JOURNAL OF GREENSCIENCE AND TECHNOLOGY

THE ANALYSIS OF HYDROLOGY IN KUPANG RIVER PEKALONGAN – BATANG

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ABSTRACT

Kupang River administratively located in Batang Regency, as well as the District and City of Pekalongan, Central Java Province. The Kupang River irrigates the Kupang Watershed with an area are 194.87 Km^2 and the river length are 67.5 km. The Kupang watershed is in the administrative area of 3 regencies and 1 city, that are Pekalongan City, then Batang, Pekalongan, and Banjarnegara districts.

In general, semi-monthly rainfall ranges between 16 mm until 299 mm. The dry season go on April until September and the rainy season go on October until March.

The purpose of this research is to do a calculation and analysis to get the amount of water potential with available data. In terms of quantity, the problem of water for agriculture especially on dry land, is about the water supply and distribution. Because the water supply is very dependent on the distribution of rainfall throughout the year which is very uneven even in the rainy season. Because of that reason the technology and methods that are effective, efficient, and can be applied in various regional characteristics are needed to meet water needs.

Flood control is also very necessary to prevent floods that can occur at any time. Flood discharge plan calculated using several methods that suitable. With this we can minimize the possibility of flooding and be responsive in an effort to minimize the worst possibilities when the floods take place.

Keywords: (Analysis, Hydrology, Water Potential, Flood discharge)

I. THE INTRODUCTION

A. BACKGROUND

Water is an essential natural resource, which is needed by humans and other living beings. With water, the Earth became a planet in the solar system that has a life. (Kodoatie dan Sjarief, 2002). As a hydrologycal system, Watershed receives input in the form of rainfall and then process in it accordance with its characteristics into the flow. Rain that falls in one watershed will partly fall on the surface of the vegetation, surface of the soil or body of water (Triatmodjo, 2009).

Kupang River flows towards to the estuary of Pekalongan, also a meeting of Retno Sumilir river with the upstream of the Kupang river are located at the foot of Mount Rogojembangan - Petungkriyono.

Kupang Watershed is part of the Watershed Management Unit SWP DAS Pemali Comal. In the northern area of Central Java province are passed over 3 Districts and 1 city. The widest are in Pekalongan District of 53.88% (9,708.13 ha), Batang District 32.04% (5,774.51 ha), Pekalongan City 14.06% (2,533.221 ha), and the smallest is Banjarnegara district amounted to 0.04% (6.332 ha). DAS Kupang position coordinates between 109°36'22"-109°45'49" East longitude and between 6°50'50"-7°12'05" South latitude. With the main river of Kupang Watershed are Kupang River with the length of the river 67,5 km. of Kupang River are 67,5 km. The wide of watershed are 195,87 km².

Hydrological analysis is one beginning part of analysis in the design of hydraulic buildings. Analysis of the hydrology in the development of water resources in the process are needed hydrological data consisting of rainfall data, discharge data and climate data.

B. FORMULATION OF THE PROBLEM

The problem and condition that will be discussed in the Hydrology Analysis of the Kupang River as follows:

1. What is the meaning of hydrological analysis?
2. How is the method and calculation of water balance analysis?
3. Are the potential of the water and the debit of the Kupang River comply the needs?
4. How is the method and calculation of flood discharge analysis?

C. INTENT AND PURPOSE OF THE RESEARCH

The purpose of Hydrology Analysis research of Kupang River are:

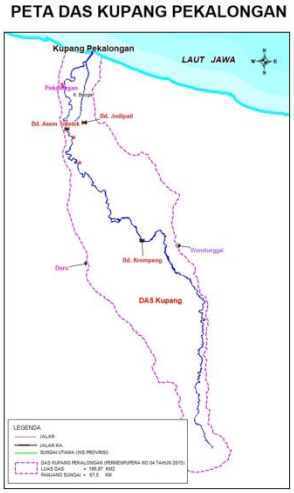
1. Analisys the potential availability of water discharge optimally to serve the irrigation area.
2. Analisys of flood discharge.
3. The result of the research are expected to be useful inputs and information to provide an overview and solution.

