Evaluation Calculation of Flood Design with Hydrograph Method Nakayasu, Limantara and Snyder in Catchhement River Way Tebu

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Abstract. Synthetic unit hydrograph is a synthetic based hydrograph of watershed parameters. One way to find out the magnitude of the flood watershed of Way Tebu River Basin is to predict the amount of flow from existing rain data, Therefore rainfall data as the main input of rain diversion process becomes a very important thing and must have a high level of accuracy. The research presents a simple approach to determine peak discharge and unit hydrograph form in the Waytebu River Basin. Several methods of unit synthesis hydrograph such as Nakayasu, Limantara and Snyder are used to calculate peak discharge and hydrograph form. Flood discharge plans with various reworks in each method, providing mixed results. The greatest result is the Limantara HSS (Q25 = 1,413.13 m3 / sec) and the smallest HSS Snyder (Q25:814,57 m3 / s), while HSS Nakayasu (Q25 = 922.93 m3 / s). From the hydrograph comparative analysis of the three methods for Limantara method, the top time is happened at (Tp: 5.57) with top flow (Qp: 10,19 m3 / s), While Nakayasu method has the same top time at (Tp: 5,93) with top flow (Qp: 11.65 m3 / s) and Snyder method top time happened ad (Tc: 5.57) with top flow (Qp: 10.19 m3 / s).
Keywords: Synthetic unit hydrograph Way Tebu, HSS Nakayasu, HSS Limantara, HSS Snyder.

1. Introduction

1.1 Description

Water is a very important need for the life of living things on this earth. The function of water for life can not be replaced by other compounds. The main water use and vital to life is drinking water. Natural water resources consist of sea water, atmospheric water (meteorological water), surface water and ground water.

Way Tebu river is a river located in Pringsewu District with a long river about 57 km, which crosses some village areas in Talang Padang Subdistrict, Pugung District and Pringsewu. The management of Way Tebu River is the authority of the central government which is managed under the Balai Besar Wilayah Sungai Mesuji Sekampung (BBWS-MS). Way Tebu River is currently used as irrigation, fishery, raw water source and other purposes.

Like other rivers in Indonesia, Way Tebu River is often flooded and has caused much harm to the people, even the loss of life. The heavy rain that hit the District of Pagelaran and Pringsewu, causing River Way cane overflowed and inundate settlements in the hamlet Umbulalang, Tanjung Dalam, Pagelaran, Pringsewu.

1.2 Purpose and objectives

The purpose of this thesis is to know the flood discharge of Way Tebu River by Limantara, Nakayasu and Snyder methods. While the purpose of this Thesis is to:

1. Rainfall analysis
2. Nakayasu Hydrograph
3. Limantara Hydrograph
4. Snyder Hydrograph
5. Comparison analysis Hydrograph

1.3 Benefits of research

After analyzing the calculation of Way Tebu River flows using the Nakayasu, Limantara and Snyder method hydrographs, it is expected to be useful as a source of data in planning future water resource buildings.

2. Theoretical basis

Hydrology is a science that explains the presence and movement of water in our nature, which encompasses various forms of water, concerning its changes between liquid, solid, and gas in the atmosphere, above and below the soil surface (Soemarto CD 1995). In general, hydrology is intended as a science concerning water problems (Sri Harto, 1990). Hydrology can be defined as a science related to processes involving the problem of depreciation and addition of hydropower in and on the surface of the earth for each stage of its existence. Hydrology is a science that deals with the Earth's water, its occurrence, its circulation and its flow, its chemical and physical properties, and its reaction to its environment, including its relationship to living beings (International Glossary of Hydrology, 1974).

2.1 Rain frequency analysis

To determine the maximum daily rainfall, the plan which will be used to calculate the flood discharge plan is used Log Pearson Type III method.

2.2 Log Pearson Type III Method

The calculation of the rainfall plan with a certain repeated Log Pearson Type III method is to use the following equation:

$$\overline{\log x} = \frac{\Sigma \log x}{n} \qquad \overline{S \log x} = \sqrt{\frac{\sum\left(\log X - \overline{\log X}\right)^2}{n-1}}$$

$$CS = \frac{n\sum\left(\log X - \overline{\log X}\right)^3}{(n-1)(n-2)\left(\overline{S \log X}\right)^3}$$

$$\log X = \overline{\log X} + k\left(\overline{S \log X}\right)$$

Keterangan :

$\overline{\log X}$ = The average value of log X ....(1)

CS = Coefficient of skewness

k = Characteristics of Pearson type III log distribution

2.3 Chi-Square Test

Tests of conformity with Spreading Test of Chi Square Method is to test whether the selected distribution in curve making matches the empirical distribution. Chi Square Test is intended to determine whether the selected opportunity distribution equation can represent the statistical distribution of the analyzed data.

