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Watershed Analysis of Potential Flood Discharge in Tlepok Village

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Abstract. *Mine drainage system is an effort to control the flow of water entering a work area so as not to interfere with mining activities. This research is intended as a form of implementation of the mine drainage system in the form of a discharge calculation by taking into account the condition of the watershed, then calculating the discharge plan for the return period to predict flood discharge at the research location. For rivers with high flow rates, it is planned to reduce the flood discharge in order to prevent the channel water level from exceeding its capacity. The research location is in Tlepok village, Karangsambung sub-district, Kebumen district, Central Java. In the study, the maximum river flow discharge was 1365.41 m3/s and the planned return period discharge was 520.46 m3/s up to 687.47 m3/s. Based on the calculation results, land conversion planning and river normalization planning were carried out to reduce the discharge in the watershed in Tlepok Village.*

INTRODUCTION

Mine drainage system is a control effort to prevent and control the flow of water that enters a work area so as not to interfere with mining activities (Cahyani, 2019). This study is intended as a form of implementation of the mine drainage system by controlling the flow of water that has the potential to interfere with activities in the work area then utilizing the discharge in the watershed for flow discharge maximum and flood discharge estimates in the study area. Then planning is carried out to reduce the maximum discharge and flood discharge that occurs when the channel water level exceeds its capacity. In this study used Synthetic Unit Hydrograph method to calculate the planned discharge for the return period, based on several case studies mining on the island of Kalimantan is often used because of the presence of rivers and forests on the island of Kalimantan which are scattered throughout the region (Prabowo & Mahmud, 2014). With theoretical analysis and a field survey beforehand, the research location can be assumed to represent each parameter that has been determined. Based on data from the Indonesian Disaster Risk Index, Kebumen is included in the class of high flood risk. So based on the survey, the research was conducted in Tlepok village, which is one of the areas in Karangsambung, Kebumen regency, Central Java.

RESEARCH METHODOLOGY

The method used in the research is a quantitative and analytical approach because of the determination of the value mathematically. In addition, descriptive methods are used to present data in the form of tables and graphs. Determination of the research location in Tlepok village is based on regional affordability and can represent every parameter needed in the study. Direct location search is assisted using Google Earth and from the survey, it was found that Tlepok Village is still dominated by forests, rice fields, with the direction of flow leading to the Kaligending watershed. This study uses primary data in the form of coordinates of the research location and river measurement data, while secondary data used is a map of the research location, a map of land functions and rainfall data. The distribution method used in calculating the planned rainfall is adjusted to the preparation for distribution selection. The data used is the maximum rainfall data from 2015 to 2020 obtained from the Center for Water Resources Management (BPSDA Prabolo). In the calculation of rainfall, the Mononobe formula is used. The data needed are the period of rain, the duration of the rain and the planned rainfall.

Calculation of the planned flood discharge using the Synthetic Unit hydrograph method, the Nakayasu Method.

In principle, this unit hydrograph curve expresses the relationship between flow and time, from the calculation data it will be obtained flood discharge in the sub-watershed area (Kodoatie Robert J, 2002). Based on data processing, the maximum flow rate of the river is determined, then the return flow is planned so that the estimated flood discharge results are obtained at the research location so that a flow discharge management plan can be determined at the research location.

RESULT AND DISCUSSION

Research Location Point

The research location is in the village of Tlepok with a geographical location of 7˚33'26" S and 109˚42'34" E. From the considerations, it is obtained 5 location points that represent each required parameter. For more details, it will be detailed in the map and table below:

