

STUDY OF CURVE NUMBER (CN) VALUES IN FLOOD-PRONE WATERSHEDS IN THE FLORES RIVER BASIN REGION

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Abstract

Floods are natural disasters that frequently occur due to global climate change, land-use conversion, and human activities that degrade the environment. According to the 2017 Water Resources Management Pattern (PSDA) for the Flores River Basin, there are 23 flood-prone areas across 12 watersheds in the region. This study focuses on the Magepanda and Kolisia watersheds in Sikka Regency, East Nusa Tenggara, with areas of 61.439 km² and 32.740 km², respectively. The purpose of this research is to determine the flood discharge in both watersheds using 22 years (2003–2024) of GPM satellite rainfall data. Rainfall distribution analysis was conducted using the Normal, Log Normal, Log Pearson Type III, and Gumbel methods. At the same time, flood discharge calculations were performed using the Synthetic Unit Hydrograph (HSS) SCS-CN method through the HEC-HMS application. The results show that the peak flood discharge in the Magepanda watershed ranges from 105,8 m³/s for a 2-year return period to 793,9 m³/s for a 1000-year return period. Meanwhile, the Kolisia watershed has peak flood discharge values ranging from 68,9 m³/s for a 2-year return period to 452,6 m³/s for a 1000-year return period.

Keywords: flood discharge, curve number, Kolisia, Magepanda, SCS-CN, HEC- HMS.

1. Introduction

Flooding is a natural disaster that frequently occurs during the rainy season in a watershed area. This condition is caused by excess water discharge in the river channel, resulting in overflow and inundation of surrounding areas (Suadnya et.al, 2017). Several factors generally influence flood vulnerability in a region; in addition to rainfall potential, it is also affected by social and physical aspects. Population conditions influence social flood vulnerability, whereas physical vulnerability is affected by land use, drainage density, and landform morphology.

According to the 2017 Water Resources Management Pattern Data for the Flores River Basin Region, 23 flood-vulnerability points were identified across 12 watersheds (Ministry of Public Works, 2014). Two of these flood-prone watersheds are the Magepanda and Kolisia Watersheds, located in Sikka Regency. Surface runoff analysis in the Magepanda and Kolisia watersheds, which are flood-prone, was conducted to determine their ability to retain runoff. In addition, the limited availability of measured hydrological data in these watersheds poses challenges for conducting proper flood analysis. Geographically, the Magepanda Watershed is located between 8°31'09.62" – 8°38'35.59" S and 121°59'31.59" – 122°5'7.13" E, with a total area of 96.816 km², while the Kolisia Watershed is

located between 8°31'39.43" – 8°37'27.48" S and 122°3'53.04" – 122°7'41.55" E, with a total area of 43.97 km².

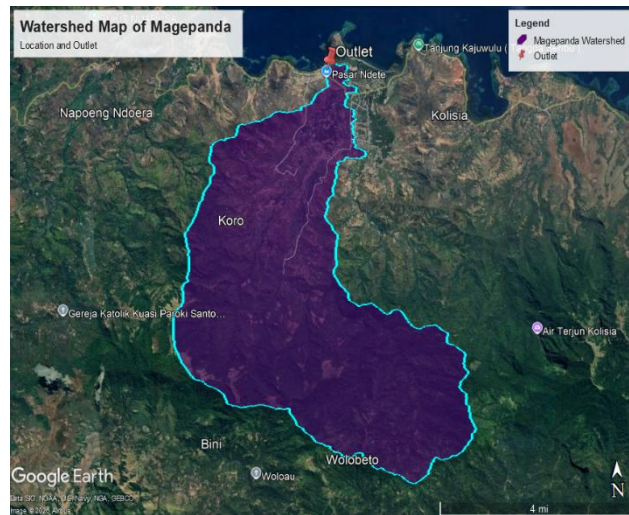
The Soil Conservation Service–Curve Number (SCS-CN) method was developed based on years of rainfall observations and has been used across numerous agricultural areas in the United States. This method attempts to relate watershed characteristics such as soil type, vegetation, and land use to the Curve Number (CN) value, which indicates the runoff potential for a given rainfall event (Ideawati et.al, 2015, Andayani et.al, 2025). This method combines Remote Sensing and Geographic Information System (GIS) technology to estimate runoff in watersheds without complete hydrological measurement instruments, while still providing reliable results highly useful for hydrological structure planning and peak discharge estimation.

