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Environmentally Considered Runaway Control (Ecodrainage) in Urban Areas (Case Study of Jatimulyo Village, Malang City)

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A B S T R A C T
Land use changes in urban areas have a significant impact on increasing surface water runoff. Jatimulyo Village, Malang City, is one of the densely populated areas that is prone to flooding during the rainy season. This study aims to plan rainwater runoff control using an ecodrainage approach. The methods used include hydrological analysis with Log Pearson III distribution to calculate the design rainfall for a 5-year return period, as well as a rational method to calculate the runoff discharge. The results of the analysis show that the capacity of the existing channel is unable to accommodate the peak discharge of 1.103 m^3/second. Infiltration wells are applied as ecodrainage components, and the calculation results show that the discharge after ecodrainage application decreases to 0.556 m^3/second, or reduces runoff by 49.59%. Therefore, ecodrainage has proven effective in reducing the volume of surface runoff and can be a sustainable solution for flood-prone areas in urban areas.

1. INTRODUCTION

Urban areas are areas that are the destination for people to visit or use as a place to live, this is inseparable from the many infrastructures in urban areas that cause the area to become the center of activities targeted by the community, so that there will be many problems, one of which is in the conversion of land functions that occur quickly and not with the specified function. There are many large-scale land conversions that have the potential to be developed as green belts or infiltration areas. So that when the dry season occurs, people will have difficulty getting water, and when the rainy season comes, people will be confused due to excessive water.

Floods are pools of water that are detrimental to the existing ecosystem and to the surrounding community. Floods can occur due to two factors, namely natural factors that cannot be avoided by humans due to the will of nature such as rainfall, physiological/geophysical influences of rivers, river capacity, and factors due to human actions themselves such as changes in land use, waste disposal, and drainage conditions that do not comply with the criteria and requirements.

Jatimulyo Village is an area located in Lowokwaru District, Malang City, located at 07° 56' 32" S, and 112° 37' 11" E. Jatimulyo Village is a densely populated residential area with very minimal infiltration areas. This area often experiences flooding almost every year. There

have been many large-scale land conversions that have the potential to be developed as green belts or infiltration areas, but in reality the areas that should be used as green belts have become residential areas. In addition, the drainage capacity cannot channel water discharge properly, which results in flooding every year.
Almost every time it rains, water overflows from the drainage channels causing flooding which is detrimental to the community (Lopa et al., 2020). According to Suripin (2004) based on the classification of structural and non-structural efforts in floodplain management, the main priority of activities must be aimed at managing surface runoff by developing facilities to retain rainwater (rainfall retention facilities). Handling flooding by normalizing channels, normalizing rivers or widening drainage channels is no longer capable because it can only overcome flooding in the short term.

Based on the problems that have been explained, efforts are needed to minimize the occurrence of runoff or flooding that occurs in Jatimulyo Village when it rains effectively and efficiently. The application of ecodrainage (rainwater harvesting) can be used as an alternative to overcome the problem of drought in the dry season and flooding in the rainy season. Ecodrainage (rainwater collection, infiltration wells, biopores, and bioretention) can reduce rainwater runoff by 52% of the total discharge in The Royal Park housing (Manto & Kadri, 2020).

Identification of problems
Jatimulyo Village is one of the villages in Lowokwaru District which is densely populated. The condition of the research area is a residential area that almost every rainy season experiences flooding. Based on observations made, the intensity of rain that falls with the condition of drainage and water catchment areas is not appropriate, and also due to overflowing rivers around the area.

Land use issues are also considered to be one of the factors causing flooding (Syambudi, 2020). The increasing population density comes from high birth rates and migration. This is what makes the land use that should be used as a green belt area become a settlement, so that the existing infiltration areas and drainage are unable to accommodate rainwater properly. It can be seen through the flood disaster hazard map of Malang City and satellite maps, Jatimulyo Village is a point that is quite prone to flooding and has minimal green open space which results in reduced water absorption areas, so that rainwater that falls can only be accommodated by existing channels and does not seep into the ground.