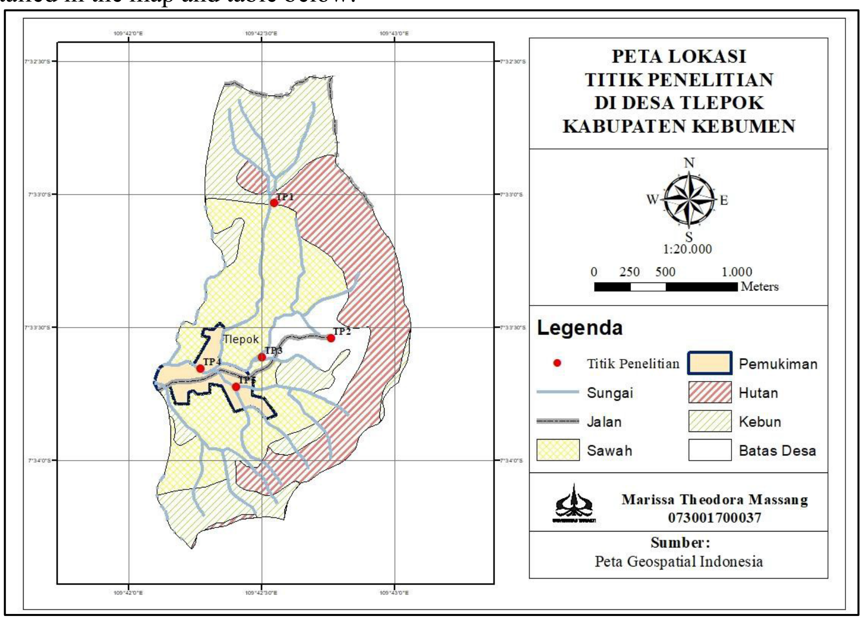

FIGURE 1. Research point map. Shows the location of the research points with their respective land functions and shown the direction of the flow of river branches leading to the main river which is a residential area.

TABLE 1. Research Point

Location (research point/TP)	South	East	Elevation (m)	Land Function
TP 1	7°33′02″S	109°42′33″E	187	Forest Area
TP 2	7°33′32.4″S	109°42′45.8″E	161	Rice fields and Farm Area
TP 3	7°33′36.7″S	109°42′30.3″E	95	Rice fields Area
TP 4	7°33′39.3″S	109°42′16.4″E	85	Residential Area
TP 5	7°33′43.4″S	109°42′24.4″E	117	Farm and Residential Area

Watershed Condition

Tlepok village has a water channel with a surface area of 1500 m^2 and a depth of 4 meters and has a water capacity of 6500 m^2. From the data, it is known that an elevation of approximately 45° and close to settlements is ineffective and at risk during the rainy season where the volume of water increases and if it exceeds the capacity limit it will cause a flood disaster. Based on interviews with the village head that the channel will later be converted into a tourist spot ((Halim, 2020).

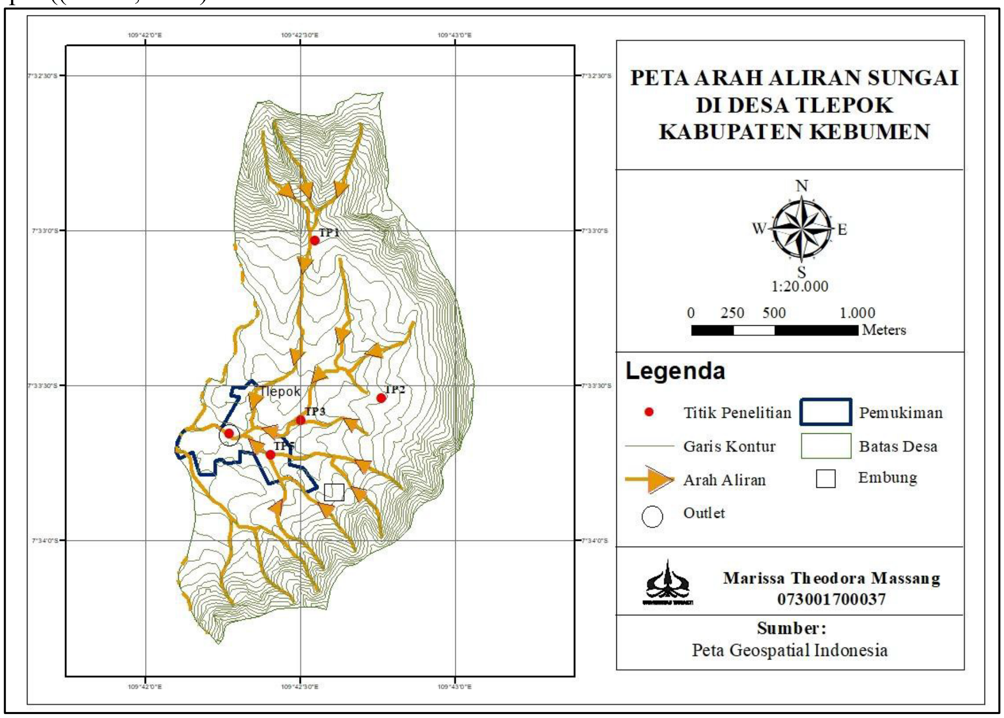

FIGURE 2. The condition of the watershed is fan-shaped with a pattern like tree branches and irregular angles, the drainage area is spread out and has many tributaries, causing the flow velocity to increase and affecting the flood discharge (Asdak, 2002). Low elevation areas are used as residential areas, so large flood discharges will endanger settlements.

