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Optimization of the Pattern of Reservoir Operating to Fulfill the Need for Irrigation Water in Rain Funded Area in Paku Beto Village, East Barito Regency, Central Kalimantan Province

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Abstract— *In agriculture, one of the critical success factors in obtaining agricultural products is sufficient water availability. There are generally two seasons in the tropics, namely, the rainy season and the dry season. In the rainy season, the available discharge is sufficient to fulfill the needs of plants. In Paku Beto Village, the land is dry and flat, with some of the vegetation in shrubs, forests, and oil palm and rubber plantations. Paku Beto Village is one of the villages experiencing water shortages to fulfill the irrigation water needs of agricultural land areas. Generally occurs in the dry season, while in the rainy season, the water is very abundant. The purpose of this study is to determine the amount of discharge filling the reservoir to fulfill irrigation water needs, the amount of release required for irrigation needs, and select the optimal pattern of reservoir operation. One of the optimization techniques used in this research is linear programming. The discharge of filling water in Paku Beto Reservoir which is used to fulfill irrigation water needs for agricultural land in each period is 24,127 m3 in October, 29,120 m3 in November, 38,422 m3 in December, 48,704 m3 in January, 42,435 m3 in February, 43,821 m3 in March, 44,422 m3 in April, 37,435 m3 in May, 29,717 m3 in June, 21,987 m3 in July, 24,123 m3 in August, 25,666 in September per period.*

Keywords— *Paku Beto Reservoir, Optimization of the pattern, Operating to fulfill the need, linier programming*.

I. INTRODUCTION

In agriculture, one of the critical success factors in obtaining agricultural products is sufficient water availability. There are generally two seasons in the tropics, namely, the rainy season and the dry season. In the rainy season, the available discharge is sufficient to fulfill the needs of plants. However, in the dry season, only a tiny amount of rain falls, so the general discharge is not sufficient to fulfill the water needs of the farmers' crops. Farmers are the primary profession of the East Barito community, especially in Paku Beto Village and several other jobs. Based on the data, East Barito Regency is one of the regencies in Central Kalimantan Province, which has an area of 3,834 km2, with a geographical location between 01°04'00"- 02°02'00" latitude and 114°55'00"- 115°20'00" East Longitude, with an area of 6,637 ha of rice fields and 59,470.12 ha of plantations [1]. In Paku Beto Village, the land is dry and flat, with some of the vegetation in shrubs, forests, and oil palm and rubber plantations. Paku Beto Village is one of the villages experiencing water shortages to fulfill the irrigation water needs of agricultural land areas. Generally occurs in the dry season, while in the rainy season, the water is very abundant. One alternative solution to the problem in fulfilling the shortage of irrigation water needs is optimizing the volume of water storage every month and optimizing the reservoir operation system so that the expected storage capacity can be achieved to fulfill irrigation water needs in the agricultural land area. In utilizing the reservoir, it must be remembered that the quantity of water is minimal, so the use of water must be done as well as possible. For this reason, it is necessary to operate the optimal service of reservoir water to fulfill the available irrigation needs [2].

In the area of agricultural land, there is already a reservoir located in the Mira Pakat farmer group, which functions to fulfill the irrigation water needs of the farmer group. In general, the physical condition of the Paku Beto Reservoir is still excellent and well-maintained; however, with the current adequate reservoir volume, the reservoir is not optimal to fulfill irrigation water needs with the hope of two planting periods in one year with a rice-paddy cropping pattern. The amount of water needed for the irrigation system at the site is generally influenced by factors such as the method of giving water, the way of managing and maintaining the existing canals and buildings, the amount of rain that falls, the time of planting and tilling the soil, as well as the cropping pattern used [3] (Nuf'a, et al., 2016). Therefore, it is necessary to have a way for the Paku Beto Reservoir so that the output of water for irrigation can be regulated optimally. The purpose of this study is to determine the amount of discharge filling the reservoir to fulfill irrigation water needs, the amount of release required for irrigation needs, and select the optimal pattern of reservoir operation.

The location of this research study is in Paku Beto Village, Paku District, East Barito Regency. Access to the location can be reached by land. With the distance from Palangka Raya City to Tamiang Layang City ± 255 km, and Tamiang Layang City to the reservoir location ± 40 km. The optimization approach used is a linear program to obtain the most appropriate policy for optimally making reservoir discharge decisions so that irrigation water needs can be fulfilled throughout the expected planting season period.

II. REVIEW OF LITERATURE

In implementing a reservoir, it is necessary to have fields of knowledge that support each other for the perfection of the

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planning results. The areas of science include geology, hydrology, hydraulics, and soil mechanics [4]. Each watershed has different unique characteristics. This requires great care in applying a suitable theory to the drainage area. In this literature review, a brief description of water requirements, hydrological analysis, theoretical basics of the implementation of the reservoir will also be described, which will be used in the calculation of construction and complementary buildings [5]. Management of reservoirs in water-scarce environments with significant hydrological uncertainty and suboptimal management can cause economic losses to water users during droughts or water spills during floods [6](Davidsen et al., 2014). An essential characteristic of a reservoir is its ability to hold water [7]. Therefore it is essential to understand the features of the reservoir. The policy for the operation of reservoir storage capacity involves the division into several sections based on the planned function in the process of the reservoir/small dam, the distribution of storage capacity can be permanent or variable depending on the season or other factors [8]. The physical condition of the Paku Beto Reservoir is currently still in good condition, and it can be seen on the sides of the wall or body of the reservoir, which is made of concrete and is still in good condition. Paku Beto Reservoir has a length of 57 m, a width of 40 m, and a depth 6 m. This reservoir consists of an adequate reservoir and a dead reservoir.