This method is based on the Curve Number (CN), which serves as an index for determining the portion of rainfall that becomes runoff and enters the river network. Determining the CN value requires a Hydrologic Soil Group (HSG) map, which in practice must be derived from other maps that contain the parameters required by the HSG classification. Transforming one map into another requires criteria that link the two map types, followed by validation through calibration using a Rainfall–Runoff Relationship Model, such as HEC-HMS (Adidarma et.al, 2013).

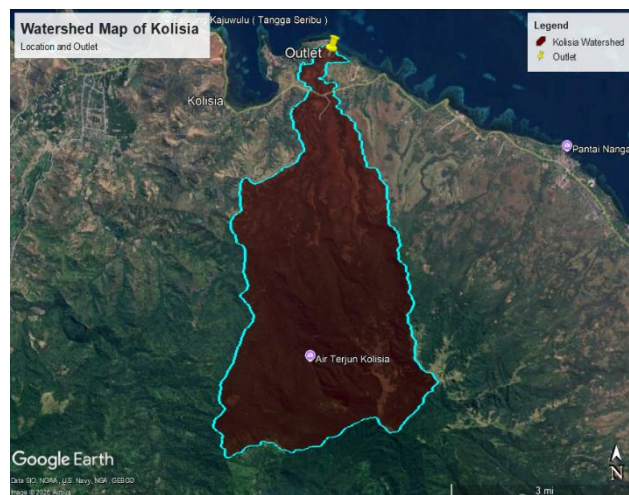
According to Tikno et.al (2012) research on curve number values has been widely conducted in watersheds across Indonesia, such as the Upper Ciliwung Watershed, the Juana Watershed in Kudus Regency and Pati Regency (Komara et.al, 2025), the Temef Watershed in East Nusa Tenggara, (Krisnayanti et.al, 2020), and the Benanain Watershed (Krisnayanti et.all, 2021 and Krisnayanti et.all, 2021). This study aims to determine the curve number values for the Magepanda and Kolisia Watersheds.

2. Method

The study area was located in the Magepanda and Kolisia Watersheds, situated in Sikka Regency, East Nusa Tenggara Province (Figure 1). The data used in this study consisted of a topographic map (Digital Elevation Model) at a scale of 1:25,000, obtained from Global Mapper, covering the Magepanda and Kolisia watersheds. The 2019 land-use map was obtained from the Forestry Service Agency website. The hydrogeological map of Timor Island was obtained from the Geological Environment Agency. The UTM zone division map was obtained from Bakosurtanal. Rainfall data were obtained from the Global Precipitation Measurement (GPM) satellite via the NASA website, covering 22 years (2003–2024) (NASA, 2024).



(a) Magepanda



(b) Kolisia

Figure 1. Research location map

The Curve Number (CN) method is based on the relationship between infiltration characteristics of each soil type and the amount of rainfall occurring during a rainfall event. The total rainfall depth (P) falling on soil with a given maximum water retention potential (S) is divided into three components: runoff (Q), infiltration (F), and initial abstraction (Ia) as follows (Chow 1988 and Ramadan et.al, 2017).

$$Q = \frac{(P-Ia)^2}{(P-Ia+S)} \quad (1)$$

Where:

Q = Surface runoff volume (mm)

Ia = Initial abstraction

P = Daily rainfall (mm)

S = Total surface retention volume (retention parameter) (mm)

The determination of the depth of excess rainfall or surface runoff can be expressed using the equation above, where the relationship between Ia and S is given as follows (Chow, 1988):

$$I_a = 0.2S \tag{2}$$

To simplify the calculation of the antecedent moisture condition, land use, and soil conservation, the US Soil Conservation Service (SCS) defines the value of S as follows:

$$S = 25,4 \left(\frac{1000}{CN} - 10 \right) \tag{3}$$

CN is the runoff curve number, which ranges from 0 to 100 (NEH, 2004).

