Hydrological Analysis Method in Selecting Flood Discharge in Watershed of Kelara River

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***Abstract*—For Engineers involved in planning and construction of water resources building, hydrology becomes very important data. In terms of planning stage in water resources especially waterworks, it is known that design flood discharge closed to field realistic conditions is often needed in order that a planned construction is able to control flood discharge. Several previous researches in choosing flood discharge selection method have diverse depending on observed watershed. One method in determining selected flood discharge by verification using Creager diagram, by comparing discharge calculation results of several Synthetic Unit Hydrograph (SUH) with infrastructure flood discharge (AWLR result) in observation point. This research aims to obtain the most suitable synthetic unit hydrograph and close to analysis result of measured discharge frequency, and Creager diagram in Kelara watershed (DAS). Based on the calculation of design flood discharge according to rainfall data using synthetic unit hydrograph of Nakayasu, ITB I, ITB II, and SCS (HEC-HMS) as well as the calculation of design flood discharge according to collected data, it is concluded that the synthetic unit hydrograph method closest to design flood discharge with measured discharge rate and Q1000 rate of Creager diagram is SCS. Flood discharge rate obtained according to HSS SCS method using HEC-HMS 4.8 application in period of 2 years is 658,40 m³/s, 25 years is 682,70 m³/s, 50 years is 787,00 m³/s, 100 years is 885,70 m³/det, and 1000 years is 1202,60 m³/s.**

Keywords—Design Flood Discharge, Synthetic Unit Hydrograph, Measured Discharge Data, Kelara Watershed (DAS).

I. Introduction

In terms of hydrology, river functions to contain rainfall and flows it to the sea. An area where river first get the rainfall water is rain catchment area known as Watershed (DAS). It is so that Watershed can be seen as a unitary unit of rainfall area becoming river flow [1].

Critical data required in hydrological analysis are topographyy, rainfall rate, land use pattern, type of soil and the data collected from measured observations including water level and discharge rate of a watershed [2].

For engineers involved in design and construction stages of waterwork building, hydrological data is crucially needed. As an example, if a city is trying to improve or fix a water availability problem, then the first step to it for the engineer is to find out a watershed in highlands area and estimate its ability to provide water. On the other hand, engineers must also be able to predict potential flood in the watershed [3].

In water resource planning, especially in waterworks design, design flood discharge closed to the field realistic condition is often needed in order to design a building capable of controlling flood discharge. Design flood discharge per period can be calculated using actual flood discharge and rainfall data. If the actual discharge data is available then the design flood discharge can be directly calculated using probability analysis method. But, if rainfall data and the watershed characteristics data are the only data available, it is recommended to calculate flood discharge of daily maximum rainfall data using hydrograph [4].

In order to make hydrograph in a watershed in which the flood hydrograph observation data is either limited or unavailable, then it is needed to know the watershed characteristics before several approaches are carried out using methods developed by experts [5].

Several previous researches in selecting flood discharge method have different results depending on the reviewed watershed [6]-[10].

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Although there have been many referable models, yet there are still doubts on how to apply the models in Indonesia with its tropical climate. This can be understood since the characteristics in tropical region varies between one area and another as well as the watershed response [11].

One of the ways in determining selected flood discharge can be done by verifying it using Creager diagram, by comparing discharge rate calculation of several Synthetic Unit Hydrograph methods with the infrastructure flood discharge of AWLR (Automatic Water Level Recorder on observed point [12].

In the Kelara watershed, there is Automatic Water Lever Recorder (AWLR) in the downstream area so that the research can be carried out to test discharge result of Synthetic Unit Hydrograph with AWLR frequency analysis of discharge rate.

II. Research Methodology

A. Location

The research is located in Kelara Watershed covering two regencies, Gowa Regency in upstream area dan Jeneponto Regency in downstream area. The Kelara Watershed belongs to the river basin of Jeneberang with researched area amounted to 288,62 km^2.

B. Data Collection Technique

The data used in this research are:

1. Rainfall data of Rainfall station of Paitana and station of Tanrang. Rainfall data period of time used is ranged from 1999 – 2018 (20 years) obtained from Large River Basin Organization of Pompengan Jeneberang (BBWS Pompengan Jeneberang).
2. Measured discharge data from water-level measuring posts situated in research location, namely AWLR of Kelara in years of 1999 – 2018 obtained from River Basin Organization of Pompengan Jeneberang (BBWS Pompengan Jeneberang).
3. Soli classification map in 2018 obtained from River Basin Organization of Pompengan Jeneberang (BBWS Pompengan Jeneberang).
4. Land use pattern map in 2019 obtained from Geospatial Information Organization (BIG).

