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Hydrological Analysis for Water Resources Conservation in the Design of Bandungrejo Lake, Indonesia

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Abstract

An artificial lake design for water resource conservation requires a hydrological analysis that must be comprehensive and detailed to be successful. . This study aims to analyze the maximum rainfall frequency, synthetic unit hydrographs (SUH), design rainfall hyetographs, adequate rainfall, design flood discharge, and lake conservation concepts. The Chi-Square and Kolmogorov-Smirnov tests were used to analyze the maximum rainfall frequency, and the Nakayasu method was used for the Synthetic Unit Hydrograph analysis. The Alternating Block Method (ABM) was employed to analyze the design rainfall hyetograph, and the φ index method was employed for the practical rainfall calculation. The design flood discharge was calculated based on the comparison between the rational method and unit hydrograph. The frequency analysis in average distribution results in 168.7 mm daily rainfall for a 10-year return period, 182.5 mm for a 20-year return period, and 198 mm for a 50-year return period. The Nakayasu analysis shows that the time to peak run-off is 0.56 hours or rounded up to the nearest hour (1st hour). The study of design rainfall hyetograph for a 50-year return period shows 109.0 mm maximum rainfall intensity at the 3rd hour. The adequate rainfall analysis results in 98.5 mm maximum effective rainfall at the 3rd hour. Meanwhile, the Nakayasu method for Synthetic Unit Hydrograph (SUH) obtains 16.68 m3/s design flood discharge for 50 years.

Keywords
lake planning; hydrology; watershed conservation

I. Introduction

The river basin of Progo-Opak-Serang (WS POS) has been enduring intensive development. As developed areas grow and conservation areas decrease and while a land-use change from agricultural to non-agricultural land occurs, water demand increases. At the same time, there is a continuous decline in the recharge area.

Bandungrejo Lake is located in the village of Bandungrejo, Central Java. Its volume is 9,353 m3 with an inundation area of 2,530 m2. Under normal conditions, the lake is 8 meters deep with an embankment height of about 9.5 meters.

The watershed is the total land and water surface bounded by a topographic wa-ter-boundary and which in one way contributes to the discharge of a river at a particular cross-section. In a given watershed, the following factors change the time sequence of nat-ural precipitation (P) into the time sequence of run-off (Q) it produces: 1. Climate Factors; 2. Soil Factors: a) Topography; b) Land; c) Geology; d) Geomorphology and 3) Land use. Variabilyt in output Q depends on the interplay among these subsystems at this site.A system is quantitatively defined by its components or dominant variables that influence Q, such as the percentages of forest land, grassland and cultivated land, etc.

The response of a watershed is not only measured by the amount of run-off it produced but also by erosion and transport of materials, including chemical material. These responses interact with each other in controlling changes in watersheds. Typically, computational models are used to analyze watershed systems. These models can be physical, analog, mathematical, or statistical.

The relationship between ongoing erosion in the catchment area and the amount of sedimentation observed in the lower reaches of a river flow within its catchment area is closely related to the hydrological system. Rainfall amount and intensity, soil type, slope, vegetation, and human activities play essential roles in the erosion-sedimentation process. Each type of soil, slope, and vegetation influences of the magnitude of erosion. Erosion hazard are more pronounced when the instable soil types are present on steeply sloping geologic formation. At the same time, the stratified structure of ground cover vegetation can reduce erosion hazards than land with predominantly tree vegetation with no or little undergrowth.

The cause of the occurrence of critical land is generally due to erosion in the ground. In Indonesia’s wet tropical climate, soil erosion is caused mainly by runoff after precipitation events. The amount and intensity of precipitation significantly differs between the rainy season and dry season and ultimately determines runoff flow pattern, aggrada-tion, and sedimentation. At the WS POS site, critical land-use change are reported because of non-compliancy with Regional Spatial Planning (RPS) protocols and the WS POS Water Resources Management plans (REF). In addition, the non-optimal protection of water sources is a result of weak community empowerment.

These conditions indicate the need multi-functional analysis of watershed characteristics and the effect of physical protection measures. One form of physical structures that might address the adverse conditions in the study area is a dam or artificial lake. The construction and conservation planning of such a structure requires basic research, namely a in-depth hydrological analysis. It is expected that an artificial water reservoirs can minimize the factors that contribute to the decreasing watershed capacity from hydrological, morphological, and geological perspectives.