Chi-Square calculation steps are as follows:

1. Sort observation data from big to small
2. Determine the number of classes with the equation *K=1 + 3,322 log* N

N = Amount of data

K = Number of classes = [100/k]

3. Calculate the value of X

Log X = Log Xrata + (G x S)

4. Calculate the theoretical / calculated frequency value Ft :

Ft = 20% x n

2.4 Flood discharge design

The calculation of the flood discharge design on the basin can be calculated by the method of Nakayasu, Limantara and Snyder based on the rainfall probability calculation data of the plan. Selection of calculation methods based on the conditions that exist in the field and the availability of supporting data.

2.5 Nakayasu Synthetic Unit Hydrograph

In this case the author, using the method of Nakayasu with the following formula:

TI = 0,21 L0.7 L < 15 km

TI = 0,527 + 0,058 L L > 15 km

TP = TI + 0,5 Tr

explanation :

TI = Time lag (hour)

L = long river (km)

Tp = peak time (hour)

Qp = C A R/3,6 (0,3Tp + 0,3)

Tg = 0,21 L0.7 L < 15km

Tg = 0,4+0,058 L L > 15 km

Tr = 0,75 Tg

T0,8 = 0,8 Tr

Tp = Tg + 0,8Tr

Tb = ∞

2.6 Limantara Synthetic Unit Hydrograph

Area (A)

Main River Length (L)

The length of the River is measured to the point of weight (Lc)

River slope (S)

Coefficient of roughness (n)

Tg = 0,4 + (0,058 * L)

Tg

tr = 0,75* tg

Tp = Tg + 0.8 Tr

Tp

T0.3 = a * Tg

T0.3

Tp + T0.3

Tp + T0.3 + 1.5 T0.3 = Tp + 2.5T0.3

Qp = 0,042*A0,451*L0,497*Lc0,356*S-0.131*n0,168

2.7 Snyder Synthetic Unit Hydrograph

Snyder's synthetic unit hydrograph model makes the following:

Tp = 0,75.Ct.(L.Lc) 0,3

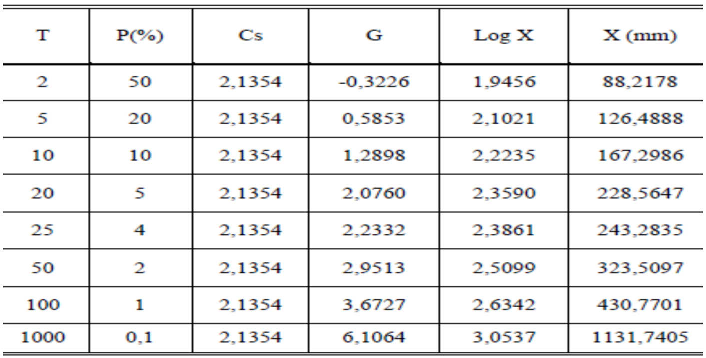
Tr = tp

Qp = 2,75 .Cp.A

2.8 Rainfall Intensity Calculation Plan T Year Re- Period

The results of rainfall anniversary design calculations on Way Tebu watershed using the Pearson Log type III distribution method can be presented in the following table:

Table 1. Results Calculation of Rainfall Design with Birthdays in Way Tebu River Basin



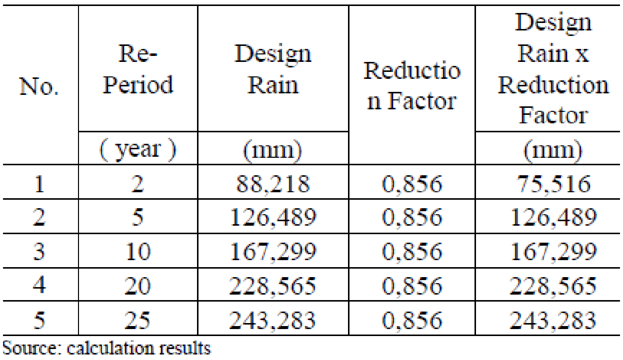
T	P(%)	Cs	G	Log X	X (mm)
2	50	2,1354	-0,3226	1,9456	88,2178
5	20	2,1354	0,5853	2,1021	126,4888
10	10	2,1354	1,2898	2,2235	167,2986
20	5	2,1354	2,0760	2,3590	228,5647
25	4	2,1354	2,2332	2,3861	243,2835
50	2	2,1354	2,9513	2,5099	323,5097
100	1	2,1354	3,6727	2,6342	430,7701
1000	0,1	2,1354	6,1064	3,0537	1131,7405

Source: calculation results

2.9 Calculations of the Nakayasu Synthetic Unit Hydrograph

To calculate the Nakayasu synthetic unit hydrograph the following parameters are required:

