

OPTIMIZATION OF IMPLEMENTATION COSTS AT MARGATIGA DAM WITH INUNDATION AREA PARAMETERS CASE STUDY: MARGATIGA DAM PROJECT, LAMPUNG

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ABSTRACT

Margatiga Dam is located at Lampung Province. The potential of high land acquisition cost may affect the total construction cost of the dam. A simulation needs to be conducted to calculate the volume of the dam reservoir with optimum reliability and benefit value. Calculation of the dam reservoir uses the storage capacity curve based on topographic map to derive the size area and reservoir volume on each elevation, a simulation is done afterwards to obtain the exact elevation of the optimum volume of reservoir. Simulation is conducted with three elevation alternatives; the spillway crest's initial elevation of +22m, the raised elevation of +22,5m, and the lowered elevation of +21m. It can be concluded from the evaluation that spillway crest's elevation with most benefit value is at an elevation of +22m with the reservoir reliability of 99,64%, BCR of 1,63, and the IRR of 13,34% with the total cost of Rp1.929.918.493.283.

Keywords: *Dam reservoir, Simulation, Reliability, Cost, Margatiga Dam*

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INTRODUCTION

The Margatiga Dam is one of several dams in East Lampung. Other dams include the Way Sekampung Dam and the Batutegi Dam. These three dams are integrated into the Way Sekampung River flow to meet raw water supply and irrigation for Jabung Kiri DI area covering 5,638 Ha and DI Jabung Kanan covering 10,950 Ha. In the implementation of the construction of the Margatiga Dam, there is a potential for land constraints in the reservoir area and the potential for the high costs of releasing land in the reservoir area, and will affect the costs of implementing the construction of the Margatiga Dam (McMahon & Mein, 1978). With these problems, it is necessary to do calculations to determine the optimum reservoir volume that can fulfill the benefits of the dam (Alrayess et al., 2018).

METHOD

Data Collection

After identifying the problems in the field, the next step is to find supporting data to solve these problems. The data in question is secondary data. Secondary data is data obtained indirectly in the form of records or research results from other parties (Elger et al., 2010; Wulandari, 2022). The secondary data includes:

1. Topographic data, to determine the elevation of the dam construction site and determine the curvature of reservoir capacity
2. Discharge Data, to find out reservoir inflow
3. Dam Technical Data, to find out the technical plan for dam construction, peak elevation, spillway elevation, and reservoir outflow.

4. Data on land acquisition plans, to determine the land affected by the reservoir inundation area.

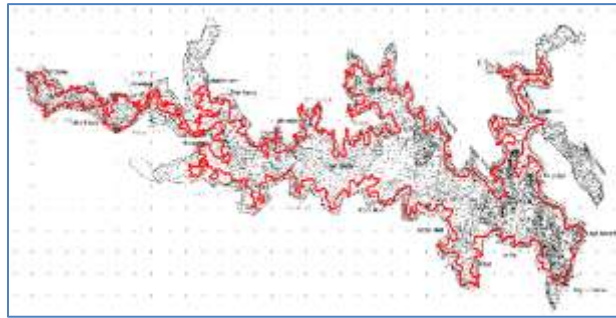


Figure 1. Inundation Map at mer + 22m elevation

Data Analysis

From the data collection stage, data processing is then carried out. The stages of data analysis/calculation process include:

- a. Debit analysis, debit data available at the Duga Air Way Sekampung Negri Jemanten Post, namely from 2002 - 2009, so it is necessary to generate inflow discharge using the *Thomas Fiering* method. Generating discharge data can be used Thomas-Fiering model. This model assumes that a year is divided into seasons or consists of 12 months.

$$r_j = \frac{\sum_{i=1}^n X_{i,b}, X_{i,b-1} - n \cdot X_b \cdot X_{b-1}}{S_{d_b} \cdot S_{d_{b-1}} \cdot (n-1)} \quad q_{1,b} = X_b + \frac{r_b \cdot S_{db}}{S_{d_{b-1}}} (q_{i,b-1} - X_{b-1}) + t_{i,b} \cdot S_{d_b} \cdot \sqrt{(1 - r^2)} \quad (2)$$

- b. Capacity curvature analysis, from existing topographic data can be made Reservoir capacity curve is the relationship between elevation, inundation area, and reservoir volume.
- c. Reservoir simulation, from outflow and inflow discharge data. In the simulation process, it is determined as input into the system is the reservoir inflow discharge and reservoir reservoir from rain / discharge that occurs and as output (output) is irrigation water needs and raw water needs. Simulation of reservoirs using 3 alternative conditions based on the elevation of the spillway +22m, with the condition of lowering the elevation of the spillway by 0.5 meters, and with the condition of lowering the elevation of the spillway by 1 meter from the plan.