2. METHOD

Overview of Research Location

The research location was conducted in Jatimulyo Village, Malang City. This location was chosen because this village is a special concern because almost every year this village experiences flooding. Many factors cause Jatimulyo Village to often experience flooding, some factors that cause Jatimulyo Village to often experience waterlogging are changes in land use functions that should be used as green areas or infiltration areas into residential areas, offices and other buildings, then the drainage area that can no longer accommodate flood discharge which causes water to overflow into roads and residential areas.

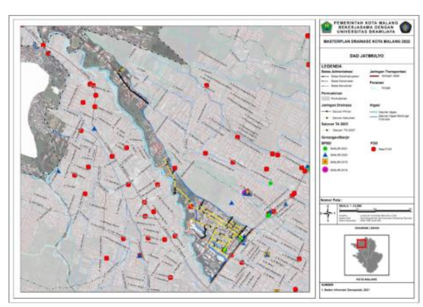

Figure 1 Map of Jatimulyo Village Drainage Area. Source: DPUPRKP Malang City

Research Stages
This study uses a quantitative research approach, which involves collecting numerical data as a tool to analyze information related to the problem to be investigated.

Preparation Stages
At this stage, literature and references are collected to form a theoretical basis. With this preparation process, it can help determine the next action.

Planning Study Stages
After knowing the condition of the research area, it is necessary to collect data to support the research. The supporting data required include:

1. Design rainfall

Design rainfall is very necessary to analyze the design flood discharge, this will affect the design of the planned runoff control capacity, so that there is no shortage or excess of runoff control capacity that will be created later.

2. Existing drainage conditions

Existing drainage conditions are a description of the condition or situation of drainage that accommodates runoff water. Existing conditions are the basis for planning so that their analysis is important for proper development.

3. Land use map

A land use map is a map that contains the results of an assessment of a land by looking at its potential where factors such as biophysical, economic and social conditions become the basis for land planning in order to achieve environmental sustainability and increase productivity (Nurdin, 2016)

4. Soil permeability

Soil permeability is the ability of the soil to drain water through the pores of the soil. Soil permeability is also defined as the speed at which water seeps into the soil vertically or horizontally. In this case, permeability is needed in the planning of infiltration wells so that the design can be carried out in such a way as to accommodate runoff water.

RESULT AND DISCUSSION

Hydrological Analysis
The hydrological analysis carried out was in the form of calculating the design rainfall with a 5-year return period which was then used to calculate the design flood discharge with the same return period. This design flood discharge will later be used as material to evaluate the existing condition of the drainage channel whether it is able to accommodate the flood discharge or not, this is also the basis for controlling runoff that will be offered in the form of eco-drainage at the study location.
In the evaluation and handling of runoff water analyzed in this study, a 5-year return period was used, taking into account the conditions of the study area, the majority of whose land use is residential.

Data Preparation
Based on rainfall data obtained from several rainfall stations closest to the study location in Jatimulyo Village, namely the rainfall station of the Irrigation Engineering Laboratory of Brawijaya University and the Ciliwung rainfall station. The data used are observations for 10 years from 2015 to 2024. The rainfall data used are as follows.

Table 1Table of Annual Maximum Daily Rainfall Data for Brawijaya University Station & Ciliwung Station.