D. LIMITATION OF THE STUDY

For this thesis limitations of the study raised as follows:

- Data used in this study are: daily rainfall data of Kupang River.
- The rainfall data used in this study is limited to only 20 years, namely from 1998-2017.
- Rainfall data is obtained from three rainfall gauge stations namely Pekalongan station, Doro station, and Wonotunggal station.
- Calculations are limited, not counting the embankment planning around the river.

E. MAP OF THE WATERSHED



Picture 1. Map

II. THE REVIEW OF LITERATURE AND THEORETICAL BASIS

A. THEORETICAL BASIS

1. Analysis

Analysis is a systematic examination and evaluation of data or information, by breaking it into its component parts to uncover their interrelationships (Bussines Dictionary – Definition of Analysis).

The general meaning of analysis is activities that consist of a series of activities such as, parse, differentiate, sorting anything to be grouped according to certain criteria and then wanted to connected and then interpreted its meaning.

2. Hydrology

Hydrology, scientific discipline concerned with the waters of the Earth, including their occurrence, distribution, and circulation via the hydrologic cycle and interactions with living things. It also deals with the chemical and physical properties of water in all its phases (Encyclopaedia Britannica).

Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle.

B. RAINFALL CALCULATION METHOD

1. Thiessen Polygon Method

This is the simplest way of simply dividing the measurements on all the rainfall stations with the number of stations in the region. In accordance with its simplicity, in this method is only recommended to use for a relatively flat area and has rain are relatively homogeneous and are not too rough.

$$\bar{R} = \frac{A_1R_1 + A_2R_2 + \ldots + AnRn}{A_1 + A_2 + \ldots + An}$$

2. The Analysis of Water Frequency

Gumble Method Tipe I

To calculate the rainfall plan with the Gumble Type I distribution method, the empirical frequency distribution equation is used as follows (Soemarto, 1999):

$$X_T = \bar{X} + \frac{S}{Sn}(Y_T - Yn)$$

$$S = \sqrt{\frac{\sum(X_i - \bar{X})^2}{n-1}}$$

$$Y_T = -In\left[-In\frac{T-1}{T}\right]$$

3. Analysis of Rainfall Intensity

Mononobe Method

When the rain data was available only in daily rainfall data, then the rain intensity for the duration of minutes or hours it can being estimated by using the Mononobe formula as follows:

$$Rt = \left(\frac{R^{24}}{t}\right)\left(\frac{t}{T}\right)^{2/3}$$

$$RT = t_n \,.\, Rt_n \,.\, -(t_n - 1) \,.\, Rt_0$$

C. FLOODS DISCHARGE PLAN

Flood discharge plan is needed to calculate the level of security of the building that you want to plan, in this case the desired high and low level of security is indicated by the size of the return period used. In calculating the planned flood discharge, the method used is the Rational Flood method, the Haspers Method, the Weduwen Method and the Nakayasu Method.

Flood Rational Method

Rational equations are developed based on the assumption that the rainfall that occurs has uniform and evenly distributed intensity throughout the drainage area for at least equal to the concentration time (tc) (Suripin, 2004).

$$tc = \left(\frac{0{,}87 \,.\, L}{1000\, s}\right)^{0{,}385}$$

$$I = \frac{R_{24}}{24} \,.\, \left(\frac{24}{tc}\right)^{2/3}$$

$$Q = 0{,}278 \,.\, C \,.\, I \,.\, A$$

Weduwen Method

By using a trial and error method by entering the value of t, so that the value of the planned flood discharge will be obtained.

1. Assumption t (t_c)
2. Reduction Coefficient (β)

$$\beta = \frac{120 + \frac{t_0 + 1}{t_0 + 9} \,.\, A}{120 \,.\, A}$$

3. Rainfall Intensity (q)

$$q = \frac{67{,}65}{t_0 + 1{,}45}$$

4. Run-off Coefficient (α)

$$\alpha = 1 - \frac{4{,}1}{\beta \,.\, q + 7}$$

5. Concentration of Time (t)

$$t = \frac{0{,}476 \,.\, A^{3/8}}{(\alpha \,.\, \beta \,.\, q)^{1/8} \,.\, i^{1/4}}$$

6. Repeat Period (Q_n)

$$Qn = \alpha \,.\beta \,.q \,.A \,.\frac{R_{24}}{240}$$

Hasper Method

To use this method a nomogram-nomogram has been prepared which states the relationship between various variables contained in formulas. By using these nomograms, calculations can be done quickly.