$$I = O \pm \Delta S$$

$$S(t+1) = S_t + Q_t - D_t - E_t - L_t, \text{ with, } 0 < S_t \leq C$$

In each simulation made, it can be known the reliability of the reservoir (Dibike & Coulibaly, 2005). The reliability of the reservoir can be known by knowing the number of periods the reservoir can meet the required water needs.

$$P_e = P/N$$

$$R_e = 1 - P_e$$

- d. Evaluation of the simulation results, the final evaluation is carried out on the efficiency of implementation costs and the benefits obtained, by comparing the BCR and IRR values of 3 spillway elevation conditions.

Benefit Cost Ratio (BCR) is a comparison between the present value of benefits with the present value of costs.

$$BCR = B / (I + PW(O + M))$$

If the $BCR > 1$ means that the project is worth building.

If the $BCR < 1$ means that the project is not worth building.

IRR is an interest rate where benefits and costs have the same value or $BCR = 1$, or also interpreted as NPV (Net Present Value) = 0. To determine alternatives to the 3 spillway elevation conditions that have been analyzed, incremental IRR analysis is carried out.

RESULTS AND DISCUSSION

Discharge Analysis

The average discharge data used in this analysis is discharge data from 2002-2009 from Pos Duga Air 124 located in Sungai Way Sekampung. With limited discharge data as in table 1, it is necessary to calculate the generation of monthly inflow discharge data using the Thomas Fiering Method.

Table 1. Average discharge years 2002-2009

Month	Period ke	Average Discharge
January	1	27,1
	2	38,6
February	1	27,3
	2	25,0
March	1	43,2
	2	40,5
April	1	29,4
	2	24,3
May	1	16,8
	2	16,2

June	1	16,9
	2	14,6
July	1	14,5
	2	11,6
August	1	8,5
	2	5,0
September	1	3,6
	2	3,0
October	1	4,0
	2	4,0
November	1	4,4
	2	7,8
December	1	10,4
	2	11,3

After data generation from 2002-2036, it is necessary to ensure the reliability of the data before calculations and analysis are carried out. For this reason, statistical tests are carried out. Testing is carried out to ensure its accuracy so that the calculation results can be used for further processing. The test carried out is by F test and T-Test (Nuramini, 2017).

Table 2. Average Discharge of Generation Results in 2002-2036

Month	Period ke	Average Discharge
January	1	27,1
	2	38,6
February	1	27,3
	2	25,0
March	1	43,2
	2	40,5
April	1	29,4
	2	24,3
May	1	16,8
	2	16,2
June	1	16,9
	2	14,6
July	1	14,5
	2	11,6
August	1	8,5
	2	5,0
September	1	3,6
	2	3,0
October	1	4,0

	2	4,0
November	1	4,4
	2	7,8
December	1	10,4
	2	11,3

Curvature Reservoir Capacity

The relationship between reservoir capacity and reservoir inundation area can be seen in figure 1.

