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The Study of Flood Discharge in Ujong Krueng in the Tripa Watershed

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ABSTRACT

The Krueng Tripa River is one of the rivers in Nagan Raya Regency that often floods. The Krueng Tripa River flows through Gayo Lues Regency in the upper reaches of the river and Nagan Raya Regency in its downstream with a watershed area of 2953,457 km². The rainfall in this watershed is about 2,197 mm per year. High rainfall has a major impact on flood disasters and is detrimental to the surrounding community. The purpose and benefits of this study are to determine the magnitude of the flood discharge of the Krueng Tripa River and as input for data related to flood mitigation problems. Analysis of flood discharge using the Synthesis Unit Hydrograph (HSS) Gama I method. From the analysis using the distribution of log person III with return periods of 2, 5, 10, 25, 50, and 100 years, respectively, 141,520 mm, 192,349 mm; 227,094 mm; 272,270 mm; 306,569 mm; 341,869mm. The results of flood analysis on the Krueng Tripa River using the HSS Gama I method with return periods of 2, 5, 10, 25, 50, and 100 years respectively are 3419.276 m³/s; 4647,384 m³/s; 5486,740 m³/s; 6578,338 m³/s; 6702.133 m³/s; 8259.949 m³/s.



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1. Introduction

There are many types of natural disasters, especially floods and landslides that often occur in urban and rural areas in Indonesia. Floods in Indonesia are triggered by high rainfall which causes rivers to overflow in residential areas. Likewise with Nagan Raya Regency in Aceh Province which has characteristics to occur flood event ranging from plains, rivers, beaches to mountains. This area is also vulnerable to land degradation, flooding and landslides. In Nagan Raya Regency there are also several rivers including Krueng Seunagan River, Krueng Tadu River, Krueng Seumayam River, Krueng Trang River and Krueng Tripa River. [1].

Flooding is a form of destructive power of water that causes rivers to overflow and natural events that can result in loss of property and objects. Suripin (2014) suggested that flooding is a manifestation of the imbalance of the environmental system in the process of releasing surface water and is influenced by the amount of water that flows beyond the capacity of the diversion area. Khanna (2005) stated that floods can be divided into 3 types, namely flash floods, river floods and coastal floods. Flooding in the river due to the release of excess water through the cross section of the river. The magnitude and duration of river flooding is strongly influenced by the characteristics of the respective watersheds. Watershed is an area where all the water flows into the river. [2].

The Krueng Tripa River is one of the rivers in the Woyla-Bateue River Basin (Marina F. et al, 2021). Based on the Decree of the President of the Republic of Indonesia No. 12 of 2012 concerning the determination of the River Basin, the Woyla-Bateue River Basin is a National Strategic River Area which has the right to cooperate with the central government. The Krueng Tripa River watershed area is 3427.90 km², and administratively flows through 2 (two) districts in Aceh Province, namely Gayo Lues Regency in the upper reaches of the river and Nagan Raya District in the lower reaches of the river. The rainfall that affects the Krueng Tripa watershed ranges from 2,197 mm per year. In the upper reaches of the Krueng Tripa River there is illegal mining and land clearing which causes frequent flooding in the area. Floods that often occur in the Krueng Tripa River reach a height of 30 cm - 150 cm in a flood period of 4-6 times a year. [24]

One of the villages frequently affected by floods is Ujong Krueng Village which covers an area of 189.41 km², Ujong Krueng Village is located at the coordinates point (3° 58' 37" N 96° 27' 32" E). Ujong Krueng village is located near the Krueng Tripa River, if it rains heavily then Krueng Tripa will overflow and flood people's houses. In Ujong Krueng village, flooding does not only occur during the rainy season, but during the dry season it can cause flooding from upstream of the watershed [3]. Therefore, it is necessary to prevent flooding and determine the flood discharge of the Krueng Tripa River using the Synthesis Unit Hydrograph (HSS) analysis using the GAMA I method.