II. Review of Literature

Water is an essential natural resource. Crucial factors affecting its availability include wa-ter quantity, quality, and seasonality. To protect water resources and ensure availability, it is therefore to understand the consequences of dry season versus wet seasons.

In addition to seasonality, the availability of water resources in an area is also influenced by physical factors (rainfall, climate, geology/rocks, topography, and soil type), biotic factors (vegetation, land cover), and socio-cultural factors (land use and people's livelihoods). Changes in each directly or indirectly affect the availability and storage of water. Three hydrological areas have to be considered for managing water resources, name-ly groundwater basins, watersheds, and river catchment areas. For instance, shape and size, topography, geology, and land use affect runoff characteristics. This relation can be quantified by the Curve Number (CN) which isa function of watershed characteristics, such as types of soil, cover crops, land use, humidity, and soil working technique. Increased CN indicates a decrease in the land's capability to retain precipitation. Consequently, there is a decrease in the infiltration volume, increasing surface run-off or peak discharge. Hence,the hydrological analysis of the process inside each of these three areas support effective implementation of water management and land-use planning measures. Development is a change towards improvement. Changes towards improve-ment require the mobilization of all human resources and reason to realize what is as-pired (Shah et al, 2020). Typically, water reservoir planning and management is based on the study of design rainfall, rainfall intensity, design flood discharge, mainstay dis-charge, and water demand. Efforts to achieve effective watershed management by syner-gizing development activities within the watershed are required.

III. Research Method

3.1 Analysis of Maximum Rainfall Data Frequency

The frequency of maximum rainfall data is analyzed with statistical parameters to predict the design rainfall in a return period. The theoretical continuous distribution functions consist of everyday, log-normal, Gumbel, and Log-Pearson distributions. The goodness of fit is tested to choose the most suitable design rainfall distribution among the distribution patterns available. The goodness-of-fit test involves the Chi-Square and Kolmogorov-Smirnov Test.

3.2 Analysis of Synthetic Unit Hydrograph (SUH)

The Nakayasu Synthetic Unit Hydrograph (SUH) was developed from the rivers in Japan (32). The watershed parameters of Bandungrejo Lake to determine Nakayasu SUH consist of the watershed extent and main river length. Such parameters are used to assess the hydrograph ordinate at a particular time (t = 0, 1, 2, ..., n) with different equations for an additional time. The discharge equation in a range of time is as follows (33).

In the ascending curve (0 < t < TP = 1 hour)

$$Q_t = Q_p \left(\frac{t}{T_p}\right)^{2.4}$$

In the descending curve (TP = 1 hour > t > TP + T0.3 = 1+ 1 = 2 hours)

$$Q_r = Q_p x 0.3^{(t-T_p)/T_{0.3}}$$

In the descending curve (TP + T03 = 2 hours < t < TP + T0.3+ 1.5 T0.3 = 3.5 hours rounded up to 4 hours)

$$Q_r = Q_p x 0.3^{[(t-T_p)+(0.5T_{0.3})]/1.5T_{0.3}}$$

In the descending curve (t > TP + T0.3 + 1.5 T0.3 = 3.5 hours rounded up to 4 hours)

$$Q_r = Q_p x 0.3^{[(t-T_p)+(1.5T_{0.3})]/2T_{0.3}}$$

The analysis of Nakayasu SUH based on the equations mentioned above begins at 0 hours and peak hours up to almost zero discharge. The results are totaled and divided by the watershed extent to obtain the practical rainfall value. If the value is not equal to 1, the SUH is reexamined by dividing the experimental rainfall values obtained.

