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The Assessment of Peak Discharge Increment Due to Land Use Change in the Serang Welahan Drainage 1 (SWD 1) River, Central Java Province, Semarang

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Abstract: Serang Welahaan Drainage (SWD) 1 River is located in one of those flood-prone areas in Central Java that generates flood hazards causing high risk to the surrounding rice fields and communities. However, a comprehensive study of flood hazards in SWD1 River has never been conducted. Nowadays, previous comprehensive flood studies in Indonesia only available for several very developed areas, such as the Jakarta, Bandung Flood and Solo Flood , or new iconic area for mangrove conservation such as Langsa City . Most previous studies conclude that flood hazards in Indonesia are commonly generated by rain runoff, tides, and dam break flows, or a combination of these generators . Existing conditions show that SWD 1 is unable to accommodate runoff from the Wulan River, causing flooding. Based on rainfall data from BMKG, the maximum rainfall per month for a year reaches 323 mm. This study is an effort to analyze the impact of land use change to know Flood impact.T.The research method used analysis of the influence of changes in CN (Curve Number) due to changes in land use on flood discharge as shown through changes in the Soil Conservation Service (SCS-CN) hydrograph on discharge and runoff volume. The selection of the SCS-CN method is due to its widespread adoption in various regions, its extensive use in numerous analytical studies, and its suitability for the characteristics of the watershed under review.The analysis results show that there has been a change in flood discharge from 2019 and 2022 with values of 366.920 and 371.154 m^3/second. The discharge values did not change significantly because the CN values were as follows, 83.25 and 83.36. Through analysis, it can be seen that an increase in discharge of 1.14% from 2011 to 2022.The several alternatives are needed to reduce flooding, such as watershed conservation upstream, minimizing land use changes and building flood mitigation infrastructure downstream.

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1. Introduction

Flood hazards are commonly increased in the northern part of Java Island, Indonesia, which consists of flat areas along main rivers, swamps, and/or coastal areas. SWD1 River is located in one of those flood-prone areas in Central Java that generates flood hazards causing high risk to the surrounding rice fields and communities.

Serang Welahan Drainage 1 River (SWD 1) or the Serang Lama River is a river whose Located in Kudus Regency in the upper part, extending to Demak Regency and Jepara Regency in the middle and lower sections.

SWD1 River is located in one of those flood-prone areas in Central Java that generates flood hazards causing high risk to the surrounding rice fields and communities.

However, a comprehensive study of flood hazards in SWD1 River has never been conducted. Nowadays, previous comprehensive flood studies in Indonesia only available for several very developed areas, such as the Jakarta Flood [1] – [5], Bandung Flood [6], [8], and Solo Flood [9], or new iconic area for mangrove conservation such as Langsa City [10]. Most previous studies conclude that flood hazards in Indonesia are commonly generated by rain runoff, tides, and dam break flows, or a combination of these generators [1] – [12]. Furthermore, those flood hazards are increased due to land use and climate change [1], [5]-[14]. Based on previous studies, several flood mitigation measures have been implemented, such as river normalization, sluice gates, reservoirs, rainwater harvesting systems, and flood early warning systems (FEWS) [5]-[15]. However, among those mitigation, FEWS is the most effective effort in reducing the flood risk [2], [6]. Meanwhile, reservoir development in Indonesia faces the risk of dam break due to the increasing trend of earthquakes [17] and water quality problems [15]. Based on previous studies, there has been no discussion related to land use changes impacting peak discharge (which supports the occurrence of floods) and no review of land use changes in 2019 and 2022, focus on discussing the impact of climate change on hydrographs. Therefore, research was conducted on the increase in peak discharge due to land use changes in the Wulan Drainage River 1 in 2019 and 2022.