Source: *berita merdeka.com*

Figure 1. Floods in Tripa Makmur Kecamatan

Objectives and Benefits

The purpose of this study is to determine the magnitude of the flood discharge for the return period of 2, 5, 10, 25, 50, 100 years and also as input for related stakeholders in solving flood control problems in the area.

Previous Research

The rainfall data used came from 4 rain stations, namely BMKG Stations Tjut Nyak Dhien, Soefindo Nagan, Takengon and Blower Blang Keujeuren. The results of the analysis of flood discharge plans for 5, 10, 25, 50 and 100 annual return periods are 1293.08 m³/s; 1490.36 m³/s; 1748.59 m³/s; 1950.66 m³/s; and 2163.51 m³/s. Similar studies have also been conducted in other rivers in Indonesia, Siby et al (2013) analyzed the planned flood discharge of the Ranoyapo River, South Minahasa Regency using the HSS Gama I method.[1] Through a study entitled "Calculation of Design Floods Using the HSS Gamma 1 Method in the Simujur Watershed" explained the main results of the study proving that the design flood discharge used a Gama 1 Synthetic Hydrograph Unit for the Simujur River with a 5-year return period of 30.68 m³/second, a 10-year return period of 34.20 m³/second, a 20-year return period of 37.45 m³/second, a 50-year return period of 41.32 m³/second, and a 100-year return period of 44.22 m³/second. The peak time is 2 hours and the base time is 37 hours. [6]

2. Metodology

Rainfall Plan

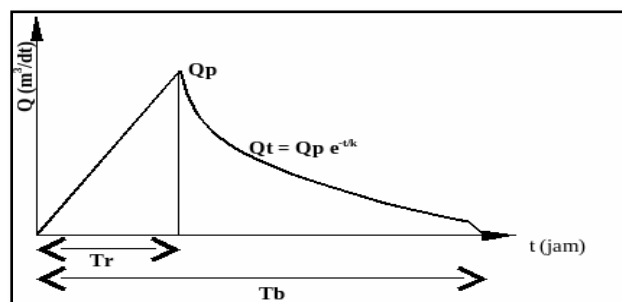
Planned rainfall is the largest rainfall that may occur in an area with a certain return period which is used as the basis for calculating the planning dimensions of a building. Planned rainfall is calculated by several methods, namely the normal distribution method, the normal log distribution method, the Gumbel distribution method, and the log person type III distribution method. [7].

Synthesis Unit Hydrograph

Synthetic unit hydrograph is one of the methods used to estimate the unit hydrograph concept for which there is no direct measurement of the flood hydrograph in a plan. The synthesis unit hydrograph used in this research is HSS Gama I. [8].

HSS Gama I

The Gama I synthetic unit hydrograph was developed by Sri Harto (1993) based on the hydrological behavior of 30 watersheds on the island of Java. Although derived from watershed data on the island of Java, it turns out that the Gama I synthetic unit hydrograph also functions well for various other regions in Indonesia [9]. The synthetic unit hydrograph consists of three main points, namely the rising limb, crest, and recession limb (Ruri. H, et al 2016) which can be seen in Figure 2.



Source: Triatmodjo

Figure 2. HSS Gamma I

In the picture above there is a fault in the recession side, this is because the recession side follows an exponential equation which does not allow the discharge to be equal to zero.

$$Q_t = Q_p e^{-(t-TR)/K} \quad (1)$$

$$Q_t = Q_p e^{(t/TR)} \quad (2)$$

With : Q_t = discharge at t hour (m^3/d)

Q_p = peak discharge (m^3/d)

t = time from the time of peak discharge (hours)

K = storage coefficient (hours)

Several parameters needed in the analysis using HSS Gama I (Tiny. M et al 2014) include:

