Climate Control Efforts that Impact Flood Disasters in the Lampung

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Abstract. The imbalance between the current availability of water resources and the need for water is an important problem in almost all regions in Indonesia, so that it requires a conception of the engineering and operation of existing facilities. control and utilization of water as well as management carried out efficiently and effectively in order to meet various needs. As an effort to avoid conflicts of interest, an engineering management of dam operations is needed. This raises the idea of the need for water management engineering existing reservoirs. Based on reservoir water inflow and outflow data from 2019 to 2022, optimization was carried out on the Minimum Demand Analysis (Firm Yield Analysis) and Maximum Analysis of Reservoir Water Release using the Non-Linear Generalized Reduced Gradient (GRG) Method. Inflow and outflow data iterations as a function of objectives and constraints Minimize Reservoir Capacity and Amount of water storage in the reservoir = Inflow, and demand at the Way Sekampung Dam = Outflow obtained by Firm Yield Analysis of 335.62 Million M3 or 335 MCM. Thus, it can be concluded that the effective storage volume that can be allocated for irrigation is located between the minimum reservoir elevation at +250 m and the maximum elevation at +255 m. The results of the volume interpolation of the optimization results obtained with an elevation elevation of + 253.74 m, as well as the optimization results for the total release of reservoir water at 281 MCM, so that the management of water resources can then become a benchmark in the distribution of irrigation water, raw water, hydropower and water conservation. continuously

Keywords: Firm Yield Analysis, Solver, Total Release

INTRODUCTION

Water resources are currently an important problem in almost all regions in Indonesia, so it requires a conception of engineering and the operation of existing facilities. Water control and utilization and management need to be carried out efficiently and effectively so that it can meet various needs. In line with the above, the government issued Law of the Republic of Indonesia Number 17 of 2019 concerning Water Resources.

The current condition that occurs is that there is an imbalance between the availability and demand for water which is increasing from time to time. Therefore, it is necessary to manage water resources wisely while still paying attention to meeting water needs for various purposes. These interests relate to agricultural land, clean water needs, industry, electricity and river maintenance (maintenance flow) and other needs.

Lampung is one of the provinces with average rainfall of 176, 131, 224 mm/year in 2021, 2020 and 2019 respectively [1] This rainfall potential must be utilized properly and requires serious handling and management from all stakeholders. One use of this water potential is the construction of the Way Sekampung Reservoir.

Since the process of filling the Way Sekampung reservoir with water in 2002-2003 and starting operations in 2004-2009, the volume of the Way Sekampung reservoir has only a few times reached the normal condition limit (NWS) at an elevation of +273 m or with an effective storage (life storage) of 576 MCM (million cubic meters). This is food for thought that requires engineering in managing reservoir water with a normal volume or with a capacity of 576 Million Cubic Metric (MCM) reservoirs or reservoirs that have been planned, analyzing tropical climate change data on reservoir inflow based on data from 2019 to 2022 to obtain high limits. optimum reservoir water level based on reservoir water management at that time. Reservoir optimization using Firm Yield Minimum Requirements Analysis [2], [3] and [4], using licensed Microsoft solver tools, it is hoped that a reservoir water level limit can be used as a basis. the next reservoir operation pattern, so that planning for future water distribution or reservoir operations can be maximally implemented.

METHOD

Data Availability

The data used in this research consists of:

1. Way Sekampung Watershed Generation Map resulting from satellite imagery
2. Hydrological and climatological data
3. Reservoir inflow and outflow data for the last 4 years (2019-2022)
4. Way Sekampung Dam Technical Data
5. Population statistical data

The location and watershed area (DAS) of the Way Sekampung Dam are presented in Figures 1 and 2 below.

