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Flood Discharge Analysis Using the SCS Hydrograph Method in the Krung Tripa Watershed

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A B S T R A C T

The purpose of this study was to analyze the flood discharge of the Krung Tripa river return period and flood behavior based on hydrographic data obtained from rainfall data and estimate the magnitude of peak flood discharge. Flooding is the main problem caused by the overflow of Krung Tripa, with administrative Krung Tripa passes through 2 (two) districts in Aceh Province. Several factors cause flooding, including slope factors or topography of an area, soil type, and land uses. The method used to analyze flood discharge is the SCS Hydrograph method using secondary data. The results of flood discharge analysis obtained flood discharge plans with 2-year return period for 2464.033 m3/s, 5-year return period for 3597.893 m3/s, 10-year return period for 4372.634 m3/s, 25-year return period for 5377.98 m3/s, 50-year return period for 6153.054 m3/s, 100-year return period for 6946.462 m3/s.

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1. Introduction

Natural disasters can occur at any time, and they can occur at any time, thus creating a risk to the lives of all people, both loss of property and loss of life [1]. In addition, [2] defines a disaster as a natural force that is not under people's control and causes disaster.

The floods occur due to high rainfall intensity that exceeds the flow capacity [3]. The most dangerous type of flood is flash flood because it occurs quickly. It can be lost and damage the materials [4]. The Changes in land use in the watershed area are one of the reasons for the increase in critical land, which provokes many problems, such as floods and droughts [5].

Almost every rainy season, floods occur, and the location and level of damage caused are very diverse. A flood disaster is a natural phenomenon that is difficult to predict because it occurs suddenly at an indefinite period, except for areas that have become flooded. At a minimum, some crucial factors cause flooding in Indonesia, including the slope and height of the land, the type of soil and land use, the density of rivers, and significant rainfall that form a flood risk.

According to [6], land use is a factor that impacts the functioning of the watershed (DAS). In the watershed area, which tends to be smaller than 100 km2, there is land use, namely high-functioning forests, when designing the watershed pattern, namely maintaining continuous river flow and minimizing flood discharge [7]. Changes in land use, soil type, topography, soil moisture can also affect the function of watersheds [8]

The river is one of the locations where the water is. Surface water or runoff water with gravity tends to be low. River water quality in an area is greatly influenced by the activities of people, especially those around the river [9]. Given that the river located in Nagan Raya Regency is essential, the flow of the river must run appropriately to benefit humans and the local ecosystem later. According to [10] river flow discharge is the total of surface runoff, rainwater that directly falls on the river water body, intermediate flow and base flow

Research Problems

Based on what is mentioned in the background of the problem above, so the research problems that the researcher will take is:

- Calculation of flood discharge to be carried out on the Krung Tripa watershed
- Calculation method using SCS hydro hydrograph
- The hydrological analysis uses data of maximum daily rainfall for 16 years from BMKG Nagan Raya.
- Plan return period 2,5,10,25,50,100.

Objectives and Benefits

The purpose of this study is to reflect the magnitude of the planned flood discharge for a specific return period of the Krung Tripa River from the analysis of rainfall data and interpret the high peak flood discharge and obtain flood control. After completing this research, it is hoped that the results will be helpful and can be used as calculation material for partners and other related parties.

2. Research Method

2.1 Data Collection Method

Some secondary data in the form of maps collected can be seen in Figure 1. Map of the Krung Tripa watershed, Figure 2. Map of topographic and Figure 3. Map of Land cover. These three data were obtained from (BAPPEDA) Nagan Raya Regency