Hydrology Analysis

Rainfall data were obtained from the Center for Water Resources Management (PSDA Pabolo). The Kaligending station data used are from 2015 – 2020. The processing of rainfall data serves as a parameter in determining the planned flood discharge.

TABLE 2. Rainfall Data (mm) Kaligending Station 2015 –2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Ags	Sep	Okt	Nov	Des
2015	590	253	689	503	6	0	0	0	0	0	436	545
2016	310	421	345	556	347	331	156	69	510	614	807	594
2017	535	463	426	283	74	138	24	10	170	551	486	587
2018	586	437	279	358	70	33	10	0	14	12	414	525
2019	691	304	462	89	111	0	0	6	0	2	10	256
2020	467	618	346	356	257	0	7	12	14	809	514	521

From a period of six years the average maximum rainfall using the Kaligending station is sorted from the highest to the lowest value. By using statistical parameters, a method is obtained for calculating the planned rainfall (mm), then determine the type of method to be used(Sosrodarsono & Takeda, 1999). In this study, the Log Pearson III method was used according to the requirements. From the table, the results obtained are:

1. Average number
   (Xi) X = 694.83
2. Standard deviation
   (S) Sx= 90.49
3. Coefficient of variation
   (Cv) Cv= 0.1302
4. Skewnes coefficient
   (Cs) Cs= 0,144
5. Peak Coefficient/Kurtosis (Ck)
   Ck= 2.701

TABLE 3. Terms and Conditions of Method

Method	**Patent**		**calculation**		**Notes**
	Cs	Ck	Cs	Ck	
Normal	0	3	0,144	2,701	Cannot be used
Log Normal	$C_v^2 + 3C_v$	$C_v^8 + 6C_v^6 + 15C_v^4 + 16C_v^2 + 3$	0,144	2,701	Cannot be used
Gumbel	1,14	5,4	0,144	2,701	Cannot be used
Log Pearson III	± 0	± 0	0,144	2,701	can be used

Then determine the type of method to be used. In this study, the Log Pearson III method was used based on existing conditions. So that from table 2 we get rainfall data for the return period (mm).

TABLE 4. Rainfall Return Period

Repeat period (Years)	**Rainfall Return Period (mm)**
2	710,38
5	700,55
10	855,07
25	921,49
50	938,76
100	938,78

Rainfall Intensity

Calculation of rainfall intensity (I) using the Mononobe equation. The parameters used to find the value of rainfall intensity are the value of the planned rainfall and the duration of the rain. In calculating this rain intensity, it is necessary to have an average maximum daily rainfall in 2015 to 2020 which is then divided by the number of days to get the average hours of rain per day. From the calculation, the average rain per day is 1.91 mm/hour. After that, the rainfall intensity value (return period 2 years) is calculated. The results of the calculation show that the intensity of rainfall for the two-year return period is 159,873 mm/hour, this proves that the intensity of rainfall at the research site is in the medium criteria according to the Meteorology, Climatology and Geophysics Agency.

Runoff Coefficient

There are several values of drainage coefficients based on topography and land use, in this study used flow coefficient SNI 2830: 2008 (Badan Standardisasi Nasional, 2008).To find out the watershed drainage coefficient in Tlepok Village, data on land use and area are needed. Because the land use in Tlepok Village varies, from the calculation, a weighted flow coefficient of 0.58 is obtained. The results of this weighted flow coefficient will be used as one of the parameters in the calculation of the planned discharge for the return period.

