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Design of Flood Discharge with Synthetic Unit Hydrograph in Comoro Watershed, Timor Leste

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ABSTRACT

Flooding events has periodically occurred in rivers and will form the flooding area. Timor Leste has two times experienced of heavy flooding and natural disaster in 2020 and 2021 respectively. The aim of this study is to determine and analyze the design flood discharge for 5, 10. 25. 50, 100 and 500 years of return periods using synthetic unit hydrograph Nakayasu. The design flood discharge will determine in 4 rivers in Dili that consist in Comoro Watershed. The hydrology analyzes of design flood discharge in four rivers has included rainfall analyze, abstraction or infiltration of soil in terms of land use, rainfall-runoff model using synthetic unit hydrograph, and baseflow analysis. Based on analyze of design flood discharge in each return periods, the biggest flood discharge is occurring in Comoro River. The smallest design flood discharge is in Kuluhun/Lahane River. For Maloa and Becora/Taibesi River have moderate value of design flooding discharge. The difference of flooding discharge is due to the difference of geometric characteristic or parameter of each river. The value of design flood discharge is useful in planning and designing the river construction to prevent the flooding. The Government should use this information and technical data to strengthening the early warning system and mitigation system in risk area of flooding.

Keywords: flooding, flood discharge, synthetic unit hydrograph, Nakayasu, watershed

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1. Introduction

Flooding is the part of natural event. Flooding event due to natural conditions and human activities. climate change with the high intensity precipitation, storm, maximum sea tide, tsunami, regional geographical conditions are the natural cause of floods while land use change and lack of drainage system are the human activities causes (Kastrati et al., 2014; Liu et al., 2021; Suripin, 2004). Flooding events has periodically occurred in rivers and will form the flooding area. Flooding impact can damage the infrastructure, causing injuries and deaths, inundate agricultural lands, afflicted by various diseases, loss of home (Balasubramanian, 2005; Munsaka and Mutasa, 2012; Suripin, 2004).

Timor Leste has two times experienced of heavy flooding and natural disaster in 2020 and 2021 respectively. The Capital of Dili has get the impact of this flooding like damage the homes, school and public infrastructures, damage the agriculture land, contaminate water distribution and impact the healthy (UN Timor Leste, 2021). High intensity of rainfall has caused 5 main rivers in the Dili city was flooded (Red Cross of Timor Leste, 2020; UN Timor Leste, 2021). Comoro watershed, which consists of the Dili City as the capital of Timor Leste (Takeleb et al., 2018). Inside the city flowing 6 rivers that include in Comoro watershed namely Comoro, Maloa, Manleuna, Kuluhun/Lahane, Taibesi/Becora and Becora/ Benemauk. The longest river is Comoro River with length is 18 kilometers. The Comoro River is the biggest water contributor for aquifer in the watershed. The river has very high groundwater potential zone which covers about 5.4 % or 13.5 km^2 of watershed (Pinto et al., 2015).

Measured river discharge is limited and impacted to data on river discharges is limited to all rivers in Dili. Data limited significantly there is no discharge record in the river, the discharge data is not long enough to be analyzed, and there are no data pairs of discharge and rainfall records with short intervals in the same time. However, the modeled streamflow and flood discharge for various return period must be estimate and analyze to know the characteristic of streamflow and flooding event. To overcome the data availability problems, a design flood hydrograph analysis can be carried out using rainfall-runoff transformation method, which involves the components of unit hydrograph, excess rainfall, and baseflow (Chow et al., 1988; Nurdiyanto, 2019). There are two methods of unit hydrograph analysis, which are measured unit hydrograph and synthetic unit

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

hydrograph. For Comoro watershed which is unavailable data, the component of unit hydrograph can be approached by synthetic unit hydrograph (Bhuyan et al., 2015). The term synthetic means that the unit hydrograph derived from watershed characteristics, rather than rainfall-runoff data records (Chow et al., 1988).