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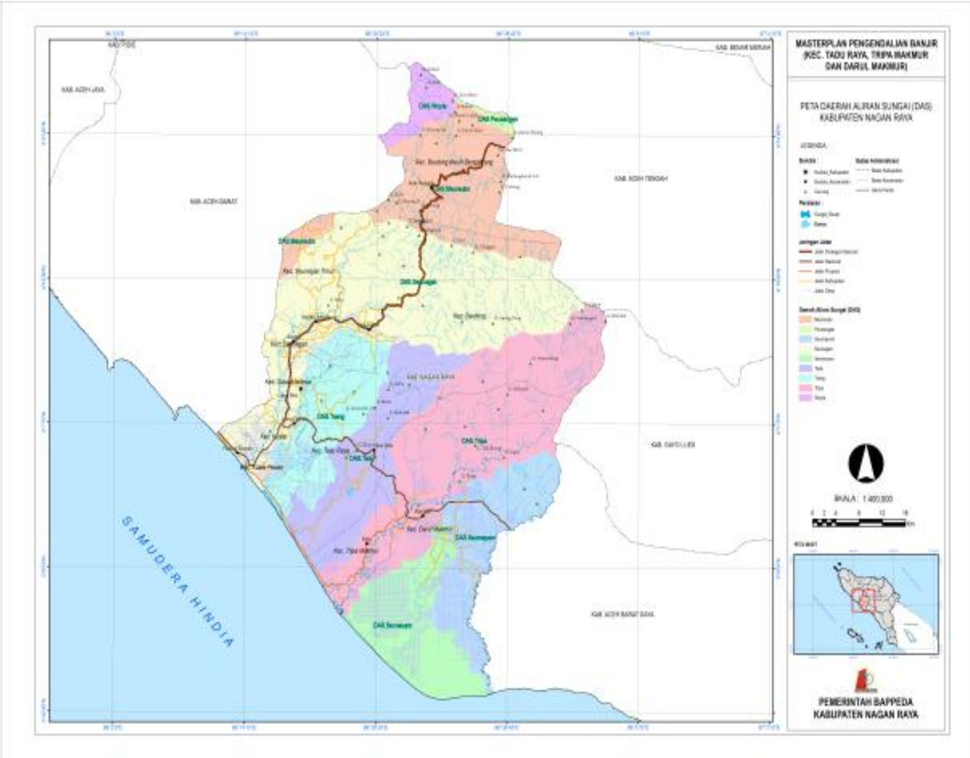
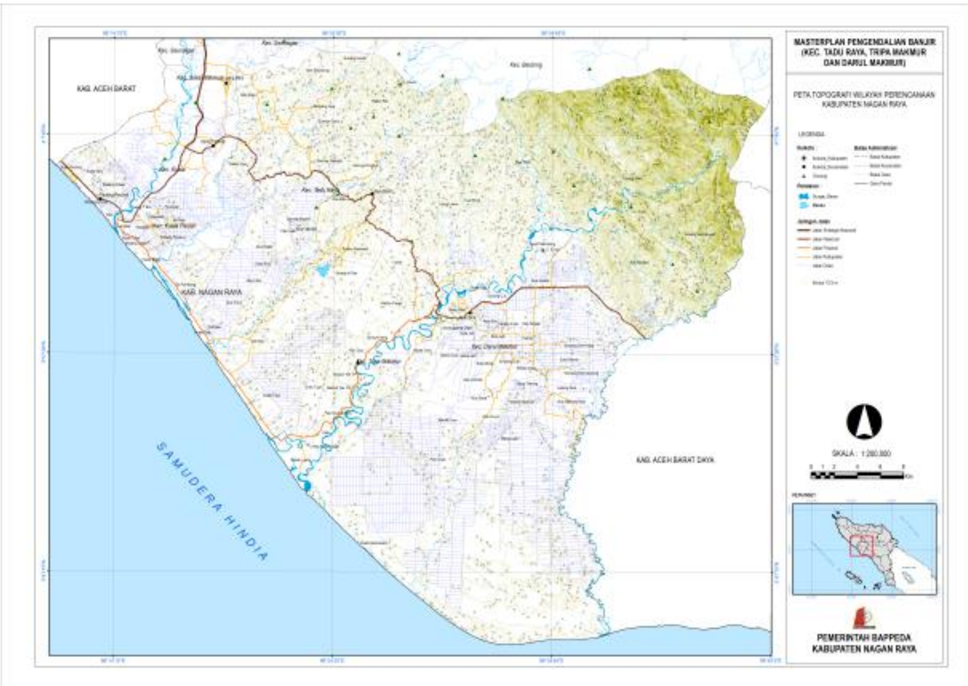