- Watershed area (A)
- Length of main river (L)
- Average slope (S)
- Length of river level 1 (L1)
- River length all levels (Lst)
- Number of rivers level 1 (N1)
- Number of rivers all levels (N)
- Drain network density (D)
- Number of river confluences (JN)

In addition to the parameters above, there are several other parameters that are used, including:

- **Source Factor (SF)**

Comparison between the total lengths of first-level rivers and the total lengths of all river levels.

$$SF = \frac{L1}{Lst} \quad (3)$$

- **Drainage Density (D)**

Comparison between the total length of the river flow (sum of the length of the river at all levels) and the area of the watershed.

$$D = \frac{Lst}{A} \quad (4)$$

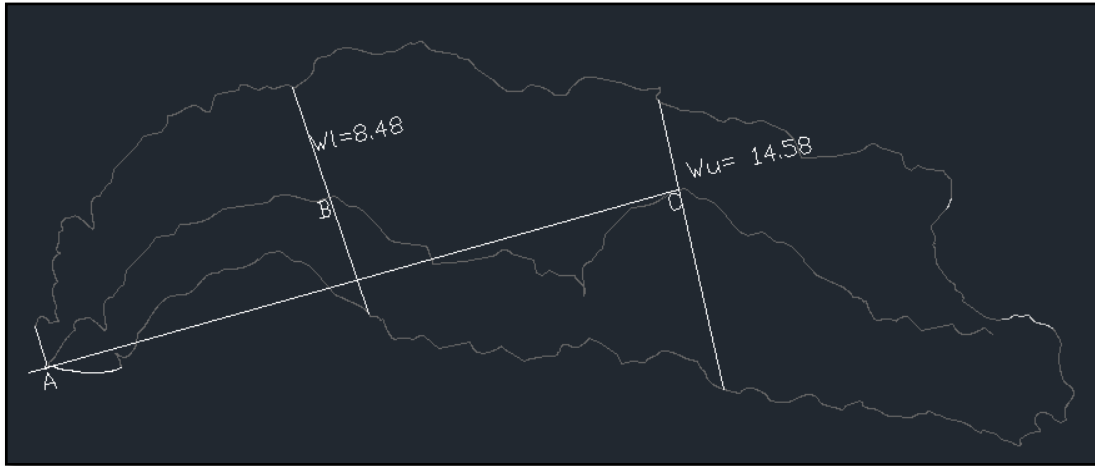
- **Source Frequency (SN)**

Comparison of the total share of the river level one with the total share of all levels.

$$SN = \frac{N1}{N} \quad (5)$$

- **Width Factor (WF)**

The comparison between the watershed width measured at the river point which is 0.75 L and the watershed width measured at the river point 0.25 L from the control point (outlet). Lines W_u and W_l (perpendicular) to the lines I draw from the outlet to the points 0.25 L and 0.75 L.



Source: Sketch of the Implementation of WF (Autocad 2013)

Figure 3. Sketch of the Implementation of WF

$$A - B = 0,25 L$$

$$A - C = 0,75 L$$

$$WF = \frac{wu}{wl} \tag{6}$$

- Upstream watershed area (RUA)

Comparison between the area of the watershed upstream of the line drawn between the control point (outlet) and the point on the river closest to the center of gravity of the watershed.



Soerce: Sketch of the Implementation of RUA (Autocad 2013)

Figure 4. Sketch of the Implementation of RUA

$$RUA = \frac{Au}{A} \tag{7}$$

- Symmetry Factor (SIM)

- Symmetry Factor (SIM)

The product of the width factor (WF) and the upstream watershed area (RUA) becomes:

$$SIM = WF \times RUA \tag{8}$$

HSS consists of four main variables that can be calculated using equations based on the book Triatmodjo (2010).

