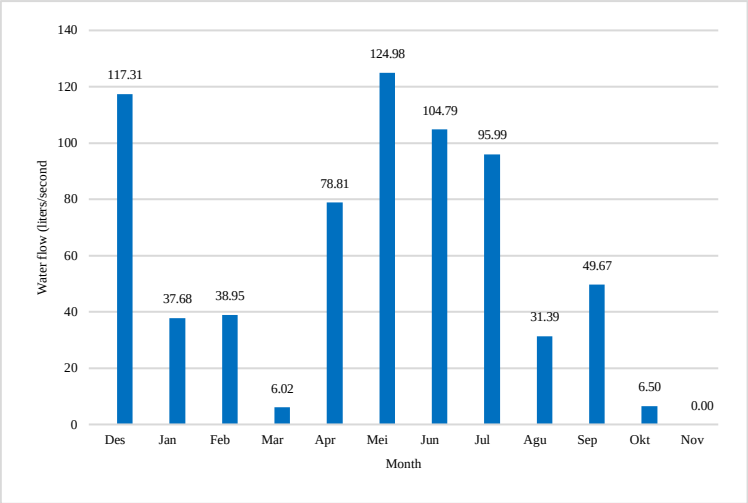


FIGURE 10. Graph of irrigation needs for 60,32 Ha

Based on this graph, the maximum value occurred in May with a value of 12,4 liters/second, while the minimum occurred in November with a value of 0.0 liters/second.

Sukabumi is included in the city category, with a population of 2021 of 350.804 [4]. So, the unit of water requirement in Sukabumi City is 100-125 l/o/h. The expected normal discharge from Batukarut is 150 liters/second, so this amount of discharge from Batukarut can meet the clean water needs of 103.680 people daily if the water requirement is 125 liters/person/day.

The total water need is the sum of clean water needs and irrigation needs. The results of the calculations are shown in Table.

TABLE 1. Total water requirements

No	Month	Irrigation Needs (liters/second)	Clean Water Needs (liters/second)	Amount
1	Jan	124,9	150	274,9
2	Feb	129,1	150	279,1
3	Mar	20,0	150	170,0
4	Apr	261,3	150	411,3
5	May	414,4	150	564,4
6	Jun	347,4	150	497,4
7	Jul	318,3	150	468,3
8	Aug	104,1	150	254,1
9	Sept	164,7	150	314,7
10	Oct	21,5	150	171,5
11	Nov	0	150	150,0
12	Dec	388,9	150	538,9

Based on this table, the maximum value occurred in May with a value of 564,4 liters/second, while the minimum value occurred in November with 150 liters/second.

Based on this table, it is known that there was a surplus in March and November. The following is a graph of the water balance. The water balance is shown in Table 2.