Meanwhile, the SWD1 River is no longer able to receive run off from the Wulan River so that flooding occurs. The history of flood measurement result in SWD 1 was 306 m^3/second. [19]

Based on the 2019 and 2018 Environmental Management Information Documents for Kudus Regency and Central Java Region, it is explained that the area of critical land in Kudus Regency is 946.8 Ha or 2.2% of the entire area of Kudus Regency. Land damage occurs due to agricultural/land processing that is not environmentally friendly, including excessive use of inorganic fertilizers. [18]

The conversion of green land into residential areas is proportional to the population growth in the districts of Jepara, Kudus, and Demak, which was between 0.9% and 1.04% from 2020 to 2024.[19]

Apart from that, there was an increase in the need for residential land in Kudus Regency in 2013 - 2017 by an average of 12%. [18]. Based on the column graph above, it shows the comparison between green land/plants and settlements dominated by plants from 2019 and 2022. An improvement in green land decreased by 1.44% from 2019-2022 and the increase of residential certainly still has an influence on increasing flood discharge at the research location.

the aim is to analyze how much the planned flood discharge is presented in the hydrograph through HEC-HMS programming due to the influence of changes in land use that occur and know how much the increment of peak discharge (with the other words to analyze the impact of landuse change to know to know flood impact.. One of the difficulties in getting satisfactory analysis results of the design flood and sedimentation rate in SWD1 River is the lack of data for hydro climatology, rating curves, and sedimentation.

2. Methods

2.1. Study Area

The research location is located on the SWD 1 River which is located across 3 districts, namely Demak, Kudus and Jepara districts. Geographically, it is located upstream at 6°50'31.32"S, 110°49'58.95" and downstream at 6°50'19.79"S, 110°48'51.15"E. The research location can be seen in Figure 1.

Figure 1. Research Location

2.2. Hydrological Analysis

The hydrological analysis carried out in this research starts from calculating rainfall (22 years of rainfall data) from 2001-2022, analyzing the rainfall return periods of 2, 5, 10, 25, 50 and 100 years, then calculating the planned flood discharge. [5] [11].

2.3. Soil Conservation Service Curve Number

The Soil Conservation Service Curve Number (SCS-CN) is one of the many methods used to estimate the amount of infiltration that occurs. The amount of runoff generated depends on the type of land cover, soil type (Hydrologic Soil Groups/HSGs), and watershed characteristics.[8] Infiltration is the flow of water into the soil through the soil surface. Conservation Service Curve Number (SCS-CN) method, which is an empirical approach that is quite widely used to calculate the volume of direct runoff from rain events, starting from the rain catchment area and is able to combine several characteristics. catchment area. Additionally, the HSS SCS method has been adopted by several regions for various land uses and climatic conditions. [9]The SCS-CN method is a method used to estimate rainfall runoff from a specific area. This method was developed in the United States and has become a common method used in hydrological studies. The main components of the SCS method are rainfall, Runoff Curve Number.

2.4. Research Methodology

The Research Methodology analysis flow chart can be seen as Figure 2. The infiltration rate as a function of time is given by Horton (1940) in the following Equation (1).

$$f_t = f_c + (f_0 - f_c)e - k \tag{1}$$

where:
ft = infiltration capacity at time t
f0 = initial infiltration capacity
fc = constant infiltration capacity, which depends on the soil type
k = constant indicating the rate of reduction in infiltration capacity