3.3 Analysis of Design Rainfall Hyetograph

The design flood calculation requires design rainfall distributed into hourly precipitation (hyetograph). The distribution of design rainfall into hourly precipitation involves the pattern of hourly rainfall distribution. The model of rainfall distribution uses the Alternating Block Method (ABM) (34). Before this, a calculation of rainfall intensity is done using the Mononobe formula:

$$I_T^t = \left(\frac{R_{24}^t}{24}\right)\left(\frac{24}{t}\right)^n$$

Where

I = rainfall intensity for t duration in T return period (mm/hour)

R = maximum daily rainfall intensity at reviewed t (mm/day)

t = rainfall duration (hours)
n = constant

3.4 Analysis of Effective Rainfall

Adequate rainfall equals the total rain on the ground minus water loss. One of the methods to calculate water loss involves the calculation of direct run-off via the φ index (35). The φ index is the mean rate of water loss because of infiltration, evaporation, and surface storage. The φ index is approached using Gama 1 below.

$$\varphi index = 10.4903 - 3.859x10^6A^2 + 1.698x10^{-13}(\frac{A}{SN})^4$$

$$= 10.4903 - 3.859x10^6 x0.78^2 + 1.698x10^{-13}(\frac{0.78}{1})^4$$

$$= 10.4903 \text{ mm/hour}$$

The φ index value will deduct the total design rainfall from earlier calculation to gain the weight of run-off depth.

3.5 Analysis of Design Flood Discharge

The design flood discharge is calculated by comparing the unit hydrograph method and the rational method (35). The sensible way estimates the peak discharge due to heavy rainfall in a small watershed (DAS). A watershed is classified as small if the extent is less than 2.5 km2.

Design flood discharge calculated with the rational method, below.

$$Q = 0.278 \text{ CIA}$$

Q: Peak discharge caused by specific rainfall intensity in an extent of the watershed (m3/s)

C: Run-off coefficient based on land-use type

I: Rainfall intensity (mm/hour)

A: Catchment area/watershed extent (Km2)

The Nakayasu unit hydrograph involves the multiplication of dimensionless hydrograph values by hourly rainfall distribution.

3.6 Concept of Conservation in Lake Watershed

The concept of conservation in a lake watershed is formulated by combining field observations and literature studies (36). Statements are made to identify the physical characteristics of the lake watershed area. In contrast, literature studies are conducted to find the appropriate concept of conservation for a room with the identified physical characteristics.

IV. Results and Discussion

4.1 Analysis of Maximum Rainfall Data Frequency

The frequency analysis is performed to obtain the design rainfall of a specific return period. The downpour, which is expected to be equaled or exceeded once in T years, can then be estimated. The goodness-of-fit test uses the Chi-Square test and Kolmogorov-Smirnov test.

4.2 Chi-Square Test

This test is practical if there are much-observed data because it is recommended that it be grouped before the test. The following tables describe the test performed.

Table 1. Chi-Square Test in Normal Distribution

Class	P(x>=X)		Ef	Discharge (m3/s)	Of	Ef-Of	(Ef-Of)2/Ef
1	0.200	000 <P<= 000	6.200	151.911	7	0.800	0.103
2	0.400	000 <P<= 000	6.200	129.516	7	0.800	0.103
3	0.600	000 <P<= 001	6.200	110.226	3	3.200	1.652
4	0.800	001 <P<= 001	6.200	87.831	7	0.800	0.103
5	1.000	001 <P<= 001	6.200	2.225	7	0.800	0.103
Total Ef =			**31.000**	**Total Of =**	**31**	**Chi^2 =**	**2.065**
Degree of Freedom =			**2.000**	**Critical Chi =**	**5.991**		**accepted**

Table 2. Chi-Square Test in Log-Normal Distribution

Class	P(x>=X)		Ef	Discharge (m3/s)	Of	Ef-Of	(Ef-Of)2/Ef
1	0.200	000 <P<= 000	6.200	152.755	7	0.800	0.103
2	0.400	000 <P<= 000	6.200	124.021	7	0.800	0.103
3	0.600	000 <P<= 001	6.200	103.645	6	0.200	0.006
4	0.800	001 <P<= 001	6.200	84.149	5	1.200	0.232
5	1.000	001 <P<= 001	6.200	37.943	6	0.200	0.006
Total Ef =			**31.000**	**Total Of =**	**31**	**Chi^2 =**	**7.333**
Degree of Freedom =			**2.000**	**Critical Chi =**	**5.991**		**rejected**