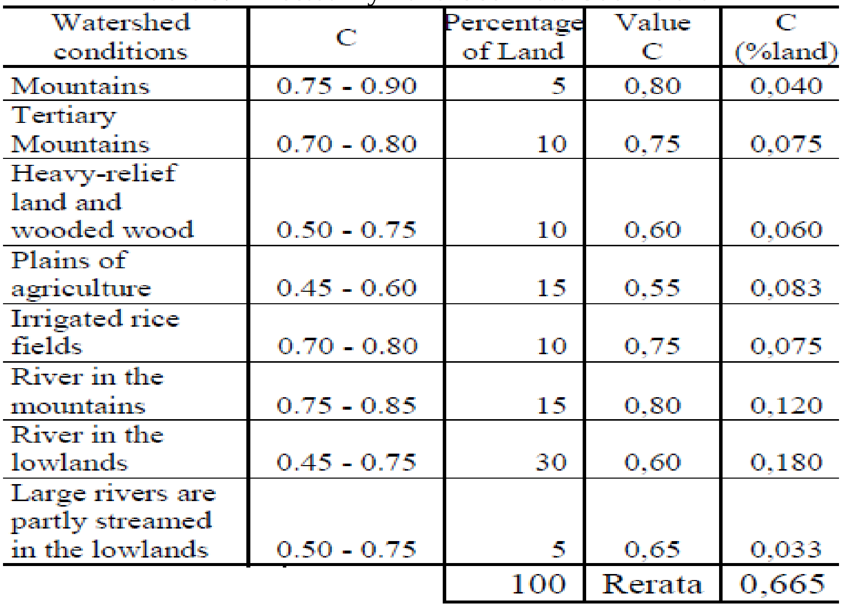
Table 2. Design Rainfall Data



No.	Re-Period	Design Rain	Reduction Factor	Design Rain x Reduction Factor
	(year)	(mm)		(mm)
1	2	88,218	0,856	75,516
2	5	126,489	0,856	126,489
3	10	167,299	0,856	167,299
4	20	228,565	0,856	228,565
5	25	243,283	0,856	243,283

Source: calculation results

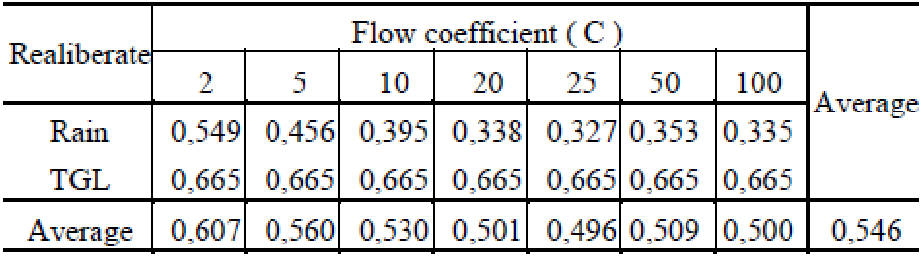
Table 3. Affected By Land Use Flow Coefficient



Watershed conditions	C	Percentage of Land	Value C	C (%land)
Mountains	0.75 - 0.90	5	0,80	0,040
Tertiary Mountains	0.70 - 0.80	10	0,75	0,075
Heavy-relief land and wooded wood	0.50 - 0.75	10	0,60	0,060
Plains of agriculture	0.45 - 0.60	15	0,55	0,083
Irrigated rice fields	0.70 - 0.80	10	0,75	0,075
River in the mountains	0.75 - 0.85	15	0,80	0,120
River in the lowlands	0.45 - 0.75	30	0,60	0,180
Large rivers are partly streamed in the lowlands	0.50 - 0.75	5	0,65	0,033
		100	Rerata	0,665

Average drain coefficient value (based on rainfall intensity & land use)

table 4 average Flow coefficient



Realiberate	Flow coefficient (C)							Average
	2	5	10	20	25	50	100	
Rain	0,549	0,456	0,395	0,338	0,327	0,353	0,335	
TGL	0,665	0,665	0,665	0,665	0,665	0,665	0,665	
Average	0,607	0,560	0,530	0,501	0,496	0,509	0,500	0,546

Calculation of the hour-time rain ratio □t = 0,5 hour= 30 minute. The hourly rain distribution from the centralized rain for 6 hours:

RT = R24/6.(6/t)(2/3) (Distribution of Rain)

Rt = t.RT-(T-1).R(T-1) (Ratio of the Hour)