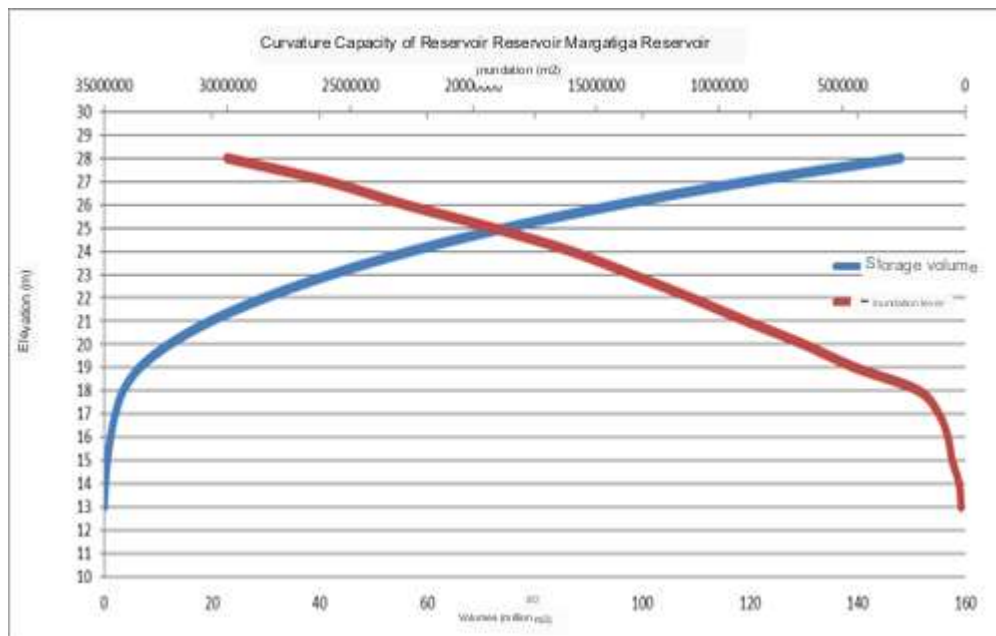


Figure 2. Curvature Capacity of Margatiga Reservoir

Reservoir Simulation Analysis

At the beginning of the analysis, it is determined in advance at what elevation the reservoir spillway produces reliability greater than 90%, with the deviation of the elevation of each condition a difference of 0.5 meters.

So that the simulation analysis of the reservoir reservoir is made under 3 conditions, namely conditions based on the elevation of the planned reservoir (+22 m), with conditions of lowering the elevation of the reservoir by 0.5 meters (+21.5 m), and with conditions of lowering the elevation of the reservoir by 1 meter from the plan (+21 m).

Table 3. Reservoir Volume and Puddle Area

Elevation of Spillway Lights (m)	Stamp Volume. Effective (m ³)	Puddle Area (m ²)
22,0	26.765.700	11.174.467
21,5	21.748.439	10.050.345
21,0	16.731.179	8.936.223



Figure 3. Inflow -Outflow Elv Discharge Chart. +22



Figure 4. Elv Spool Chart. +22



Figure 5. Inflow -Outflow Elv Discharge Chart. +21,5



Figure 6. Elv Spool Chart. +21,5



Figure 7. Inflow -Outflow Elv Discharge Chart. -21



Figure 8. Elv Spool Chart. +21

Reservoir Reliability and Failure Analysis

From simulating reservoir reservoirs with 3 conditions, the opportunity for failure and reliability of reservoirs is obtained. Reservoir reliability is the percentage of circumstances under which the reservoir is able to meet its needs. After knowing the reliability of the reservoir, then analysis was carried out on the affected land (land acquisition costs), construction costs, the value of reservoir benefits, until the Benefit Cost Ratio was obtained in 3 simulated reservoir conditions.

Table 4. Number of periods served against MAN reservoir conditions +22

Reservoir	Period Served	In years
Fulfilled	837	34,88
Unfulfilled	3	0,13
Total	840	35

$$\% \text{ Sukes} = \frac{\sum \text{period fulfilled}}{\sum \text{period total}} = \frac{837}{840} = 99,64\%$$

$$\% \text{ failed} = 1 - \% \text{ success} = 0,36\%$$

Table 5. Number of periods served against MAN reservoir reservoir conditions +21.5

Reservoir	Period Served	In years
Fulfilled	807	33,63
Unfulfilled	33	1,38

Total	840	35
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$$\% \text{ Sukes} = \frac{\sum \text{period fullfied}}{\sum \text{period total}} = \frac{807}{840} = 96,07\%$$

$$\% \text{ failed} = 1 - \% \text{ success} = 3,93\%$$

Table 6. Number of periods served against MAN reservoir conditions +21

Reservoir	Period Served	In years
Fulfilled	788	32,83
Unfulfilled	52	2,17
Total	840	35

$$\% \text{ Sukes} = \frac{\sum \text{period fullfied}}{\sum \text{period total}} = \frac{788}{840} = 93,81\%$$

$$\% \text{ failed} = 1 - \% \text{ success} = 6,19\%$$

Analysis of affected land

With an inundation area at an elevation of +22 m, the affected villages include Negri Jemanten Village, Margatiga Village, Mekar Mulyo Village, Trisinar, Mekar Mukti, Negri Agung, Tri Mulyo, Sido Mukti, Sido Mulyo, Rejo Agung, Balai Kencana, Purwodadi, Margototo, Adi Warno.

The cost for land acquisition for houses is 1.6 million / m², oil palm plants are 500 rb / principal or around 15 rb / m².