Table 3. Chi-Square Test in Gumbel Distribution

Class	P(x>=X)		Ef	Discharge (m3/s)	Of	Ef-Of	(Ef-Of)2/Ef
1	0.200	000 <P<= 000	6.200	147.261	9	2.800	0.771
2	0.400	000 <P<= 000	6.200	122.677	6	1.200	4.200
3	0.600	000 <P<= 001	6.200	105.33	5	0.200	0.771
4	0.800	001 <P<= 001	6.200	88.612	3	3.200	0.771
5	1.000	001 <P<= 001	6.200	45.371	7	0.800	0.343
Total Ef =			**31.000**	**Total Of =**	**31**	**Chi2 =**	**3.28**
Degree of Freedom =			**2.000**	**Critical Chi =**	**5.991**		**accepted**

Table 4. Chi-Square Test in Log-Pearson III Distribution

Class	P(x>=X)		Ef	Discharge (m3/s)	Of	Ef-Of	(Ef-Of)2/Ef
1	0.200	000 <P<= 000	6.200	153.435	7	0.800	0.103
2	0.400	000 <P<= 000	6.200	128.95	7	0.200	0.103
3	0.600	000 <P<= 001	6.200	108.403	5	1.200	0.2332
4	0.800	001 <P<= 001	6.200	85.996	6	0.200	0.006
5	1.000	001 <P<= 001	6.200	25.302	6	0.200	0.006
Total Ef =			**31.000**	**Total aOf =**	**31**	**Chi2 =**	**0.452**

Degree of Freedom =	1.000	Critical Chi =	3.841		accepted

4.3 Kolmogorov-Smirnov Test

This test calculates the goodness of fit based on the distance of data-point deviation from the theoretical curve. The result is accepted if the most considerable deviation distance(Δmax) is less than Δcritical. The best distribution provides the minor Δmaximum. the following table shows the Kolmogorov-Smirnov test for the Bandungrejo Lake watershed.

Table 5. Kolmogorov-Smirnov Test

Rainfall (mm)	m	P = m/(N+1)	NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
			P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do
193.000	1	0.031	0.027	0.004	0.067	0.035	0.047	0.015	0.034	0.003
184.000	2	0.063	0.046	0.016	0.086	0.023	0.063	0.000	0.056	0.007
168.000	3	0.094	0.103	0.009	0.133	0.040	0.105	0.011	0.116	0.023
167.000	4	0.125	0.108	0.017	0.137	0.012	0.108	0.017	0.121	0.004
162.000	5	0.156	0.134	0.022	0.157	0.001	0.127	0.029	0.147	0.009
159.000	6	0.188	0.152	0.035	0.170	0.018	0.140	0.048	0.165	0.023
154.000	7	0.219	0.185	0.034	0.194	0.025	0.163	0.056	0.196	0.023
150.000	8	0.250	0.214	0.036	0.215	0.035	0.184	0.066	0.224	0.026
149.000	9	0.281	0.222	0.059	0.220	0.061	0.190	0.091	0.231	0.050
145.000	10	0.313	0.255	0.058	0.244	0.069	0.214	0.098	0.261	0.051
138.000	11	0.344	0.317	0.027	0.289	0.054	0.263	0.081	0.319	0.025
135.000	12	0.375	0.346	0.029	0.311	0.064	0.286	0.089	0.345	0.030
133.000	13	0.406	0.365	0.041	0.326	0.080	0.303	0.103	0.363	0.043
132.000	14	0.438	0.375	0.062	0.334	0.104	0.311	0.126	0.372	0.066
121.000	15	0.469	0.488	0.019	0.427	0.042	0.418	0.051	0.476	0.008
117.000	16	0.500	0.530	0.030	0.465	0.035	0.461	0.039	0.515	0.015
113.000	17	0.531	0.572	0.040	0.504	0.028	0.507	0.024	0.555	0.024
109.000	18	0.563	0.612	0.050	0.544	0.018	0.555	0.007	0.594	0.032
109.000	19	0.594	0.612	0.019	0.544	0.050	0.555	0.039	0.594	0.000
106.000	20	0.625	0.642	0.017	0.575	0.050	0.592	0.033	0.623	0.002
103.000	21	0.656	0.671	0.015	0.607	0.049	0.629	0.027	0.652	0.004
101.000	22	0.688	0.690	0.002	0.628	0.060	0.654	0.034	0.671	0.017
93.000	23	0.719	0.760	0.041	0.712	0.007	0.750	0.032	0.743	0.024
88.000	24	0.750	0.799	0.049	0.763	0.013	0.807	0.057	0.784	0.034
87.000	25	0.781	0.806	0.025	0.773	0.009	0.817	0.036	0.792	0.011
79.000	26	0.813	0.858	0.046	0.846	0.034	0.892	0.079	0.850	0.038
73.000	27	0.844	0.891	0.047	0.893	0.049	0.934	0.091	0.887	0.044
70.000	28	0.875	0.905	0.030	0.913	0.038	0.951	0.076	0.904	0.029
69.000	29	0.906	0.909	0.003	0.920	0.013	0.956	0.049	0.909	0.003
67.000	30	0.938	0.918	0.020	0.931	0.006	0.964	0.027	0.919	0.019
42.000	31	0.969	0.980	0.011	0.997	0.029	1.000	0.031	0.989	0.020
Critical Delta =	0.238			0.062		0.104		0.126		0.066
				Accepted		Accepted		Accepted		Accepted