Table 5. Calculation of hourly rain ratio

Hours (t)	Rain distribution (RT)	Rainfall	Rasio	Cumulative
	Hours	hours-to	(%)	[%]
1,00	0,55 R_{24}	0,55 R_{24}	55,03	55,03
2,00	0,35 R_{24}	0,14 R_{24}	14,30	69,34
3,00	0,26 R_{24}	0,10 R_{24}	10,03	79,37
4,00	0,22 R_{24}	0,08 R_{24}	7,99	87,36
5,00	0,19 R_{24}	0,07 R_{24}	6,75	94,10
6,00	0,17 R_{24}	0,06 R_{24}	5,90	100,00
	Jumlah	**1,000**	**100,00**	

Source: calculation results

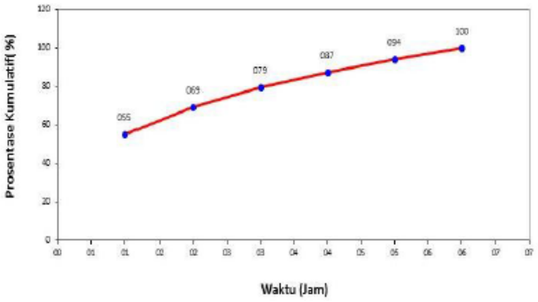


Figure 1. Rain distribution pattern

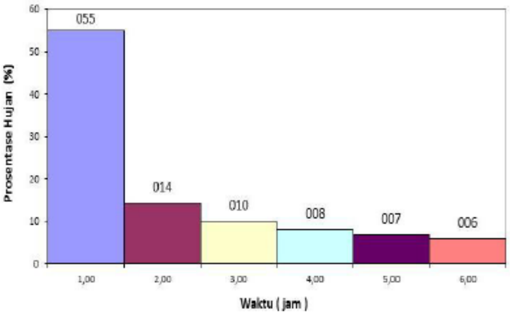


Figure 2. Graph of Rain Distribution

2. Calculation of the Rainy-Time Ratio

Table 6. Calculation of hourly rain ratios

re-time (Tr)	(year)	2	5	10	20	25
R $_{Rancangan}$	(mm)	75,52	108,28	143,21	195,66	208,25
Flow Coefficient (C)		0,546	0,546	0,546	0,546	0,546
R_n	(mm)	41,210	59,087	78,151	106,770	113,646
To hour-	**Ratio (%)**					
1,00	0,550	22,679	32,517	43,008	58,758	62,542
2,00	0,143	5,895	8,452	11,179	15,272	16,256
3,00	0,100	4,135	5,929	7,842	10,713	11,403
4,00	0,080	3,292	4,720	6,243	8,529	9,078
5,00	0,067	2,780	3,986	5,272	7,202	7,666
6,00	0,059	2,430	3,484	4,608	6,296	6,701

Source: calculation results

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3. The calculation of the flood design of the Nakayasu Method

Area = 307,63 km2

Main River Length (L) = 57,00 km

□ = 1,50

R0 = 1 mm

3.1 Parameter Tg

Tg = 0,4 + (0,058 * L)

Tg = 0,4 + (0,058 * 57) = 3,71 hour

Tr = 0,75 * Tg
Tr = 0,75 * 3,71 = 2,78 hour

3.2 Parameter Tp

Tp = Tg + 0.8 Tr
Tp = 3,71 + 0,8 * 2,78 = 5,93 hour

3.3 Parameter T0,3

T0,3 = a * Tg
T0,3 = 1,50 * 3,71 = 5,56 hour
Tp + T0.3 = 11,49 hour
Tp + T0.3 + 1.5 T0.3 = Tp + 2.5T0.3 = 19,83 hr

Parameter Qp

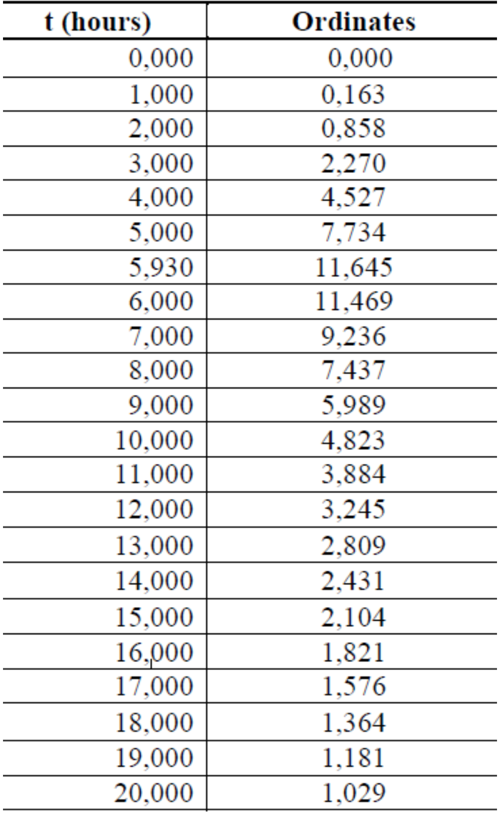
$$Qp = \frac{A\ R_0}{3{,}6\left(0{,}3Tp + T_{0,3}\right)}$$

$$Qp = \frac{307{,}63 * 1}{3{,}6(0{,}3 * 5{,}93 + 5{,}56)} = 11{,}60\ m3/s \qquad ....(2)$$