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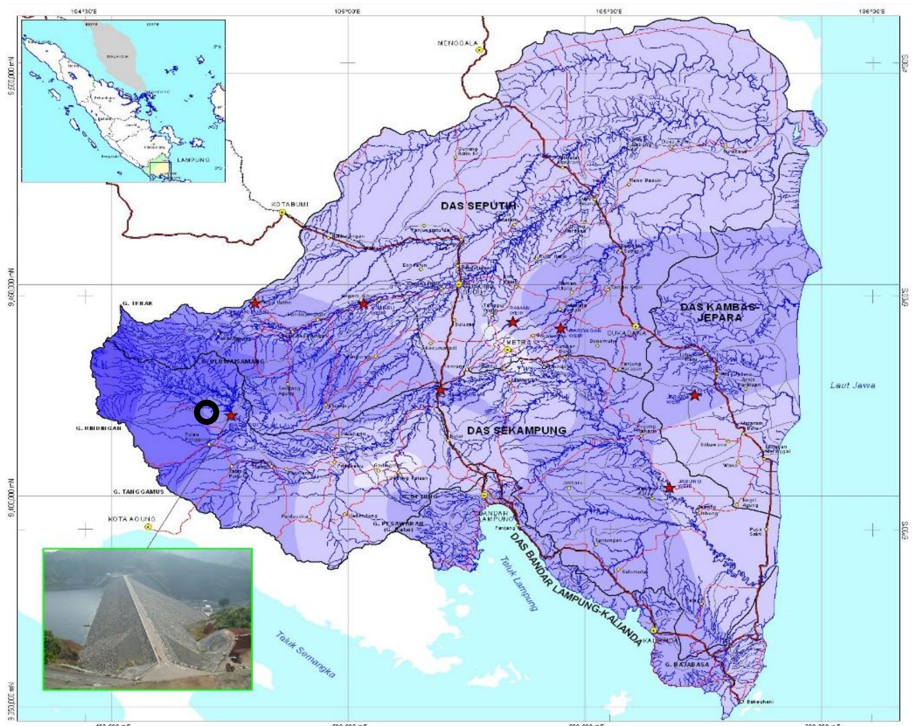

Figure 1. Way Sekampung Reservoir Location Map

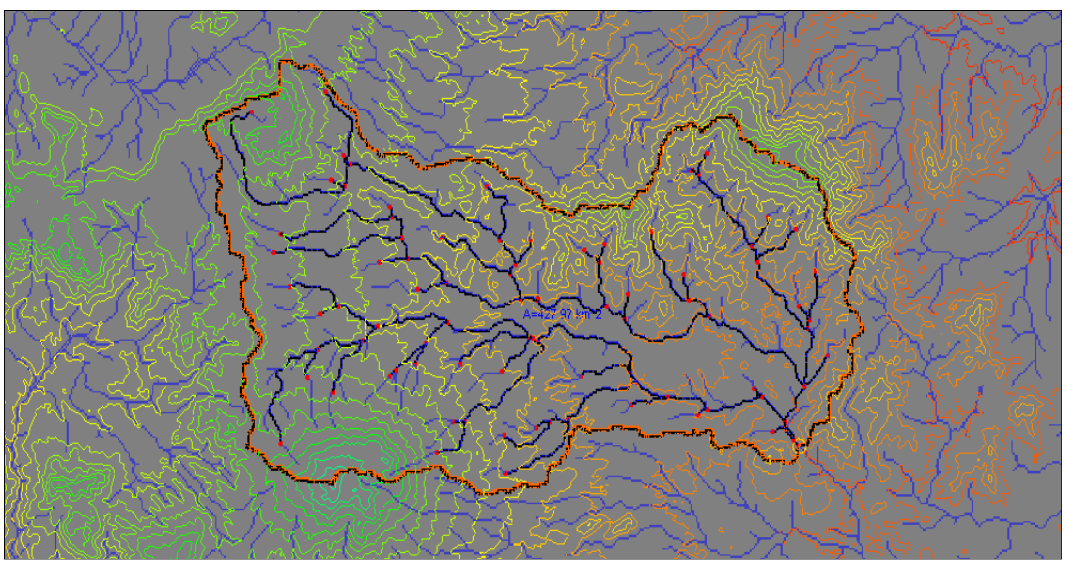

Figure 2. Map of the Way Sekampung Reservoir watershed

Way Sekampung Reservoir technical data from the PUPR Working Unit and BBWS Mesuji Sekampung O&M Source are as follows:

a. Dam Body
- Dam Type : A pile of rock with a waterproof soil core
- Peak length : 701.00 m
- Width of the lighthouse : 12.00 m
- Width of the lighthouse : + 283 m (Edge)
+284.5 m(middle)
- Dam height : 122 m
- Heap volume : 9.641.071 m^3
- Long Inspection Gallery : 841 m
- Long Access Gallery : 233 m
- River bed elevation (Upstream of Bendung) : +200.00

b. Reservoir Flooding
- (*Catchment Area*) : 424 km^2
- Max flood water level (FWL) : +281.50 m
- Normal water level max (NWL) : +274.00 m
- Min water level for electrical operation (LWL) : +226 m
- Min water level for irrigation operations (LWL) : +208 m
- Area of inundation El. 281,5 : 25 km^2
- Area of inundation El. 274 : 21 km^2
- Area of inundation l. 226 : 5,5 km^2
- Area of inundation El. 208 : 2,1 km^2
- Area of inundation El. 208 : 2,1 km^2
- Inundation capacity at El. 281.5 : 860 x 10^6 m^3
- Inundation capacity at El. 274.0 : 690 x 10^6 m^3
- Inundation capacity at El. 226 : 90 x 10^6 m^3
- Inundation capacity at El. 208 : 25 x 10^6 m^3
- Effective storage capacity (El 208 – 274) m : 665 x 10^6 m^3

c. Cross section

A cross section of the Way Sekampung Dam is shown in Figure 3 below. At the effective storage elevation (El. 208 – 274) m it is known that the available storage volume is 665 x 106 m3. This storage volume will be optimized in this research to determine the effective storage volume that can be used to meet irrigation and hydropower water needs.

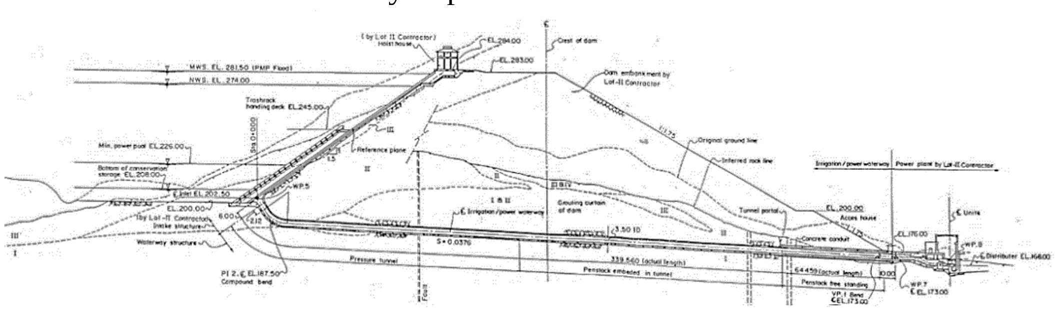

Figure 3. Cross section of the Way Sekampung Reservoir

Design Method

The creation of the research location watershed is assisted by a satellite image map with several points that have been calibrated using GPS. The map of the Way Sekampung reservoir service area has also been verified based on aerial photographs taken using drones. This data needs to be calibrated and verified to ensure the suitability of the data and is in accordance with the latest conditions. Optimization in this research uses the Firm Yield Model Reservoir Analysis method which can be formulated as in equations 1 and 2 below.

$$S_t - S_{t-1} + r_t = I_t - Y_t \quad (1)$$

$$S_t + \Delta_t - S_t = I_{vol} - O_{vol} \quad (2)$$

Application of the Firm Yield Reservoir Model using the Non-Linear Generalized Reduced Gradient (GRG) Method

The equations and objective functions and constraints for the operation of the cascade reservoir are solved by non-linear programming with the GRG method, which is an implicit variable elimination algorithm. This algorithm is a numerical derivation and partial differential equation for necessary and sufficient conditions as expressed in [3] as follows:

$$\nabla\tilde{f}\ (x^{(t)}) = \nabla\bar{f}\ (x^{(t)}) - \nabla\ \hat{f}(x^{(t)})J^{-1}C \quad (3)$$

The Firm Yield Model, also known as an engineering system, is a method for studying and analyzing various aspects of a system. For this reason, by using models, whether in the form of mathematical models or physical models, the best strategy can be found from various existing alternatives by taking into account the limitations of the system. Figure 4 shows a simple diagram of how a system can process input values into an output.