Rainfall (mm)	m	P = m/(N+1)	NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
			P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do

Note. : m = Rank

P = Probability in the field

Do = Difference between field probability and theoretical probability

Table 6. Design Rainfall in Different Return Periods

Probability by Order	Return Period	DISCHARGE (M³/S) CHARACTERISTICS BY PROBABILITY							
		Normal		Log-Normal		Gumbel		Log Pearson III	
P(x>=X)		KA	XA	KA	XA	KA	XA	KA	XA
20.00%	5	0.842	130.100	0.722	126.022	0.719	125.938	0.819	125.128
10.00%	10	1.282	145.087	1.274	144.839	1.305	145.871	1.313	146.289
5.00%	20	1.645	157.464	1.792	162.479	1.866	164.991	1.740	167.419
4.00%	25	1.751	161.069	1.954	168.010	2.044	171.056	1.867	174.307
2.00%	50	2.054	171.394	2.451	184.914	2.592	189.740	2.240	196.145
1.00%	100	2.326	180.680	2.939	201.567	3.137	208.286	2.586	218.836
0.50%	200	2.576	189.179	3.425	218.119	3.679	226.764	2.912	242.569
0.20%	500	2.878	199.479	4.068	240.010	4.395	251.143	3.318	275.799
0.10%	1000	3.090	206.703	4.557	256.663	4.936	269.568	3.610	302.512

In this frequency analysis, the normal distribution is used because of its most minor deviation among the other probabilities. Based on the analysis of frequency using the normal distribution, the daily rainfall of the 10-year return period is 168.7 mm with 182.5 mm in a 20-year return period and 198 mm in a 50-year return period.

4.4 Analysis of Synthetic Unit Hydrograph

The parameters of the lake watershed for identifying the Nakayasu SUH include the watershed extent of 0.77 Km2 and river length of 2.05 Km. The analysis results in the time to peak run-off of 0.506 hours in Bandungrejo Lake, indicating that the peak run-off occurs in less than one hour. This condition is considered normal in a river with a relatively large slope and a short length. Because the rainfall-runoff analysis uses the hourly rainfall method, the time to peak can be shifted to one hour to make the calculation easier. On the other hand, the T03 value is less than one hour and then changed into one hour to simplify the analysis. The following table shows the results of Nakayasu synthetic unit hydrograph analysis.

Table 7. Nakayasu Synthetic Unit Hydrograph for Bandungrejo Lake

Hour	Nakayasu SUH (m^3/s)	Nakayasu SUH Volume (m^3)	Corrected Nakayasu SUH (m^3/s)	Corrected Nakayasu SUH Volume (m^3)
0	0.000	0.000	0.000	0.000
1	0.274	986.765	0.169	608.811
2	0.037	132.663	0.023	81.850
3	0.018	65.726	0.011	40.551

Hour	Nakayasu SUH (m³/s)	Nakayasu SUH Volume (m³)	Corrected Nakayasu SUH (m³/s)	Corrected Nakayasu SUH Volume (m³)
4	0.010	36.000	0.006	22.211
5	0.005	19.718	0.003	12.165
6	0.003	10.800	0.002	6.663
7	0.002	5.915	0.001	3.650
8	0.001	3.240	0.001	1.999
9	0.000	0.000	0.000	0.000
Total		**1260.827**	**-**	**777.900**
Effective R		**1.621**	**-**	**1.000**

Source: Data proceed

From the data above, it can be seen that at 1 o'clock, Nakayasu SuH was at 0.274 m3/s and dropped to 0.037 the next hour. This also happened to Nakayasu SUH Volume; at 1 o'clock, the volume of water reached its highest importance, which was at 986,765 m3, and continued to decrease in the following hours.