3.4 Looking for Ordinate Hydrograph

1. 0 < t < Tp 0 < t < 5,93
Qt = Q max (t/Tp)2.4
2. Tp < t < (Tp + T0.3) 5,93 < t < 11,49
Qt = Q max (0.3)^(t-Tp/(T0.3))
3. (Tp + T0.3) < t < (Tp + 2.5T0.3) 11,49 < t < 19,83
Qt = Qmax (0.3)^((t-Tp) + 0.5 T0.3) / 1.5 T0.3)
4. t > (Tp + 2.5 T0.3) t > 19,83
Qt = Qmax (0.3)^((t- Tp) + 1.5 T0.3)/(2 T0.3))

Table 7. Ordinat Hydrograph Nakayasu synthetic unit



t (hours)	Ordinates
0,000	0,000
1,000	0,163
2,000	0,858
3,000	2,270
4,000	4,527
5,000	7,734
5,930	11,645
6,000	11,469
7,000	9,236
8,000	7,437
9,000	5,989
10,000	4,823
11,000	3,884
12,000	3,245
13,000	2,809
14,000	2,431
15,000	2,104
16,000	1,821
17,000	1,576
18,000	1,364
19,000	1,181
20,000	1,029

21,000	0,923
22,000	0,828
23,000	0,743
24,000	0,667
25,000	0,599
26,000	0,537
27,000	0,482
28,000	0,433
29,000	0,388
30,000	0,348
31,000	0,313
32,000	0,280
33,000	0,252
34,000	0,226
35,000	0,203
36,000	0,182
37,000	0,163
38,000	0,146

0 < t < 5,93

5,93 < t < 11,49

11,49 < t < 19,83

t > 19,83

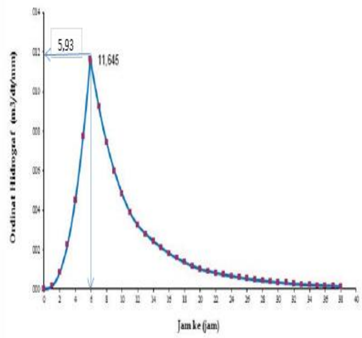


Figure 3. of Ordinat Nakayasu

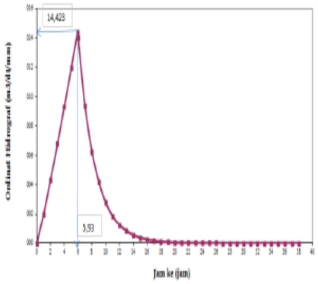


Figure 4. Limantara ordinate graph

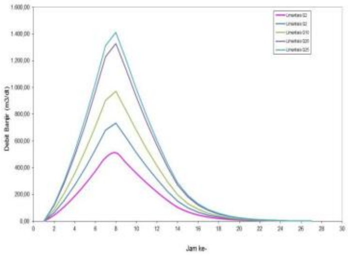


Figure 5. Graph of flood discharge design of Limantara HSS

3.5 Calculation of Synthetic Limit Unit Hydrograph

The synthesis of Limantara Synthetic Unit is influenced by the physical parameters of the watershed. These parameters include: Area of River Basin (A), length of main river (L), length of river measured to center of watershed (Lc), river slope (S) and coarse coefficient (n).

Calculation of Hierarchical Synthesis Hydrograph of Limantara is as follows:

3.6 River Flow Parameters

Area (A) = 307,63 km2
Main River Length (L) = 57,00 km
The length of the River is measured to the point of weight (Lc) = 19,00 km
River slope (S) = 0,006
Coefficient of roughness (n) = 0,06
Tg = 0,4 + (0,058 * L)
Tg = 3,71 hour
tr = 0,75* tg = 2,78 hour

Tp = Tg + 0.8 Tr

Tp	=	5,93	hour
T0.3 = a * Tg			
T0.3	=	5,56	hour
Tp + T0.3	=	11,49	hour
Tp + T0.3 + 1.5 T0.3 = Tp + 2.5T0.3	=	19,83	hour
Parameter Qp			
Qp = 0,042*A0,451 *L0,497*Lc0, 356*S- 0.131*n0,168	=	14,42	m3/dt