HSS Gamma I peak time (TR)

$$TR = 0,43 \left(\frac{L}{100 SF}\right)^3 + 1,0665 SIM + 1,2775 \quad (9)$$

Peak flood discharge (QP)

$$QP = 0,1836 A^{0,5886} TR^{-0,4008} JN^{0,2381} \quad (10)$$

Base time (TB)

$$TB = 27,4132 TR^{0,1457} S^{-0,0986} SN^{0,7344} RUA^{0,2574} \quad (11)$$

Recession coefficient (K)

$$K = 0,5617 A^{0,1798} S^{-0,1446} SF^{-1,0897} D^{0,0452} \quad (12)$$

Base flow (QB)

$$QB = 0,4715 A^{0,6444} D^{0,9430} \quad (13)$$

With:

Tp : time required to reach peak flow rate (hours)

Tr : duration of rain (hours)

Tb : base time (hours)

B : fall time (hours)

Qp : peak discharge or peak runoff rate

A : watershed area

An additional equation related to HSS Gama I is the infiltration index or ϕ index. The magnitude of index can be calculated by the following equation:

$$\phi = 10,4903 - 3,859 \times 10^{-6} \times A^2 \left(\frac{A}{SN}\right)^4 \quad (14)$$

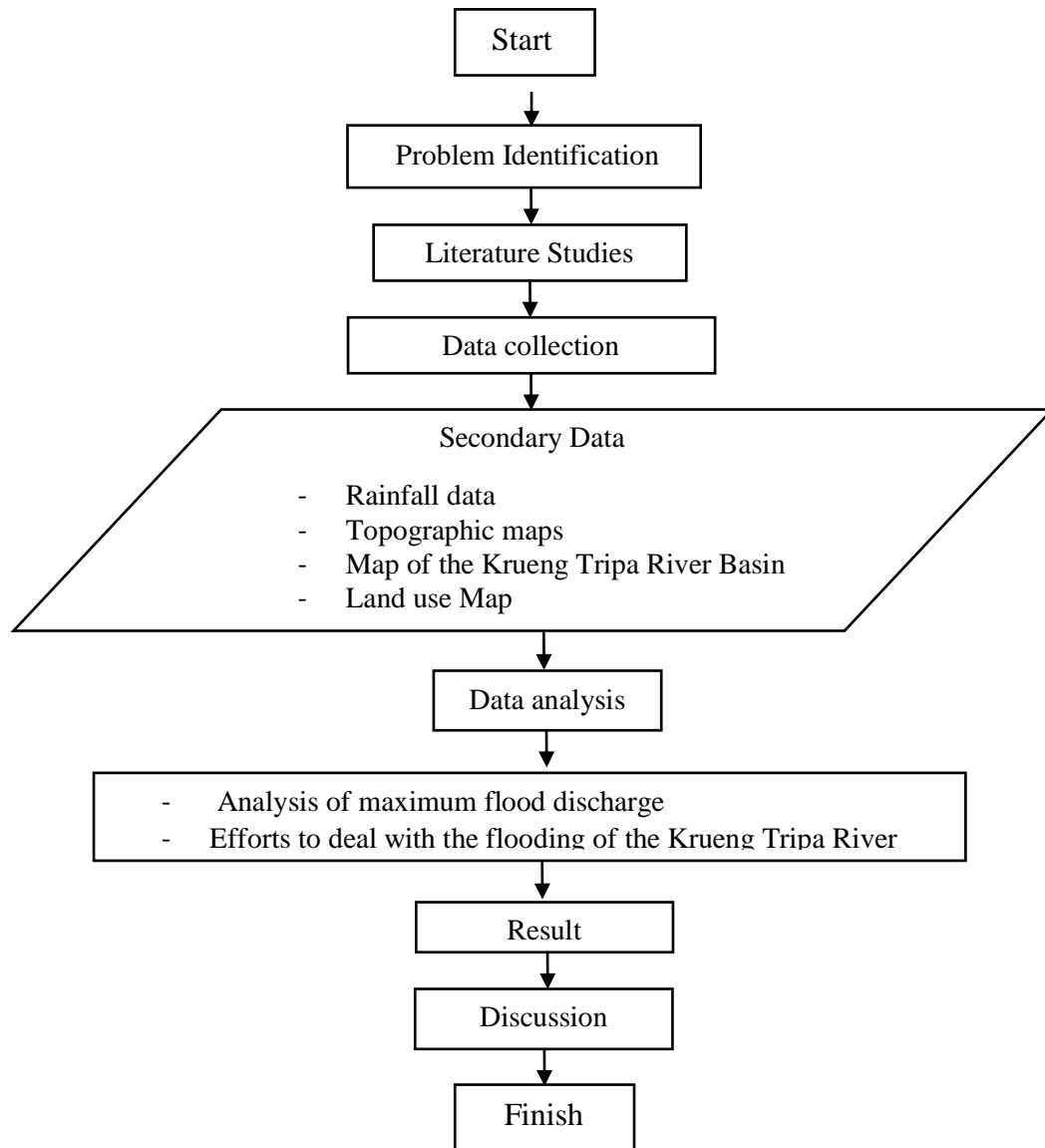
With : ϕ index : infiltration index (mm/hour)