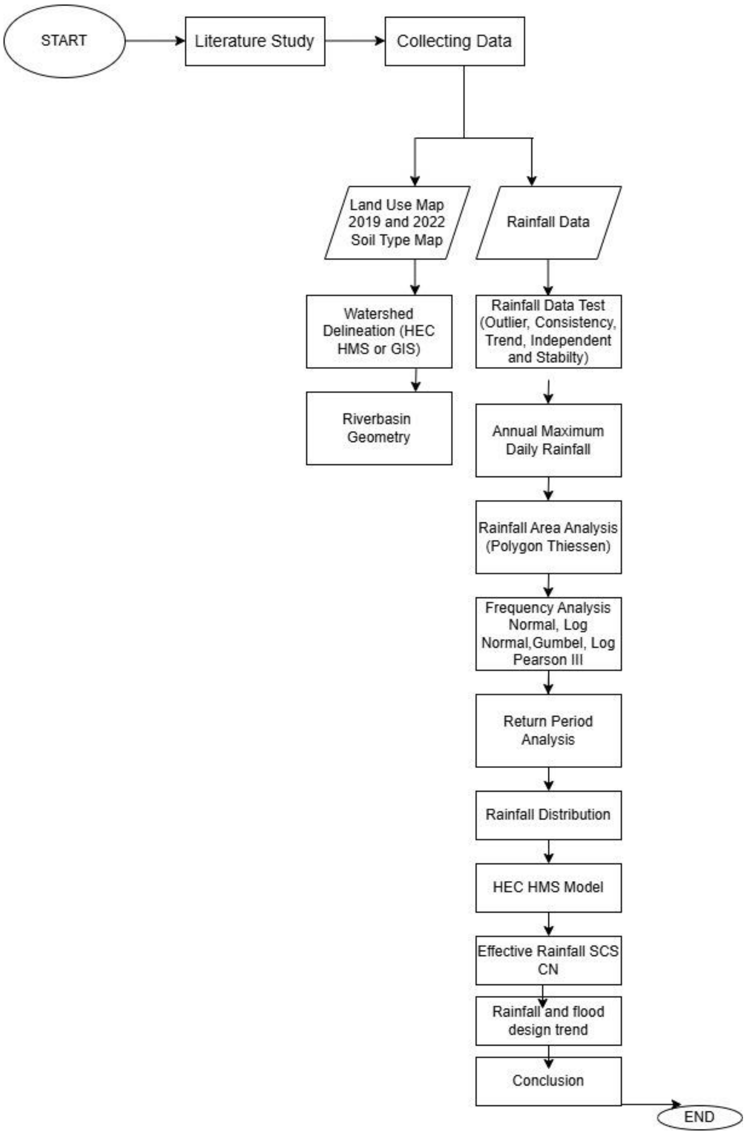

Figure 2. Research Methodology Flowchart Image

The SCS-CN calculation stages are:

1. Determining the CN (Curve Number) Value The formulas related to CN are depicted in Equation (2)-(4).
2. $\frac{P-Q}{S} = \frac{Q}{P}$ (2)
3. $\frac{P-I\alpha-Q}{S} = \frac{Q}{P-I\alpha}$ (3)
4. $S = \frac{1000}{CN} 10$ (4)

Where:
P = Total Rainfall (Total Rain)
Q = Actual Runoff (actual runoff)
Ia = Initial Abstraction
S = Potential Retention
CN = Curve Number

2.5. Synthetic Unit Hydrograph (SCS)

The synthetic unit hydrograph method was developed in the United States by Victor Mockus in 1972. The discharge ordinate is the ratio between the discharge (q) and the peak discharge (qp), and the time abscissa is the ratio between time (t) and peak time (tp), where the rise time (Tp) can be expressed as a portion of the peak time (tp) and the duration of effective rainfall (tl).[7][12]

Some formulas used in the SCS Synthetic Unit Hydrograph method (5-9)are as follows

$$S = \frac{25400 - 254\,X\,CN}{CN} \tag{5}$$

$$I_a = 0{,}2S \tag{6}$$

$$t_C = \frac{l^{0.8}(S+0.1)^{0.7}}{1.140\,y^{\,0.5}} \tag{7}$$

$$t_l = 0.6t_c \tag{8}$$

$$U_p = C\frac{A}{Tp} \tag{9}$$

Where
C = Conversion constant
Tp = Time to Peak (Hour)

3. Result and Discussion

3.1. Hydrological Modelling

The modeling was conducted on SWD 1 watershed with an area of 89.72 km² divided into 3 Sub-watersheds. The modeling using HEC HMS and ARCGIS depicted in Figure 3.