Source: BAPPEDA Nagan Raya Regency
Figure 1. Map of the Krung Tripa watershed



Source: BAPPEDA Nagan Raya Regency
Figure 2. Map of topographic

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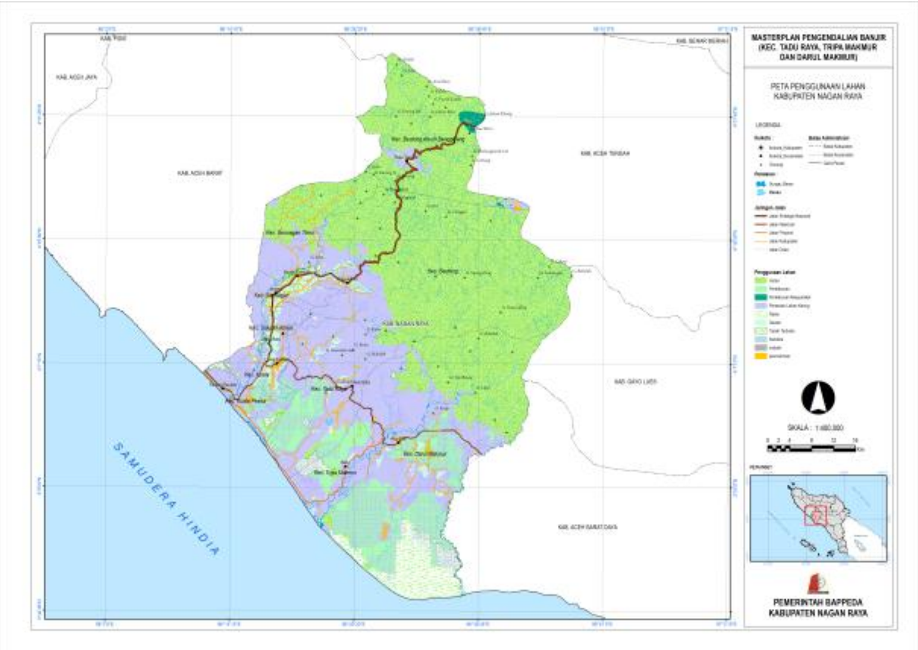

Source: BAPPEDA Nagan Raya Regency
Figure 3. Map of Land cover

2.2 Rainfall Plan

The planned rainfall is calculated using several methods, namely the standard distribution method, regular log, Gumbel, and log person type III.

2.2.1 Normal Distribution

The equation for the standard distribution method [11] is:

$$X_{Tr} = \bar{x} + K_{Tr} + S_x \quad (1)$$

Description:

X_{Tr} = high rainfall (CH) planned for PU T year..
$\bar{x}$ = average value of data
$= \frac{\sum_1^n i}{n}$
Sx = standard deviation
$= \sqrt{\frac{\sum (xi - \bar{x})^2)}{n-1}}$
K_{Tr} = Gaussian reduction variable

2.2.2 Log-Normal Distribution

The equations for the standard log distribution method are:

$$\text{Log } X_{Tr} = \log \bar{X} + K_{Tr} \,.\, S_{\log x} \quad (2)$$

description:
Log x_{Tr} = height of CH plan to use PU T years.
Log $\bar{x}$ = Average price
$= \frac{\sum_1^n \log (X_i)}{n}$
$S_{\log x}$ = Standard Deviation
$= \sqrt{\frac{\sum (\log x - \log \bar{x})^2}{n-1}}$
K_{Tr} = Gaussian reduction variable

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2.2.3 Gumbel Distribution

The equation for the Gumbel method is:

$$X_{Tr} = \bar{x} + K.S_x \quad (3)$$

Description:

X_{Tr} = height CH plan to use T years

$\bar{x}$ = Average price of data

$= \frac{\sum_1^n i}{n}$

S_x = Standard Deviation

$= \sqrt{\frac{\sum (xi - \bar{x})^2)}{n-1}}$

K = fac frequency which is a function of PU and edge frequency

To calculate the Gumbel frequency factor pulling the price:

$$K = \frac{Y_t - y_n}{S_n}$$

Description:

Yt = reduction as a function of probe

Yn and sn = large, which is a function of the total

2.2.4 Pearson Type III Log Distribution

The equation for the log person III methods is:

$$\text{Log } XT = \log \bar{X} + \text{Slogx} . K \quad (5)$$

Description:

Log X_T = high CH plan to use T years

Log x = Average price $= \frac{\sum_1^n i}{n}$

$S_{\log x}$ = Standard Deviation

$= \sqrt{\frac{\sum (xi - \bar{x})^2)}{n-1}}$

K_{Tr} = frequency coefficient obtained based on the interaction of the value of Cs with PU T.

2.3 Synthetic Unit Hydrograph (HSS)

This method is well-known and plays a crucial function when many plans in the natural resource sector, including the analysis of watershed flood discharge, are not measured. In developing this hydrograph, some methods already exist. The HSS methods, such as the Nakayasu, Snyder-Alexeyev, SCS, and GAMA-1, are very well known and commonly used in Indonesia to calculate peak discharge and the shape of the flood hydrograph [12]. HSS is one of them used to interpret the HSS concept, which has no size directly related to the flood hydrograph in a plan, the HSS used in this study is HSS SCS. The unit hydrograph of a watershed [13] is a direct runoff caused by one unit of effective rainfall volume which is evenly distributed in time and space.