C. Rainfall Data Analysis

1. Lost Data Entry

In order to fill out the lost rainfall data caused by damaged devise/equipment or that the observer did not take notes in a station, it can be filled by estimating estimation value based on previous three stations surrounding. The filling of the lost rainfall data can use normal comparative method and reciprocal method [13]. In this research the method used in filling out the lost data is reciprocal method.

$$P_x = \frac{\sum_{i=1}^{n} \frac{Pi}{Li^2}}{\sum_{i=1}^{n} \frac{1}{Li^2}} \quad (1)$$

Where Px is the lost rainfall data in station x (mm), Pi is rainfall data in surrounding stations in the same period of time (mm) dan Li : Distance of station x and the surrounding stations (km).

2. Consistent Test

Consistent test is carries out to view the provided data whether it is consistent or not so that it is feasible to use. Consisten test means to use the validity of field data not affected by the mistakes at the time of delivery or measurement. Data consistency test can be done by using Double Mass Curve method and Rescaled Adjusted Partial Sums (RAPS) [14].

In this research the used method in consistency test is Double Mass Curve method.

3. Regional rainfall

Regional rainfall (in units of mm) is daily maximum rainfall in the whole region. Regional rainfall is needed in calculating design flood discharge [13]. The calculation of regional rainfall in this research used Thiessen Polygon method :

$$\bar{p} = \frac{A_1 p_1 + A_2 p_2 + \dots + A_n p_n}{A_1 + A_2 + \dots + A_n} \quad (2)$$

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Where A is the area representing each station.

4. Frequency analysis

In terms of rainfall frequency analysis or discharge data to obtain design rainfall value or design discharge, it is known that several continuous probability analysis distributions are often used, namely Gumbel, Normal, Log Normal, and Log Pearson Type III.

The determination of probability distribution suited to the data is carried out by matching the parameters like average value, deviation standard, drag coefficient (Cs), and kurtosis coefficient (Ck) [13].

5. Data distribution compatibility test

To find out whether the selected probability distribution equation is representable for analyzed data sample statistic distribution, probability distribution test is needed. The method used for the test are Chi-Square and Kolmogorov-Smirnov test [15].

6. Rainfall Intensity

Rainfall intensity is the ratio of the total amount of rain (rainfall depth) falling during a certain period to the duration of the period expressed in unit of mm/second. The using of the method for rainfall intensity calculation depending on the provided rainfall data. In this research as the provided rainfall data is in the daily period then Mononobe method is used [15].

7. Net Rain Analysis

Net rain in this research is calculated with SCS-CN method. The equation is as follows:

$$Pe = (P - Ia)2 / (P - Ia + S) \quad (3)$$

$$S = (25400/CN) - 254 \quad (4)$$

$$Ia = 0{,}2\ S \quad (5)$$

Where Pe is effective rain depth (mm), P is rain depth (mm), Ia is initial abstraction (mm), S is maximum potential water retention by soil mainly caused by infiltration (mm), and CN is constant value determined by type of soil [13].

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Table 1. SCS Classification of Soil Hydrology Group According to Soil Texture.

No.	Soil Texture	Min. Infiltration Rate(mm/jam)	SCS Soil Hydrology Group
1	Sand	210	A
2	Loamy sand	61	A
3	Sandy loam	26	B
4	Loam	13	B
5	Silty loam	6,9	C
6	Sandy clay loam	4,3	C
7	Silty clay loam	2,3	D
8	Clay loam	1,5	D
9	Sandy clay	1,3	D
10	Silty clay	1,0	D
11	Clay	0,5	D

Table 2. CN Value according to Land Use Pattern

Types of Land Use Pattern	Soil Type			
	A	B	C	D
Processed and Planted Land				
1. With Conservation	72	81	88	91
2. Without Conservation	62	71	78	81
Meadow				
1. Bad Condition	68	79	86	89
2. Good Condition	39	61	74	80
Meadow: Fine Condition	30	58	71	78
Jungle 1. Rare Plants, Bad Closure	45	66	77	83
2. Good Closure	25	55	70	77
Open Place, Grassfields, Golf Field, Cemetery, etc.				
1. Good Condition: Grass-coverage 75%	39	61	74	80
2. Medium Condition: Grass coverage 50%-75% of area	49	69	79	84
Commerce and Business Area (85% waterproof)	89	92	94	95
Industry Area (72% waterproof)	81	88	91	93
Settlement				
Area %waterproof				
1/8 acre or less 65	77	85	90	92
1/4 acre 38	61	75	83	87
1/3 acre 30	57	72	81	86
1/2 acre 25	54	70	80	85
1 acre 20	51	68	79	84
Roof Parking, Car Road	98	98	98	98
1. Drainage Pavement	98	98	98	98
2. Gravel	76	85	89	91
3. Soil	72	82	87	89