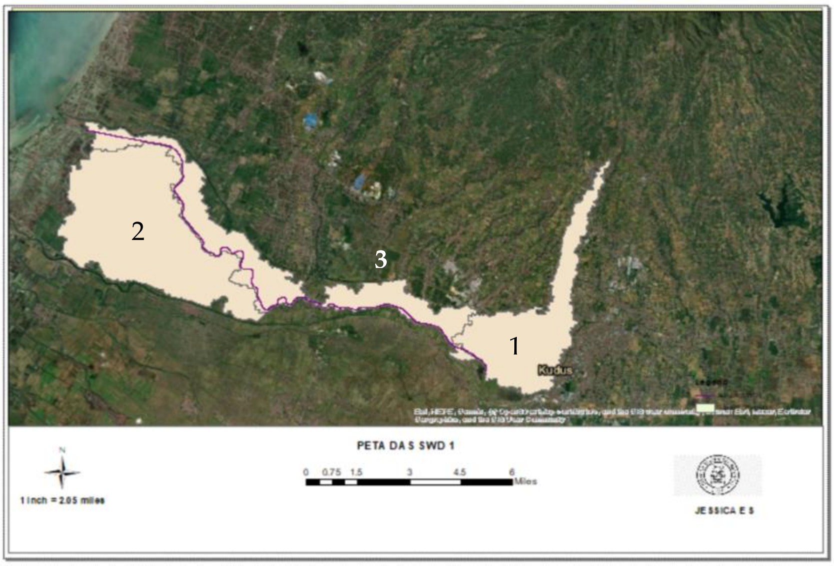

Figure 3. Watershed of SWD 1

3.2. Intensity Duration Frequency Curve (IDFC)

The IDFC graph shows the relationship between rainfall intensity and duration. The IDFC graph indicates that high rainfall intensity is associated with a short duration, and conversely, lower intensity is associated with longer durations based on calculation with stastic method. The IDF graph is shown in Figure 4.

Hourly Rain Distribution Method PSA-007 Hourly rain distribution is calculated based on PSA-007. The distribution of rain over time used is 6 hours and the results of rain for return periods of 2.5 years and so on are as **Table 1**.

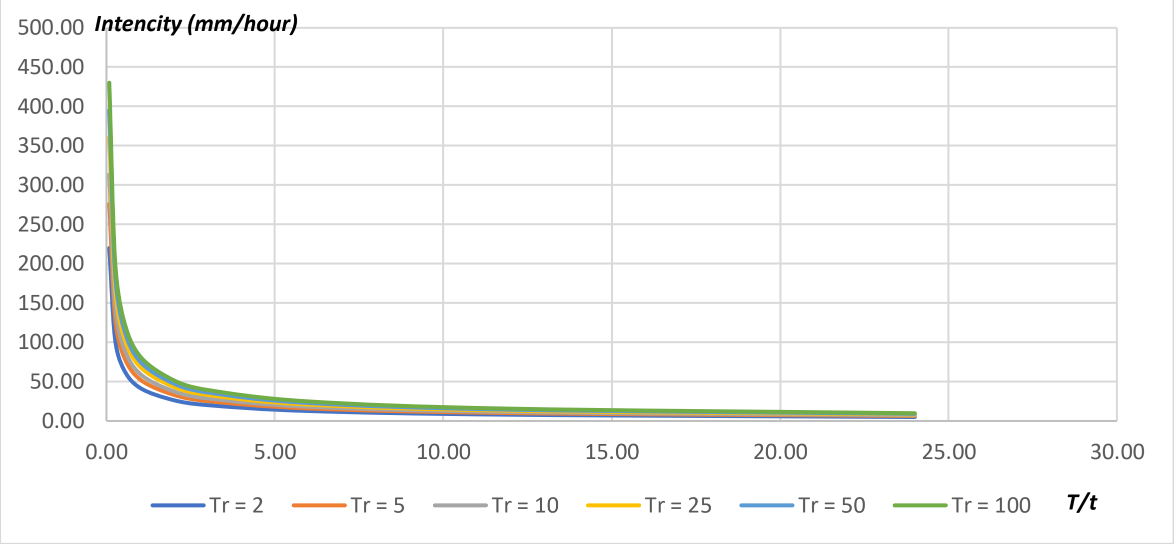

Figure 4. IDFC Curve

Table 1. Re Maximum Rain Value (24 Hour Return Period)

T (Second)	P (1/T)	R_{24} (mm)
20	0.05	198.014
25	0.04	203.457
50	0.02	219.886
100	0.01	235.793