Looking for Ordinate Hydrograph

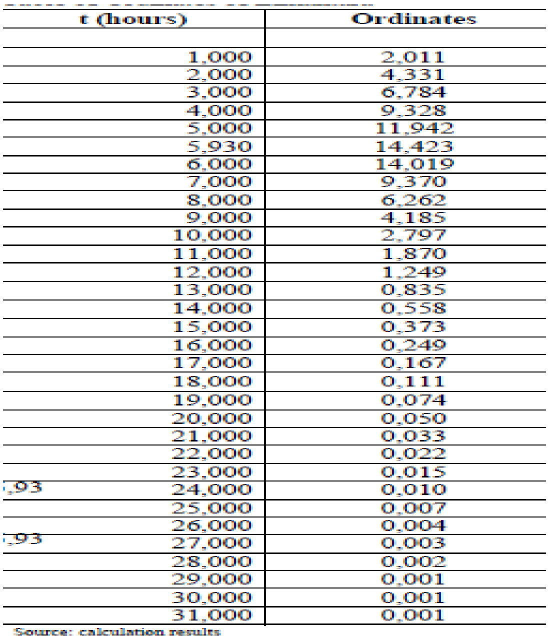
1. 0 < t < Tp ------> t < 5,93

Qt = Q max (t/Tp)^1,107

2. (T > Tp) ------> t > 5,93

Qt = Qmax (10)^(0.175 x (Tp-t))

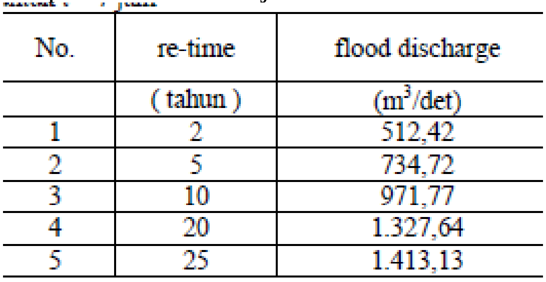
Table 8. Ordinates of Limantara



	t (hours)	Ordinates
	1,000	2,011
	2,000	4,331
	3,000	6,784
	4,000	9,328
	5,000	11,942
	5,930	14,423
	6,000	14,019
	7,000	9,370
	8,000	6,262
	9,000	4,185
	10,000	2,797
	11,000	1,870
	12,000	1,249
	13,000	0,835
	14,000	0,558
	15,000	0,373
	16,000	0,249
	17,000	0,167
	18,000	0,111
	19,000	0,074
	20,000	0,050
	21,000	0,033
	22,000	0,022
	23,000	0,015
,93	24,000	0,010
	25,000	0,007
	26,000	0,004
,93	27,000	0,003
	28,000	0,002
	29,000	0,001
	30,000	0,001
	31,000	0,001

Source: calculation results

Tabel 9. Rekapitulasi Debit Banjir HSS Limantara untuk t = 7 jam

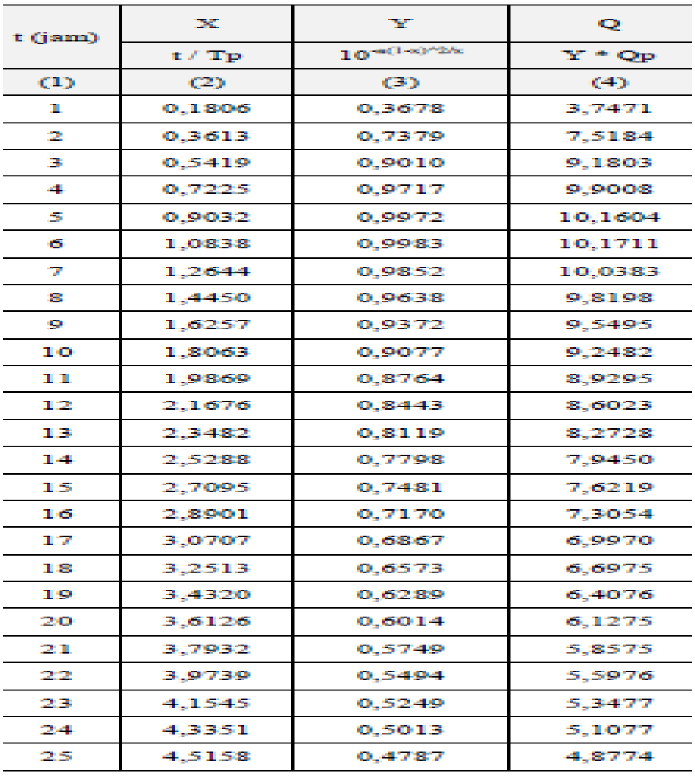


No.	re-time (tahun)	flood discharge (m^3/det)
1	2	512,42
2	5	734,72
3	10	971,77
4	20	1.327,64
5	25	1.413,13