D. *Design Flood Discharge Analysis*

In this research design flood discharge analysis uses 4 method, Synthetic Unit Hydrograph of Nakayasu, ITB-I, ITB-II, and SCS (HEC-HMS). The following is the explanation of the four method :

1. Nakayasu

Nakayasu researched unit hydrograph in Japan and produced the equation as follows [13].

a. Lag time (t_g)

$$t_g = 0{,}4 + 0{,}058 \times L \text{ (for L>15 km)} \quad (5)$$

$$t_g = 0{,}21 \times L^{0,7} \text{ (for L<15 km)} \quad (6)$$

b. Peak time

$$t_p = t_g + 0{,}8Tr \quad (7)$$

c. Discharge time is equal to 0,3 times peak discharge

$$t_{0,3} = \alpha \times t_g \quad (8)$$

d. Hydrograph peak discharge

$$Q_p = \frac{1}{3{,}6} \times A \times R_0 \times \frac{1}{(0{,}3 \times t_p + t_{0,3})} \quad (9)$$

Where t_g is the gap time (hour), L is river length (km), $t_{0,3}$ is discharge time equal to 0,3 kali peak (jam), t_p is peak time (hours), α is coeffiecient with the value ranges from 1,5 – 2,0, Q_p is peak discharge (m^3/sec), T_r is rainfall duration (hours), R_0 is rain depth unit (mm).

2. ITB Synthetic Unit Hydrograph (HSS ITB)

ITB Synthetic Unit Hydrograph, also called HSS ITB-I was developed according to the experience of Dantje Kardana Natkusumah when doing evaluation toward design flood hydrograph in physical model test of two dam spillways in Citepus dan Sadawarna Dam [16].

The following is the equation used in ITB-I:

a. Lag time (t_p)

$$t_p = C_t 0{,}81225 \cdot L^{0,6} \quad (10)$$

b. Peak time

$$Tp = t_p + 0{,}50Tr \quad (11)$$

c. Unit hydrograph base time

$$Tb = (10 \text{ s/d } 20)\ Tp \quad (12)$$

d. Hydrograph peak discharge

$$Qp = \frac{R}{3{,}6Tp} \frac{A_{DAS}}{A_{HSS}} \quad (13)$$

The following is the equation used in ITB-II :

a. Lag time (t_p)

$$t_p = C_t \times (0{,}527 + 0{,}058 \cdot L)(\text{untuk L>15 km}) \quad (14)$$

$$t_p = C_t \times (0{,}21 \cdot L^{0,7})(\text{untuk L<15 km}) \quad (15)$$

b. Peak time

$$Tp = t_p + 0{,}60t_p \quad (16)$$

The equation of unit hydrograph base time and peak discharge is the same as ITB I.

Where tp is Lag time (hours), L is river length (km), C_t Calibration coefficient =1, T_r is rain duration (hours), Tp is peak time (hours), Tb unit hydrograph base time, Q_p is peak discharge rate (m^3/det), R is unit rainfall rate (mm), A_{DAS} is watershed area value (km^2), and A_{HSS} is dimensionless unit hydrograph curve area.

3. SCS Synthetic Unit Hydrograph (HEC-HMS)

SCS Synthetic Unit Hydrograph is dimensionless unit hydrograph, where this method calculates the influence of soil type and land use pattern and can be calculated using HEC-HMS software. The following is the equation used in SCS method [17] :

a. Hydrograph peak discharge and peak time

$$U_p = C\frac{A}{T_p} \quad (17)$$

$$T_p = \frac{\Delta t}{2} + t_{lag} \quad (18)$$

b. Lag time (t_p)

$$t_p = 0{,}6 \cdot t_c \quad (19)$$

c. Kirpich time of concentration

$$t_c = \left(\frac{0{,}87 \times L^2}{1000 \times S}\right)^{0,385} \quad (20)$$

Where Up is peak discharge, A is watershed area, Tp is peak time, C is constant value (2,08), t is period of excess rain, tp is Lag time (hours), tc is time of concentration, L is river length (km), dan S is river slope (m/m).

E. Research flowchart

Generally, research flowchart can be seen in Fig. 1.