The PSA 007 approach results in a uniform hourly rainfall distribution, where the rainfall is low in the first hour, increases in the second hour, reaches its peak in the third hour, and then starts to decrease again from the fourth hour to the sixth hour. From the table above, it is observed that as the return period increases, the daily maximum rainfall intensity over 24 hours also increases

3.3. Effective Rainfall

Effective rainfall is obtained from the rainfall for the 25 year return period PSA (24 hours) multiplied by the ARF (Area Reduction Factor)[15]. Because the watershed area reaches 89.97 km^2, the ARF value from the graph is 0.85. The effective rainfall used is the return period rainfall value from the Gumbel method which has the smallest MAE value and is transposed. Effective rainfall is input into the HEC HMS to produce a flood hydrograph.

The water he watershed studied is the Wulan River Drainage 1 (SWD 1) watershed which has an area of 89 km2, but due to the influence of the Wulan River, delineation was carried out resulting in a total area of the watershed studied of 89.97 km2, the length of the SWD 1 river is 32 km). The distribution of land use per each Sub Watershed SA-1 in SWD 1 is as **Table 2-4.** After obtaining the CN values, calculations for effective rainfall and infiltration were carried out for the years 2019 and 2022. R total is the total amount of rainfall recorded during the period, infiltration is the process of water entering the soil from the surface. The results of rainfall and infiltration in 2019 (**Table 5**).

Table 2. Sub Watershed SA-1 (Land Use)

Land Use	HSG	Area (Km^2)		CN		Impervious	
		2019	2022	2019	2022	2019	2022
Residential	D	6.33	8.43	92	92	30	30
Rice Field	D	13.97	12.97	81	81	5	5
	CN Composit			85.11	82.4		

Table 3. Sub Watershed SA-2 (Land Use)

Land Use	HSG	Area (Km$^{2)}$		CN		Impervious	
		2019	2022	2019	2022	2019	2022
Residential	D	6.33	8.43	92	92	30	30
Rice Field	D	13.97	12.97	81	81	5	5
	CN Composit			81.7	85.33		

Table 4. Sub Watershed SA-3 (Land Use)

Land Use	HSG	Area (Km^2)		CN		Impervious	
		2019	2022	2019	2022	2019	2022
Residential	D	5.215	5.22	92	92	30	30
Rice Field	D	17.498	17.49	81	81	5	5
Fish Pond	D	2.178	2.086	81			
Water Area	D	0	0.003	100			
	CN Composit			84.27	83.32		

Table 5. Effective Rainfall and Infiltration in 2019 and 2022

Hours	R total (mm)		Infiltration (mm)		R effective (mm)	
	2019	2022	2019	2022	2019	2022
0	0.0	0.0	0.0	0.0	0.0	0.0
1	10.2	10.2	9.9	9.9	0.3	0.3
2	20.3	20.3	14.7	14.5	5.6	5.8
3	122.1	122.1	25.7	24.5	96.4	97.6
4	32.6	32.6	2.3	2.2	30.2	30.4
5	12.2	12.2	0.7	0.7	11.5	11.5

From ARC-GIS program shows the total land area.The total land area of 2 years (2019 and 2022) is 89.72 km^2.

3.5. Change in Land Use Map

The following is an analysis of changes in land cover due to changes in CN, as follows (Figure 5) shows that the area of residential development increased from 2019 to 2022.