Table 1. CN value based on land use

No	Land Cover	A	B	C	D
1	Airport	79	86	90	92
2	Swamp Shrubs	100	100	100	100
3	Primary Dryland Forest	25	55	70	77
4	Secondary Dryland Forest	25	55	70	77
5	Primary Mangrove Forest	100	100	100	100
6	Secondary Mangrove Forest	100	100	100	100
7	Primary Swamp Forest	100	100	100	100
8	Secondary Swamp Forest	100	100	100	100
9	Plantation Forest	25	55	70	77
10	Settlement	79	86	90	92
11	Plantation	62	71	78	81
12	Mining Area	62	71	78	81
13	Dryland Agriculture	51	67	76	80
14	Mixed Dryland Agriculture and Shrub	51	67	76	80
15	Swamp	100	100	100	100
16	Grassland	30	58	71	78
17	Rice Field	59	70	78	81
18	Shrubs	29	57	70	77
19	Fish Pond	59	70	78	81
20	Bare Land	30	58	71	78
21	Transmigration	59	74	82	86
22	Water Body	100	100	100	100

The Soil Conservation Service (SCS) developed a soil classification system based on soil characteristics, grouping soils into four Hydrologic Soil Groups (HSGs). The definition of each soil group is determined based on similarities in surface runoff potential under the same weather conditions and land use. These groups are classified as shown in Table 2.

Table 2. Hydrologic soil group classification

Soil Group	Information	Infiltration Rate (mm/hr)
A	The lowest runoff potential. Includes deep sandy soils with silt and clay content. High infiltration rate.	8-12

B	Low runoff potential, sandy soils shallower than Group A, with fine to medium texture and moderate infiltration rate.	4-8
C	Moderate runoff potential. Shallow soils containing a sufficient amount of clay, with medium to fine texture and low infiltration rate.	1-4
D	High runoff potential, mostly clay soils, shallow, with an impermeable layer close to the soil surface. Very low infiltration.	0-1

Soil permeability was determined by converting the hydrogeological map into Hydrologic Soil Groups (HSGs), as presented in Tables 3 and 4.

Table 3. Conversion of the hydrogeological map to HSG for deep groundwater (not light blue color), greater than 100 cm (Adidarma et.al, 2024).

Permeability				
Very High	High	Moderate	Low	Very low
A				
	B			
		C		
			D	

Table 4. Conversion of the hydrogeological map to HSG for shallow groundwater (not blue), less than 100 cm, [4]

Permeability				
Very High	High	Moderate	Low	Very low
A				
	B			
		C		
				D

3. Results and Discussion

Based on digitization in ArcGIS 10.8, the Magepanda Watershed had an area of 61.439 km². The Kolisia Watershed, with an area of 45.63 km², was divided into 9 sub-watersheds. The determination of the Curve Number (CN) is the main focus of this study and requires validation through a calibration stage; therefore, the observed hydrograph is of great importance.

The land cover map for the Magepanda Watershed is presented in Table 5 and Figure 2, while the land cover map for the Kolisia Watershed is shown in Table 6 and Figure 3.