3.7 Calculation of Snyder Synthetic Unit Hydrograph

The parameters required in the Snyder HSS analysis are the area of the watershed (A), the length of the main river (L), the distance of the watershed with the outlet (Lc). The calculation of HSS Snyder is as follows:
Area of the watershed (A) = 307,63 km2
Length of the main river (L) = 57,00 km
Distance of River Flow Point to outlet (Lc) = 19,00 km
The tributary coefficient
of the Watershed (Ct) = 1,250
Characteristic coefficient of Watershed (Cp) = 0,60
n = 0,20
1 Waktu dari titik berat ke puncak hidrograf
tr = 6 jam
tp = Ct (L.Lc)n = 5,06 hours
Tp' = tp + 0,5 Tr = 5,56 hours
tc=tp/5,5
Ɛ = 0,92 jam > Tr Ɛ = 0,92 jam > Tr
t'p = tp + 0,25 * (tƐ – tR) = 5,04 hours
Tp = t'p + 0,50 * Tr = 5,54 hours
qp=0,278$*cp/t'p$ = 0,03
2 Peak discharge hydrograph
Qp = qp * A = 10,19 m3/s
The unit hydrograph ordinate is calculated by (Qp*Tp) / (h.A)
the Alexeyev equation: λ =
λ = 0,18
a = 1,32 * λ2 + 0,15 λ + 0,045 = 0.12

Table 10. Synthetic Unit of Way Tebu Cane (Snyder Method) Hydrograph



t (jam)	X	Y	Q
	t / Tp	$10^{-a(1-x)^2/x}$	Y * Qp
(1)	(2)	(3)	(4)
1	0,1806	0,3678	3,7471
2	0,3613	0,7379	7,5184
3	0,5419	0,9010	9,1803
4	0,7225	0,9717	9,9008
5	0,9032	0,9972	10,1604
6	1,0838	0,9983	10,1711
7	1,2644	0,9852	10,0383
8	1,4450	0,9638	9,8198
9	1,6257	0,9372	9,5495
10	1,8063	0,9077	9,2482
11	1,9869	0,8764	8,9295
12	2,1676	0,8443	8,6023
13	2,3482	0,8119	8,2728
14	2,5288	0,7798	7,9450
15	2,7095	0,7481	7,6219
16	2,8901	0,7170	7,3054
17	3,0707	0,6867	6,9970
18	3,2513	0,6573	6,6975
19	3,4320	0,6289	6,4076
20	3,6126	0,6014	6,1275
21	3,7932	0,5749	5,8575
22	3,9739	0,5494	5,5976
23	4,1545	0,5249	5,3477
24	4,3351	0,5013	5,1077
25	4,5158	0,4787	4,8774

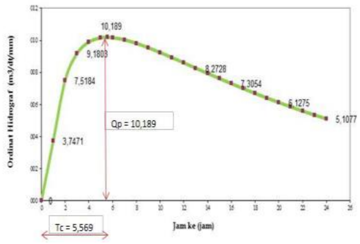


Figure 6. Snyder ordinate Graph

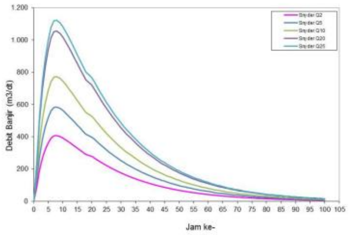


Figure 7. Graph of flood discharge design of HSS Snyder

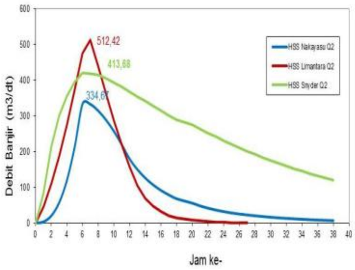


Figure 8 Graph of flood design Hydrograph of Nakayasu Synthesis Unit, Limantara and Snyder Q2

Table 11. Results of Flood Debit calculation Hynrograph Synthesis Unit Snyder for t = 6 hours

No.	Realiberate	Flood Discharge
	(tahun)	(m^3/det)
1	2	419,88
2	5	602,03
3	10	793,19
4	20	1.087,86
5	25	1.157,92

Source: calculation results

3.8 Comparison of Synthetic Hydrographs Nakayasu, Limantara and Snyder

From the above synthesized Hydrographs, we can illustrate the comparison graph between the Nakayasu Synthesizing Units, Limantara and Snyder for Q2, Q5, Q10, Q20 and Q25 as shown below.