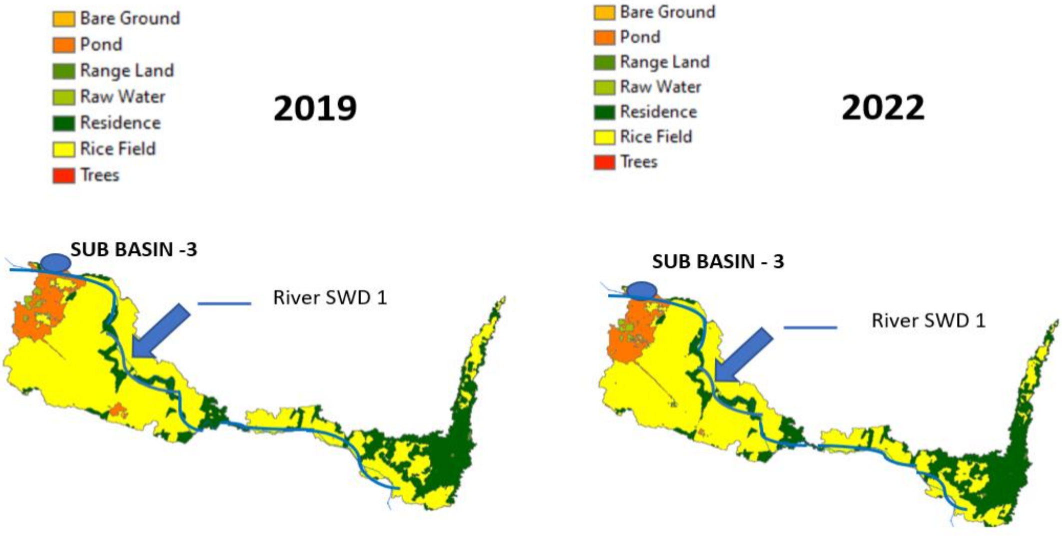

Figure 5. SWD 1 Watershed Land Use Change Map

The decrease in green land area and the increase residential affect the increase of CN. The recapitulation of land area for each sub watershed as **Table 6** and **Table 7.**

Table 6. Recapitulation of Land Cover Area in 2019 and 2022

No	Land Use	SA-1		SA-3		SA-4	
		2019	**2022**	**2019**	**2022**	**2019**	**2022**
		Area (km^2)	**(%)**	**Area (km^2)**	**(%)**	**Area (km^2)**	**(%)**
1	Residence	8.3	37.4	8.4	39.4	2.6	6.1
2	Rice Field	14.0	62.6	13.0	60.6	32.4	76.1
3	Fish Pond	0.0	0.0	0.0	0.0	7.6	17.8
4	Water Area	0.0	0.0	0.0	0.0	0.0	0.0
	Total	22.3	100.0	21.4	100.0	42.5	100.0

Based on from the land cover in 2019 and 2022 the decrease area average is 2.05% from 2019,, with the calculation parameters of SCS CN, the value of time lag (the time between rainfall and peak rainfall), Initial Abstraction (initial loss), Curve Number, and Impervious (level of imperviousness) is obtained. The value is used as input for the calculation of Runoff Discharge in Hec-HMS software. The result of the CN calculation for each Sub Watershed each year as **Table 7**.

Table 7. CN Values for each Sub Watershed in 2019 and 2022

Sub Watershed	Area (Km2)		CN		TL (Minutes)		IA (Initial Abstraction)		Impervious (%)	
	2019	**2022**	**2019**	**2022**	**2019**	**2022**	**2019**	**2022**	**2019**	**2022**
SA-1	22.30	21.40	85.1	85.3	192.84	191.33	8.9	8.7	14.34	8.21
SA-3	42.52	43.52	81.7	82.4	196.73	192.02	11.4	10.8	6.52	14.85
SA-4	24.89	24.80	84.3	83.3	331.43	342.30	9.5	10.2	10.24	10.27
Average			83.25	83.36						

3.6. Analysis of Flood Discharge due to Changes in Land Cover

The CN value for each year (2019 and 2022) is entered into the HSS' Calculation to calculate the planned flood discharge value for each year, which is obtained as Figure 6.