Table 5. Land cover in the Magepanda Watershed

No	Symbol	Land Cover	Area (Km ²)	(%)
1		Secondary Dryland Forest	16.317	26.559


















2		Settlement	0.370	0.602
3		Plantation	0.351	0.571
4		Dryland Agriculture	2.778	4.522
5		Grassland	3.037	4.943
6		Rice Field	2.483	4.041
7		Shrubs	34.695	56.471
8		Bare Land	0.723	1.176
9		Water Body	0.686	1.116
Total Land Cover Area			61.439	100

Table 6. Land Cover in the Kolisia Watershed

No	Symbol	Land Cover	Area (Km ²)	(%)
1		Secondary Dryland Forest	16.386	50.048
2		Settlement	0.041	0.125
3		Plantation	0.004	0.012
4		Dryland Agriculture	0.249	0.760
5		Grassland	4.958	15.144
6		Rice Field	0.562	1.716
7		Shrubs	10.147	30.992
8		Bare Land	0.346	1.055
9		Water Body	0.048	0.147
Total Land Cover Area			32.740	100

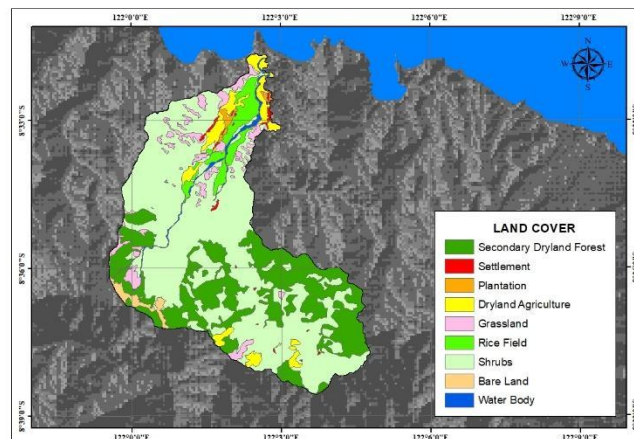


Figure 2. Land cover map of the Magepanda Watershed

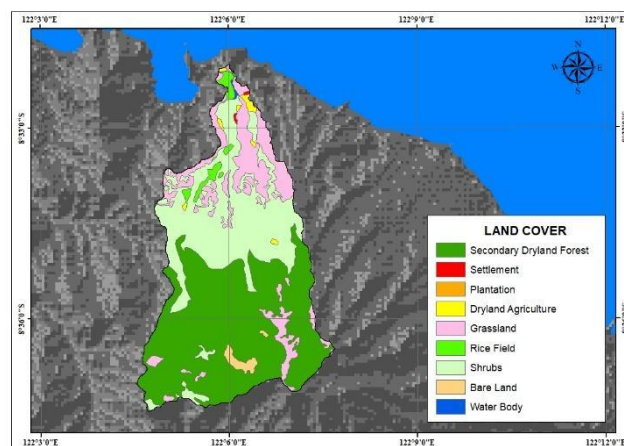


Figure 3. Land cover map of the Kolisia Watershed

The digitization results showed that the Magepanda Watershed is predominantly covered by shrubland. With an area of 34.695 km², the Curve Number (CN) values based on land use, as presented in Table 1, are A = 29, B = 57, C = 70, and D = 77. Meanwhile, the digitization results for the Kolisia Watershed indicated that it is predominantly covered by secondary dryland forest, with an area of 16.386 km², and the Curve Number (CN) values based on land use, as presented in Table 1, are A = 25, B = 55, C = 70, and D = 77. The hydrogeological maps of the Magepanda Watershed and Kolisia Watershed are presented in Figure 4 and Figure 5, respectively.