1. Concentration of Time (t)

$$t = 0{,}10 \,.\, L^{0{,}8} \,.\, i^{-0{,}3}$$

2. Reduction Coefficient (β)

$$\frac{1}{\beta} = 1 + \frac{t + 3{,}70 \,.\, 10^{-0{,}4t}}{t^2 + 15} \,.\, \frac{A^{0{,}75}}{12}$$

3. Run-off Coefficient (α)

$$\alpha = \frac{1 + 0{,}012 \,.\, A^{0{,}70}}{1 + 0{,}075 \,.\, A^{0{,}70}}$$

4. Rainfall Plan (Rt)

$$Rt = \frac{t \,.\, R_{24}}{t + 1}$$

$$\mathrm{Rt} = 0{,}707 \,.\, \mathrm{R}_{24}\sqrt{t + 1}$$

5. Rainfall Intensity (q)

$$q = \frac{Rt}{3{,}6 \,.\, t}$$

6. Flood Discharge (Q)

$$Q = \alpha \,.\, \beta \,.\, q \,.\, A$$

Nakayasu Method

This method is based on the effective distribution of rainfall every hour, then to spread rain done the calculation of distribution and effective rainfall every hour, the calculation is done based on the curve up, means that debit approaching the top of the graphics, and the down curve which means a debit slowly or rapidly leaving the top hydrograph graphs, from results then get the hydrograph graph.

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

III. RESEARCH METHODOLOGY

A. METHOD OF RESEARCH DATA

The methods used in this research is qualitative method which means tend to use inductive approach to analysis. In this research, the data obtained in several ways:

1. Looking for a various data such as the primary data and secondary data to related institution (in this case DINAS PUSDATARU Pemali - Comal)
2. The study of literature as literature review either from a various books or journals or internet.
3. Process and analyse all the data who already obtained. Then taking the conclusions and suggestions of the results study of the thesis.

B. TYPES AND SOURCES DATA

1. Technical Data
   - Manual Rainfall Data obtained rainfall daily record during the last twenty years, in some rainfall post around the area of Kupang River.
   - Watershed Map used in the calculation of average rainfall in the area around the river.
   - Kupang River Morfology Data.

C. FRAMEWORK

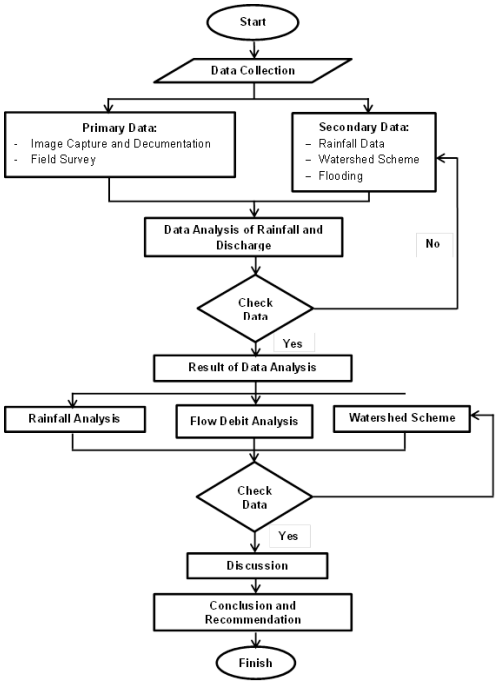


Figure 2. Framework

IV. ANALYSIS AND DISCUSSION OF THE PROBLEMS

A. WATERSHED DETERMINATION

The area is known by using the thiessen polygon method at three rain station locations in the map of watershed area. Then connecting the lines between all the stations so that its form a triangle, then look for the weight lines of the second lines, that is the lines that devides two exact same and perpendicular lines and then connect the third weight lines from the triangle so as to make a center of gravity that will form a polygon.