Return Period Flood Discharge

Based on the calculation of hourly rainfall and effective rainfall, a planned discharge analysis was carried out using the Nakayasu Synthetic Unit Hydrograph (HSS) method(Suwignyo, 2001). In the calculation, data and parameters are needed, as follows:

1. Area of the Tlepok village watershed (A) = 15,912 Km
2. River Length (L) = 10.188 m
3. Runoff coefficient (C) = 0.58
4. Rainfall unit (Ro) = 1 mm
5. Tg (Time lag)
   River length L < 15
   km: $Tg = 0.21L^{0,7}$
   =1,066 hour
6. Tr (Long time of rain)
   Terms: Tr = 0,5 Tg –
   1,0 Tg Tr=0.75×Tg =
   0,7997 hours
7. Tp (peak time)
   Tp=Tg+(0.8×Tr) =
   1,7061 hour
8. $T_{0.3}$, Coefficient of comparison a = (1.5 - 3) and
   = 1.57 $T_{0,3}$=α×Tg = 1,677 hour
9. Debit (Peak)
   Q_P=2.0193 m^3/s
10. Base Flow (Qb)
    Q_b= 0,5 x Q_p=1,00965 m^3/s
11. Hydrograph ordinat
    Ascension curve = 0 < t < 1,71 hour
    Descending curve (I) = 1,71 hour ≤ t ≤ 3,38
    hour Descending curve (II) = 3,38 hour ≤ t
    ≤ 5,90 hour Descending curve (1II) = t >
    5,90 jam
12. Hourly Rainfall

Because it does not have hourly rainfall data, so to get hourly rainfall data, the Mononobe formula is used (Fattah, 2018). The length of time for the concentration of rain (t) in Indonesia with an average of t = 5 hours, so that the rainfall hours are as follows:

TABLE 5. Houry Rainfall

Hourly Rainfall	R_{24} (hours	Time, t (hour)	It (mm/hour)	Rt (hour)	Rt (%)
I1		1	0,3467	0,585	58,48
I2		2	0,2184	0,152	15,2
I3	1	3	0,1667	0,107	10,66
I4		4	0,1376	0,085	8,49
I5		5	0,1186	0,072	7,17
				1	100

I_1= [1 · 0,5848R_{24}] - [(1 - 1) · (1 - 1)] = 0,5848 × 100% = 58,48%
I_2= [2 · 0,3684R_{24}] - [(2 - 1) · (0,5848R_{24})] = 0,1520 × 100% = 15,2%
I_3= [3 · 0,2646R_{24}] - [(3 - 1) · (0,3467R_{24})] = 0,1066 × 100% = 10,6%
I_4= [4 · 0,2184R_{24}] - [(4 - 1) · (0,2646R_{24})] = 0,0849 × 100% = 8,49%
I_5= [5 · 0,1882R_{24}] - [(5 - 1) · (0,2184R_{24})] = 0,0717 × 100% = 7,17%

13. Effective Rainfall
    The data needed in calculating the effective hourly design rainfall in a certain
    period are: Tr (period) = 2 Years
    Rmax = 710.38 mm
    C = 0.58
    Rn = C x Rmax = 413.84 mm/day

As a notes, further calculations can be calculated using the same method and stated in the table, as follows:

TABLE 6. Effective Rainfall

Time (Hours)	**Ratio (%)**	**Commulative**	**%**	**Rainfall Plan (mm)**					
				2	**5**	**10**	**25**	**50**	**100**
1	58,48	58,48	0,58	242,01	238,66	291,30	313,93	319,82	319,82
2	15,2	73,681	0,15	62,90	62,03	75,72	81,60	83,13	83,13
3	10,66	84,343	0,11	44,12	43,50	53,10	57,23	58,30	58,30
4	8,49	92,832	0,08	35,13	34,65	42,29	45,58	46,43	46,43
5	7,17	100	0,07	29,67	29,26	35,72	38,49	39,21	39,21
Effective Rainfall (mm)				413,84	408,11	498,13	536,82	546,88	546,89
Runoff Coefficient				0,58	0,58	0,58	0,58	0,58	0,58
Maximum Rain Probability (mm)				710,38	700,55	855,07	921,49	938,76	938,78

Based on the calculations, it is obtained that the rising curve is in the time range 0 to 1.71 hour. Then the descending curve for stage 1 is in the time range (t) 1.71 hour to 3.38 hour, the descending curve for stage 2 is in the time range 3.38 hours to 5.90 hour, and the downward curve of stage 3 is at time 5.90 hour to 24 hour. Then to calculate the return period discharge, the hydrograph ordinate, interval of rise and fall, flood discharge, and correction flood discharge are determined, which are stated in the following table:

TABLE 7. HSS Nakayasu Hydrograph

Time (Hours)	Maximum Peak Discharge, Qt (m^3/s)	Maximum Peak Discharge Correction, Qt Corection (m^3/s)	Notes	
0,00	0,00	0,0000	Qd_0	Increment of Curve Interval
1,00	0,56	0,3483		
1,71	2,019	1,2552		
2,00	1,635	1,0164	Qd_1	
3,00	0,798	0,4958		
3,38	0,606	0,3766		
4,00	0,451	0,2803	Qd_2	
5,00	0,279	0,1737		
5,90	0,182	0,1130		
6,00	0,175	0,1089		
7,00	0,122	0,0761		
8,00	0,085	0,0531		
9,00	0,060	0,0371		
10,00	0,042	0,0259		

11,00	0,029	0,0181	Decreasing Curve Internal
12,00	0,0203	0,0126	
13,00	0,0142	0,0088	
14,00	0,0099	0,0062	Qd_3
15,00	0,0069	0,0043	
16,00	0,0048	0,0030	
17,00	0,0034	0,0021	
18,00	0,0024	0,0015	
19,00	0,0016	0,0010	
20,00	0,0012	0,0007	
21,00	0,0008	0,0005	
22,00	0,0006	0,0003	
23,00	0,0004	0,0002	
24,00	0,0003	0,0002	

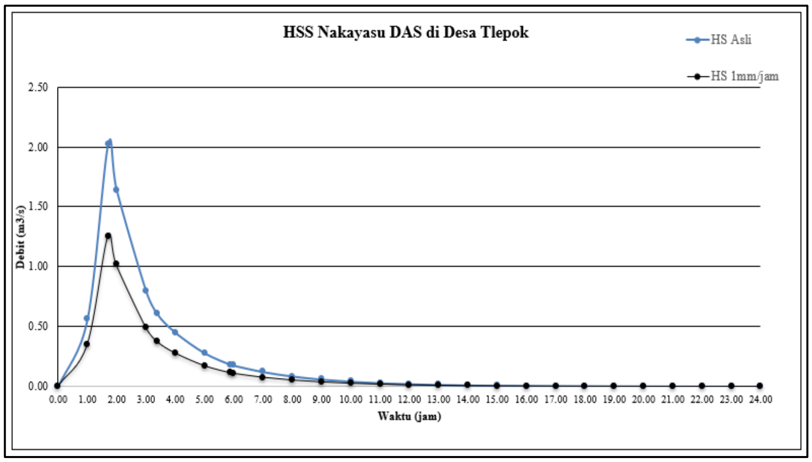

FIGURE 3. HSS Nakayasu Design Hydrograph Chart**.** The blue graph represents the calculated hydrograph (Original HS) while the black graph represents the hydrograph resulting from the discharge correction with 1 mm/hour (HS 1 mm/hour).

TABLE 8. HSS Nakayasu Method Return Period Discharge

Time (Hours)	**Hydrograph unit**	**Grand debit Total Return Period**					
	(m^3/s)	**Q_2**	**Q_5**	**Q_{10}**	**Q_2**	**Q_{50}**	**Q_{100}**
0,00	0,00	1,01	1,01	1,01	1,01	1,01	1,01
1,00	0,3483	145,13	143,14	174,49	187,97	191,47	191,47
1,71	1,2552	520,46	513,27	626,26	674,83	687,45	687,47
2,00	1,0164	421,65	415,82	507,32	546,65	556,87	556,88
3,00	0,4958	206,18	203,34	247,97	267,16	272,15	272,15
3,38	0,3766	156,84	154,69	188,58	203,15	206,94	206,95
4,00	0,2803	117,01	115,40	140,63	151,48	154,30	154,30
5,00	0,1737	72,89	71,89	87,53	94,25	96,00	96,00
5,90	0,1130	47,76	47,11	57,28	61,65	62,79	62,79
6,00	0,1089	46,09	45,47	55,27	59,49	60,58	60,59
7,00	0,0761	32,50	32,06	38,91	41,85	42,62	42,62
8,00	0,0531	23,00	22,70	27,48	29,53	30,07	30,07
9,00	0,0371	16,37	16,15	19,50	20,93	21,30	21,31
10,00	0,0259	11,74	11,59	13,92	14,92	15,18	15,18
11,00	0,0181	8,50	8,40	10,03	10,73	10,91	10,91