The objective of this study is to determine and analyze the design flood discharge for 5, 10. 25. 50, 100 and 500 years of return periods using synthetic unit hydrograph Nakayasu. The return periods that using is significant to safety and risk reduction of flooding. The hydraulics structure to prevent flooding is design base on the return periods. The higher the return period used, the more guaranteed the safety of a flood control structure.

The design flood discharge will determine in 4 rivers in Dili that consist in Comoro Watershed. The result of design flood discharge will be using in the design of flood prevention infrastructure and also as an information for government in the decision-making process to prevent the flooding disaster in Dili.

2. Literature Review

2.1. Flood

Flooding as water with a big volume and inundate the dry areas (Samuels, 2013; Suripin, 2004). Flooding associate with natural extreme event in a watershed. Flooding always comes in the rainy season and happened due to the rainfall with maximum intensity. The maximum rainfall caused river and sea water to overflow into the surrounding area (Balasubramanian, 2005). In general, floods were caused by 3 factors such static natural conditions, Dynamic natural events and human activity. Geographical conditions, topography, river geometry, river meandering, sedimentation, etc., are some of the static natural conditions (Balasubramanian, 2005; Boahemaa et al., 2017). Dynamic natural events have the potential to cause flooding. Natural events such as rain with maximum intensity (Balasubramanian, 2005; Samuels, 2013). Human activity such population growth causes changes in function and land use. Increasing urbanization affects the social, economic and conditions of an urban area. Many people build houses on the banks of rivers, burn forests to open settlements and plant crops (Wilk, 2018).

Types of flooding that occur in urban areas are first, river floods, occur when the runoff through the channel or river body exceeds the capacity of the riverbed or channel so that water comes out of the river and inundates low areas near the river (Balasubramanian, 2005; Wright, 2007). Second, Flash floods are floods with fast and large flows, resulting from high river overflows, flowing quickly and carrying sediment such as stones, sand, silt, wood and other materials.(Balasubramanian, 2005; Zain et al., 2021). Third, Sea flooding occurs due to high sea waves along the coast. Storms that occur at sea cause the height of the sea waves to increase due to the small barometric pressure (Flores, 2020; Wright, 2007).

2.2. Nakayasu Synthetic Unit Hydrograph

Unit Hydrograph is a direct runoff hydrograph generated by active rain (net rain) that occurs evenly throughout the watershed and with constant integration for a certain time unit (Chow et al., 1988). The unit hydrograph shows the direct runoff hydrograph at the downstream end of the river flow which is covered by one millimeter of active rain. The watershed parameters as characteristic have used in this method as follow (Bhuyan et al., 2015; Chow et al., 1988; Krisnayanti et al., 2019) **:** a) time lag from the rainfall run-off until the peak of hydrograph; b) time lag from the weighted point of rainfall until the weighted point of hydrograph; c) time base of hydrograph: d) area of watershed: e) the length of main river**.**

The Synthetic Unit Hydrograph is a method that is used in ungauged watershed for designs of hydraulic structure in analyzing the design flood. One of them that is usually used in Indonesia is the Nakayasu Synthetic Unit Hydrograph. Nakayasu was developed based on some researches in Japan (Chalid and Prasetya, 2020; Krisnayanti et al., 2019). The election of the Nakayasu Method was based on the climate and topography of Timor Leste, which has a relatively high intensity of rainfall between December, January, and February (Takeleb and Ximenes, 2018) and the topography is dominated by mountainous areas. In addition, the calculation of flood discharge in the small watershed using the Nakayasu method is more appropriate because the Nakayasu Synthetic Unit Hydrograph diagram provides an overview of the discharge at the beginning of the rain, during the flood and when the flood ends (Chalid and Prasetya, 2020; Nurdiyanto, 2019). However, the Nakayasu method depends on the correction factor of physical parameter which affects the ordinate and time base of the unit hydrograph (Kamila et al., 2019) therefore using the Nakayasu method in large watersheds is strongly influenced by the the physical parameters of watershed.