Figure 3. Watershed Area

Table 1. Large Catchment Area

No	Station	Large (km²)	Percentage (%)
1.	St. Pekalongan	39,07	20%
2.	St. Wonotunggal	102,34	52%
3.	St. Doro	54,46	28%
	Total	185,97	100%

Table 4.2. Large Catchment Area

B. THE RAINFALL ANALYSIS

The rainfall data that was displayed are already grouped in every two weeks. These the average of high monthly rainfall for each station can be seen in the table below:

Half Monthly Rainfall Data Wonotunggal Station 1998-2017 (mm)

Year	Month																							
	January		February		March		April		May		June		July		August		September		October		November		December	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
1998	71	273	263	134	123	153	123	78	152	45	76	58	41	65	47	47	16	137	161	175	146	240	92	448
1999	274	264	296	412	116	167	239	50	59	7	39	15	26	15	45	31	0	72	118	135	217	97	150	245
2000	138	532	395	89	338	214	180	92	118	67	153	43	3	51	17	0	4	34	19	218	147	229	60	142
2001	246	263	180	196	212	165	79	76	44	4	102	1	46	82	3	13	33	20	94	45	155	202	186	123
2002	228	461	1082	432	220	121	95	82	131	6	1	0	0	82	1	8	0	6	5	0	30	122	160	63
2003	147	392	581	272	133	183	149	102	51	0	41	22	0	0	0	6	17	35	48	1	87	210	167	353
2004	134	108	379	250	241	49	46	58	103	86	46	8	44	33	0	0	35	1	0	37	77	140	101	84
2005	157	196	316	107	104	99	123	49	53	23	77	7	42	22	8	0	2	26	31	59	53	63	77	236
2006	151	708	101	226	242	73	130	101	73	75	21	18	0	0	5	0	0	0	0	1	11	1	81	121
2007	31	251	455	263	420	73	165	110	59	63	49	28	0	2	3	6	1	10	7	30	334	74	61	299
2008	226	178	335	334	195	46	115	86	15	100	11	5	0	0	15	65	1	0	55	45	139	110	159	121
2009	216	283	552	181	94	109	83	64	105	134	85	1	15	47	0	0	0	7	14	49	91	129	165	84
2010	193	217	257	118	106	261	175	175	100	189	213	71	32	71	68	71	127	150	117	84	60	17	203	313
2011	251	484	289	256	84	317	115	79	126	45	29	0	32	24	0	0	73	5	5	78	158	229	244	295
2012	403	229	128	62	159	133	260	56	14	25	64	3	0	0	0	0	67	54	24	72	123	127	219	
2013	396	377	231	398	138	125	170	130	35	94	86	44	155	41	0	108	27	3	38	23	131	81	225	286
2014	192	844	727	377	203	110	74	131	87	143	39	141	57	46	14	13	0	6	0	34	29	93	115	126
2015	120	316	592	187	189	89	224	67	127	15	43	0	0	7	3	0	0	0	0	0	37	81	100	166
2016	92	144	368	366	313	119	96	206	27	128	59	219	47	180	85	64	102	201	169	129	158	84	281	217
2017	207	207	270	138	165	182	125	115	103	61	209	43	1	31	10	7	0	79	34	124	162	162	166	290
Min	31	108	101	62	84	46	46	49	14	0	1	0	0	0	0	0	0	0	0	0	1	17	61	63
Average	194,0	334,4	388,4	240,0	189,8	138,9	138,6	94,9	79,1	65,4	72,2	36,4	27,1	40,0	16,2	22,0	21,9	42,7	48,5	65,1	114,2	130,4	147,0	211,6
Max	403	844	1082	432	420	317	260	206	152	189	213	219	155	180	85	108	127	201	169	218	334	240	281	448