12,00	0,0126	6,24	6,17	7,31	7,80	7,92	7,92
13,00	0,0088	4,66	4,61	5,41	5,75	5,84	5,84
14,00	0,0062	3,56	3,53	4,08	4,32	4,38	4,38
15,00	0,0043	2,79	2,77	3,15	3,32	3,36	3,37
16,00	0,0030	2,25	2,24	2,51	2,62	2,65	2,65
17,00	0,00210	1,88	1,87	2,06	2,14	2,16	2,16
18,00	0,00147	1,62	1,61	1,74	1,80	1,81	1,81
19,00	0,00102	1,43	1,43	1,52	1,56	1,57	1,57
20,00	0,00072	1,31	1,30	1,37	1,39	1,40	1,40
21,00	0,000500	1,22	1,21	1,26	1,28	1,28	1,28
22,00	0,000349	1,15	1,15	1,18	1,20	1,20	1,20
23,00	0,000244	1,11	1,11	1,13	1,14	1,14	1,14
24,00	0,000170	1,08	1,08	1,09	1,10	1,10	1,10
Qmax		520,46	513.27	626,26	674,83	687,45	687,47

The flood discharge is 2,019 m3/s and after correction is 1,2552 m3/s at the same time of 1.71 hours, to reduce the discharge after 30% it only takes time from the peak time of 1.71 hours to 3.38 hours. However, after a 30% decrease, it was followed by a gradual decrease in discharge from 5.9 hours to 24 hours. The graph shows that the discharge at the study site is in accordance with the statement which states that the characteristics of the watershed in Indonesia are almost the same as the characteristics of rivers in Japan where flood discharge reaches its peak very quickly. From the determination of the flood discharge, the return time discharge is calculated which is shown in table 8.

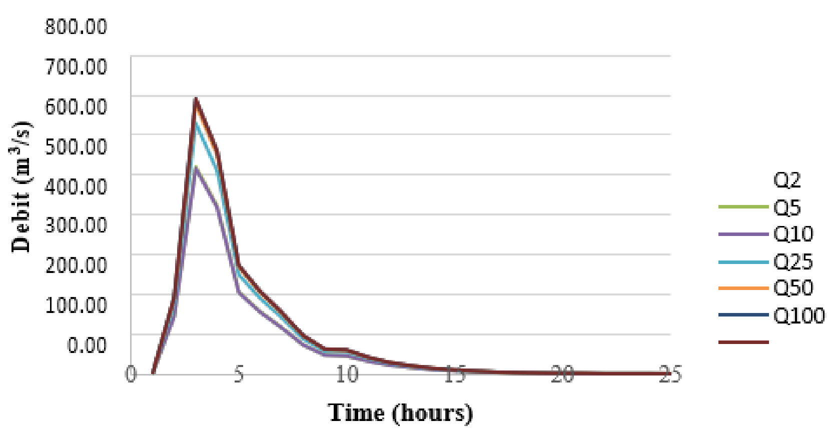

FIGURE 4. HSS Nakayasu Chart Return Period. This graph shows the plan for re-debit against time in 24 hours. The planned debit for the return period of Q100 is the maximum debit for the return period, which is 687.47 m3/s.

Hydraulic Analysis

The hydraulics analysis in this study is based on technical guidelines for measuring river discharge (Tanika, 2009) and SNI 8066: 2015 regarding the procedure for measuring the flow of rivers and open channels using current measuring instruments and buoy (SNI 8066: 2015, National Standardization Agency, 2015).

TABLE 9. Maximum Discharge of River Flow at the Research Point

Research Point (TP)	Measurement Length (m)	Cross Section Area, A (m^2)	Velocity, V (m)	Qs_{max} (m^3/s)
TP1	50	427,51	0,3058	130,72
TP2	50	475,54	0,3677	174,84
TP3	50	218,17	0,2860	62,39
TP4	50	3668,1	0,3722	1365,41
TP5	50	1201,9	0,3722	447,29

Based on table 9 shows the maximum river flow rate (Qs_{max}). The maximum discharge result is in TP 4, because TP 4 is the meeting point of the river branches of TP 1, TP 2, TP 3, and TP 5. The results of this calculation show that the discharge from the branching point affects the amount of flow discharge in the main river. This proves that the condition of a branching watershed and supported by differences in elevation and high rainfall can affect the maximum discharge in the channel(Septriawan, 2018).