The formula of Nakayasu Synthetic Unit hydrograph is as follow (Krisnayanti et al., 2019):

$$Q_p = \frac{C.A.R_O}{3.6.(0.3.T_p + T_{0.3})} \quad (1)$$

With, Q_p= Flood peak discharge (m^3/sec); R_o= Rainfall (mm); T_p = Time base from beginning rain until peak of flood (hour); $T_{0,3}$ = Required time for decreasing discharge, from peak to 30% of peak discharge; A= Wide of catchment área until outlet; C= Runoff coefficient

Determine T_p and $T_{0,3}$ using equation:

$$T_p = t_g + 0{,}8\ tr; \quad (2)$$

$$T_{0,3} = \alpha\ t_g; \quad (3)$$

$$Tr = 0{,}5\ t_g \text{ to } 1\ t_g, \quad (4)$$

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

with t_g = time lag as the time taken from the center of rain to get to the peak / delay time (hour), α = alpha coefficient or hydrograph parameter, ranging from 1.5 - 3.0 (for α =2 on ordinary catchment area, α=1,5 ascending/increasing part the hydrograph is slow, and α= 3 on descending/decreasing part the hydrograph is slow) and Tr = time of rainfall. Calculation of t_g follow the condition

if length of river (L)15 km then $t_g = 0,4 + 0,058L$, (5)

if length of river (L) 15 km then $t_g = 0,21\ L0,7$, (6)

Nakayasu determine the equations to calculate the hydrograph ordinates. The equation as follows (Chalid and Prasetya, 2020) :

- On increasing limb: $0 < t < T_p$

$$Q_P = \left(\frac{t}{T_p}\right)^{2.4} . Q_P \tag{7}$$

- On decreasing limb

a. For Interval: $0 \le t \le (T_p+T_{0,3})$

$$Q_{(t)} = Q_p . 0.3^{\frac{(t-Tp)}{T_{0.3}}} \tag{8}$$

b. For Interval: $(T_p + T_{0,3}) \le t \le (T_p + T_{0,3} + 1,5\ T_{0,3})$

$$Q_{(t)} = Q_p . 0.3^{\frac{(t-Tp+0.5T_{0.3})}{1.5.T_{0.3}}} \tag{9}$$

c. For Interval: $t > (T_p + T_{0,3} + 1,5\ T_{0,3})$

$$Q_{(t)} = Q_p . 0.3^{\frac{(t-Tp+1.5T_{0.3})}{2.0.T_{0.3}}} \tag{10}$$

2.3. Excess Rainfall

The most important component in hydrology process is rainfall. Rainfall will be transformed to be flow in the river. Flow in river have form as surface runoff, interflow, subsurface flow, or groundwater flow. The Dili rainfall have tendency is not significant and the distribution is unevenly (Takeleb and Ximenes, 2018). Therefore, the measurement and analysis of rainfall must be done carefully

The excess rainfall is the rainfall that causes the direct runoff. The intensity of excess rainfall determines by subtracting the precipitation with the losses. The equation of excess rainfall as follow (Chow et al., 1988; Sri Harto Br, 2000):

$$Pe = \frac{(P-Ia)^2}{P-Ia+S} \tag{11}$$

$$Ia = 0,2\,S \tag{12}$$

with Pe= excess rainfall (mm), P = normal rainfall (mm), Ia = initial abstraction (mm), S=losses (mm)

The one method to calculate the losses is the Soil Conservation Service Curve Number method as the following equation (Chow et al., 1988; Lal et al., 2017):

$$S = \frac{25400}{CN} - 254 \tag{13}$$

with CN= Curve Number

Curve Number (CN) is based on soils, plant cover, number of impervious areas, interception, and surface storage (Lal et al., 2017). The Soil Conservation Service (SCS) determine values of CN base on land use and condition of soil for 4 group of soil that can be used as the reference (Chow et al., 1988; Soulis et al., 2017; USDA, 2007).