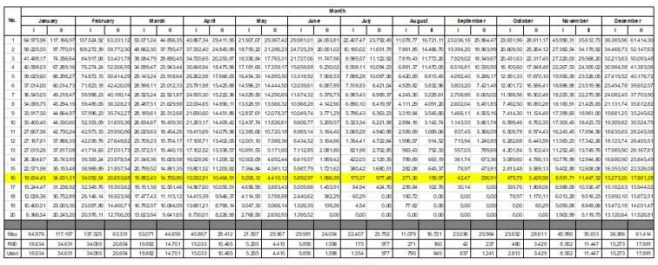
4.10. The Complete Monthly Rainfall Data of Wonotunggal Station

Figure 4. Rainfall Data Wanotunggal

C. THE ANALYSIS OF POTENTIAL WATER

The Analysis of Potential Water divided into two kind that are when rain fell to the rain or measure tool and the rain that fell directly into a rice field. To calculate the potential of water the rainfall data at one station multiplied by the area of the rice fields in the water catchment area of the station. From the multiplication results from every five stations are added from January to December in one year.

SORTED WATER POTENTIAL (L/S)



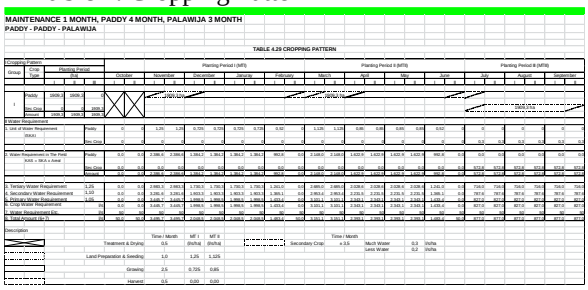
4.19. Sorted Water Potential

Figure 5. Water Potential

D. DEBIT REQUIREMENT

Half-monthly or fifteen daily water needs are used to calculate water requirements based on planting area by planting area multiplied by the coefficients of each type of planting.

Table 2. Cropping Pattern



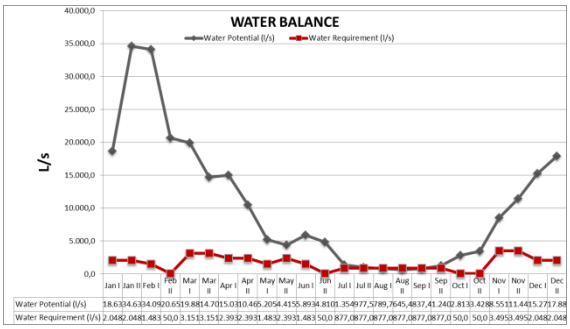


Figure 6. Water Balance

E. Gumbel Method Analysis

To calculate the rainfall plan with the Gumble Type I distribution method:

Table 3. Calculation of Rainfall Plan for Return Period T (Years)

Return Period	Yt (1)	K (2)	Xr (3)	Sx (4)	Xt (5) (3) + (2)*(4)
2	0,3665	-0,1478	149,1372	44,4625	142,5654029
5	1,4999	0,91865	149,1372	44,4625	189,9825615
10	2,2504	1,62473	149,1372	44,4625	221,3768464
25	3,1985	2,51687	149,1372	44,4625	261,0436086
50	3,9019	3,17872	149,1372	44,4625	290,4706788
100	4,6001	3,83567	149,1372	44,4625	319,6804641

Table 4.32. Calculation of Rainfall Plan for Return Period T (Years)

F. ANALYSIS OF RAINFALL INTENSITY WITH MONONOBE METHOD

To calculate the intensity of rainfall, the Mononobe formula are used.

Table 4. Effective Rainfall

Hour to	Ratio	Hourly Rainfall (mm) 2	5	10	25	50	100
1	55,03%	54,92	73,19	85,28	100,56	111,90	123,15
2	14,30%	14,27	19,02	22,17	26,14	29,08	32,01
3	10,03%	10,01	13,34	15,55	18,34	20,40	22,45
4	7,99%	7,97	10,62	12,38	14,60	16,24	17,88
5	6,75%	6,73	8,97	10,45	12,33	13,72	15,09
6	5,90%	5,88	7,84	9,14	10,77	11,99	13,19
Rainfall Plan		142,57	189,98	221,38	261,04	290,47	319,68
Flow Coefficient		0,70	0,70	0,70	0,70	0,70	0,70
Effective Rainfall		99,80	132,99	154,96	182,73	203,33	223,78

Table 4.34. Effective Rainfall

G. THE ANALYSIS OF FLOOD DISCHARGE PLAN

1. The Analysis of Flood Rational Method

Plan discharge (QT) is a discharge with a certain return period (T) which is expected to pass through a river or water building. To find the flood discharge plan can be used several methods including the empirical relationship between rainfall and runoff.