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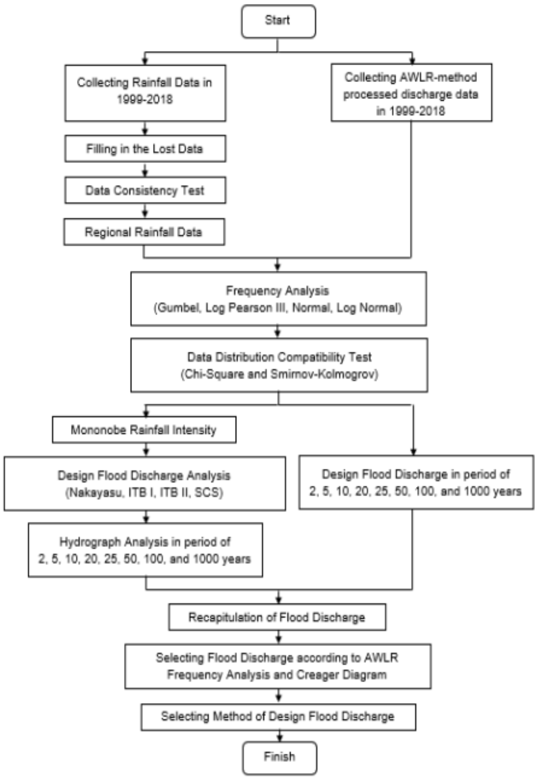

Figure 1. Research Stages

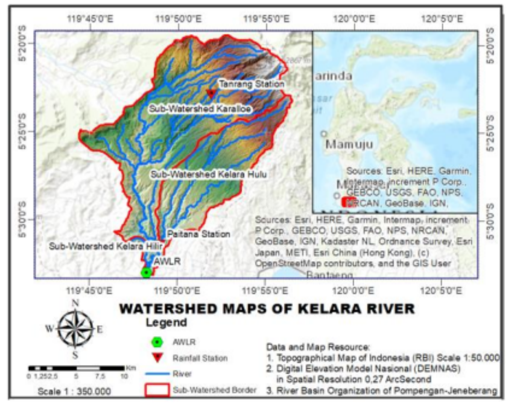

Figure 2. Map of Kelara Watershed

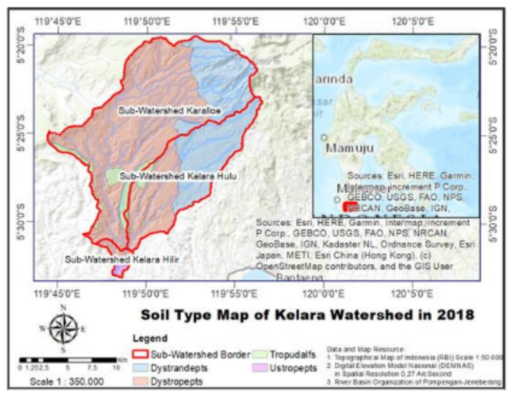

Figure 3. Soil Type Map of Kelara Watershed

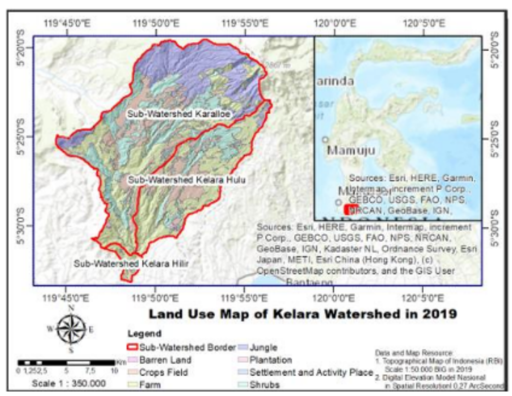

Figure 4. Land Use Pattern Map of Kelara Watershed

III. Results and Discussion

A. Characteristic Analysis of Kelara sub-watershed

The map of Kelara Sub-Watershed is needed in order to obtain the characteristics of the watershed like area, main river length, slope incline, and Sub-Watershed boundaries needed in analysis process. The following is the map of the watershed, soil type, and land use pattern of research location.

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Table 3. Characteristics Recapitulation of Kelara Sub-Watershed

No.	Physical Parameter	Sub-Watershed		
		Karalloe	Kelara Hulu	Kelara Hilir
1	Area (km^2)	195,23	86,89	6,52
2	River Length (km)	27,27	12,62	5,38
3	Upstream Elevation(msl)	848,00	753,42	140,13
4	Downstream Elevation (msl)	140,13	140,13	99,87
5	River Slope	0,026	0,049	0,007
6	Max. Potential Retention (mm)	117,01	81,67	111,19
7	Initial Abstraction (mm)	23,40	16,33	22,24
8	Imoervious (%)	0,58	0,93	0,59
9	Curve Number (CN)	68	76	70
10	Lag Time (min)	124,17	53,887	57,41

B. Yearly Maximum Rainfall Analysis

Design rain is needed in calculation of design flood discharge in which the value is obtained from yearly maximum daily rainfall analysis. The data range provided in rainfall station of Kelara Watershed is in period of 20 years starting from 1999 until 2018. The lost rainfall data or the uncompleted one is complemented by using reciprocal method. The uncompleted one is in Paitana station in years of 2004–2007. Yearly Maximum Daily Rainfall Data which is influential is tabled in Table 4.