CONCLUSION

Flow Discharge Control Plan

This land use change plan can be recommended to reduce flood discharge because the productive level of land with cover vegetation has a very large influence on rainwater runoff. For the scenario of a change of 30% and divided into 2 zones, namely in the upstream and in the middle (Andikha, 2017), but after conducting an experiment (trial and error), it is planned to be re-planned with the following values:

TABLE 10. Plans for Conversion of Land to Forest

Type of Land Use	Total Area (hectares)	land use change (%)	Total Area land use change (ha)
Rice Field	121,6	40	72,96
Farm Area	98,3	30	58,98
Forest	99,4	-	177,6

From the plan to convert land to forest, the resulting forest area is 177.6 ha. Then based on table 6 the coefficient value is obtained after the transfer function. From the land conversion plan into forest, the resulting forest area is 177.6 ha. From the calculation results obtained runoff coefficient of 0.55. Based on this land use change plan, it was found that there was a decrease in the value of the flow coefficient, so that a re-flood discharge calculation was carried out because the flow coefficient affected the flood discharge.

TABLE 11. Return Period Flood Discharge Plan

Qtr (m3/s)					
2 Years	5 Years	10 Years	25 Years	50 Years	100 Years
497,12	490,25	598,17	644,56	656,62	656,63

This proves that the planning for the transfer of functions is useful for reducing flood discharge(Suripin, 2004), so that it can be applied to the watershed in Tlepok Village. For a given plan, it needs support and participation from the government and the community in Tlepok village to support the success of the land use change plan.

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Normalization Plan

River normalization is an effort to increase the capacity of the river(Nusanto & Nurkhamim, 2020). In planning, it is necessary to know the dimensions of the channel in order to obtain an overview of the plan. This normalization plan is based on technical considerations, namely areas with large river discharges are located in residential areas.

TABLE 12. Manning Method Calculation Parameters (1)

Measure Distance (m)	P left (m)	P central (m)	P right (m)	As left (m)	As central (m)	As right (m)
	4,45	4,45	2,12	0,27	109,94	0,44
	3,72	3,75	1,97	0,48	77,52	0,3
50	2,66	2,20	1,35	0,2	42,49	0,13
	10,40	26,83	4,05	2,4	483,86	3,14
	5,68	13,93	1,94	0,84	216,79	0,45

TABLE 13. Manning Method Calculation Parameters (2)

�$^{2/3}$ left (m)	�$^{2/3}$ center (m)	�$^{2/3}$ right (m)	�$^{1/2}$ left (m)	�$^{1/2}$ center (m)	�$^{1/2}$ right (m)
0,0012	203,22	0,0003	0,006	0,007	0,004
0,0055	142,69	0,0014	0,007	0,008	0,004
0,0019	123,94	0,0010	0,004	0,006	0,006
0,0178	108,43	0,0011	0,014	0,018	0,001
0,0073	80,79	0,0019	0,008	0,017	0,001

TABLE 14. Manning Method Flow and Maximum Discharge

Qsr left (m^3/s)	Qsr center (m^3/s)	Qsr right (m^3/s)	Qsr max (m^3/s)
0,00014	27,42	0,00002	27,42
0,00080	23,45	0,00011	23,45
0,00014	14,45	0,00012	14,45
0,00497	38,28	0,00003	38,28
0,00123	28,20	0,00005	28,20

Based on the formula for the Manning method, calculations are carried out for each parameter. For the area (As) right and left use the formula for the area of a triangle while for the middle area the formula for the area of a rectangle is used. Then for the wet cross-sectional area (P) using a combination of formulas from trapezoidal and quadrilateral channels so that we get three hydraulic radii and three hydraulic gradients of the river (left, middle, and right). For the Manning roughness coefficient used is 0.05 which has been adjusted to SNI 2830:2008. So that we get a decrease in the maximum flow discharge (Qsrmax) normalization of the river as shown in the table 14.

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