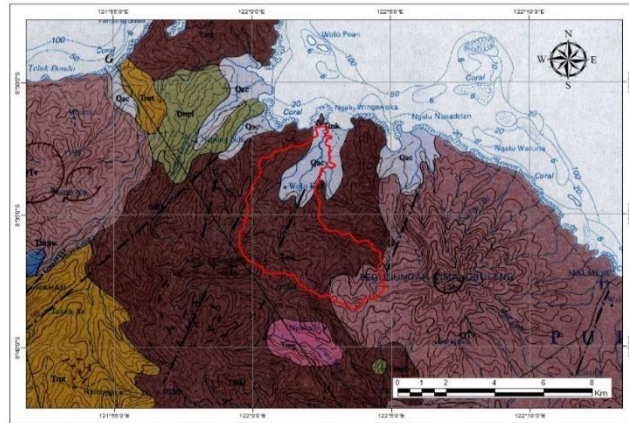


Figure 4. Geological map of the Magepanda Watershed

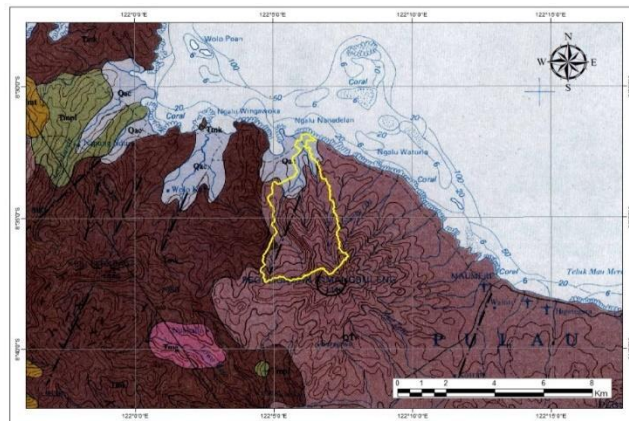


Figure 5. Geological map of the Kolisia Watershed

Furthermore, the Curve Numbers (CNs) were obtained from the overlay of the geological and land cover maps, which were then tabulated as presented in Tables 7 and 8. The Curve Number for the Magepanda Watershed was calculated to be 78.174, indicating that runoff generated during rainfall events is relatively well retained, as the watershed has the potential to function as a water storage area, with lithological conditions dominated by the Kiro Formation.

Table 7. Land cover in the Magepanda Watershed

Sub watershed	Area (Km ²)	CN Value	S (mm)	Ia (mm)
W_1	7.444	77.520	73.65	14.73
W_2	3.100	79.200	66.71	13.34

W_3	2.324	77.571	73.44	14.69
W_4	3.752	79.333	66.17	13.23
W_5	4.509	73.833	90.08	18.00
W_6	2.269	79.000	67.59	13.50
W_7	2.405	80.800	60.36	12.07
W_8	13.42	77.692	72.93	14.59
W_9	1.625	79.143	66.94	13.39
W_10	6.596	79.622	65.01	13.00
W_11	2.344	73.500	91.58	18.32
W_12	0.595	73.500	91.58	18.32
W_13	5.048	82.129	55.26	11.05
W_14	0.656	79.000	67.52	13.50
W_15	5.349	80.766	60.49	12.09

Meanwhile, the Curve Number for the Kolisia Watershed was calculated to be 75.275, indicating that runoff generated during rainfall events is relatively well retained, as the Kolisia watershed has the potential to function as a water storage area, with lithological conditions dominated by old volcanic deposits. Detailed CN values for each sub-watershed in the Magepanda Watershed are presented in Table 7.

Based on Table 7, the Curve Number (CN) values in the Magepanda Watershed range from 73.500 to 82.129, indicating that the watershed still has the capacity to generate surface runoff while maintaining some degree of water retention within the watershed storage system. Based on calculations using HEC-HMS 4.11, the design flood discharge values for the Magepanda Watershed were obtained, as presented in Figure 6.