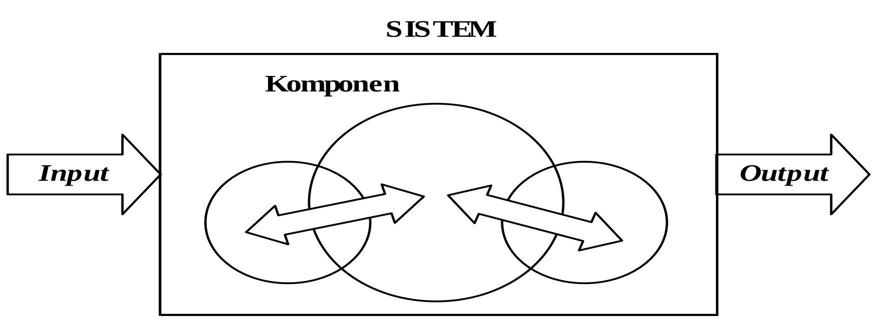

Figure 4. System Diagram

Firm Yield Reservoir conditions to ensure the minimum storage capacity required to maintain the required management [2] and [5] with the following formulation:

- ✓ Constraint Factors and Goals
- ✓ $S_t - C \leq 0$ Where t =1,2,..4 year
- ✓ $S_t \geq 0$ Where t =1,2,..4 year
- ✓ $r_t \geq 0$ Where t =1,2,..4 year
- ✓ $C \geq 0$ (4)
- ✓ $S_t - S_{t-1} + r_t = I_t - Y_t$ (5)

Where :

Yt: Needs for a certain time

C: Reservoir storage capacity

St: Total storage at the end of the period

It: Inflow during a certain time

rt: all overflows and outflows at time, other than Yt

t : the time number to be analyzed

In general, all of these research activities can be simplified in a research flow diagram as in Figure 6.

Reservoir or reservoir management

A reservoir is a building that functions to store excess water during the rainy season, which can then be utilized when there is a water shortage in the dry season [6]. It is hoped that the construction of the reservoir can change flow patterns to make it more beneficial for human life, where the reservoir capacity becomes very important in relation to fulfilling the above. The most important characteristic of a reservoir is related to its ability to store water, where the characteristic of active capacity (life storage) plays a very important role [7][8] and [9]).

The operation and management of reservoirs based on the functions planned above will be related to the division of storage capacity into certain parts. This distribution of capacity can be permanent or change based on season or other factors.

Calculation of the inflow discharge entering the reservoir based on the discharge in the reservoir body containing the TMA height measurement is converted to a graph of the relationship between elevation, volume and inundation area of the Way Sekampung reservoir as shown in Figure 5 and Table 1 [4], [10] and [9]

Figure 5. Graph of the relationship between elevation, volume and inundation area of Way Sekampung Reservoir Source PUPR Work Unit and O&M PSDA BBWS Mesuji Sekampung