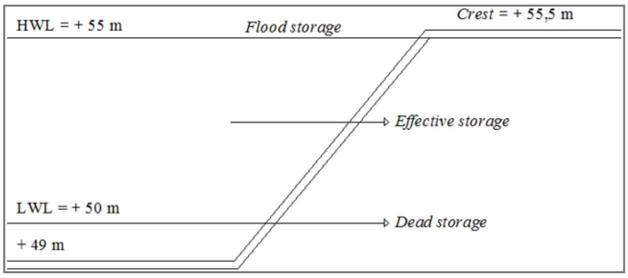

Fig. 1. Paku Beto Reservoir Zone Source: Observations.

The dead reservoir is at an elevation of 49 m, and the maximum adequate water level is at the height of 55 m. The reservoir capacity is 13,680 m^3. In operation, rainwater is stored in the reservoir building and operated to fulfill water needs during the dry season. During the dry season and the water stored in the reservoir is below the adequate storage, to fulfill the water needs of plants, a pump can be used to pump water from the reservoir to agricultural land. The location of the reservoir is also equipped with a pump house. The operation of a reservoir is the process of collecting the water flow into a reservoir and releasing water that has been holded for various specific purposes [9] Completion or policy-making of reservoir operations cannot be separated from optimization to determine maximum profits and or minimum losses for optimal utilization of reservoir water [10]. The guideline for the operation of the reservoir is how to use the reservoir storage capacity in determining the regulation of flow for specific purposes where the purpose of this reservoir is irrigation water. In the operation and optimization of reservoirs, an optimal operating policy is needed to determine the actual optimal value of the decision and state variables [11](G. Naadimuthu and E. S. Lee, 1982).

One form of reservoir equation that is often used for reservoir/reservoir operations is the reservoir/small dam balance equation which gives the relationship between inflow (rain), outflow, and changes in the reservoir which is called behavioral analysis (simulation model) in this case is a stage transformation for linier programs. The equation is stated as follows.

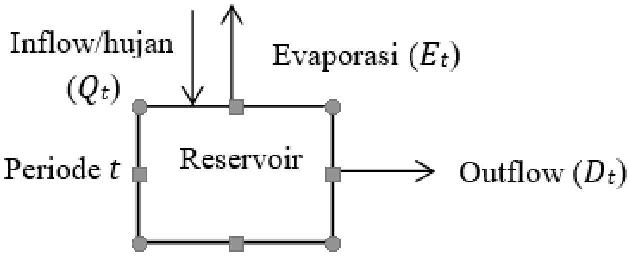

Fig. 2. Optimization Model.

For the simulation model of reservoirs (small dam), the simulation period can cover one year of operation or more depending on the needs. One year of operation is further divided into several periods: monthly, 15 days, ten days, weekly, or daily. The general equation for simulating reservoir operations is the reservoir balance equation. In this case, it can be seen in the previously described equation. One form of reservoir equation that is often used for reservoir operations is the reservoir/small dam balance equation which gives the relationship between the inflow (rain), outflow, and changes in the reservoir which is called behavioral analysis (simulation model) in this case is a stage transformation for linier programs. The equation is stated as follows.

III. Research Methodology

In reservoir optimization, it means finding the best value from the purpose function. First, a survey and investigation must be carried out from the area or location in question to obtain data related to optimization and flow patterns that are completed and observed.

A. Data collection

Every time researching optimization will need supporting data, both primary data and secondary data.

(1) Primary data is obtained from direct interviews with interested parties and other actual data related to current conditions in the field.

(2) Secondary data, namely archival data obtained from relevant agencies and data that affect this research. Every time researching optimization will need supporting data, both primary data and secondary data.

In research on the optimization of reservoirs in Paku Beto Village, Paku District, East Barito Regency, the data collected is.

1. Topographical data

This data is used to determine the elevation, the layout of the reservoir's location, and estimate the

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reservoir's volume.

2. Irrigated crop data

This data is used to determine the amount of water reservoir required by the reservoir to fulfill the need for irrigation water and plan an efficient cropping pattern.

3. Hydrological data

This data is in the form of climatological data, evapotranspiration and other supporting data for the last ten years to determine the nature and characteristics of the hydrology above the ground surface, wherein this thesis the most influential hydrological factor is rainfall (precipitation).

4. Soil data

This soil data is needed to determine the condition of the soil at the location of the reservoir. This data is in the form of physical data and soil mechanics (Das, 1995). This aims to determine the chance of water loss due to infiltration in the reservoir.

B. Implementation Methodology

The implementation method is used to determine the steps to be taken in the optimization and pattern of reservoir operation in Paku Beto Village, Paku District, East Barito Regency. The methodology used is.

1. Problem Identification

   To be able to solve the problem correctly, the main concern must be known first. The solution to the problem that will be made must refer to the issues that occur.