Table 5. Calculation of Flood Rational Method

T (years)	A (km²)	L (km)	i	tc (hr)	R24 (mm/day)	I (mm/hr)	Q (m³/s)
2	195,87	67,5	0,0028	16,34	142,57	7,68	217,38
5	195,87	67,5	0,0028	16,34	189,98	10,23	289,67
10	195,87	67,5	0,0028	16,34	221,38	11,92	337,54
25	195,87	67,5	0,0028	16,34	261,04	14,06	398,02
50	195,87	67,5	0,0028	16,34	290,47	15,64	442,89
100	195,87	67,5	0,0028	16,34	319,68	17,21	487,43

Table 4.35. Calculation of Flood Rational Method

2. The Analysis of Weduwen Method

Table 6. The Calculation of Flood Discharge Plan Weduwen Method

Luas DAS (A) =	195,87	km²	R_{II} =	213,19	mm
Panjang (L) =	67,5	km	m_{70} =	1	
Slope (i) =	0,0028		m_n =	0,811	
Banyak Data (n) =	20	tahun	R_{70} =	262,87	mm

No	t_0 (jam)	β	q (m³/s/km²)	α	t (jam)
1	1,01000	0,50442	27,50000	0,80356	11,07676
2	11,07676	0,75291	5,40044	0,62950	13,31327
3	13,31327	0,77768	4,58232	0,61187	13,58274
4	13,58274	0,78033	4,50018	0,60996	13,61303
5	13,61303	0,78062	4,49113	0,60974	13,61641
6	13,61641	0,78066	4,49012	0,60972	13,61678
7	13,61678	0,78066	4,49001	0,60972	13,61683
8	13,61683	0,78066	4,49000	0,60972	13,61683

m_{70}	α	β	q
1	0,61	0,78	4,49

Rainfall Plan (R_{24}) (mm)	T (Tahun)	m_n	Q_n (m³/s)
142,5654	2	0,490	248,66
189,9826	5	0,602	331,36
221,3768	10	0,705	386,12
261,0436	25	0,845	455,31
290,4707	50	0,948	506,63
319,6805	100	1,050	557,58

Table 4.36. The Calculation of Flood Discharge Plan Weduwen Method

3. The Analysis of Hasper Method

Table 7. The Calculation of Flood Discharge Plan Hasper Method

T (years)	A (km²)	L (km)	i	t (hours)	β	α	R_{24} (mm)	Rt (mm)	q m³/s/km²	Q (m³/s)
2	195,87	67,5	0,0028	16,95	0,80	0,37	142,57	427,10	7,00	406,53
5	195,87	67,5	0,0028	16,95	0,80	0,37	189,98	569,15	9,32	541,74
10	195,87	67,5	0,0028	16,95	0,80	0,37	221,38	663,20	10,87	631,26
25	195,87	67,5	0,0028	16,95	0,80	0,37	261,04	782,03	12,81	744,37
50	195,87	67,5	0,0028	16,95	0,80	0,37	290,47	870,19	14,26	828,28
100	195,87	67,5	0,0028	16,95	0,80	0,37	319,68	957,69	15,69	911,57

Table 4.37. The Calculation of Flood Discharge Plan Hasper Method

4. The Analysis of Nakayashu Method

This method is based on the effective distribution of rainfall every hour, then to spread rain done the calculation of distribution and effective rainfall every hour.