No.	Year	Station	Date	Rain Height (mm)	
				Ciliwung	UB
1	2015	UB	03-May	98	111.0
		Ciliwung	03-May	98	111.0
2	2016	UB	27-February	37	118.2
		Ciliwung	12-April	64	0
3	2017	UB	25-March	15	103.2
		Ciliwung	04-April	104	3.7
4	2018	UB	05-January	0	111.0
		Ciliwung	21-June	97	0
5	2019	UB	30-January	5	96.5
		Ciliwung	11-February	82	0
6	2020	UB	20-November	2	114.0
		Ciliwung	22-March	97	0
7	2021	UB	19-October	0	90.0
		Ciliwung	23-March	102	0
8	2022	UB	01-February	-	99.0
		Ciliwung	15-March	115	10
9	2023	UB	09-December	-	113.0
		Ciliwung	9-February	102	21
10	2024	UB	09-April	-	101.0
		Ciliwung	03-April	94	70

Table 4.1 Continued

Source: Irrigation Engineering Laboratory, Brawijaya University & BMKG East Java Climatology Station (2025)

Consistency Test of RAPS (Rescaled Adjusted Partial Sum) Method

The steps for calculating the consistency test of the RAPS method are as follows.

- First, calculate the average value of X, for example for the RAPS test at Brawijaya University station, the number of data samples (n) is 10, so the calculation is as follows.

$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} Xi = 105.69$

- Then calculate the Sk* value for each data sample, for example for 2017, Brawijaya University Station, the calculation is as follows.

$Sk^{*} = (X - Xrerata)$= 103.2 – 105.69 = -2.49

- Calculating Dy2 for each data sample, for example for 2017, Brawijaya University Station, the calculation is as follows.

Dy2 =$\frac{Sk^{*2}}{n}$= = 0.62$\frac{-2,49^2}{10}$

- After calculating the Sk** value for each data sample, an example was taken for 2017 at Brawijaya University Station as follows.

Sk^{**}=$\frac{Sk^{*}}{Dy}$= = -0.290$\frac{-2,49^2}{\sqrt{73,90}}$

- Determine the maximum and minimum Sk** values from the Sk** results of each data sample to calculate the Q and R values. The Q value is the maximum Sk** value while the R value is the maximum Sk** value – minimum Sk** value. For example, for the Brawijaya University station, the following values were obtained.

Sk^{**}Minimum = -1.825

Sk^{**}Maximum = 1.455 (Q)

SoSk^{**}Maximum - Minimum = 1.455 – (-1.825) = 3.280 (R)Sk^{**}

- From the Q and R values, the calculation results are divided by the square root of the number of data per station, namely n = 10. For example, at Brawijaya University station, the calculation is as follows.

$\frac{Q}{\sqrt{n}}$count =$\frac{1,455}{10}$= 0.46

$\frac{R}{\sqrt{n}}$count = = 1.04$\frac{3,280}{10}$

- Then the valueQ/n0.5 and R/n0.5 calculated compared with Q/n0.5 and R/n0.5 from the table. The values of Q/n0.5 and R/n0.5 from the table are obtained for n=10 with a probability of 90%. If the results of Q/n0.5 and R/n0.5 calculated are smaller than Q/n0.5 and R/n0.5 table, then the RAPS test is accepted and includes consistent data.

Table 2 Results of RAPS Test Calculations at Brawijaya University Rain Station

No.	Year	X (mm)	Sk*	I Sk*I	Dy2	**S**	I Sk**I
1	2016	118.2	12.51	12.51	15.65	1,455	1,455
2	2020	114.0	8.31	8.31	6.91	0.967	0.967
3	2023	113.0	7.31	7.31	5.34	0.850	0.850
4	2015	111.0	5.31	5.31	2.82	0.618	0.618
5	2018	111.0	5.31	5.31	2.82	0.618	0.618

6	2017	103.2	-2.49	2.49	0.62	-0.290	0.290
7	2024	101.0	-4.69	4.69	2.20	-0.546	0.546
8	2022	99.0	-6.69	6.69	4.48	-0.778	0.778
9	2019	96.5	-9.19	9.19	8.45	-1,069	1,069
10	2021	90.0	-15.69	15.69	24.62	-1,825	1,825
	Average	**105.69**					
	Amount				**73.90**		
	n				**10**		
	Sc min**				**-1,825**		
	Sk max**				**1,455**		
	Sk max – Sk** min**				**3,280**		

Source: Calculation Results (2025)