3. Research Methodology

3.1. Study Area

This research was conducted on one of watersheds in Timor Leste namely Comoro watershed. Comoro watershed localize between 8°43’12” – 8°33’40” North and between 125°19’24” – 125°40’48” East (Pinto et al., 2015). There have six (6) rivers. This research has conduct for 4 rivers as Comoro, Maloa, Culuhun/Lahane, Taibesi/Becora river. Width and length of main rivers for each river as in Table 1 (Takeleb et al., 2018). The map of Comoro watershed and river as in Figure 1(Takeleb et al., 2018).

Table 1.Watershed Geometric

No	River	Width (km^2)	Length (km)
1	Comoro	215	18
2	Maloa	9.6	6.5
3	Kuluhun/Lahane	5.6	6.2
4	Taibesi/Becora	11.7	5.6

3.2. Data Collection

Research method using quantitative method. Field research was the type of research which conducted the collection data from the field. The direct observation in 4 rivers due to collect the river geometric (river width, river depth), water level, velocity and determine the discharge. In this study was conducted the maximum discharge calculation in the downstream of river not include the upstream part due to the flooding that always happened in the downstream area. The data collection was used the instrument as roll meter, Geographic Position System (GPS), compass, stopwatch, pong ball, survey form and camera.

The research also using the secondary data. The data collection has done in the government institution such Nacional Authorities of Water and Sanitation, Department of Meteorological and Geophysical, Minister of Agriculture and Fisher, Minister of Planning and Territories. The secondary data include Rainfall data for ten (10) years from 2010-2021. The rainfall data was collected from three (3) daily rainfall station as Aeroportu, EDTL and Remexio station. The other documents such as Hydrogeology map, soil type, report and scientific article.

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

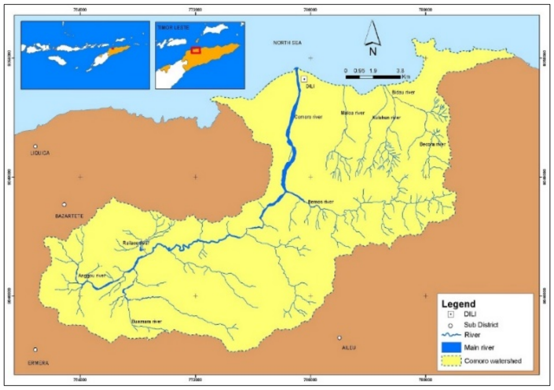

Figure 1. Comoro Watershed and the 4 Rivers

3.3. Data Analysis

Data analysis has carried out as follows:

a) Frequency analyses of daily maximum rainfall data with return period of 2, 5, 10, 25, 50,100, 500 years.
b) Analysis of Excess rainfall using Soil Conservation Service (SCS) method.
c) Analysis of maximum discharge (flood) in rivers using Nakayasu Synthetic Unit Hydrograph method. The analysis includes determine and calculate the watershed area, measuring the length of the river, calculate the parameter using Nakayasu Synthetic Unit Hydrograph. The parameter such duration of rainfall 1mm, Time lag (Tg), Time Peak (Tp), hydrographic model and maximum discharge (Qp), analyses the value of α (alpha) parameter, calculating the flood peak discharge based on the α (alpha) value that has been obtained.

4. Result

Hydrology analyze with it is objective to determine the Design Flood Discharge. The analyze was include maximum rainfall frequency, excess rainfall and design flood discharge analyze.

4.1. Maximum Rainfall Frequency

Base on the hydroclimatic condition, the extreme value using to analyze the extreme event such flooding no maximum rainfall. The rainfall probability distribution as an input in frequency analysis comes from daily rainfall data for 12 years. Distribution type which is using in this study is distribution Log Normal. The analog of Normal distribution therefore can calculate using Normal distribution function.

Test of goodness of fit has used Chi Square method due to test good or fit the distribution of sample data from the population. The test result has showed that the probability of Log Normal distribution has accepted. The following Table showing the value of maximum rainfall intensity for each return periods.