The calculation of the cost of acquiring affected land for each spillway elevation condition is as follows:

1. Cost of land acquisition for the elevation condition of the spillway +22 m: Rp. 392,128,957,450, with an affected land area of 1,117.45 Ha
2. Cost of land acquisition for elevation condition of the spillway +21.5 m: Rp. 354,461,931,392, the affected land area is 1,005.53 Ha
3. Cost of land acquisition for elevation condition of the spillway +21 m: Rp. 316,794,905,335, the affected land covering an area of 893.62 Ha

Construction Cost Analysis

The calculation of the construction cost of the Margatiga Dam is based on 3 alternative elevation conditions of Mercur Pelimpah, as follows:

1. Construction cost at spillway elevation +22 m : Rp. 813.707.950.000
2. Construction cost at spillway elevation +21.5 m : Rp. 812.251.352.000
3. Construction cost at spillway elevation +21 m : Rp. 810,985,483,000

Operation and Maintenance Analysis

The calculation of Operation and Maintenance Costs (O&P) of Margatiga Dam is based on the estimated costs incurred annually for operation and maintenance that begin to be incurred in the first year and periodic maintenance every 5 years. With an estimated routine maintenance cost per year of 1% of the total construction cost and 5% for periodic maintenance every 5 years.



Operating and Maintenance Costs are assumed to increase by 8.86% per year based on bank loan interest rates. The effective interest rate for Period (i) used is 8.6% which is obtained from the average percentage of effective interest rate in Indonesia in the last 1 year.

The following are the costs of routine and periodic operations and maintenance for 50 years with various spillway elevation conditions:

1. Total Cost of Operation and Maintenance with Elevation Conditions of Mercur Pelimpah +22 m is: Rp. 724,081,585,833
2. Total Operation and Maintenance Costs with Spillway Elevation Conditions +21.5 m are: Rp. 722,859,489,101
3. Total Operation and Maintenance Costs with Spillway Elevation Conditions +21 m are: Rp. 721,797,415,441.46.

Reservoir Benefit Analysis

Before the construction of the Margatiga Dam, the irrigated area that could be irrigated was 5,638 Ha (DI Jabung Kiri). With the construction of this dam, the target irrigation area that can be irrigated is 16,588 Ha (DI Jabung Kanan 10,950 Ha and DI Jabung Kiri 5,638 Ha).

Table 7. Calculation of Increased Agricultural Product Benefits Conditions in some spillway elevation conditions

Elevation of Spillway Lights (m)	Benefits Before Reservoirs Are Built (Billion)	Benefits After the Reservoirs Are Built (Billion)	Net Sales Results (Billion)
+22	55,291	162,096	106,804
+21,5	55,291	156,286	100,995
+21	55,291	152,606	97,315

Benefit Cost Ratio (BCR) Analysis

The value of benefits is derived from the total increase in benefits after the operation of the reservoir for 50 years. While the Cost value is obtained from a combination of initial investment costs (land acquisition costs and construction costs) as well as operational and maintenance costs for the next 50 years. The following is the calculation of BCR after the operation of the reservoir with 3 reservoir reliability conditions based on spillway elevation.

From the results of BCR analysis with 3 conditions based on the spillway elevation above, it was obtained that each condition has a BCR value of > 1, then the Margatiga Dam is feasible to build.

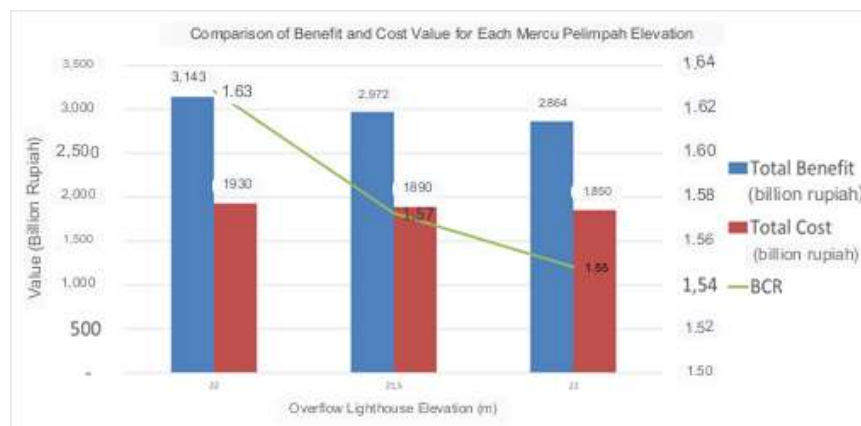


Figure 9. Comparison of BCR Values in Several Spillway Elevation Conditions

Analisa Pengembalian Internal (Internal of Return)

IRR is an interest rate where benefits and costs have the same value or $BCR = 1$, or also interpreted as NPV (Net Present Value) = 0. By interpolating the NPV value and interest rate, the $NPV = 0$ or $BCR = 1$ value can be obtained. With an interest rate of 8.6% it produces a positive NPV while with 13.5% it produces a negative NPV .