4.5 Analysis of the Design Rainfall Hyetograph

The following table shows the hyetograph calculation using ABM for different return periods of T years.

Table 8. Rainfall Distribution using ABM with Different Return Periods

T (Hour)	P5 (mm)	P10 (mm)	P25 (mm)	P50 (mm)	P100 (mm)
1	10.2	11.4	12.6	13.4	14.1
2	15.2	16.9	18.7	19.9	20.9
3	83.6	92.8	102.6	109.0	114.7
4	21.7	24.1	26.7	28.3	29.8
5	12.1	13.5	14.9	15.8	16.6
6	9.0	9.9	11.0	11.7	12.3

Source: Data proceed

From the data above, it can be seen that the distribution of rainfall at P5 reaches its peak at the 3rd hour, which is 88.6 mm, and reaches the minimum at the 6th hour, which is 9.00 mm. at P10, the distribution of rainfall in P10 reached its peak at the 3rd hour, which was 92.8 mm, and reached the minimum at the 6th hour, which was 9.9 mm. At P25, the distribution of rainfall at P25 reaches its peak at the 3rd hour, which is 102.6 mm and gets a minimum at the 6th hour, which is 11.7 mm. At P100, the distribution of rainfall in P100 reached its peak at the 3rd hour, which was 114.7 mm, and got the minimum at the 6th hour, which was 12.3 mm.

4.6 Analysis of Effective Rainfall

The following table shows the calculation of adequate rainfall using the φ index in different return periods of T years.

Table 9. Adequate Rainfall in Different Return Periods

T (Hour)	P5 (mm)	P10 (mm)	P25 (mm)	P50 (mm)	P100 (mm)
1	0.0	0.9	2.1	2.1	3.6
2	4.8	6.4	8.2	8.2	10.4
3	73.1	82.3	92.2	92.2	104.2
4	11.2	13.6	16.2	16.2	19.3
5	1.6	3.0	4.4	4.4	6.2
6	0.0	0.0	0.5	0.5	1.8

Source: Data proceed

In the table above, it can be seen that the adequate rainfall in the P5 period reached its peak at the 3rd hour, which was 73.1 mm, and reached its minimum at the 6th hour, which was 0.0 mm. In P10, the rainfall reaches its peak at the 3rd hour, 82.3 mm, and reaches its minimum at the 6th hour, which is 0.0 mm. At P25, the precipitation reaches its peak at the 3rd hour, 92.2 mm, and reaches its minimum at the 6th hour, which is 0.5 mm. At P50, the precipitation reaches its peak at the 3rd hour, 92.2 mm, and reaches its minimum at the 6th hour, which is 0.5 mm. At P100, rainfall peaked at the 3rd hour, which was 104.2 mm, and arrived at its minimum at the 6th hour, which was 1.8 mm.

4.7 Analysis of Design Flood Discharge

a. Design Flood Discharge Calculated Using The Rational Method

The parameters used to determine the design flood discharge in the sensible approach include the watershed extent and river length and the average channel slope (S) of 0.12. The results and the Intensity – Duration – Frequency (IDF) curve are as follows.

Table 10. IDF Calculation Results for Different Return Periods

Duration	Return Period				
t	5	10	20	50	100
5	276.0	306.5	338.9	359.8	378.7
10	173.9	193.1	213.5	226.7	238.6
20	109.5	121.7	134.5	142.8	150.3
30	83.6	92.8	102.6	109.0	114.7
60	52.7	58.5	64.7	68.6	72.2
120	33.2	36.8	40.7	43.2	45.5
180	25.3	28.1	31.1	33.0	34.7
240	20.9	23.2	25.7	27.2	28.7
300	18.0	20.0	22.1	23.5	24.7
360	15.9	17.7	19.6	20.8	21.9