Table 2. Maximum Rainfall for each Return Period

Return Periods (years)	Maximum Rainfall (mm/day)
5	108
10	139
25	182
50	216
100	253
500	346

4.2. Excess rainfall

Calculation of excess rainfall using SCS-CN method. The *Curve Number* (CN) variable using as a function of watershed characteristic such soils, vegetation, urban planning and humidity. Soil type has influenced the excess rainfall and infiltration value. Soils type of Comoro watershed include in Sandy Loamy soils or type B. (Seed of Life, 2012).

Table 3. CN and Initial abstraction value

Watershed	CN (III)	Initial Abstraction (mm)
Comoro	74.02	17.83
Maloa	75.46	16.52
Lahane/Kuluhun	78.71	13.74
Becora/Taibesi	76.24	15.83

The CN value for each river was different. The value was various from 0 to 100. The CN (II) value showed that soils have a normal condition or no water contain. The CN (III) value has showed that the condition of soil started to wet or contain with water and causing the run off. The increasing of CN value indicates the capacity of soil to catch water has reduce. Therefore, it has impacted the infiltration was reduced and caused the inundation.

Table 4. Excess Rainfall in Comoro River

Return Periods	Excess Rainfall (mm)		
Hours	1	2	3
5	0.00	31.3	14.1
10	0.00	49.9	19.9
25	0.28	78.0	28.4
50	0.91	101.2	35.5
100	1.94	127.0	43.5
500	5.84	193.2	64.8

Excess rainfall has happened for 3 hours.to all river. The characteristic of excess rainfall is for first hour, rainfall intensity still minimum. In second hours the intensity has

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

increased and impacted to runoff. On the third hours, the rainfall intensity has reduced. and stopped gradually. The excess rainfall for each return periods and each river as show in Table 4.

Table 5. Excess Rainfall in Maloa river

Return Periods	Excess Rainfall (mm)		
Hours	1	2	3
5	0.00	33.54	14.53
10	0.01	52.70	20.43
25	0.47	81.29	29.08
50	1.24	104.75	36.30
100	2.44	130.78	44.47
500	6.74	197.27	66.15

Table 6. Excess Rainfall in Kuluhun/Lahane river

Return Periods	Excess Rainfall (mm)		
Hours	1	2	3
5	0.00	38.98	15.53
10	0.20	59.24	21.64
25	1.10	88.77	30.70
50	2.24	112.73	38.24
100	3.83	139.11	46.76
500	9.12	206.01	69.30

Table 7. Excess Rainfall in Becora/Taibesi River

Return Periods	Excess Rainfall (mm)		
Hours	1	2	3
5	0.00	34.80	14.78
10	0.04	54.26	20.71
25	0.60	83.09	29.45
50	1.45	106.69	36.75
100	2.74	132.81	44.99
500	7.27	199.43	66.88

4.3. Nakayasu Unit Hydrograph

The calculating of peak discharges using the Nakayasu method including the parameter of watershed such river length, watershed area and rain depth unit. In this study the length of river for each river has been taken in the downstream part as the principal river and location of river flooding. The longest length is for Comoro River and follow by Maloa, Lahane/Kuluhun and Becora/Taibesi respectively. The area of the Comoro watershed is the widest and follow by Becora/Taibesi, Maloa and Lahane/Kuluhun respectively. The watershed parameter details can see in Table 8.

Table 8. Watershed Parameter

Parameter	Unit		River			
			Comoro	Maloa	Lahane/Kuluhun	Becora/Taibesi
Area	A	km2	215	9.6	5.6	11.7
Length	L	km	18	6.5	6.2	5.6
Slope	S	%	0.01	0.03	0.02	0.03
Rainfall	R_0	mm	1	1	1	1
Time Lag	tg	hr	1.44	0.78	0.75	0.70
Time Rainfall	tr	hr	1	0.5	0.5	0.5
Constanta	α		2	2	2	2
$T_{0.3}$	$T_{0.3}$	hr	3	1.5	1.5	1.5
Time Peak	Tp	hr	2	1	1	1
1.5 Tp	$1.5T_{0.3}$	hr	5	2.5	2.5	2
Discharge Peak	Qp	m^3/s	16.59	1.48	0.86	1.81
	0.3 Qp	m^3/s	4.98	0.44	0.26	0.54
	0.09 Qp	m^3/s	1.49	0.13	0.08	0.16