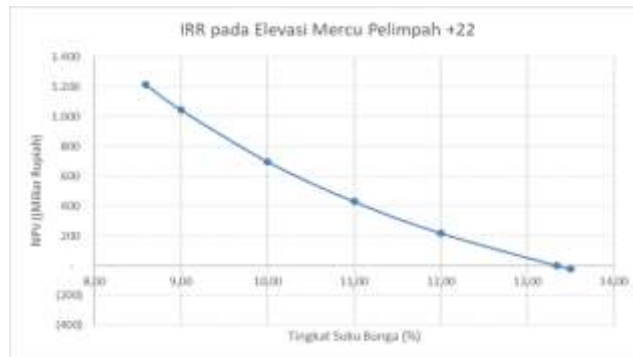


Figure 10. IRR graph on Spillway Elevation +22

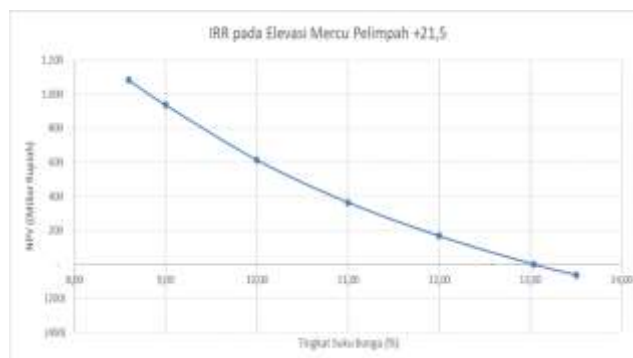


Figure 11. IRR graph on Spillway Elevation +21,5

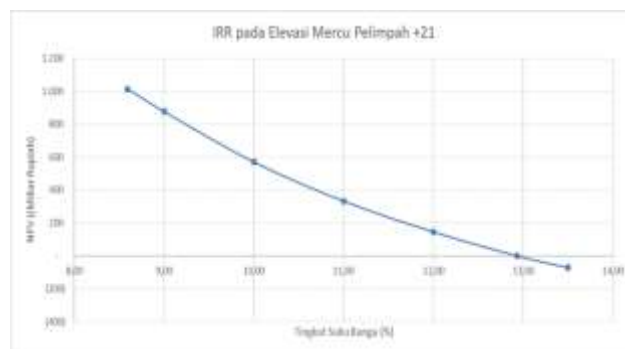


Figure 12. IRR graph on Spillway Elevation +21

Alternative Selection with Incremental IRR Analysis

To determine alternatives to the 3 spillway elevation conditions that have been analyzed, incremental IRR analysis is carried out. Incremental IRR analysis (ΔIRR) is a continuation of IRR analysis if the number of available alternatives is not singular and we need to determine

the rank/priority of alternatives. This happens because the largest IRR cannot be used as a guideline to determine the best alternative.

The ranking of the best temporary alternatives based on the alternative that has the smallest investment value is at the elevation of the spillway +21 (alt 3). Then the IRR deviation is calculated between alternatives 2 and 3 and alternatives 1 and 2. So from this analysis, it was obtained that alternative 1 (Elevation of Spillway + 22) is the best alternative.

CONCLUSION

From the calculation analysis, the most effective reservoir volume of the Margatiga Dam is at a spillway elevation of +22 m, with an effective reservoir volume of 26,765,700 m³. From the analysis of the calculation of land acquisition costs, the most optimal condition is in the condition of the elevation of the spillway +22 m with an area of inundation of 11,174,467 m² (1,174 Ha), obtained land acquisition costs of Rp. 392,128,957,450.

With BCR and IRR Incremental Analysis, it is found that the economic condition of the construction of the Margatiga Dam is at the spillway elevation + 22 m with:

1. Reservoir reliability 99.64%,
2. Investment costs (land acquisition costs, construction costs, operation and maintenance costs) amounted to Rp. 1,929,918,493,283
3. The value of benefits obtained is IDR 3,142,898,693,974
4. BCR value 1.63.
5. IRR value 13.34%

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