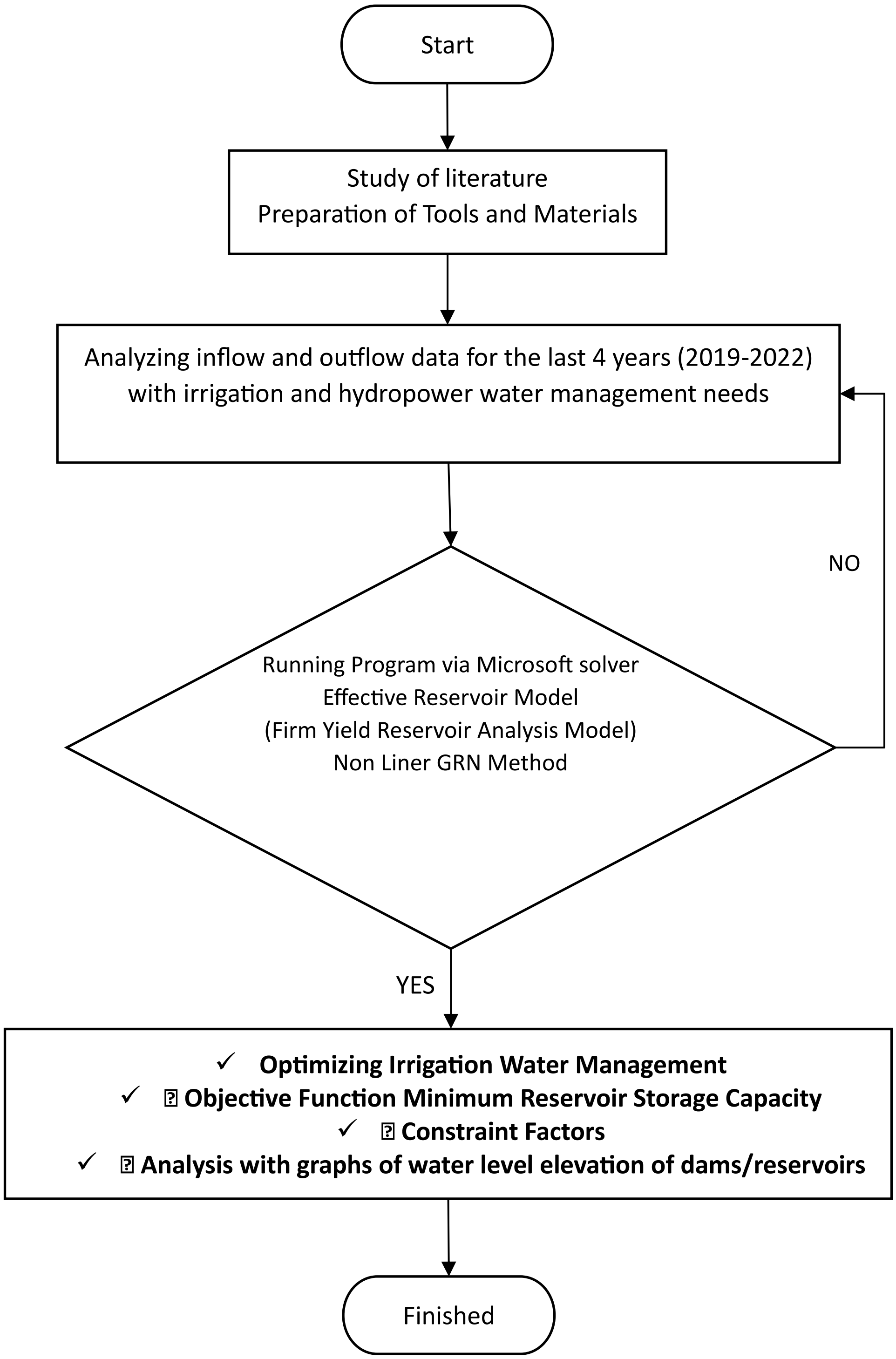

Figure 6. Research Flow Diagram

Table 1. Relationship between Elevation, Volume and Inundation Area of the Way Sekampung Reservoir

Elevasi (m)	Luas Genangan (km^2)	Volume (m^3)
300	36,042	1421,1
295	32,844	1248,9
290	29,794	1092,4
285	26,893	950,7
280	24,14	823,2
274	21,1	687,8
270	19,401	606,8
265	17,378	514,9
260	15,466	432,8
255	13,666	360
250	11,977	296
245	10,444	240
240	9,017	191,4
235	7,694	149,6
230	6,476	114,2
225	5,363	84,7
220	4,248	60,7
215	3,262	42
210	2,407	27,9
205	1,681	17,7
200	1,085	10,9
195	0,753	6,3
190	0,482	3,2
185	0,271	1,4
180	0,121	0,4
175	0,03	0,1
170	0	0

RESULT AND DISCUSSION

Optimization and analysis were carried out based on iterations of monthly inflow and outflow data recorded over the last 4 years (2019-2022). The results of recording monthly inflow and outflow are presented in Table 2.