2. Literature Study

   This literature study was conducted to obtain a reference in the analysis of calculation data to optimize reservoirs.

3. Data Collection

   The data is used to determine the cause of the problem and plan the optimization of the reservoir. In addition, data collection was carried out by direct interviews with resource persons from relevant agencies (PSDA) for problem-solving.

4. Data Analysis

   The data that has been obtained is processed and analyzed according to their needs. Each information is different in processing and analysis. With appropriate processing and analysis, variables will be accepted that will be used in optimization planning and reservoir operation patterns.

5. Optimization Planning

   The results of the data analysis are used to determine the appropriate reservoir optimization plan and appropriately adapted to the field conditions that support the reservoir optimization.

C. Thesis Flowchart

Optimizing the reservoir operation pattern is closely related to a clear flowchart, appropriate analytical methods, and completeness of supporting data. The stages of optimization analysis and reservoir operation patterns are as follows.

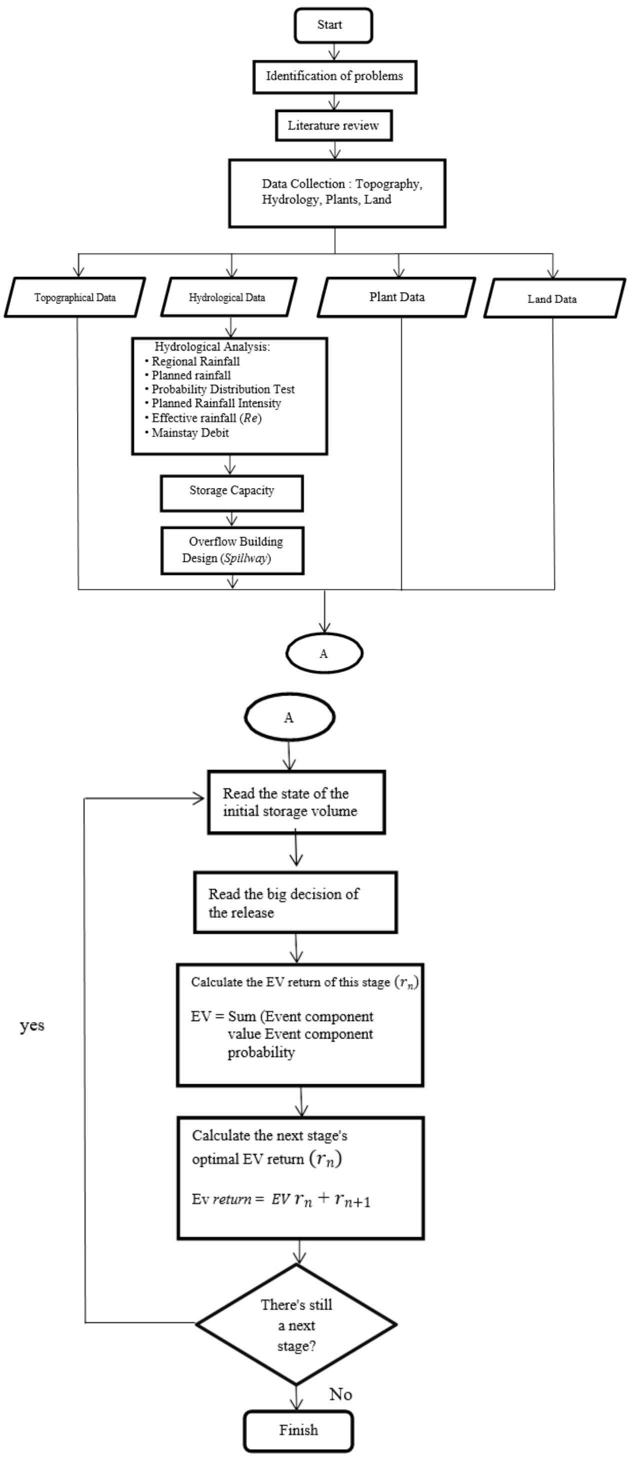

Fig. 3. Linear Program Optimization Flowchart.

Figure 4 is a Reservoir simulation flowchart.

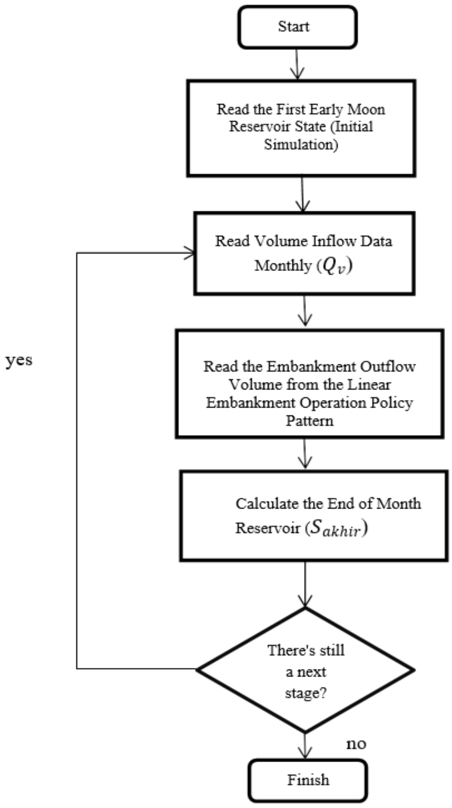

Fig. 4. Reservoir Simulation Flowchart.