2.4 HSS SCS (Soil Conservation Service)

The unit hydrograph is defined as a direct runoff hydrograph written at the downstream end of the watershed generated by an adequate rainfall of 1 mm, which is evenly distributed on the surface of the watershed at a constant intensity for a specific duration [14]. The HSS SCS method is a dimensional hydrograph whose ordinate describes the discharge ratio to the peak discharge, and the abscissa describes the ratio of the time interval to when the peak discharge

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exists. [15] stated that SCS-CN is a method developed in the fields of hydrology, agriculture, and environmental engineering. The hydrograph of the SCS method produces a peak discharge that is closer to the observed peak flow due to factors that affect runoff discharge [16]

3. Result and Discussion

3.1 Analysis Of Planned Rainfall

The maximum daily CH data used is CH data for a return period of 16 years, from 2006 to 2021, obtained from the BMKG Cut Nyak Dien Nagan Raya Station.

Table 1. Regional Average Maximum Rainfall

No	Tahun	Maks (mm)
1	2006	107
2	2007	135
3	2008	100
4	2009	100
5	2010	100,5
6	2011	105
7	2012	106,5
8	2013	85,5
9	2014	146
10	2015	172,7
11	2016	193,8
12	2017	203,99
13	2018	179,7
14	2019	203,99
15	2020	250
16	2021	237

Source: BMKG Nagan Raya, 2022

3.2 Analysis of Frequency Distribution of Rainfall Data

Estimated flood discharge using the SCS method produces different design floods. So it is necessary to know the value of which method will be used. Four methods are used to analyze the frequency distribution of CH data: Normal, Log-Normal, Gumbel, and Log Pearson Type III. After conducting the frequency distribution analysis, the suitability test for the CH data on the type of distribution can be observed in (Table 2).

Table 2. Conformity of Rainfall Data to Types of Distribution

No	Distribution type	Requirement	Calculation		Conclusion
1	Normal	$Cs \approx 0$	0,464	0	Does not meet the
		$Ck \approx 3$	2,353	3	Fulfill
2	Log Normal	$Cs = cv^3 - 3cv$	0,020	0,209	Does not meet the
		$Ck = cv^8 - 6cv^6 - 15cv^4 - 16cv^2 - 3$	2,010	3,078	Fulfill
3	Gumbel	Cs = 1,1396	0,464	1,1396	Does not meet the
		Ck = 5,4002	2,353	5,4002	Fulfill
4	Log Pearson Type III	Other than above	0,158	-	Does not meet the
			2,010	-	Fulfill

Source: Count from excel data

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3.3 Distribution Analysis

This distribution channel analysis uses the Chi-Square method, a test of the difference between the sample data and the probability distribution.

Table 3. Chi-Square Test Results

Class	Interval	Oi	Ei	Oi-Ei	$(Oi-Ei)^2/Ei$
1	64,938-106,063	2	3,2	-1,2	0,450
2	106,063-147,188	6	3,2	2,8	2,450
3	147,188-188,313	5	3,2	1,8	1,013
4	188,313-229,438	1	3,2	-2,2	1,513
5	229,438-270,563	2	3,2	-1,2	0,450
	Σ	16	16		5,875

Source: Count from excel data

3.4 Analysis of CN. Value

The CN value's progress indicates a decrease in the land's ability to store precipitation water. According to [17] the CN value expresses the effect of hydrology along with soil, land use, and soil moisture. This effect is that the infiltration volume decreases, connecting the surfce runoff volume or increasing the peak discharge [18]. Research [19] also analyzed the increase in the value of the curve number on flood discharge.

According to [20], the Curve Number is widely used in hydrological studies to show high runoff areas. The CN coefficient is an indicator of the watershed's runoff value, which is determined using the HSG value and the land use coefficient.

Steps in searching for CN results:

- The first step is to open the ArcGis software and have some initial data in the form of shapefiles from the region
- Opens the command tool "union" in ArcToolbox.
- Then, the two files are taken with "input features" and set the file name
- Then, the shape of the results of the overlay of the two maps is formed
- The next step is to calculate the area. First, click the new field for the location to display the area calculation and select the type double.
- If the shape file has a matrix projection system such as UTM, the area calculation could do immediately.
- After that, you can return to the table, right-click on the "wide" field title, select "calculate geometry," then in the window, select "area" in "property," select units in "units," then click OK so it will be filled automatically.
- The next stage is to form a recap of the calculation so it is easy to read
- Afterward, select all the "cells" entered into the Privot table.
- Then to the "privot table" menu, done. The land cover area can be observed in (Table 4).

Table 4. CN Value Result

Luas Km^2	X=Nilai CN X Luas	CN=X/Luas Km^2
1956,56925	142380,0081	72,77

Source: Count from excel data

3.5 Return Period Analysis

This analysis is used to determine the size of NC with PU 2, 5, 10, 25, 50, and 100 years. Calculations can be observed in (Table 5).