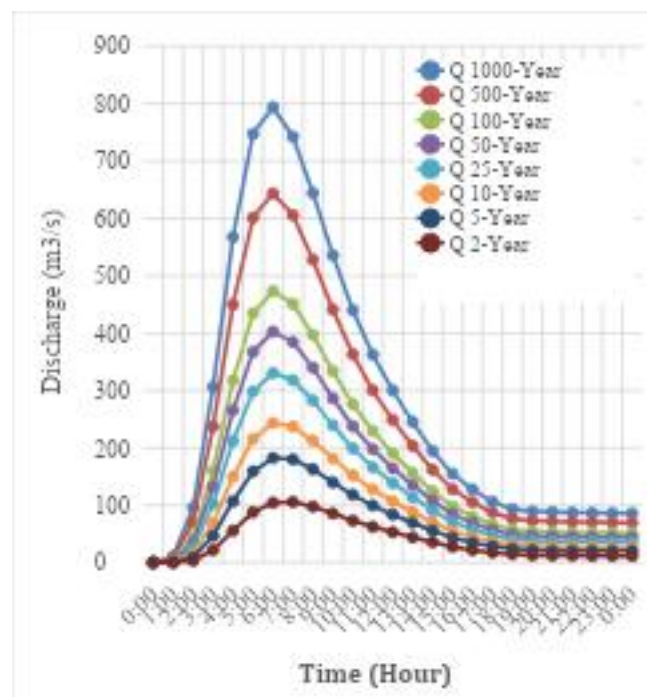


Figure 6. SCS CN Synthetic unit hydrograph in the Magepanda Watershed

Based on Figure 6, the design flood discharge calculated using the SCS-CN Synthetic Unit Hydrograph (SUH) method for the Magepanda Watershed yielded the following results: $Q_2 = 105.8 \text{ m}^3/\text{s}$; $Q_5 = 182.2 \text{ m}^3/\text{s}$; $Q_{10} = 243.3 \text{ m}^3/\text{s}$; $Q_{25} = 330.4 \text{ m}^3/\text{s}$; $Q_{50} = 402.6 \text{ m}^3/\text{s}$; $Q_{100} = 473.6 \text{ m}^3/\text{s}$; $Q_{500} = 643.8 \text{ m}^3/\text{s}$; and $Q_{1000} = 793.9 \text{ m}^3/\text{s}$.

The detailed CN values for each sub-watershed in the Kolisia Watershed are presented in Table 8.

Table 8. Land cover in the Kolisia Watershed

Sub watershed	Area (Km ²)	CN Value	S (mm)	Ia (mm)
W_1	2.211	73.000	93.945	18.78
W_2	3.094	74.000	89.243	17.84
W_3	9.329	77.400	74.165	14.83
W_4	4.704	75.429	82.742	16.54
W_5	5.344	74.889	85.169	17.03
W_6	5.889	73.056	93.681	18.73
W_7	0.066	72.200	97.801	19.56
W_8	1.603	77.000	75.870	15.17
W_9	0.500	80.500	61.528	12.30

Based on Table 8, the Curve Number (CN) values in the Kolisia Watershed range from 72.200 to 80.500, indicating that the watershed still has the capacity to generate surface runoff while maintaining some degree of water retention within the watershed storage system. Based on calculations using HEC-HMS 4.11, the design flood discharge values for the Kolisia Watershed were obtained, as presented in Figure 7.