IV. RESULT

A. *Reliability Discharge*

Reability discharge is a predetermined minimum discharge that can be used to fulfill water needs to calculate the reliability discharge used daily rainfall data for ten years. In calculating the reliability discharge, rainfall data is used from 1 (one) rain station, namely Tampa Station. This calculation uses the water balance analysis method from Dr. F.J. Mock based on monthly rainfall data, number of rainy days, evapotranspiration, and hydrological characteristics of the drainage area. Rainfall data required is rainfall data that is exceeded 80% based on the amount of rain each year.

B. *Crop Patterns and Planting Planning*

A cropping pattern is a pattern of planting plants for one year, a combination of plant sequences. Planned cropping patterns and arrangements are intended to increase water use efficiency and maximize profits based on the planned cropping pattern. An irrigated area generally has a specific cropping pattern, but a paddy-paddy-Palawija cropping pattern is recommended if there is no suitable pattern in the area. After obtaining water requirements for land management and growth, look for the amount of water needed for irrigation based on cropping patterns and cropping plans from the area observed [12](Directorate General of Irrigation, 1985).

TABLE I. Reliability Discharge Recapitulation Calculation.

No	**Year**	**Reliability Discharge (m³/s)**						
		Month						
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	2020	0,0000369	0,0000303	0,0000312	0,0000309	0,0000215	0,0000229	0,0000152
2	2019	0,0000441	0,0000533	0,0000338	0,0000586	0,0000374	0,0000234	0,0000232
3	2018	0,0000247	0,0000327	0,0000330	0,0000222	0,0000195	0,0000212	0,0000131
4	2017	0,0000340	0,0000309	0,0000282	0,0000318	0,0000304	0,0000289	0,0000170
5	2016	0,0000281	0,0000419	0,0000467	0,0000289	0,0000261	0,0000220	0,0000232
6	2015	0,0000376	0,0000312	0,0000390	0,0000343	0,0000266	0,0000174	0,0000118
7	2014	0,0000170	0,0000151	0,0000109	0,0000090	0,0000070	0,0000058	0,0000122
8	2013	0,0000230	0,0000210	0,0000120	0,0000099	0,0000077	0,0000063	0,0000049
9	2012	0,0000312	0,0000324	0,0000267	0,0000171	0,0000289	0,0000153	0,0000109
10	2011	0,0000386	0,0000295	0,0000267	0,0000365	0,0000216	0,0000173	0,0000123

TABLE II. Theoretical Cropping Patterns.

No	**Description**	**Oct**		**Nov**		**Dec**		**Jan**	
(1)	(2)	(3)		(4)		(5)		(6)	
1	Period	I	II	I	II	I	II	I	II
2	Paddy planting period I (100%)	LP	LP	PD-1	PD-1	PD-1	PD-1	PD-1	PD-1
3	Paddy planting period II								
4	Paddy planting period III								
5	Water Needs	1,35	1,30	0,69	0,72	0,81	0,84		
6	S = Paddy field	1,35	1,30	0,69	0,72	0,81	0,84		
7	T = Secondary = S*1,15	1,55	1,49	0,79	0,83	0,93	0,96		
8	S = Primary = T*1,11	1,72	1,66	0,87	0,92	1,03	1,07		
9	Palawija planting period I								
10	Palawija planting period II								
11	Palawija planting period III								
	Area								
12	Q (water needs) (m³/s)	0,020	0,019	0,010	0,010	0,012	0,012	0,010	0,010

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TABLE II. Theoretical Cropping Patterns.

No	Description	Feb		Mar		Apr		May	
(1)	(2)	(3)		(4)		(5)		(6)	
1	Period	I	II	I	II	I	II	I	II
2	Paddy planting period I (100%)								
3	Paddy planting period II	LP	LP	PD-2	PD-2	PD-2	PD-2	PD-2	PD-2
4	Paddy planting period III								
5	Water Needs								
6	S = Paddy field	1,23	0,98	0,38	0,50				
7	T = Secondary = S*1,15	1,23	0,98	0,38	0,50	0,71			
8	S = Primary = T*1,11	1,41	1,13	0,44	0,57	0,72			
9	Palawija planting period I	1,57	1,25	0,49	0,64	0,62			
10	Palawija planting period II					0,61			
11	Palawija planting period III					0,71	0,72	0,62	0,61
	Area								
12	Q (Water needs) (m³/s)	0,040	0,032	0,013	0,016	0,023	0,024	0,020	0,020

TABLE II. Theoretical Cropping Patterns.

No	Description	Jun		Jul		Aug		Sept	
(1)	(2)	(3)		(4)		(5)		(6)	
1	Period	I	II	I	II	I	II	I	II
2	Paddy planting period I (100%)								
3	Paddy planting period II								
4	Paddy planting period III	LP	LP	PD-3	PD-3	PD-3	PD-3	PD-3	PD-3
5	Water Needs								
6	S = Paddy field								
7	T = Secondary = S*1,15	1,29							
8	S = Primary = T*1,11	1,20							
9	Palawija planting period I	0,75							
10	Palawija planting period II	0,76							
11	Palawija planting period III	0,81							
	Area								
12	Q (water needs) (m³/s)	0,025	0,028	0,013	0,015	0,016	0,017	0,017	0,016

C. Availability of Water and Rainfall

Figure 5 is a graph of the relationship between the availability of the Paku Beto Reservoir Discharge method F.J. Mock and water availability.