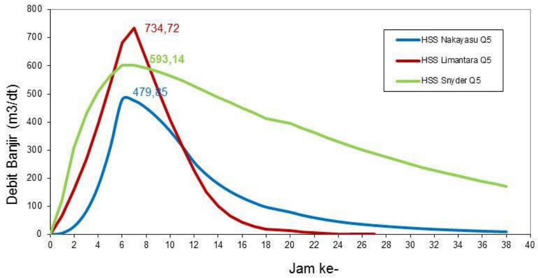


Figure 9. Graph of flood design of Hydrograph of Nakayasu Synthesis Unit, Limantara and Snyder Q5

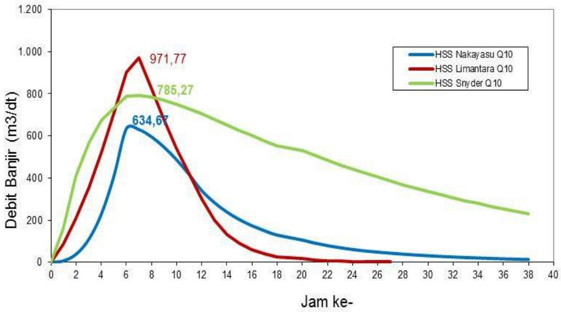


Figure 10. Graph of flood design of Hydrograph of Nakayasu Synthesis Unit, Limantara and Snyder Q10

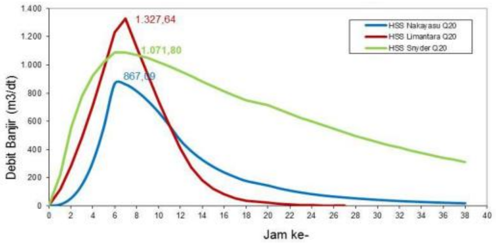


Figure 11. Graph of flood design of Hydrograph of Nakayasu Synthesis Unit, Limantara and Snyder Q20

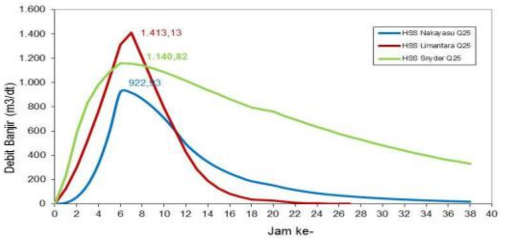
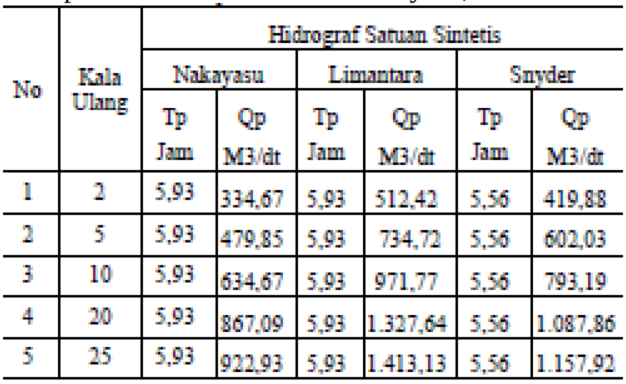


Figure 12. Graph of flood design of Hydrograph of Nakayasu Synthesis Unit, Limantara and Snyder Q25

Table 12. Comparison of HSS debit of Nakayasu, Limantara and Snyder



No	Kala Ulang	Hidrograf Satuan Sintetis					
		Nakayasu		Limantara		Snyder	
		Tp Jam	Qp M3/dt	Tp Jam	Qp M3/dt	Tp Jam	Qp M3/dt
1	2	5,93	334,67	5,93	512,42	5,56	419,88
2	5	5,93	479,85	5,93	734,72	5,56	602,03
3	10	5,93	634,67	5,93	971,77	5,56	793,19
4	20	5,93	867,09	5,93	1.327,64	5,56	1.087,86
5	25	5,93	922,93	5,93	1.413,13	5,56	1.157,92

Sumber : Hasil perhitungan

4. Conclusion

From the results of the discussion thesis "Evaluation of Flood Calculation Plan With Hydrograph Method Nakayasu, Limantara and Snyder on Sub Catchhement Way River Cane" can be concluded as follows:

a. From the analysis of rainfall, the selected rain frequency distribution using Log Person Type III method.

b. Flood discharge plans with various reworks in each method, providing mixed results. The greatest result is the Limantara HSS (Q25 = 1,413.13 m3 / sec) and the smallest HSS Nakayasu (Q25 = 922.93 m3 / s), while the HSS Snyder (Q25: 1,157.92 m3 / s).

c. From the hydrograph comparative analysis of the three methods it is concluded that the peak flood time (Tp) is almost simultaneously no significant difference, but for the peak discharge (Qp) there are differences in each of these methods. Limantara peak time occurs at hours (Tp: 5,93) with peak discharge (Qp: 14,42 m3 / s), Nakayasu peak time occurs at hour (Tp: 5,93) peak discharge (Qp: 11.65 m3 / st) and Snyder peak time occurs at hour (Tc: 5.57) peak discharge (Qp: 10.19 m3 / s).

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