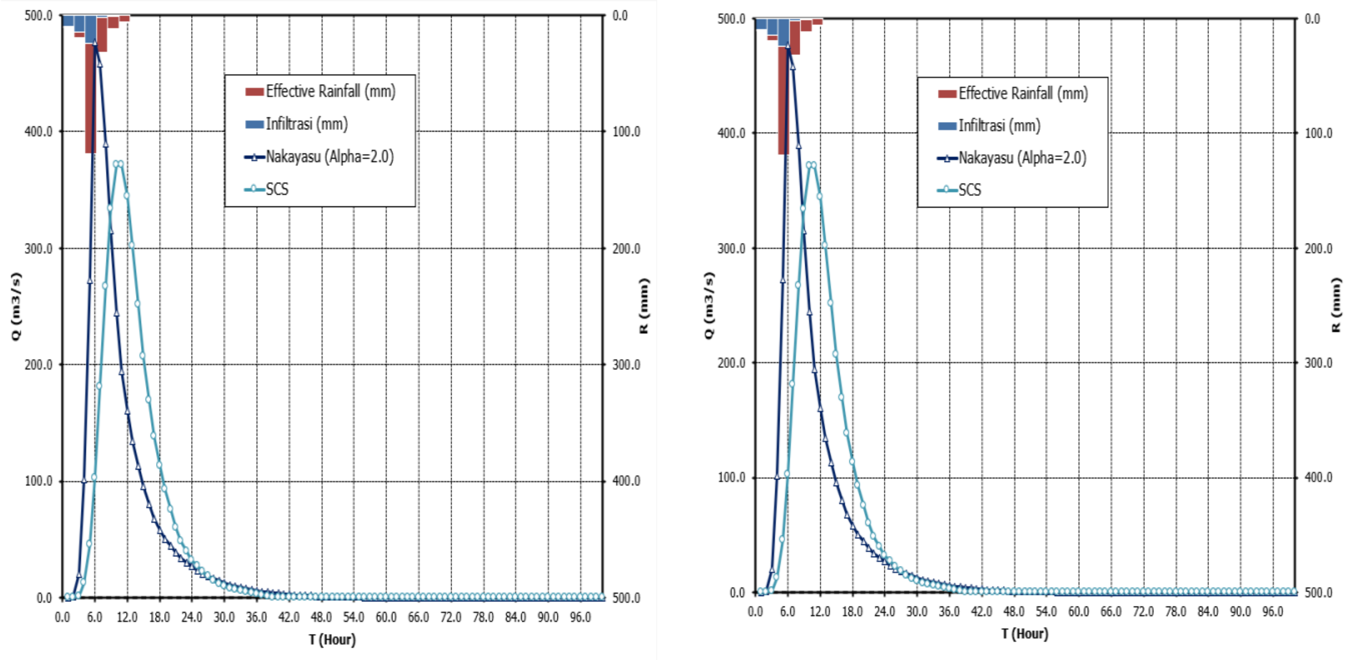

Figure 6. Flood Hydrograph Graphic (left 2019, right 2022)

The discharge value obtained based on the hydrograph results above is shown in **Table 8**.

Table 8. The Result of Discharge Return Period With SCS Method

No	Return Period	Discharge (m^3/s)	Land Use Year SCS	CN (Curve Number)
1	Q25 th	**366.920**	2019	83.25
2	Q25 th	**371.154**	2022	83.36

Based on the calibration approach using creager method discharge calculation, what is close to the measurement results is the discharge for the 25 year return period in 2022, namely 371,154 m^3/second, which is the same as the discharge is 377.43 m3/s (from creager). When compared to the discharge measurement in 2019, which was 306 m^3/s, the chosen method that is the closest is SCS-CN with Q25 of 366.920 m^3/s. Based on the results of the analysis, the increase in flood discharge is due to the increasing value of CN (Curve Number), the relationship between CN and flood discharge directly proportional,The increase in discharge from 2019 to 2022 was 1.15% and discharge is 1.13%. CN value is a number that shows the potential for soil infiltration of rainfall. A comparison between effective rainfall and the resulting discharge was conducted. This was done to ensure whether the increase in effective rainfall had an impact on the rise in flood discharge capacity. Through analysis, it was found that there was an increase peak discharge from 2019 to 2022 is 1.13%.

4. Conclusion

Based on the analysis of peak flow increases due to changes in land cover between 2019 and 2022 show several conclusions is An increase in CN value occurred due to the rise in peak discharge from 2019 to 2022, with the discharge increasing from 366.92 m^3/second to 371.154 m^3/second, while the CN value increased from 83.25 in 2019 to 83.36 in 2022.The increase in flood discharge and CN value is proportional to the reduction in green land and the increase in settlements.

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