Table 8. Parameter of Synthetic Unit Hydrograph of Nakayasu

Watershed Area (A)	=	195,87	km^2
River Length (L)	=	67,5	km
Unit Hujan Efektif (R0)	=	1	mm
Time lage (Tg)	=	4,315	hr
Rain Time Unit (Tr)	=	3,24	hr
Peak Time (Tp)	=	6,90	hr
Hydrograph Parameter (α)	=	**3,00**	
T_{03}	=	12,95	hr
0,5 T_{03}	=	6,47	hr
1,5 T_{03}	=	19,42	hr
2 T_{03}	=	25,89	hr
Tp + T_{03}	=	19,85	hr
Tp + T_{03} + 1,5 T_{03}	=	39,27	hr
Qp	=	3,62	m^3/s

Table 4.38. Parameter of Synthetic Unit Hydrograph of Nakayasu

Table 9. Design Flood for Return Period of Synthetic Uni Hydrogaph of Nakayasu

Return Period (yr)	Design Flood (m^3/s)
2	363,40
5	483,67
10	563,29
25	663,90
50	738,54
100	812,62

Table 4.45. Design Flood for Return Period of Synthetic Uni Hydrogaph of Nakayasu

H. THE RECAP DATA OF FLOOD DISCHARGE ANALYSIS

Result of calculation results from the Rational Rain Method, Weduwen Method, Hasper Method, Nakayasu Method.

Table 10. The Result of Discharge Plan Use Rainfall and Debit Data

Repeat Period (Year)	Flood Discharge Plan (m^3/s)				Average
	Rasional	Weduwen	Haspers	HSS Nakayasu	
2	217,38	248,66	406,53	**363,40**	308,99
5	289,67	331,36	541,74	**483,67**	411,61
10	337,54	386,12	631,26	**563,29**	479,55
25	398,02	455,31	744,37	**663,90**	565,40
50	442,89	506,63	828,28	**738,54**	629,09
100	487,43	557,58	911,57	**812,62**	692,30

4.46. The Result of Discharge Plan Use Rainfall and Debit Data

Based on all of the methods of calculation in flood control, to find out which method is most ideal for use then we calculate the average of all the methods that are already counted before.

Obtained average results as above. And the value of the most approaching the average yield is a result of Nakayasu method. Therefore set the Nakayasu method will be used.

V. CONCLUSIONS AND SUGGESTION

A. CONCLUSIONS

From all of the analysis of the research that have been carried out in the previous chapters, can be concluded that:

1. The Large of Kupang Waterhed is 195,87 km^2 with the length of the Kupang River are 67,5 km.
2. The rainy season start form October – March, and the sry season start from April – September.
3. From the previous analysis was found that the highest amount of water potential was in first half of January 34.631,3 l/s and the lowest amount is in second half of August 645,4 l/s.
4. The method that used to find the value of rain distribution is Gumble method because this method is considered the most suitable for use in the research area.
5. The method that used to calculate the planned flood discharge are Rational Flood method, the Haspers Method, the Weduwen Method and the Nakayasu Method. And from the analysis that has been done, obtained the value are:

Repeat Period (Year)	Flood Discharge Plan (m^3/s)				Average
	Rasional	Weduwen	Haspers	HSS Nakayasu	
2	217,38	248,66	406,53	**363,40**	308,99
5	289,67	331,36	541,74	**483,67**	411,61
10	337,54	386,12	631,26	**563,29**	479,55
25	398,02	455,31	744,37	**663,90**	565,40
50	442,89	506,63	828,28	**738,54**	629,09
100	487,43	557,58	911,57	**812,62**	692,30

4.46. The Result of Discharge Plan Use Rainfall and Debit Data

6. And the value of the most approaching the average yield is a result of Nakayasu method. Therefore set the Nakayasu method will be used.
7. Based analysis in this research, the availability of water in Kupang watershed can still comply the needed for plant periode in a year.

B. SUGGESTION

Based on the result of the analysis the author can provides the suggestion as follows:

1. The availability of water potential from three rainfall stations are expected to be truly optimized so it can be utilized as much as possible.
2. It is expected the results of this analysis can be a reference or reference for all parties, especially the relevant agencies.
3. Further research is still needed so that hydrological analysis on the Kupang River can be utilized more optimally.

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