The result of parameter from each river has showed that,

a) The parameter of rainfall with 1 mm intensity. The unit hydrograph significant the run off occurs due to 1mm rainfall intensity (Chow et al., 1988; Sri Harto Br, 2000).
b) The parameter of Time lag significant the time among rainfall that occurs until a flood occurs. The duration of Time Lag depends on river length (L). River for a long distance has long time lag while river at a short distance the time lag is small. The longest Time lag occurs in river Comoro with 1.4 hours and the shortest one is in Becora/Taibesi due to short distance of Principal River.
c) The parameter of Time Peak has significant the initial time base until reach the maximum discharge. The duration of time peak depends on time lag and time rainfall. The Time peak for Comoro watershed is 2 hours and for the small watershed the time peak is 1 hours.
d) The model of hydrograph is depending on α value. The Constanta of α showing the model of hydrograph curve. The hydrograph model has illustrated when the rain started occurs, the curve has decrease and the curve will increase until the maximum discharge occurs then form the curve peaks. The Constanta α depend to accept

Timor-Leste Journal of Engineering and Science

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

rainfall and transform it to be run off in rivers. In this study, for all river has α = 2. It is significant that the river has generally normal to transform rainfall be runoff in rivers.

e) The parameter of maximum discharge is the parameter that occurs due to the rainfall and occurs base on the time lag and time peak. Maximum discharge for Comoro River is the biggest due to the watershed characteristic that widest and has resulted the big volume of water that stored above ground and underground. The small watershed has maximum discharge small and the smallest is river Kuluhun/Lahane.

The parameter of watershed that has determined then resulted the unit hydrograph for each watershed. The unit hydrograph significant the transformation of rainfall be direct run off but not including the baseflow. The model of unit hydrograph for each watershed as seen in the Figure 2 & 3.

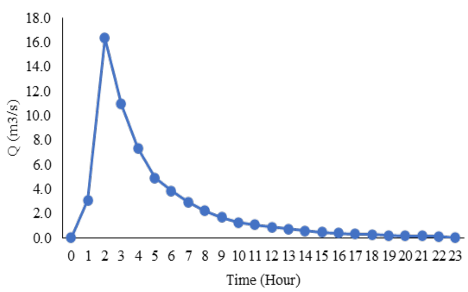

Figure 2. Unit Hydrograph of Comoro watershed

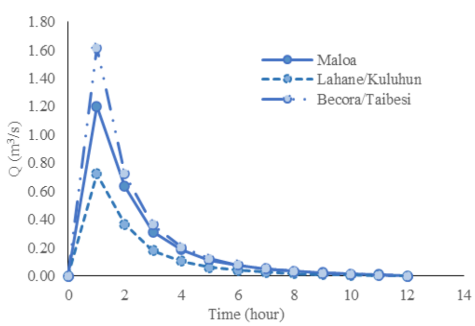

Figure 3. Unit Hydrograph of 3 sub-watershed.

The unit hydrograph curve for each watershed showing that the time from rain occurs to end in Comoro watershed is not the same with others sub-watershed. Time needs for run off occurs starting from rainfall occurs to end, will need 23 hours for Comoro watershed. While for 3 other sub-watersheds have the same time for 12 hours.

4.4. Analysis of Design Flood Discharge

The analysis of flood design has determined using Nakayasu Synthetic Unit Hydrograph. The value of flood discharge depends on unit hydrograph discharge, excess rainfall and baseflow. Excess rainfall is rain which is occurs during 3 hours in the watershed. Baseflow has assume from the flow of existing water in rivers during dry season. The seepage has occurred from ground to river as a baseflow. To calculate the discharge design, require the field flow data minimum 5years however, the data has not available and has used the flow data that direct measured in rivers. The design flood discharge result from watersheds as seen in Figure 4 to 7.