Table 4. Kelara Watershed Max. Daily Rainfall

No.	Year	Max. Daily Rainfall (mm)	
		Paitana Sta.	Tanrang Sta.
1	1999	90	90
2	2000	90	95
3	2001	75	80
4	2002	100	80
5	2003	75	100
6	2004	135	45
7	2005	39	68
8	2006	131	125
9	2007	68	90
10	2008	73	136
11	2009	90	92
12	2010	95	91
13	2011	77	51
14	2012	65	94
15	2013	85	125
16	2014	80	125
17	2015	80	85
18	2016	95	79
19	2017	75	75
20	2018	75	105

C. Data Consistency Test

It is known that to evaluate the consistency in data series, consistency test is used. The method used in this test is Double Mass Curve Method.

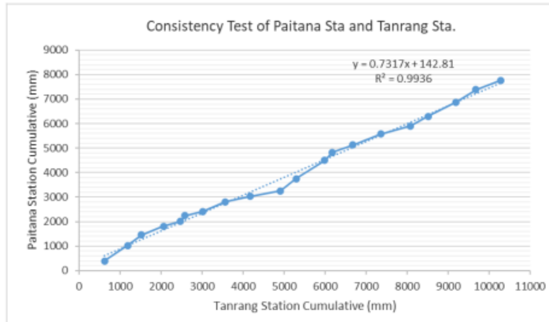

Figure 5. Consistency Test Result of Paitana Sta. and Tanrang Sta.

From the consistency test of yearly rainfall data, each station shows that the data is consistent enough with correlation value amounted to 99,36%.

D. Regional Rainfall

This analysis is needed to know the influence of rainfall station toward a watershed. This analysis will result in obtaining Thiessen Coefficient which will be multiplied by each station. Thiessen coeff, value on Kelara Watershed can be seen in Table 5.

Table 5. Thiessen Coeff. of Kelara Watershed

No.	Sub-Watershed	Thiessen Coeff. (mm)	
		Paitana Sta.	Tanrang Sta.
1	Karalloe	0,21	0,79
2	Kelara Hulu	0,45	0,55
3	Kelara Hilir	1	-

E. Frequency Analysis

There are 4 methods used in frequency analysis i.e. Normal Distribution, Log Normal, Gumbel, dan Log Pearson III.

Table 6. Frequency Analysis Sub-Watershed Karalloe

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No.	Period	Log Pearson III	Gumbel Tipe I	Normal	Normal Log
	(yrs)	(mm)	(mm)	(mm)	(mm)
1	2	89.012	87.349	90.172	88.237
2	5	106.010	107.722	106.220	105.751
3	10	115.578	121.212	114.626	116.273
4	20	124.441	134.151	121.503	125.655
5	25	126.293	138.255	122.809	127.519
6	50	133.486	150.899	129.336	137.266
7	100	140.106	163.450	134.685	145.806
8	1000	159.616	204.921	149.204	171.760

Table 7. Frequency Analysis of Sub Watershed Kelara Hulu

No.	Period	Log Pearson III	Gumbel Tipe I	Normal	Normal Log
	(yrs)	(mm)	(mm)	(mm)	(mm)
1	2	88.183	86.261	88.584	87.251
2	5	101.774	103.026	101.790	101.515
3	10	109.050	114.126	108.707	109.895
4	20	115.545	124.774	114.366	117.263
5	25	116.890	128.151	115.440	118.716
6	50	121.979	138.556	120.812	126.258
7	100	126.534	148.884	125.213	132.794
8	1000	139.406	183.010	137.161	152.292

Table 8. Analisis Frekuensi Sub DAS Kelara Hilir

No.	Period	Log Pearson III	Gumbel Tipe I	Normal	Normal Log
	(yrs)	(mm)	(mm)	(mm)	(mm)
1	2	83.203	81.878	84.938	82.653
2	5	101.273	103.955	102.327	101.144
3	10	111.943	118.571	111.435	112.427
4	20	122.014	132.591	118.887	122.589
5	25	124.135	137.039	120.302	124.619
6	50	132.503	150.740	127.374	135.285
7	100	140.351	164.339	133.171	144.703
8	1000	164.251	209.275	148.903	173.704

F. Data Distribution Compatibility Test

This test is meant to know hypothesis truth of frequency distribution. There are 2 ways to carry out the test i.e. Chi-Square and Smirnov-Kolmogorov Test. The following is the result test on Kelara Watershed:

Table 9. Data Distribution Compatibility Test Sub-Watershed Karalloe

No.	Method	Compatibility Test			
		Chi-Square		Smirnov – Kolmogorov	
		χ^2_{hit}	χ^2_{kr}	$\Delta_{hit.}$	Δ_{kr}
1	Gumbel	4,6000	7,8150	0,1143	0,2940
		Qualified		Qualified	
2	Log Pearson III	4,000	7,8150	0,1063	0,2940
		Qualified		Qualified	
3	Normal	4,600	7,8150	0,1195	0,2940
		Qualified		Qualified	
4	Log Normal	4,000	7,8150	0,0888	0,2940
		Qualified		Qualified	

With the same way, it is done to Sub-Watershed Kelara Hulu and Kelara Hilir. Chi – Square and Smirnov-Kolmogorov test shows that design daily rainfall distribution of Sub-Watershed Karalloe and Kelara Hilir follows Log Normal frequency distribution, and Sub Watershed Kelara Hulu follows Gumbel distribution.

G. Rainfall Intensity and Net Rainfall

Observation in Indonesia shows that centered rain do not last more than 7 hours, then in this calculation it is assumed that maximum centered rain period is 6 hours a day. Hourly rainfall distribution is calculated using Mononobe equation and Net rainfall analysis using SCS-CN method which can be seen in following Table.

Table 10. Net Rainfall Calculation Sub-Watershed Karalloe

Period	Design Rainfall	Curve Number	Potential Retention	Initial Abstraction	Net Rain
(yrs)	(mm)		(mm)	(mm)	(mm)
2	88.24	68.46	117.01	23.40	23.12
5	105.75	68.46	117.01	23.40	34.02
10	116.27	68.46	117.01	23.40	41.10
20	125.65	68.46	117.01	23.40	47.69
25	127.52	68.46	117.01	23.40	49.02
50	137.27	68.46	117.01	23.40	56.16
100	145.81	68.46	117.01	23.40	62.58
1000	171.76	68.46	117.01	23.40	82.94

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Table 11. Calculation of Effective Rainfall Sub-Watershed Karalloe

t	Rt	Net Raifall (Rn, mm) in Certain Period (years)							
		2	5	10	20	25	50	100	1000
		23.12	34.02	41.10	47.69	49.02	56.16	62.58	82.94
(hour)	(%)	Hourly Net Rainfall = Rn x Rt							
1	55.03%	12.72	18.72	22.62	26.24	26.98	30.90	34.44	45.65
2	14.30%	3.31	4.87	5.88	6.82	7.01	8.03	8.95	11.86
3	10.03%	2.32	3.41	4.12	4.78	4.92	5.63	6.28	8.32
4	7.99%	1.85	2.72	3.28	3.81	3.92	4.49	5.00	6.63
5	6.75%	1.56	2.29	2.77	3.22	3.31	3.79	4.22	5.59
6	5.90%	1.36	2.01	2.42	2.81	2.89	3.31	3.69	4.89

Table 12. Calculation of Net Rainfall Sub-Watershed Kelara Hulu

Period	Design Rainfall	Curve Number	Potential Retention	Initial Abstraction	Net Rain
(yrs)	(mm)		(mm)	(mm)	(mm)
2	86.26	75.67	81.67	16.33	32.26
5	103.03	75.67	81.67	16.33	44.64
10	114.13	75.67	81.67	16.33	53.29
20	124.77	75.67	81.67	16.33	61.86
25	128.15	75.67	81.67	16.33	64.62
50	138.56	75.67	81.67	16.33	73.27
100	148.88	75.67	81.67	16.33	82.02
1000	183.01	75.67	81.67	16.33	111.8

Table 13. Calculation of Effective Rainfall Sub-Watershed Kelara Hulu

t	Rt	Net Raifall (Rn, mm) in Certain Period (years)							
		2	5	10	20	25	50	100	1000
		32.26	44.64	53.29	61.86	64.62	73.27	82.02	111.87
(hour)	(%)	Hourly Net Rainfall = Rn x Rt							
1	55.03%	17.75	24.57	29.33	34.04	35.56	40.32	45.14	61.56
2	14.30%	4.61	6.39	7.62	8.85	9.24	10.48	11.73	16.00
3	10.03%	3.24	4.48	5.35	6.21	6.48	7.35	8.23	11.22
4	7.99%	2.58	3.57	4.26	4.94	5.16	5.85	6.55	8.94
5	6.75%	2.18	3.01	3.59	4.17	4.36	4.94	5.53	7.55
6	5.90%	1.90	2.63	3.14	3.65	3.81	4.32	4.84	6.60