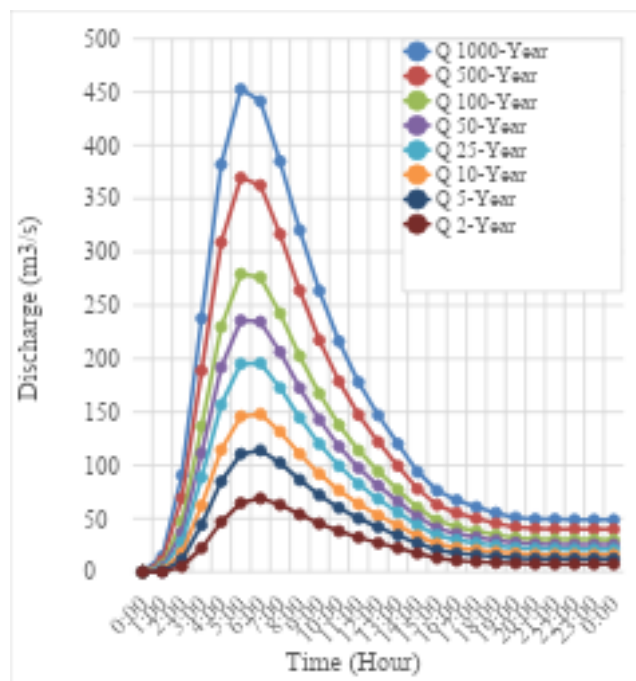


Figure 7. SCS CN Synthetic unit hydrograph in the Kolisia Watershed

Based on Figure 7, the design flood discharge calculated using the SCS-CN Synthetic Unit Hydrograph (SUH) method for the Kolisia Watershed yielded the following results: $Q_2 = 68.9 \text{ m}^3/\text{s}$; $Q_5 = 114.1 \text{ m}^3/\text{s}$; $Q_{10} = 148.1 \text{ m}^3/\text{s}$; $Q_{25} = 195.7 \text{ m}^3/\text{s}$; $Q_{50} = 235.7 \text{ m}^3/\text{s}$; $Q_{100} = 279.4 \text{ m}^3/\text{s}$; $Q_{500} = 369.7 \text{ m}^3/\text{s}$; and $Q_{1000} = 452.6 \text{ m}^3/\text{s}$.

4. Conclusion

Design rainfall, calculated using the Log Pearson Type III Method, resulted in the following values: $R_2 = 107.956 \text{ mm}$; $R_5 = 151.398 \text{ mm}$; $R_{10} = 183.498 \text{ mm}$; $R_{25} = 227.803 \text{ mm}$; $R_{50} = 263.729 \text{ mm}$; $R_{100} = 302.185 \text{ mm}$; $R_{500} = 381.282 \text{ mm}$; and $R_{1000} = 453.480 \text{ mm}$.

The Curve Number (CN) values in the Magepanda Watershed ranged from 73.500 to 82.129. The highest CN value was found in sub-watershed W_13, with an area of 5.048 km², dominated by the Kiro Formation lithology, consisting of breccia, lava, sandy tuff, and tuffaceous sandstone, covering 3.217 km². The lowest CN value was found in sub-watershed W_11, with an area of 2.334 km², also dominated by the Kiro Formation lithology, covering 1.682 km². Meanwhile, the CN values in the Kolisia Watershed ranged from 72.200 to 80.500. The highest CN value was found in sub-watershed W_9, with an area of 0.500 km², dominated by alluvial and coastal deposits, consisting of boulders and gravel from andesite, basalt, and granite; sand, mud, and silt, covering 0.294 km². The lowest CN value was found in sub-watershed W_7, with an area of 0.066 km², also dominated by alluvial and coastal deposits, covering 0.064 km².

The flood discharge calculations for the Magepanda Watershed, using HEC-HMS software with the SCS-CN method, produced the following peak discharges: $Q_2 = 105.8 \text{ m}^3/\text{s}$, $Q_5 = 182.2 \text{ m}^3/\text{s}$, $Q_{10} = 243.3 \text{ m}^3/\text{s}$, $Q_{25} = 330.4 \text{ m}^3/\text{s}$, $Q_{50} = 402.6 \text{ m}^3/\text{s}$, $Q_{100} = 473.6 \text{ m}^3/\text{s}$, $Q_{500} = 643.8 \text{ m}^3/\text{s}$, and $Q_{1000} = 793.9 \text{ m}^3/\text{s}$. Meanwhile, the flood discharge calculations for the Kolisia Watershed, using HEC-HMS

software with the SCS-CN method, produced the following peak discharges: $Q_2 = 68.9 \text{ m}^3/\text{s}$, $Q_5 = 114.1 \text{ m}^3/\text{s}$, $Q_{10} = 148.1 \text{ m}^3/\text{s}$, $Q_{25} = 195.7 \text{ m}^3/\text{s}$, $Q_{50} = 235.7 \text{ m}^3/\text{s}$, $Q_{100} = 279.4 \text{ m}^3/\text{s}$, $Q_{500} = 369.7 \text{ m}^3/\text{s}$, and $Q_{1000} = 452.6 \text{ m}^3/\text{s}$.

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