A : watershed area (km²)

SN : source frequency

3.1 Flow Chart

The process to be carried out in this research is described in the flow chart below:



Source: research diagram

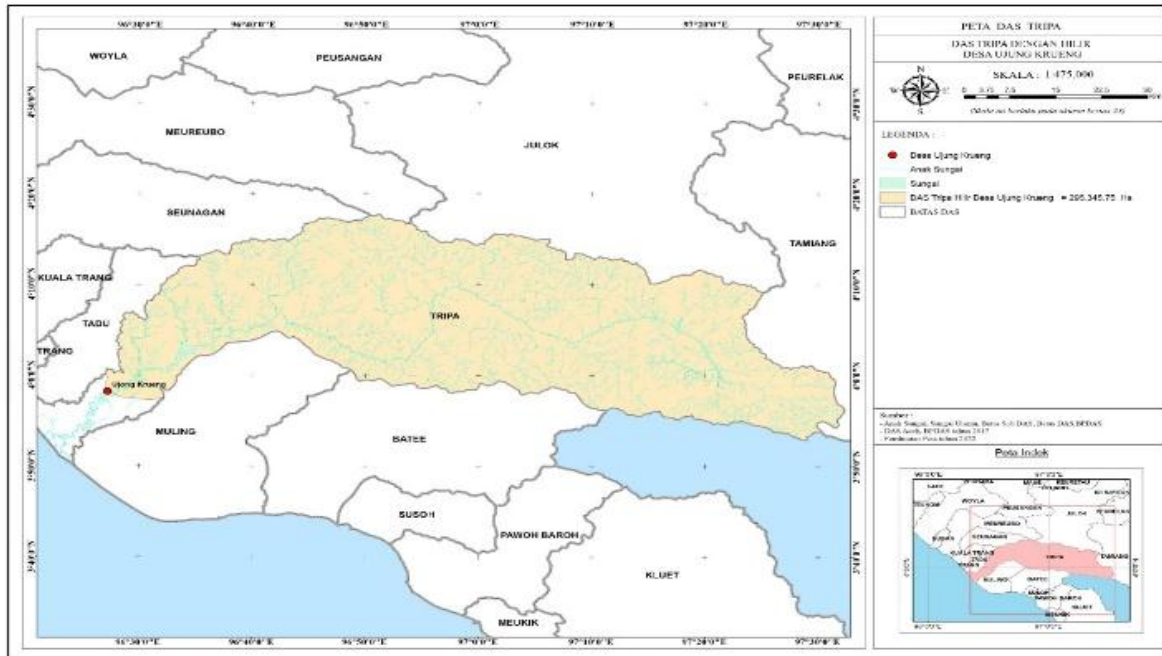
Figure 5. Flowchart

In the flowchart it is described that the initial process carried out is problem identification, literature study, then the data collection process is carried out, the data obtained is then analyzed, the results of the analysis are used as a discussion