Table 3The results of the RAPS test calculation for the Ciliwung Rain Station

No.	Year	X (mm)	Sk*	I Sk*I	Dy2	**S**	I Sk**I
1	2021	123	25.4	25.4	64.52	1,641	1,641
2	2022	115	17.4	17.4	30.28	1,124	1,124
3	2017	104	6.4	6.4	4.10	0.414	0.414
4	2023	102	4.4	4.4	1.94	0.284	0.284
5	2015	98	0.4	0.4	0.02	0.026	0.026
6	2020	97	-0.6	0.6	0.04	-0.039	0.039

Table 4 Continued

7	2018	97	-0.6	0.6	0.04	-0.039	0.039
8	2024	94	-3.6	3.6	1.30	-0.233	0.233
9	2019	82	-15.6	15.6	24.34	-1,008	1,008
10	2016	64	-33.6	33.6	112.90	-2,171	2,171
	Average	97.6					
	Amount				239.44		
	n				10		
	Sc** min				-2,171		
	Sk** max				1,641		

Sk** max – Sk** min	3,813

Source: Calculation Results (2025)

Table 5. Comparison Results of Q/n0.5 and R/n0.5 Values

Station		Calculation Results	Table Values	Information
University of Brawijaya	Q/n0.5	0.91	1.05	Accepted
	R/n0.5	0.88	1.21	Accepted
Ciliwung	Q/n0.5	0.52	1.05	Accepted
	R/n0.5	1.20	1.21	Accepted

Source: Calculation Results (2025)

Analysis of Average Regional Rainfall Using Algebraic Method

Calculation of regional average rainfall using the algebraic average method from data from 2 stations located in the south and near east of the study location, namely the Universitas Brawijaya rainfall station (7°56´35" LS 112°36'82" BT), and the Ciliwung rainfall station (07° 57´2.4" LS 112°38´9.4" BT). The arithmetic average method can be formulated as follows:

$$\bar{X} = \frac{X1 + X2 + \cdots Xn}{n}$$

Where X is the rainfall on the same day at different stations.

The following are the steps for calculating average regional rainfall using the algebraic average method.

- The first step is to collect maximum daily rainfall data for each year for 10 years at two stations.
- Calculating the average value of two rainfall data on the same day, so that the result is that each year there are two average rainfall values for the area. For example, for the maximum daily rainfall in 2015, with the number of data (n) known to be 2 data, the calculation is as follows.

$$\bar{X} = \frac{X1 + X2 + \cdots Xn}{n}$$

$$\bar{X} = 0000000\ mm$$

- Then from the two average rainfall values of the area for each year, the largest value is taken. For example in 2007, between the values 93 mm and 71 mm, the larger is 93 mm. So the average rainfall of the area in 2007 was 93 mm.

The complete calculation is shown in the following table.

Table 6. Calculation of Average Regional Rainfall Using Algebraic Method

No	Year	Measured Annual Maximum Rainfall (mm)		Average Regional Rainfall (mm)	Maximum Area Average Rainfall (mm)
		UB	Ciliwung		
1	2015	111.0	98.0	104.5	111.0
2	2016	118.2	64.0	91.1	118.2
3	2017	103.2	104.0	103.6	104.0
4	2018	111.0	97.0	104.0	111.0
5	2019	96.5	82.0	89.3	96.5
6	2020	114.0	97.0	105.5	114.0
7	2021	90.0	123.0	106.5	123.0
8	2022	99.0	115.0	107.0	115.0
9	2023	113.0	102.0	107.5	113.0
10	2024	101.0	94.0	97.5	101.0

Source: Calculation Results (2025)

From the calculation results above, it can be seen that the highest regional average rainfall occurred in 2021, which was 106.5 mm, while the lowest occurred in 2019, which was 89.3 mm. Furthermore, the results of the calculation of the maximum regional average rainfall will be used to determine the type of distribution and design rainfall.