Source: Data proceed

The data above shows that the IDF in the 5th return period reached a maximum peak at t5, which is 276.0, and reached a minimum number at t = 360, which is 15.9. The 10th payback period reaches its maximum peak at t=5, 276.0 and gets a minimum number at t=360, which is 15.9. The 10th payback period reaches its maximum peak at t=10, 306.5, and runs a minimum number at t=360, which is 17.7. The 20th payback period reaches its maximum peak at t = 5, 338.9, and gets a minimum number at t = 360, 19.6. The 50th payback period reaches its maximum peak at t=5, 359.8, and receives a minimum number at t=360, which is 20.8. The 100th payback period reaches its maximum peak at t5, 378.7 and gets a minimum number at t = 360, which is 21.9.

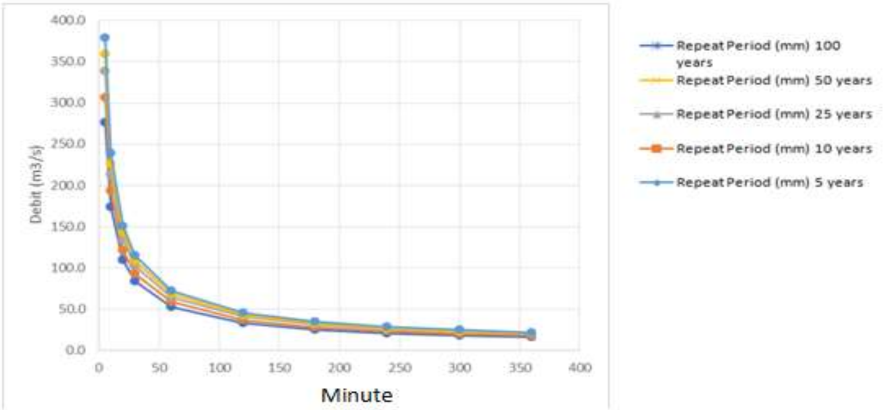

Figure 1. *IDF Curve for the Results of Data Analysis*

The analysis indicates the time of concentration (TC) in Bandungrejo of 0.28 hours. The following table shows the results of the run-off coefficient (C) analysis.

Table 11. Runoff Coefficient Analysis Results

No	Land Use Type	Extent (ha)	C	C_iA_i
1	Rainfed rice field	47.9	0.15	7.18
2	Plantation/Garden	20.2	0.4	8.07
3	Residential area	8.8	0.7	6.14
Total		**76.8**		
$C_{composite\ run\text{-}off}$			**0.28**	

The following table shows the design flood discharge calculated for different return periods.

Table 12. Design Flood Discharge by Rational Method

T	Extent (Km2)	R24 (mm)	Tc (jam)	I (mm)	C	QTc (m3/s)
5	0,768	151,9	0,13	202,37	0,28	12,03
10	0,768	168,7	0,13	224,75	0,28	13,36
25	0,768	182,5	0,13	243,13	0,28	14,45
50	0,768	198	0,13	263,78	0,28	15,68
100	0,768	208,4	0,13	277,64	0,28	16,50
T	Extent (Km^2)	R24 (mm)	Tc (jam)	I (mm)	C	Q (m^3/s)

The table shows that the flood discharge is 12.03 m^3/s for a 25-year return period (Q25), whereas for a return period of 50 years (Q50), it is 15.68 m^3/s and 16.5 m^3/s for a 100-year return period (Q100).

The design flood discharge using Nakayasu synthetic unit hydrograph is calculated via the hourly rainfall distribution's multiplication of the dimensionless hydrograph value. The result indicates a peak discharge at the third hour. In addition, for flood tracking purposes, the flood discharge is 15.594 m³/s in a return period of 25 years (Q25), 16.684 m³/s for a 50-year return period (Q50), and 17.670 m3/s for a 100-year return period (Q100). Such values are lower than the peak flood discharge analyzed using the rational method. Given the different results of the design flood discharge calculation, the following analysis is obtained.