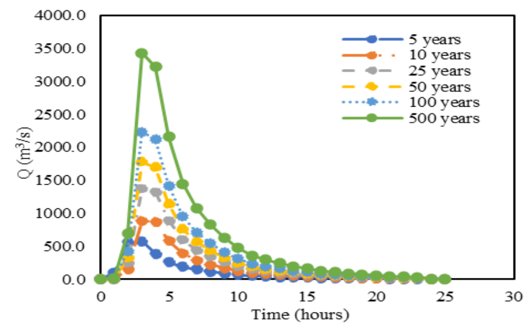

Figure 4. Design Flood Discharge in Comoro River

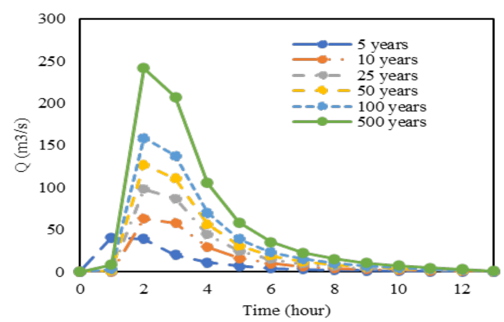

Figure 5. Design Flood Discharge in Maloa River

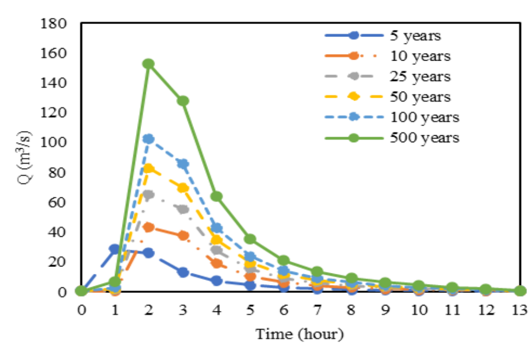

Figure 6. Design Flood Discharge in Lahane/Kuluhun River

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

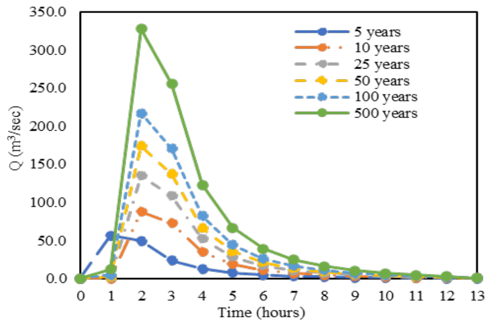

Figure 7. Design Flood Discharge in Becora/Taibesi River

The summary of design flood discharge for all watersheds and return periods as seen in the Table 9.

Table 9. Design Flood Discharge

Return Periods	Flood Discharge (m^3/s)			
	Comoro	Maloa	Kuluhun/ Lahane	Becora/ Taibesi
5	576.58	40.45	28.64	56.43
10	881.19	63.50	43.35	87.94
25	1369.81	98.16	65.02	134.99
50	1777.70	126.87	82.75	173.79
100	2235.69	158.92	102.40	216.99
500	3426.26	241.61	152.68	328.06

5. Discussion

The characteristic of rainfall at four watersheds (Comoro, Maloa, Kuluhun, Taibesi/Becora) have homogeny due to the geographic and geometric aspect. Rainfall that occurs in watershed have potentially to cause the flooding. Rainfall with maximum intensity has impacted to runoff flows in rivers. The result of maximum rainfall for each return 5, 10, 25, 50, 100 and 500 years showing significantly increased when the return periods have big. Maximum rainfall on 5 years returns periods have intensity of 108 mm/day. This value as the maximum value and probable could occurs highest or smaller than its value. This maximum rainfall will impact to occur the flooding in Dili city for 5 years return periods. The value of maximum rainfall that has determined for each return periods in this study, will be an information or as a data for government to make a mitigate plan due to the threat of maximum rainfall. Government together with community and stakeholder should set up the mitigate plan to minimize the risk due to maximum rainfall and flooding impact.