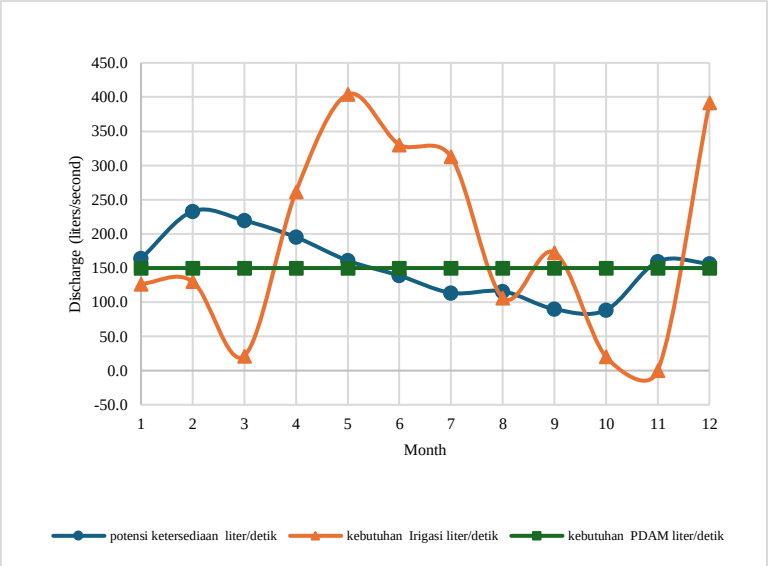


FIGURE 11. Water balance

There is still a need for more water, so fulfillment must be distributed based on priority needs. For there to be an adjustment between demand and availability, it is essential to reduce the demand for clean water when the amount of irrigation demand increases; even for irrigation demand during land processing, it is necessary to divide land preparation time so that availability and demand are balanced. The following is a division of meeting clean water needs and irrigation needs based on priority.

TABLE 1. Water balance

Month	Potential water availability	Water Requirements		Water Balance	Information
		Irrigation	PDAM		
	lt/sec	lt/sec	lt/sec	lt/sec	
Jan	162,2	124,9	150,0	-112,8	Deficit
Feb	231,5	129,1	150,0	-47,7	Deficit
Mar	218,4	20,0	150,0	48,4	Surplus
Apr	194,1	261,3	150,0	-217,2	Deficit
May	160,2	414,4	150,0	-404,2	Deficit
Jun	137,2	347,4	150,0	-360,2	Deficit
Jul	111,0	318,3	150,0	-357,3	Deficit
Aug	113,5	104,1	150,0	-140,6	Deficit
Sept	87,3	164,7	150,0	-227,4	Deficit
Oct	87,8	21,5	150,0	-83,8	Deficit
Nov	156,9	0,0	150,0	6,9	Surplus
Dec	154,1	388,9	150,0	-384,9	Deficit

TABLE 3. Distribution of water needs

Month	Water availability	PDAM	Fulfillment of Irrigation		
			Right intake	Left intake	Dam
Jan	162,2	50	10,8	26,9	74,5
Feb	231,5	125	11,1	27,8	67,5
Mar	218,4	150	1,7	4,3	62,3
Apr	194,1	100	22,5	56,3	15,3
May	160,2	50	8,9	22,3	78,9
Jun	137,2	50	7,5	37,4	42,3
Jul	111,0	50	27,4	17,1	16,4

Month	Water availability	PDAM	Fulfillment of Irrigation		
			Right intake	Left intake	Dam
Aug	113,5	50	9,0	22,4	32,1
Sept	87,3	50	3,5	8,9	24,8
Oct	87,8	50	1,9	4,6	31,3
Nov	156,9	150	0,0	0,0	6,9
Dec	154,1	75	8,4	21,0	49,8

After dividing the fulfillment of water needs based on priorities, there is a balance between needs and water availability. The following is a graph of the distribution.

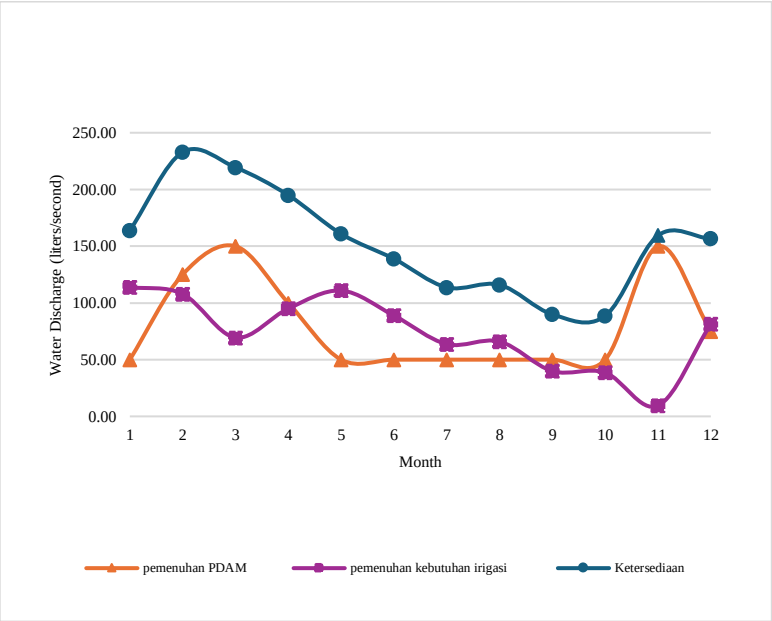


FIGURE 12. Graph of distribution of water needs based on priority.