Table 13. Comparison of Design Flood Discharge Calculations in Bandungrejo Lake

Return Period	Peak Discharge (m^3/s)	
	Nakayasu	Rational
Five years	12.02862	12.31214
Ten years	13.35897	13.9035
25 years	14.45176	15.59435
50 years	15.67917	16.68364
100 years	16.50273	17.67044

Based on the 2018 guidelines for lake construction by the Research and Development Division of the Ministry of Public Works and Housing, the return-period discharge for the design of this lake is the 50-year return period discharge (Q50y) of 16.68 m3/s using the rational method.

b. Concept of Conservation in Lake Watershed

An artificial lake, which functions as a conservation area, should be given a sustainability guarantee since it can prevent floods and droughts. To obtain an optimum function, the following efforts can be made: 1) To comply with the terms of Basic Building Coefficient (KDB) to increase the water infiltration ability; 2) To maintain at least 70% of the mountainous area to be covered by permanent vegetation; 3) To conduct cultivation, maintenance, and other activities for soil conservation in barren and critical land, especially in the upstream watershed area; 4) To terrace cultivation areas in sloping land; 5) To build infiltration wells and ponds; 6) To build control dams and reservoirs in feasible areas; 7) To manage environmentally-oriented land use and increase the number of green open spaces; and 8) To allocate more land for social and environmental functions and alignment with the unprivileged, which therefore requires landform and land data updates.

Buildings should not be constructed in water catchment areas since they will block massive infiltration of rainfall. In this area, existing vegetation is protected, and commercial logging is prohibited. Riverbanks should not be used for buildings, roads, or even cultivation activities. Instead, they should be planted with trees, increasing the infiltration capacity and protecting from vegetation logging and harvesting. The areas around the lake should be free from logging, while deforested areas should be replanted with trees. At a radius of 200 meters of the surrounding areas of the spring, cultivation activities should be banned.

The lake should also be free from erosion and sedimentation. Sedimentation is determined by such factors as climate, soil properties, topography, and vegetation conditions, while the water becomes the major erosion factor. Consequently, the efforts to prevent such problems correlate with flood prevention. In addition, riverbanks can suffer from erosion because river cliffs cannot hold soil exposed to river currents. The following activities can be done to prevent erosion and sedimentation: 1) Preventing cultivation on land with steep sloping. Land with more than 40% slope degree is prohibited from being cultivated with any seasonal crops. Meanwhile, an area with 15-25% slope can be developed after terracing is prepared; 2) Constructing sediment traps in various locations of sloping land to prevent sedimentation in rivers, including building dead-end trenches that are parallel to the land contour and with different lengths, widths, and depths of the channel. These trenches should have periodical cleaning to optimize their sediment trap function, especially during the rainy season; c) 3) Reinventing intensive use of the land with an altitude exceeding 1000 m above sea level, and 4) Preventing land use exceeds the tolerable erosion value.

The technical-civil conservation method works by regulating surface run-off to prevent damage to the topsoil, which is helpful for the growth of plants. This method is used in conservation efforts through the construction of conservation structures, such as contour-wise cultivation and terraces, mounds, and water channels. Implementing the technical-civil process as a soil conservation technique can include controlling the dam or sediment trap, gully plug, and check the dam. In addition, vegetative efforts to prevent erosion and sedimentation can be made by plating bamboos or other suitable vegetation.

V. Conclusion

Some conclusions can be drawn from the analysis results: 1) The frequency analysis with normal distribution shows daily rainfall of 168.7 mm in a 10-year return period, 182.5 mm in a 20-year return period, and 198 mm in a 50-year return period; 2) The Nakayasu synthetic unit hydrograph analysis shows 0.56 hour of the time to reach peak run-off in Bandungrejo Lake, indicating a peak run-off achieved before one hour. Since the hourly rainfall method is employed in the rainfall-runoff analysis, this time to peak is rounded up to the nearest hour or the first (1st) hour; 3) The design rainfall hyetograph analysis in the lake watershed for a 50-year return period shows a maximum rainfall intensity of 109.0 mm at the 3rd hour; 4) The practical rainfall analysis shows a maximum adequate rainfall of 98.5 mm at the 3rd hour; 5) The Nakayasu Synthetic Unit Hydrograph (SUH) analysis shows a design flood discharge of 16.68 m3/s for a 50-year return period (Q50); and 6) The lake has a conservation function; to guarantee the sustainability of lake watershed, conservation should be conducted through such methods as vegetative techniques and technical-civil methods.

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