The excess rainfall has defined to be occurs during 3 hours for all watershed. Excess rainfall significant, the residual volume of rainfall after some of rainfall infiltrate to ground. Based on the approach model of rainfall distribution per hours has showed that the distribution of rainfall in all watershed is the same. Maximum rainfall for each return periods will distribute and occurs in time duration of 3 hours which potentially cause the flooding. For first hour the intensity is small, the increase maximum in second hours, and then decrease slowly in third hours.

Based on the direct observation in the field, the community converse that when rainy season, the rain has occurred during 3 hours and end, and started again after 3 hours rainy. The condition of rainfall intensity showing that rainfall could not increase proportionally base on the time change. (Triatmodjo, 2008). If the time duration is long will impacted the rainfall increasing slowly. This is significant during the long duration sometimes rain can stop follow the distribution. The Government has to understand and prepare the mitigate plan in terms of the maximum rainfall distribution model that will be occur in the second hour during the rainy season. The potential of flooding will be occurring in the second hours of rainfall occurs.

Rainfall will transform as a runoff flow in the rivers. Based on analysis result of design flooding value, showed that the biggest flooding discharge will occurring in Comoro River and the smaller flooding discharge occurs in Kuluhun/Lahane river. The big and small flooding discharge due to the geographic and geometric characteristic from each river. Comoro watershed is wider and the principal river is longest compared than another watershed. With this geometric condition, Comoro River will causing the direct runoff in river with maximum discharge. The baseflow in the Comoro River has big volume and when it accumulates with rainfall and direct runoff will impact the river is flooding. The flooding discharge will increase based on the return periods. The longest return period the biggest flooding discharge. From this result of design flood discharge will be an information and technical data to Government. The flooding mitigate system can immediately form in all rivers area that has potentially to flooding. Government should share this information to community that live near the rivers. Government should work together with the community to implement the prevention of flooding from Comoro, Maloa, Kuluhun and Taibesi/Becora River to minimize the risk of flooding in the rainy season.

6. Conclusion and Implication.

The hydrology analyzes of design flood discharge in four watersheds has including rainfall analyze, abstraction or infiltration of soil in terms of land use, rainfall-runoff model using synthetic unit hydrograph, and baseflow analysis.

Based on analyze of design flood discharge in each return periods, the biggest flood discharge is occurring in Comoro river. The design flood discharge in Comoro River for return periods of 5, 50, 500 years is 576.58 m^3/s, 1777.70 m^3/s no 3426.26 m^3/s respectively. The smallest design flood discharge is in Kuluhun/Lahane River. The design flood discharge of Kuluhun/Lahane River for return periods of 5, 50, 500 years is 28.64 m^3/s, 82.75 m^3/s, 152.68 m^3/s

Vol.4, Issue 1, pp.1-9, 2023
Available online at: http://tljes.org/index.php/tljes/data

respectively. For Maloa and Becora/Taibesi River have moderate design flooding discharge. The difference of flooding discharge for each watershed is due to the difference of geometric characteristic or parameter of each river.

The value of design flood discharge is useful in planning and designing the river construction (DAM, retaining wall, check DAM, retention pond, etc.) to prevent the flooding. The value is also useful for Government as an information and technical data to create the mitigation system in risk area of flooding. The mitigation system can design until long period based on the flooding that will occurs in the future. This value also useful for government as an information to set up the early warning system to minimize risk due to rainfall and natural hazard.

7. Limitation and Future Research

The limitation of pair's data rainfall-runoff from rainfall and discharge Automatic measuring instrument has impacted to analysis result. Unavailable this data leading this study to use the Synthetic Unit Hydrograph to analyses the flooding discharge. Therefore, to improve the quality of data and the accurate of analysis, government should fully support by strengthening the availability of automatic measure instrument of rainfall and discharge in river. Government also can develop the data and be a center or bank of data to research and design necessity.

The continuing of another research should do by using the hourly data of rainfall-runoff to resulting the accurate value of flooding discharge and to reflect the real condition of flooding in the river. The another model of unit hydrograph has recommended to using in the continuing research. In the future should including another parameter that causing flooding such geology factors, climate change and urban mobilize.

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