The water discharge entering the dam will then be used for irrigation needs with an area of 139.68 Ha. For there to be stability in water storage in the dam, it is necessary to reorganize the fulfillment of irrigation needs by dividing the land preparation period.

The following is the condition of water storage in the dam after adjusting irrigation requirements to the availability at the dam, shown in Table 4.

TABLE 2. Dam condition.

Month	Dam inflow (lt/sec)	Availability of water in the dam (liters)	Exflow for irrigation (lt/sec)	Water in the dam (%)	Runoff
Jan	74,5	226,684,384,3	87,3	86,8	0,0
Feb	67,5	189,111,704,2	90,3	72,4	0,0
Mar	62,3	318,696,230,0	14,0	100,0	22,0
Apr	15,3	241,281,236,5	45,7	92,4	0,0
May	78,9	258,716,439,8	72,4	99,1	0,0
Jun	42,3	214,686,926,4	60,7	82,2	0,0
Jul	16,4	109,767,875,7	55,6	42,0	0,0
Aug	32,1	130,808,291,6	24,2	50,1	0,0
Sept	24,8	122,743,888,4	28,8	47,0	0,0
Oct	31,3	166,163,233,5	15,1	63,6	0,0
Nov	6,9	184,536,648,5	0,0	70,7	0,0
Dec	49,8	135,821,423,8	68,0	52,0	0,0

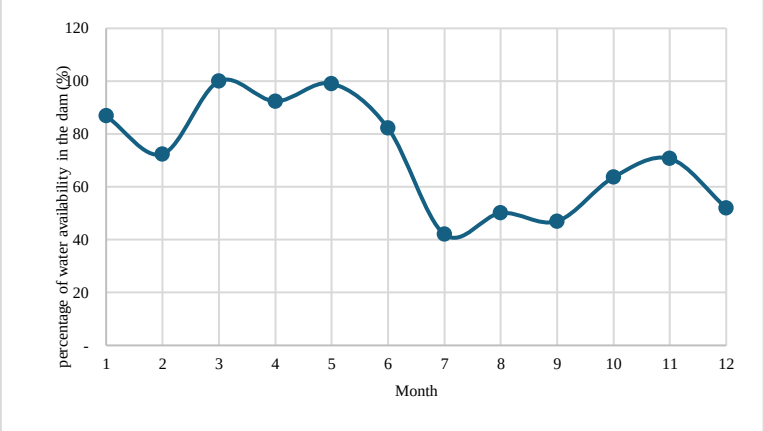


FIGURE 13. Condition of water availability in the dam

Based on this graph, normal dam conditions occur in March, April, May, and June; apart from these months, there are shortages, but this is still in a safe condition,

CONCLUSION

Water availability in Batukarut using the reliable discharge Q 90%, the maximum discharge occurs in February with a value of 231,5 liters/second and the minimum value occurs in September and October with a value of 87,3 liters/second, PDAM Tirta Bumi Wibawa Sukabumi's average capacity for clean water is 150 liters/second, Regarding water requirements for irrigation, the maximum requirement occurs in May with a discharge of 414,4 liters/second, while the minimum requirement occurs in November with a value of 0,00 liters/second, Maximum water availability occurred in February with a value of 231,5 liters/second divided by two for clean water needs of 54% or 125 liters/second and for irrigation needs of 46% or 10 6,45 liters/second, In terms of minimum water availability which occurs in October, the value is 87,3 liters/second divided by two for clean water needs of 57,3% or 50 liters/second and irrigation needs of 42,7% or 37,26 liters/second,

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