Determining the Type of Distribution

From the results of the maximum daily rainfall data, statistical parameter calculations are carried out to determine the appropriate type of distribution. The results of the frequency & probability analysis are as follows.

Table 7 Frequency and probability analysis table

No.	Rain Height (R)	(Xi-X)	(Xi-X)2	(Xi-X)3	(Xi-X)4
1	123.0	12.33	152,0289	1874,5163	23112,7864
2	118.2	7.53	56,7009	426,9578	3214.9921
3	115.0	4.33	18,7489	81,1827	351,5213
4	114.0	3.33	11,0889	36,9260	122,9637
5	113.0	2.33	5,4289	12,6493	29.4730
6	111.0	0.33	0.1089	0.0359	0.0119
7	111.0	0.33	0.1089	0.0359	0.0119

8	104.0	-6.67	44,4889	-296,7410	1979,2622
9	101.0	-9.67	93,5089	-904,2311	8743,9144
10	96.5	-14.17	200,7889	-2845,1787	40316,1824
Amount	1106.7				
Average (X)			110.7		
Standard deviation (Sd)			8,0485		
Coefficient of Variation			0.0727		
Skewness Coefficient (Cs)			-0.4299		
Kurtosis Coefficient (Ck)			1,8557		

Source: Calculation Results (2025)

For a normal distribution it is required that the probability of a variation between () = 68.27% and () = 95.44%.$x \pm sx \pm 2s$

Value () = (110.7 – 8.05) = 102.65$x - s$

Value () = (110.7 + 8.05) = 118.75$x + s$

From Table 4.2. the number of data that is smaller than 102.65 is 2, the number of data that is larger than 118.75 is 1, so:

Number of Variants =$\frac{10-3}{10} \times 100\%$= 70%

Mark() = (110.7 – 2x 8.05) = 94.6$\bar{x} \pm 2s$

Value () = (110.7 + 2x 8.05) = 126.8$\bar{x} \pm 2s$

From Table 4.2. The number of data smaller than 94.6 is 0, the number of data larger than 126.8 is 0, so:

Number of variations =$\frac{10-0}{10} \times 100\%$= 100%

Table 8. Statistical Parameter Table to Determine Distribution Type

No.	Distribution	Condition	Calculation Results	Information
1	Normal	() = 68.27%$x \pm s$ () = 95.44%$x \pm 2s$ C_S= 0 C_k= 3	70% 100% -0.43 1.86	No No No No
2	Normal Log	C_S= CV3 + 3CV = 0.702 C_k= CV8 + 6CV6 + 15CV4 + 16CV2 + 3= 3.89	--0.43 1.86	No No
3	Pearson III	C_S> 0 C_k= 1.5 + 3 = 3.00$C_S{}^2$	-0.43 1.86	No No

4	Gumball	C_S= 1.14 C_k= 5.4	-0.43 1.86	No No
5	Person Log III	Apart from the above values		Yes

Source: Triatmodjo (2008)

From Table 4.3. That the data distribution is not suitable for normal, log normal, Pearson III, or Gumbel distribution, so the data distribution above uses the Log Pearson III distribution.

CONCLUSIONS

Based on the results of data analysis and discussion, the author obtained the following conclusions that can be drawn from the research discussing Environmentally Conscious Runoff Control in the Jatimulyo sub-district area: The results of this study indicate that the rainfall for the 5-year return period using the Log Pearson III method based on the rainfall station closest to the study location, namely the Brawijaya University station and the Ciliwung rainfall station, is 117.62 mm. The Existing Dimensions of the reviewed channels amount to 41 channels, with 30 channels capable of accommodating flood discharge at a 5-year recurrence period and 11 channels unable to accommodate flood discharge. The planned ecodrainage in this study is the Infiltration Well. The number of infiltration wells that can accommodate flood discharge at the study location is 325, but the ideal number to be applied is only 195, with a diameter of 120 cm and a depth of 650 cm.

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