After knowing the objective and constraint functions, the next step is to create a mathematical model for the two parts. Each process will be described in the existing condition with 2 (two) planting seasons and in the optimization condition with 3 (three) planting seasons.

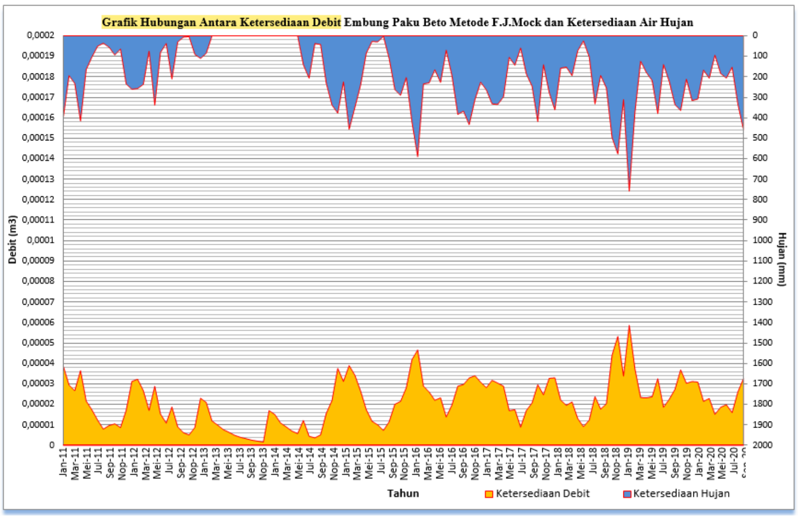

Fig. 5. Graph of the Relationship between the Availability of the Paku Beto Reservoir Discharge Method F.J. Mock and Rainwater Availability.

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TABLE III. Water Availability and Water Demand.

No	Months	Period	Irigation water	Volume				Inflow-outflow
				Water needs (Outflow)		Reability Discharge (Inflow)		
			m³/sec	m³/sec	m³	m³/sec	m³	m³
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Okt	I	0,020	0,020	25.428,61	0,019	24.127,82	-1.300,79
		II	0,020	0,020	24.518,30	0,019	24.127,82	-390,48
2	Nov	I	0,010	0,010	12.924,50	0,022	29.120,38	16.195,89
		II	0,010	0,010	13.540,22	0,022	29.120,38	15.580,17
3	Dec	I	0,012	0,012	15.220,44	0,030	38.422,30	23.201,86
		II	0,012	0,012	15.776,72	0,030	38.422,30	22.645,58
4	Jan	I	0,010	0,010	12.357,23	0,038	48.704,33	36.347,10
		II	0,010	0,010	12.031,91	0,038	48.704,33	36.672,42
5	Feb	I	0,040	0,040	52.188,55	0,033	42.435,46	-9.753,10
		II	0,032	0,032	41.722,86	0,033	42.435,46	712,59
6	Mar	I	0,013	0,013	16.316,48	0,034	43.821,36	27.504,88
		II	0,016	0,016	21.162,12	0,034	43.821,36	22.659,25
7	Apr	I	0,023	0,023	30.157,33	0,034	44.422,80	14.265,46
		II	0,024	0,024	30.630,07	0,034	44.422,80	13.792,73
8	May	I	0,020	0,020	26.501,35	0,029	37.435,68	10.934,33
		II	0,020	0,020	25.823,87	0,029	37.435,68	11.611,82
9	Jun	I	0,025	0,025	32.488,10	0,023	29.717,68	-2.770,43
		II	0,028	0,028	36.735,68	0,023	29.717,68	-7.018,00
10	Jul	I	0,013	0,013	17.327,55	0,017	21.987,80	4.660,25
		II	0,015	0,015	19.289,42	0,017	21.987,80	2.698,38
11	Aug	I	0,016	0,016	21.076,87	0,019	24.123,41	3.046,54
		II	0,017	0,017	21.936,52	0,019	24.123,41	2.186,89
12	Sept	I	0,017	0,017	21.728,67	0,020	25.666,50	3.937,83
		II	0,016	0,016	21.116,69	0,020	25.666,50	3.937,83
Amount								251.970,98