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Table 5. Return period analysis

T (Year)	PT (%)	KT	KT x S	Log XT (Log X + (Kt x S))	XT (mm)
2	50	-0,026	-0,004	2,151	141,507
5	20	0,832	0,129	2,284	192,327
10	10	1,297	0,201	2,356	227,067
25	4	1,804	0,280	2,435	272,160
50	2	2,137	0,332	2,487	306,555
100	1	2,442	0,379	2,534	341,808

Source: Count from excel data

Based on Table 5, the results of the return period analysis for PU 2 years = 141,507, PU 5 years = 192,327, PU 10 years = 227.067, PU 25 years = 272.160, PU 50 years = 306.555, PU 100 years = 341.808.

3.6 Analysis of Design Flood Discharge Method SCS

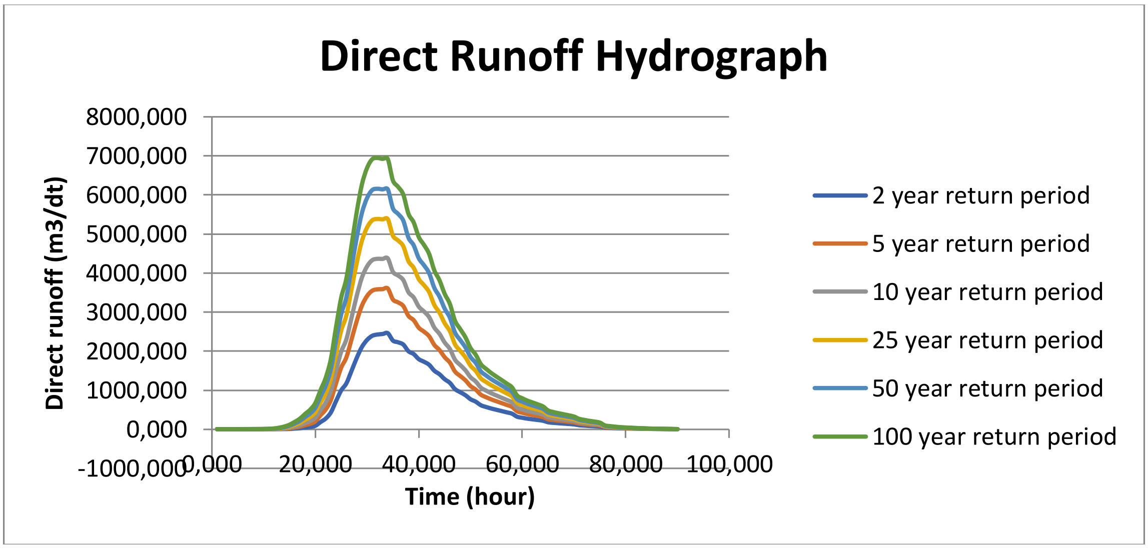
From the results of the calculation of CH for the number of repetitions, so that the design flood discharge of the SCS method is obtained as follows.

Table 6. SCS method flood discharge

T (Tahun)	Q_T (m^3/dtk)
2	2464,033
5	3597,893
10	4372,634
25	5377,981
50	6153,054
100	6946,462

Source: Count from excel data

It can be seen in Table 6 the flood discharge plan for 2-year PU is 2464,033 m3/s, 5-year PU is 3597 m3/s, 10-year PU is 4372,634 m3/s, 25-year PU is 5377,981 m3/ sec, PU for 50 years is 6153,054 m3/s, PU for 100 years is 6946,462 m3/s.



Source: Count from excel data

Figure 4. SCS Recap Graph

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Based on Figure 4. The graph of the direct runoff hydrograph shows that the model from the slope graph is steep, meaning that the direct runoff water rises quickly and recedes quickly.

4. Conclusions

Based on the presentation of the results and discussion, it can be concluded that:

- The cause of flooding in the Nagan Raya Regency is the overflow of the Krung Tripa river, which overflows almost every year up to 4-6 times per year with a maximum duration of 14 days.
- By testing the probability distribution of the log person III, it still meets the requirements so that the confidence level in the data still meets the predetermined requirements.
- Planned flood discharge using the SCS Synthetic Unit Hydrograph method:
  - When repeat 2 year: 2464,033 m^3/s
  - When repeat 5 year: 3597,893 m^3/s
  - When repeat 10 year: 4372,634 m^3/s
  - When repeat 25 year: 5377.98 m^3/s
  - When repeat 50 year: 6153,054 m^3/s
  - When repeat 100 year: 6946,462 m^3/s

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