Way Sekampung Reservoir Inflow and Outflow Data

MONTH	2019		2020		2021		2022	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
	($10^6 m^3$)		($10^6 m^3$)		($10^6 m^3$)		($10^6 m^3$)	
1	23,346	17,323	27,459	0,495	23,488	27,049	17,220	47,555
2	47,502	9,750	26,614	17,100	32,450	4,559	34,571	35,374
3	34,724	6,441	37,761	7,491	31,242	8,335	21,167	0,000
4	34,744	16,420	41,347	0,000	20,443	23,327	22,995	28,506
5	19,927	10,999	39,424	0,000	16,500	33,747	25,127	20,464
6	12,621	12,926	31,605	22,861	12,406	26,503	19,503	17,972
7	9,690	24,943	21,273	21,989	8,215	0,000	16,932	23,245
8	8,886	23,889	15,791	25,642	8,607	22,251	17,349	11,109
9	6,642	43,937	12,839	22,529	7,105	4,892	18,818	0,000
10	5,111	36,696	10,754	21,521	9,652	8,231	21,394	12,184
11	6,257	26,871	16,435	43,159	15,419	10,214	28,712	42,308
12	11,360	18,489	17,090	41,386	28,947	12,021	29,598	30,455

Processing Results of Average Inflow and Outflow of Way Sekampung Reservoir

Data 2019-2022

The Inflow (It) value is the result of recording on the peil scale in the Way Sekampung reservoir, and the Outflow (Yt) is the water requirement for hydropower, irrigation and maintenance flow. Based on this data, a simulation was carried out using formulas 4 and 5 taking into account the following constraint factors and objectives:

a. Constraint Factors

- $St - C \leq 0$ where t =1,2,..4 years
- $St \geq 0$ where t =1,2,..4 years
- $rt \geq 0$ where t =1,2,..4 years
- $C \geq 0$
- $St - St – 1 + rt = It – Yt$; Mass Balance

b. And the goal: Minimum St (Storage) as well as variables to be optimized in the Storage (St) and Release (rt) sections.

Based on the non-linear GRG optimization method in Microsoft Excel, optimization results were obtained as shown in the optimization results as shown below:

Microsoft Excel 16.0 Answer Report
Worksheet: [Data Hujan dan Debit rev 28042023 REV 00 (ok 1) - Copy.xlsx]Kapasitas Waduk 4 Thn 2023
Report Created: 4/28/2023 5:32:50 PM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: GRG Nonlinear
Solution Time: 51.046 Seconds.
Iterations: 85 Subproblems: 0
Solver Options
Max Time 100 sec, Iterations 100, Precision 0.000001
Convergence 0.0001, Population Size 100, Random Seed 0, Derivatives Forward, Require Bounds
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 5%, Solve Without Integer Constraints

Objective Cell (Min)

Cell	Name	Original Value	Final Value
H56	C rt	-	335.62

Figure 6. Non-Linear GRG Program Optimization Results

From the optimization results of minimizing objects from Storage (St), the maximum value of the reservoir volume that can be used or allocated for irrigation and hydropower is 335.62 million m3. When compared to the elevation-area-volume curve in Table 1, it is found that the reservoir volume value is between an elevation of +255 m and +250 m. By interpolation, the volume of 335.62 million m3 will occur at an elevation of +253.74 m.

CONCLUSIONS

From the optimization results, it can be seen that the effective storage of the Way Sekampung reservoir in the 2019–2022 period can reach a volume of 335.56 MCM or 335.56 million M3. In accordance with the table and curve for the elevation-area-volume relationship of the reservoir reservoir, the volume is at an elevation of +253.74 m. Thus, the effective storage value and elevation can be a limitation of the next reservoir water allocation. This limit can also be used as a reference or guideline for determining the need for irrigation water, raw water and hydropower as well as to support water sources from dams that have been built below in facing climate change in the future.

Suggestion

As one of the dams in Indonesia, it is hoped that it can maximize its function and purpose as a water resource tool that can prosper Indonesian society by maximizing various methods and means that can be used to overcome climate change that is currently occurring.

Thank-you note

Ministry of PUPR Work Unit and O&M PSDA BBWS Mesuji Sekampung for providing the space and data needed for this research process.

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