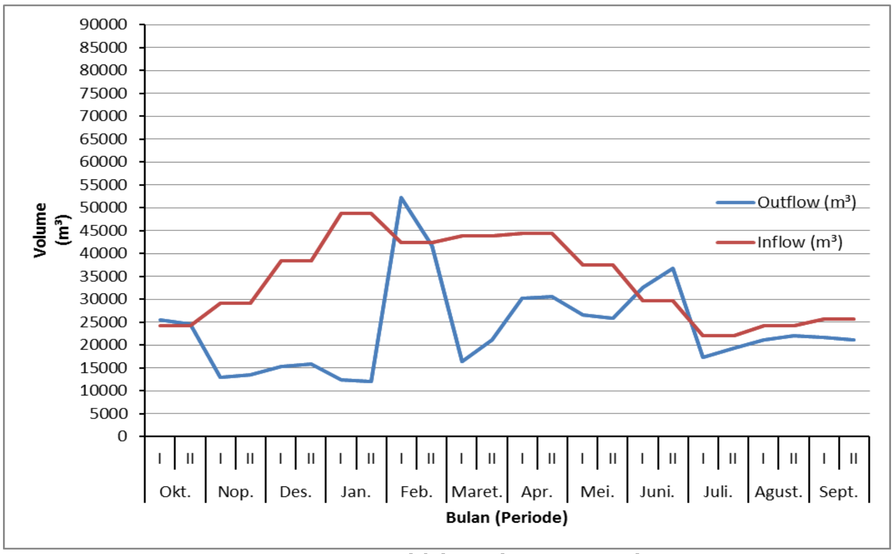

Fig. 6. Water Availability and Water Demand.

TABLE IV. Water Needs and Availability in Existing Conditions.

Months	No	Paddy Water Needs (m^3/sec)	Water Needs (m^3)	Period	Palawija Water Needs (m^3/sec)	Water Needs (m^3)	Period	Water Availability (m^3)	Water Availability (m^3/detik)	Cultivated Plants
Okt	1	0,065403	84.762,03	I	0,0000	0,00	I	24.127,82	0,01862	50 ha paddy
	2	0,063061	81.727,65	II	0,0000	0,00	II	24.127,82	0,01862	
Nov	3	0,033242	43.081,66	I	0,0000	0,00	I	29.120,38	0,02247	
	4	0,034826	45.134,06	II	0,0000	0,00	II	29.120,38	0,02247	
Dec	5	0,039147	50.734,80	I	0,0000	0,00	I	38.422,30	0,02965	
	6	0,040578	52.589,07	II	0,0000	0,00	II	38.422,30	0,02965	
Jan	7	0,031783	41.190,76	I	0,0000	0,00	I	48.704,33	0,03758	
	8	0,030946	40.106,37	II	0,0000	0,00	II	48.704,33	0,03758	
Amount		0,338986	439.326,40		0,0000	0,00		280.749,67	0,216628	
Feb	9	0,059658	77.316,38	I	0,0000	0,00	I	42.435,46	0,03274	50 ha paddy

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	10	0,047694	61.811,65	II	0,0000	0,00	II	42.435,46	0,03274	
Mar	11	0,018652	24.172,56	I	0,0000	0,00	I	43.821,36	0,03381	
	12	0,024191	31.351,28	II	0,0000	0,00	II	43.821,36	0,03381	
Apr	13	0,034473	44.677,53	I	0,0000	0,00	I	44.422,80	0,03428	
	14	0,035014	45.377,88	II	0,0000	0,00	II	44.422,80	0,03428	
May	15	0,030294	39.261,27	I	0,0000	0,00	I	37.435,68	0,02889	
	16	0,029520	38.257,58	II	0,0000	0,00	II	37.435,68	0,02889	
Amount		0,279495	362.226,13		0,0000	0,00		336.230,61	0,259437	
Jun	17	0,000000	0,00	I	0,0000	0,00	I	29.717,68	0,02293	Rainfed
	18	0,000000	0,00	II	0,0000	0,00	II	29.717,68	0,02293	
Jul	19	0,000000	0,00	I	0,000000	0,00	I	21.987,80	0,01697	
	20	0,000000	0,00	II	0,000000	0,00	II	21.987,80	0,01697	
Aug	21	0,000000	0,00	I	0,000000	0,00	I	24.123,41	0,01861	
	22	0,000000	0,00	II	0,000000	0,00	II	24.123,41	0,01861	
Sep	23	0,000000	0,00	I	0,000000	0,00	I	25.666,50	0,01980	
	24	0,000000	0,00	II	0,000000	0,00	II	25.666,50	0,01980	
Amount		0,000000	0,00		0,000000	0,00		202.990,77	0,156629	

TABLE V. Water Needs and Availability at Optimal Conditions.