3.2 Study Area

The research location is the Krueng Tripa watershed with an area of 3427.90 km². Administratively, the Krueng Tripa watershed passes through 2 (two) districts in Aceh Province, namely Gayo Lues Regency and Nagan Raya Regency. Geographically, Krueng Tripa is located between 3^o 48'00"-4^o 24'00"N and 96^o 20'00"-97^o 32'00"E. The survey location is located in Ujong Krueng Village, Tripa Makmur District, Nagan Raya Regency, which is one of the areas that are often flooded, covering an area of 189.41 km². Ujong Krueng

Village is located at the coordinates (3° 58' 37" N 96° 27' 32" E). The survey area is about 700 km. The methodological plan includes river characteristics, data collection, data analysis. Data collection is carried out in the form of rainfall data and topographic maps.



Source: BPDAS 2017

Figure 6. Map of the Krueng Tripa watershed

The picture above is a map of the DAS Krueng Tripa which is passed by several subdistricts, including Tadu Raya and Darul Prosperous subdistricts. The study conducted was in the village of Ujong Krueng which is one of the villages that often has the potential for flooding.

3.2 Data collection

Data collection is carried out by conducting field surveys and information from related agencies or parties to support the calculations to be carried out, and by collecting data from previous research reports as a basic reference material for conducting research. This study uses maximum monthly rainfall data from the BMKG Cut Nyak Dhien Station from 2006 – 2021 [10].

3. Results and Discussion

Rainfall Plan

The maximum daily rainfall data with a return period of 16 years, from 2006 – 2021 was obtained from the BMKG Station Cut Nyak Dhien Nagan Raya.

Table 1. Maximum daily rainfall data.

No	Year	Max (mm)
1	2006	107,00
2	2007	135,00
3	2008	100,00
4	2009	100,00
5	2010	100,50
6	2011	105,00
7	2012	106,50
8	2013	85,50
9	2014	146,00
10	2015	172,00
11	2016	193,80
12	2017	203,99
13	2018	179,70
14	2019	203,99
15	2020	250,00
16	2021	237,00

Source: *BMKG Cut Nyak Dhien (2006-2021)*

Rainfall Frequency Analysis

Frequency analysis is a prediction that obtains the probability of a hydrological event in the form of discharge/rainfall which is planned as the basis for calculating the hydrological plan to predict every possibility that will occur. The rainfall distribution test uses statistical parameter values as test variables to be determined by comparing the coefficient of variation (Cv), skewness coefficient (Cs), and kurtosis coefficient (Ck) with the requirements of each method [6].

Table 2. Distribution test results

No	Distribution	Condition	Calculation		Conclusion
1	NORMAL	$Cs \approx 0$	0,464	0	Does not meet the criteria
		$Ck \approx 3$	2,351	3	meet the criteria
2	LOG NORMAL	$Cs = Cv^3 + 3Cv$	0,158	0,000	Does not meet the criteria
		$Ck = Cv^3 + 6Cv^2 + 15Cv + 16Cv^2 + 3$	2,009	3,000	Does not meet the criteria
3	GUMBEL	$Cs = 1,1396$	0,464	1,1396	Does not meet the criteria
		$Ck = 5,4002$	2,351	5,4002	Does not meet the criteria
4	LOG PORSEN III	Apart from above	0,158	-	meet the criteria
			2,009	-	meet the criteria

Source : *Data Calculation from Excel*

Based on the distribution test results from the table above, the suitable distribution is Log Person III with the standard deviation value (S) = 0.155, the coefficient of variation (Cv) = 0.072, the deviation (a) = 0.0006, the slope coefficient (C) = 0.158 , Coef kurtosis (Ck) = 2.009.