Table 14. Calculation of Net Rainfall Sub-Watershed Kelara Hilir

Period	Design Rainfall	Curve Number	Potential Retention	Initial Abstraction	Net Rain
(yrs)	(mm)		(mm)	(mm)	(mm)
2	82.65	69.55	111.19	22.24	21.27
5	101.14	69.55	111.19	22.24	32.75
10	112.43	69.55	111.19	22.24	40.39
20	122.59	69.55	111.19	22.24	47.60
25	124.62	69.55	111.19	22.24	49.08
50	135.28	69.55	111.19	22.24	56.99
100	144.70	69.55	111.19	22.24	64.19
1000	173.70	69.55	111.19	22.24	87.34

Table 15. Calculation of Effective Rainfall Sub-Watershed Kelara Hilir

t	Rt	Net Raifall (Rn, mm) in Certain Period (years)							
		2	5	10	20	25	50	100	1000
		21.27	32.75	40.39	47.60	49.08	56.99	64.19	87.34
(hour)	(%)	Hourly Net Rainfall = Rn x Rt							
1	55.03%	11.70	18.02	22.23	26.20	27.01	31.36	35.32	48.07
2	14.30%	3.04	4.68	5.78	6.81	7.02	8.15	9.18	12.49
3	10.03%	2.13	3.29	4.05	4.78	4.92	5.72	6.44	8.76
4	7.99%	1.70	2.62	3.23	3.80	3.92	4.55	5.13	6.98
5	6.75%	1.43	2.21	2.72	3.21	3.31	3.84	4.33	5.89
6	5.90%	1.25	1.93	2.38	2.81	2.89	3.36	3.78	5.15

H. Design Flood Discharge Analysis

Design flood discharge is carried out in 4 method i.e. Synthetic Unit Hydrograph of Nakayasu, ITB I, ITB II and SCS (HEC-HMS). The result in this research is the result of superposition of the three Sub-Watershed to obtain total design flood discharge of Kelara Watershed located in outlet location of AWLR Kelara. The following is the superposition result of three Sub-Watershed in the four methods:

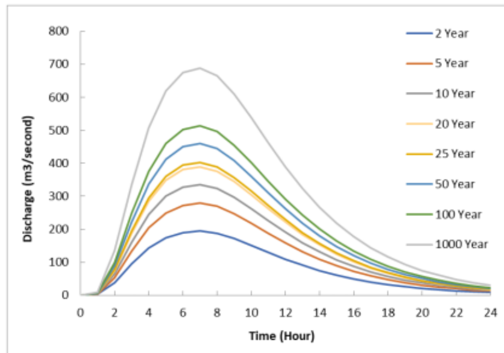

Figure 6. ITB I, Kelara Watershed

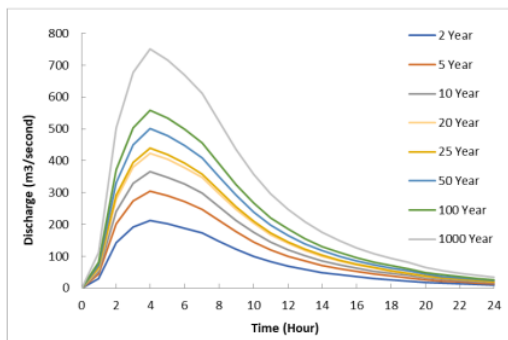

Figure 7. ITB II, Kelara Watershed

I. Discharge Data Frequency Analysis

Maximum river discharge data used in this analysis is in period of 1999 – 2018 from AWLR processed by River Basin Organization of Pompengan Jeneberang (BBWS Pompengan Jeneberang) as seen in Table 16.

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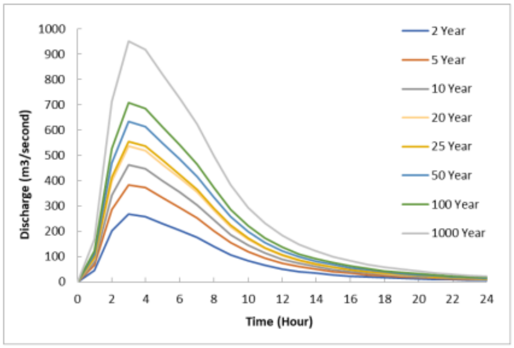