Months	**No**	**Paddy Water Needs (m^3/sec)**	**Water Needs (m^3)**	**Period**	**Palawija Water Needs (m^3/sec)**	**Water Needs (m^3)**	**Period**	**Water Availability (m^3)**	**Water Availability (m^3/detik)**	**Cultivated Plants**
Okt	1	0,019621	25.428,61	I	0,0000	0,00	I	24.127,82	0,01862	6 ha paddy
	2	0,018918	24.518,30	II	0,0000	0,00	II	24.127,82	0,01862	
Nov	3	0,009973	12.924,50	I	0,0000	0,00	I	29.120,38	0,02247	
	4	0,010448	13.540,22	II	0,0000	0,00	II	29.120,38	0,02247	
Dec	5	0,011744	15.220,44	I	0,0000	0,00	I	38.422,30	0,02965	
	6	0,012173	15.776,72	II	0,0000	0,00	II	38.422,30	0,02965	
Jan	7	0,009535	12.357,23	I	0,0000	0,00	I	48.704,33	0,03758	
	8	0,009284	12.031,91	II	0,0000	0,00	II	48.704,33	0,03758	
Amount		0,101696	131.797,92		0,0000	0,00		280.749,67	0,216628	
Feb	9	0,040269	52.188,55	I	0,0000	0,00	I	42.435,46	0,03274	13,5 ha paddy
	10	0,032194	41.722,86	II	0,0000	0,00	II	42.435,46	0,03274	
Mar	11	0,012590	16.316,48	I	0,0000	0,00	I	43.821,36	0,03381	
	12	0,016329	21.162,12	II	0,0000	0,00	II	43.821,36	0,03381	
Apr	13	0,023270	30.157,33	I	0,0000	0,00	I	44.422,80	0,03428	
	14	0,023634	30.630,07	II	0,0000	0,00	II	44.422,80	0,03428	
May	15	0,020449	26.501,35	I	0,0000	0,00	I	37.435,68	0,02889	
	16	0,019926	25.823,87	II	0,0000	0,00	II	37.435,68	0,02889	
Amount		0,188659	244.502,64		0,0000	0,00		336.230,61	0,259437	
Jun	17	0,025068	32.488,10	I	0,0000	0,00	I	29.717,68	0,02293	8 ha paddy, 4,7 ha palawija
	18	0,023201	30.069,06	II	0,0051	6.666,62	II	29.717,68	0,02293	
Jul	19	0,014490	18.779,48	I	0,0000	0,00	I	21.987,80	0,01697	
	20	0,014845	19.239,11	II	0,0000	50,31	II	21.987,80	0,01697	
Aug	21	0,015702	20.349,89	I	0,0006	726,98	I	24.123,41	0,01861	
	22	0,015960	20.684,62	II	0,0010	1.251,90	II	24.123,41	0,01861	
Sept	23	0,015846	20.535,77	I	0,0009	1.192,90	I	25.666,50	0,01980	
	24	0,015483	20.066,57	II	0,0008	1.050,12	II	25.666,50	0,01980	
Amount		0,140596	182.212,60		0,008440	10.938,84		202.990,77	0,156629	

D. Optimization Calculation

After the mathematical model has been created and the objective function equations along with the limiting function have been entered into the QM for Windows program, the next step is to run the QM for Windows process to display the optimization results.

Objective Function (existing condition)

$Z = A \cdot X1a + B \cdot X2b$

Objective Function (optimization condition)

$Z = A \cdot X1 + A \cdot X2 + A \cdot X3 + B \cdot P3$

Limit Function

Maximum area (existing condition)

$X1a \leq Xt$

$X2b \leq Xt$

Where:

Xt = Paku Beto's total farm area (ha)

Maximum area (optimization condition)

$X1 \leq Xt$

$X2 \leq Xt$

$X3 + P3 \leq Xt$

$P1,2,3 \leq Xt$

Where:

Xt = Paku Beto's total land area (ha)

Available water volume (existing condition)

$V1p \cdot X1a \leq X1s$

$V2p \cdot X2b \leq X2s$

Where:

Vt = Paddy water needs in the planting season t (m^3/ha)

Available water volume (optimization condition)

$V1p \cdot X1 \leq X1s$

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$V2p \cdot X2 \quad \leq X2s$

$V3p \cdot X3 + V3u \cdot P3 \quad \leq X3s$

Where:

Vtu = Palawija water needs in the planting season t (m^3/ha)

Reservoir capacity (existing condition)

$V1p \cdot X1a \quad \leq Qe$

$V2p \cdot X2b \quad \leq Qe$

Where :

$Q_e =$ Reservoir capacity (m^3).

Reservoir capacity (optimization condition)

$V1p \cdot X1 \quad \leq Qe$

$V2p \cdot X2 \quad \leq Qe$

$V3p \cdot X3 + V3u \cdot P3 \leq Qe$

Where :

$Q_e =$ Reservoir capacity (m^3).

After the value of the optimum land areas of each plant in each planting season is known, the value of the area is entered into the goal equation. The following is a table for the values of the optimum land areas, including the following:

TABLE VI. Optimization Calculation Results for Existing Cropping Patterns.

No	Type of Irrigation plant	Net Income (per/ha)	Land Area (ha)	Total Income (Rp.)
(1)	(2)	(3)	(4)	(5)
1	Paddy MT 1	31.680.000	8	253.440.000
2	Paddy MT 2	29.680.000	4	118.720.000
Total				372.160.000

TABLE VII. Optimization Calculation Results for the Planned Cropping Pattern.

No	Type of Irrigation plant	Net Income (per/ha)	Land Area (ha)	Total Income (Rp.)
(1)	(2)	(3)	(4)	(5)
1	Paddy MT 1	31.680.000	6	190.080.000
2	Palawija MT 1	0	0	-
3	Paddy MT 2	29.680.000	13,5	400.680.000
4	Palawija MT 2	0	0	-
5	Paddy MT 3	28.620.000	8	237.600.000
6	Palawija MT 3	20.500.000	4,7	96.350.000
Total				916.070.000

TABLE VIII. Comparison of Optimization Results of Existing Conditions and Planned Conditions.