Distribution Analysis

Distribution analysis was carried out using the Chi Square method, the Chi Square test was a test of the difference between the sample data and the probability distribution.

Table 3. Field Sondir Test Result Data.

Class	Interval	O _i	E _i	O _i - E _i	(O _i - E _i) ² / E _i
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 : Data Calculation from Excel

Based on the table above with the number of classes (G) = 5 classes, Parameter (P) = 2, Degree of freedom (DK) = 2, Crisis Cr 5,991, (degree of confidence) = 0.05 and the result is calculated Cr < critical Cr = 5,875 < 5,991.

Rainfall Intensity

The design rainfall intensity was calculated using the mononobe method. The intensity of rain is for 24, then hourly rain is presented.[11]. The planned rain periods are 2, 5, 10, 25, 50 and 100 years.

Table 4. Rainfall Plan.

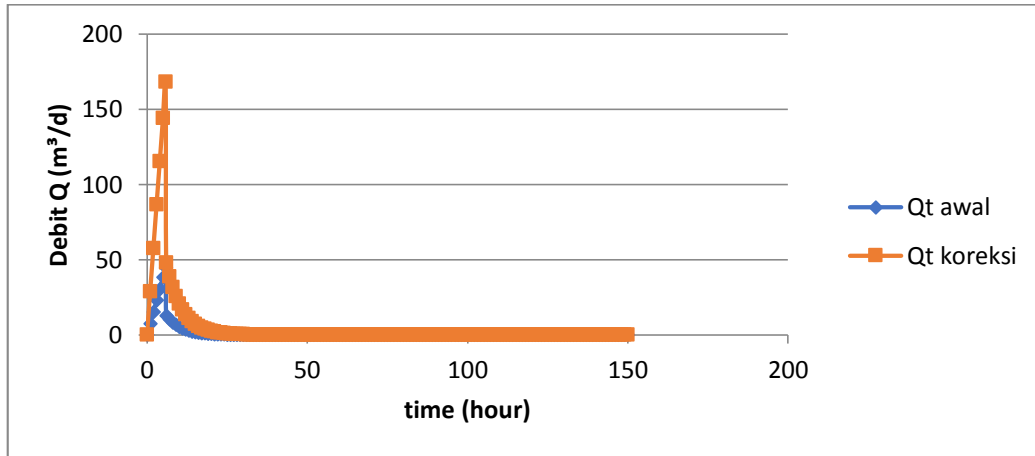
T (tahun)	P _T	K _T	K _T x s	Log X _T	X _T (mm)
(1)	(2)	(3)	(4)	(5)	(6)
2	50	-0,026	-0,004	2,151	141,52
5	20	0,833	0,129	2,284	192,35
10	10	1,297	0,201	2,356	227,09
25	4	1,804	0,246	2,435	272,27
50	2	2,137	0,332	2,487	306,57
100	1	2,422	0,379	2,534	341,87

Source: Data Calculation from Excel

From the table above, the results of the planned rainfall for each return period of 2, 5, 10, 25, 50 and 100 years in a row are 141,552 mm; 192.35 mm; 227.09 mm; 272.27 mm; 306.57 mm and 341.87 mm.