Figure 8. Nakayasu, Kelara Watershed

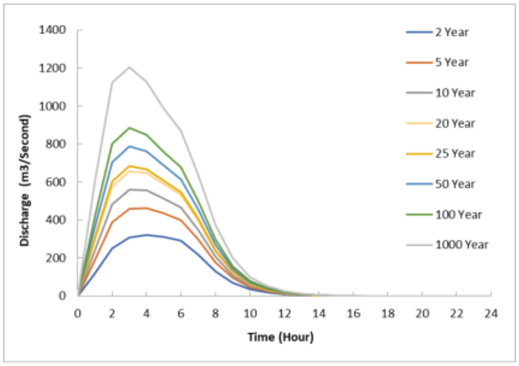

Figure 9. SCS (HEC-HMS), Kelara Watershed

Table 16. Maximum Discharge Rate of Kelara Watershed

No.	Year	Max. Discharge Rate of Kelara River (m^3/sec)
1	1999	111.16
2	2000	121.30
3	2001	76.14
4	2002	156.35
5	2003	142.36
6	2004	158.09
7	2005	87.53
8	2006	51.14
9	2007	21.48
10	2008	7.86
11	2009	8.68
12	2010	25.34
13	2011	4.89
14	2014	20.70
15	2016	39.73
16	2017	67.89
17	2018	45.29

From measured discharge data frequency analysis uses normal distribution, log normal distribution, gumbel distribution and log pearson type III distribution and distribution compatibility test using Chi-Square Test and Smirnov-Kolmogorov Test it is concluded that the design flood discharge as follows in Table 17.

Table 17. Design Flood Discharge according to Measured Discharge

No.	Period (yrs)	Flood Discharge (m^3/sec)
1	2	43.597
2	5	109.728
3	10	177.948
4	20	264.297
5	25	284.906
6	50	414.717
7	100	564.122
8	1000	1300.345

J. Selection of Design Flood Discharge according to Measured Discharge and Creager Diagram

It is given that to determine method of selected design flood discharge can be controlled using Measured Discharge and Creager Diagram.

Creager diagram is used to compare design flood discharge Q in 1000-years period, in which the closest one to it according to Creager diagram is selected.

Value of C = 100 is used to calculate peak discharge of the biggest potential flood only happens once for the relevant river lifespan and various experiences show that the numbers are realistic [18].

According to above idea, it can be conluded that Creager coefficient used is C = 100. Creager diagram can be seen in Figure 10. According to Figure 10 shows that 1000-years period viewed by all four methods the closest one to C = 100 of Creager diagram and measured discharge is SCS (HEC – HMS) and to optimize the river waterworks building design performance considering the discharge produced of SCS method (HEC – HMS) is greater than compared to another method.

Table 18. Design Flood Discharge Recapitulation

Period (Tr)	Peak Discharge (m3/sec)				
	AWLR Frequency Analysis	SCS	Nakayasu	ITB I	ITB II
2	43.60	322.70	268.52	194.35	211.76
5	109.73	464.10	384.53	278.76	303.68
10	177.95	560.40	462.28	335.22	365.18
20	264.30	658.40	536.70	389.16	423.96
25	284.91	682.70	555.82	402.83	438.90

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Period (Tr)	Peak Discharge (m3/sec)				
	AWLR Frequency Analysis	SCS	Nakayasu	ITB I	ITB II
50	414.72	787.00	633.96	459.57	500.71
100	564.12	885.70	708.11	513.24	559.21
1000	1300.35	1202.6	951.49	688.99	750.88

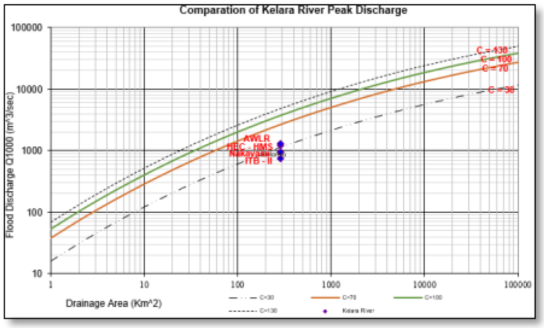

Figure 10. Creager Diagram Kelara Watershed

IV. Conclusion

According to data analysis result and discussion, it can be concluded that the calculation of design flood discharge according to rainfall data using Synthetic Unit Hydrograph of Nakayasu, ITB I, ITB II, and SCS (HEC-HMS), and it is known from calculation of design flood discharge that the value of design flood discharge which is the closest to design flood discharge with measured discharge rate and 1000-years Creager value is SCS method. Flood discharge obtained according to SCS method using HEC-HMS 4.8 software application is 2-years period is 322,70 m^3/sec, 5-years period is 464,10 m^3/sec, 10-years period is 560,40 m^3/sec, 20-years period is 658,40 m^3/sec, 25-years period is 682,70 m^3/sec, 50-years period is 787,00 m^3/sec, 100-years period is 885,70 m^3/sec, and 1000-years period is 1202,60 m^3/sec.

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