No	Season	Paddy Planting		Palawija Planting		Profit	
		Paddy (existing) (Ha)	Paddy (optimation) (Ha)	Palawija (exsisting) (Ha)	Palawija (optimation) (Ha)	Existing (Rp)	Optimation results (Rp.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	MT I	8	6	0	0	372.160.000	916.070.000
2	MT II	4	13,5	0	0		
3	MT III	0	8	0	4,7		

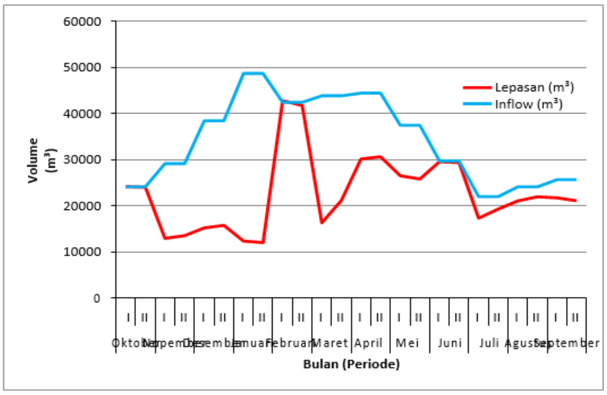

Fig. 7. Chart of Reservoir Water Fluctuation in Wet Years.

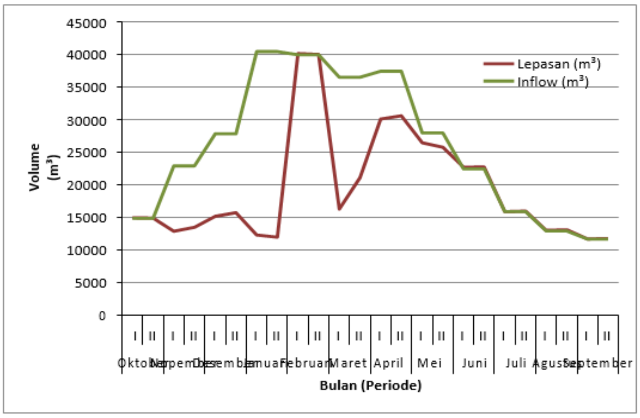

Fig. 8. Graph of Reservoir Water Fluctuation in Normal Years.

Total revenue is obtained from the data from the optimization results. For example, the calculation for Planting Period 1 and Planting Period 2 = Planted area x net income of rice and corn per hectare. The production of agricultural products in Paku Beto irrigated land after optimization is 5.0 Ton/ha of dry corn, where the price of dry corn in the area is Rp4.100/kg.

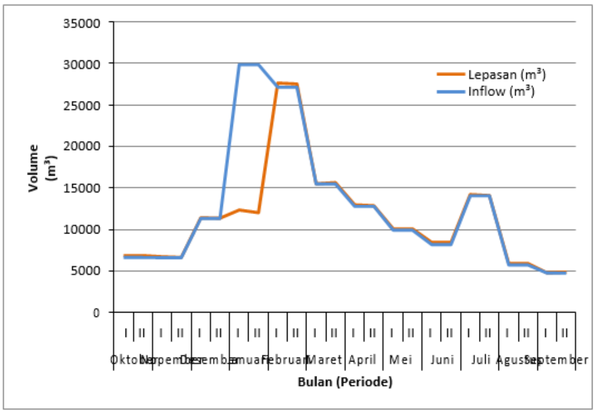

Fig. 9. Graph of Reservoir Water Fluctuation in Dry Years.

In this study, optimizing the service for downstream needs requires guidelines for the operation of the reservoir. Optimal is meant to maximize the release for downstream markets by the inflow and reservoir conditions. If the storage conditions decrease, the percentage of releases as needed will also

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decrease and vice versa.

TABLE IX. Embankment Simulation Reliability Results.

No	Mainstay Debit (20%)	Mainstay Debit (40%)	Mainstay Debit (60%)	Mainstay Debit (80%)	Mainstay Debit (100%)	Information
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	24	24	24	23	21	Success
2	0	0	0	1	3	Fail
3	100%	100%	100%	96%	88%	Constraint Level

V. CONCLUSION

The discharge of filling water in Paku Beto Reservoir which is used to fulfill irrigation water needs for agricultural land in each period is 24,127 m^3 in October, 29,120 m^3 in November, 38,422 m^3 in December, 48,704 m^3 in January, 42,435 m^3 in February, 43,821 m^3 in March, 44,422 m^3 in April, 37,435 m^3 in May, 29,717 m^3 in June, 21,987 m^3 in July, 24,123 m^3 in August, 25,666 in September per period. Based on the volume of the reability discharge and the existing water needs, then an analysis is carried out to determine the maximum area of each type of plant. From the optimization results, it was found that the most optimal cropping pattern was the rice - secondary cropping pattern for the I Planting Season (MT I) in October - January which was 6 ha of rice area, the rice - secondary cropping pattern for the Planting Season II (MT II) in the month February-May is rice covering an area of 13.5 ha, and in the Third Planting Season in June-September with an area of 8 ha of rice with crops covering an area of 4.7 ha. From the results of the optimum area for each type of plant with the above planting period, the maximum income is obtained for one year. Income after optimization is Rp. 916,070,000, -, while in the existing condition of Rp. 372.160.000,-. Thus obtained an increase in production profits compared to the existing conditions of Rp. 543.910,000,-.

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