Analysis of Planned Flood Discharge

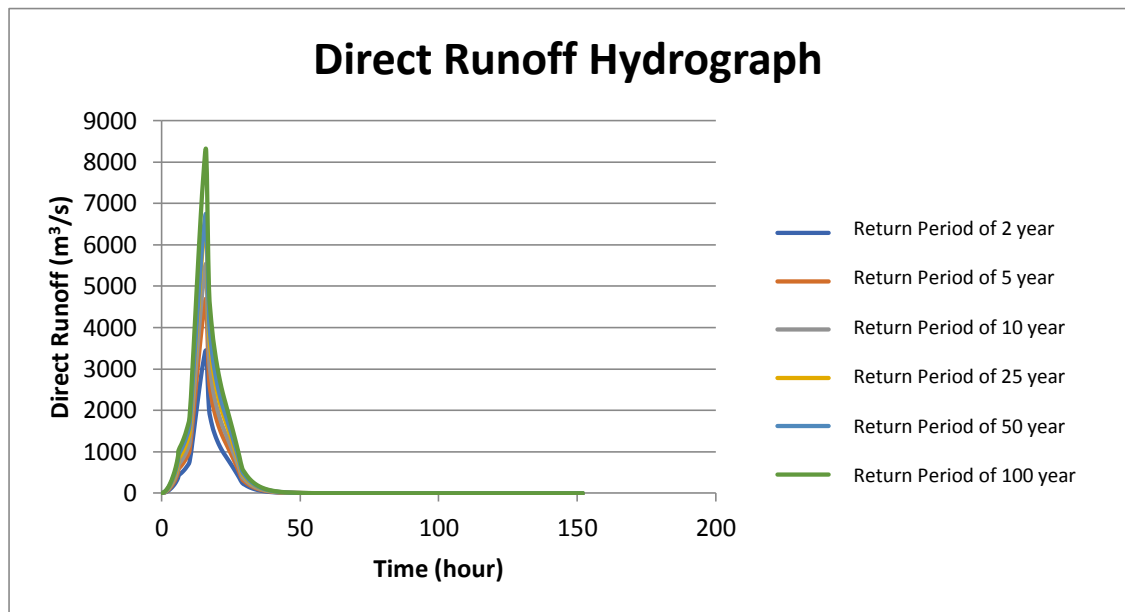
The maximum river discharge data used is from 2006-2021, based on data that has been analyzed from the Gama I method, the peak discharge (Q_p) is 45, 377 m³/s with the time needed to reach the peak discharge (T_r) which is 5,625 hours. The shape of the hydrograph can be seen in the image below:



Source: Gamma I Graph of the Count Data (Excel)

Figure 7. HSS Gama I Krueng Tripa River

The next step is to analyze the planned flood discharge using the planned return period of 2, 5, 10, 25, 50 and 100 years [12]. The results of the flood discharge analysis can be seen in Figure 5 and the difference in the planned flood discharge in the return periods of 2, 5, 10, 25, 50, and 100 years respectively can be seen in the following table:



Source: Graph of the Count Data (Excel)

Figure 8. Flood hydrograph of Krueng Tripa River

Based on the flood hydrograph graph above, the results of each return period can be seen in table 5 below:

Table 5. Flood Discharge of the Krueng Tripa Watershed in Ujong Krueng Village

Qt Return Period Planned Flood Discharge (m ³ /s)					
2	5	10	25	50	100
3419,276	4647,384	5486,740	6578,338	6702,133	8259,949

Source: Data Calculation from Excel

4. Conclusions and suggestions

Conclusions

Floods that occurred in Nagan Raya Regency were natural disasters caused by overflowing of the Krueng Tripa River which experienced seasonal flooding in a year. Nagan Raya Regency is also surrounded by several rivers including the Krueng Seunagan River, Krueng Trang River, Krueng Seumayam River, Krueng Tadu River and Krueng Tripa River. Rainfall analysis using log percent distribution III with return periods of 2, 5, 10, 25, 50 and 100 years respectively obtained 141,520 mm; 192,349 mm; 227.094 mm; 272.270 mm; 306,569 mm; 341,869 mm.

The results of the analysis of the planned flood discharge of the Krueng Tripa watershed in Ujong Krueng Village with an area of 2953,457 km² and a river length of 177.88 km using the HSS Gama I method with return periods of 2, 5, 10, 25, 50 and 100 years respectively 3419 ,276 m³/s; 4647.384 m³/s; 5486,740 m³/s; 6578,338 m³/s ; 6702.133 m³/s ; 8259.949 m³/s.

Suggestions

To get validated results, recommendations and responses from this study are needed as a more accurate reference.

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