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The Revitalization of Makassar Urban Drainage System Based on Eco Drainage Retention Pond

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***Abstract*- One of the causes of flooding in Makassar City is the management of the water system that is not optimal. It is necessary to arrange a drainage system to overcome flooding in Makassar City. In this study the topography on Catchment area analysis, analysis of hydrology and hydraulics analysis. Modeling the distribution of flood performed using HEC-RAS applications. This research was conducted in the Tallo watershed which consists of the Upper Tallo sub-watershed and the Mangalarang sub-watershed. The results of the analysis of flood discharge in the Tallo Hilir sub-watershed are 523.76 m^3/s and in the Mangalarang sub-watershed are 886.82 m^3/s. The flood overflow of the Tallo River spread over 6.48 km^2 of Manggala District, 0.31 km^2 of Rappocini District, 4.24 km^2 of Panakukang District, 3.37 km^2 of Tallo District, 11.59 km^2 of Tamalanrea District and 0.01 km^2 of Biringkanaya District. The total area of flood distribution is 26 km^2. The solution to overcome the flooding of the Tallo River with an environmentally sound drainage system, it is necessary to plan the construction of a retention pond in Tamalanrea District, with a normal total storage volume of 2.48 million m^3 and a maximum capacity of 5.31 million m^3. The construction of this retention pond can reduce 17.7 km^2 of flood-affected area.**

Keywords— Flood; Hydrology; Tallo River

I. Introduction

One of the main causes of inundation and flooding in urban areas is the occurrence of changes in land use patterns that are not followed by the arrangement of the drainage system [1]. The development of the area is no longer in accordance with spatial planning or the concept of sustainable development resulting in changes in land use patterns so that low areas and riverbanks become residential areas [2].

Almost every year the flood disaster in Makassar occurs at every arrival of the rainy season [3].

The worst flooding in the last decade in Makassar City occurred in 2019 which submerged 4 sub-districts, namely Panakukang District, Manggala District, and Biringkanaya District as high as 50 cm to 200 cm. The main cause of the flood was due to the relatively high intensity of rainfall on January 21 and 22, 2020 so that the Tallo and Jeneberang Rivers were unable to accommodate the flood discharge [4]. Floods in Makassar City are not only influenced by the relatively high intensity of rainfall, topographical conditions in the form of a basin, increased flow discharge, changes in land use patterns and sea water tides, are also influenced by the inadequate drainage system, although the city government has programmed and building infrastructure but the problem of flooding is still a serious problem [5]. Ujung Pandang District has not been free from the threat of flooding and inundation, so that drainage arrangements are needed as city infrastructure that is useful for draining excess water in an area [6].

Floods and puddles in a residential area still occur in many cities in Indonesia. Floods or puddles in an area occur when the drainage system is unable to accommodate the flowing discharge. In urban areas, drainage functions to drain parts of the city's administrative area and urban areas from puddles of water, both from local rain and overflowing rivers that pass through the city. River revitalization itself is an effort to restore river functions which include functions as irrigation and ecological functions [7]. River revitalization is a concept to correct the previous concept of river development [8]. The drainage system as an integral part of the water management system, the drainage system revitalization program uses a participatory approach with the aim of changing people's behavior towards the importance of a good drainage system [9].

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II. Research Methodology

A. Data Collection

The data needed in this study is divided into two types, namely primary data and secondary data. Data collection was carried out by directly observing the Tallo River in several areas to determine the condition and function of the river in that area. This research was conducted in the Tallo River Basin starting from the Nipa – Nipa Regulatory Pool to the Muara or at coordinates $5^{o}10'3.13''$ South Latitude and 119^{o} $31'10.93''$ East Longitude to $5^{o}6'15.15''$ South Latitude and $119^{o}26'56.08''$ East Longitude.

B. Data Analysis

The topographic data used in this study were obtained from the Indonesian Earth Map (RBI) Scale 1:50,000 and DEMNAS data to determine the catchment area that will be used in the 2D HECRAS flood simulation.

C. Hydrological Analysis

Rainfall data used were taken from Panakkukang Station, Tamangapa Kassi Station, Senre Station, Sungguminasa Station and Malino Station. The Rainfall data obtained from 1995 to 2019. Calculation of the average rainfall using the algebraic, isohyet and thiesen average methods. It was analyzed by using the Gumbell and Log Person III distribution Methods. Then, a statistical test of the rainfall data and a "Chi Squared and Smirnof-Kolmogorof" distribution test was carried out to determine the most suitable Frequency Distribution Method. The calculation of the planned rainfall intensity is analysis using the Mononobe method. The analysis method of the flood discharge design was calculated using the Nakayasu Synthesis Unit Hydrograph[10]. The stages of the Nakayasu synthetic hydrograph unit are:

Hydrograph peak discharge

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

Lag time

$$t_g = 0{,}4 + 0{,}058.L \qquad (L > 15\text{ km}) \qquad (2)$$

$$t_g = 0{,}21.L^{0{,}7} \qquad (L < 15\text{ km}) \qquad (3)$$

Discharge time

$$t_{0,3} = \alpha.t_g \qquad (4)$$

Peak time

$$t_p = t_g + 0{,}8T_r \qquad (5)$$

Where Q_p is peak discharge (m^3/sec), t_g is the gap time (hour), A is Watershed Area (km^2), L is river length (km), $t_{0,3}$ is discharge time equal to 0,3 peak (jam), t_p is peak time (hours), α is coefficient with the value ranges from 1.5 – 2, T_r is rainfall duration (hours), R_0 is rain depth unit (mm). Analysis of the river flood modeling using HEC-RAS application based on river geometry data and planned flood discharge inflow. Outflow modeling is the flood water level elevation for each flood discharge plan. Furthermore, simulation of flood control is carried out.

D. Alternative Countermeasures

Alternative countermeasures are carried out if the river's capacity is insufficient. The alternative to overcome this problem can be in the form of revitalizing the drainage system with eco drainage. The application of ecodrain can be done in several ways. Retention methods are divided into two types, namely "offsite retention", for example the creation of ponds or reservoirs and "on site retention", for example retention on building roofs, parks, parking lots, open fields, and yards. The method of "infiltration" is by making artificial recharge in certain areas in the form of infiltration wells, infiltration ditches, infiltration areas, pavements that pass water. The flowchart of methodology as can be seen on Figure 1.

E. Research Flow Chart

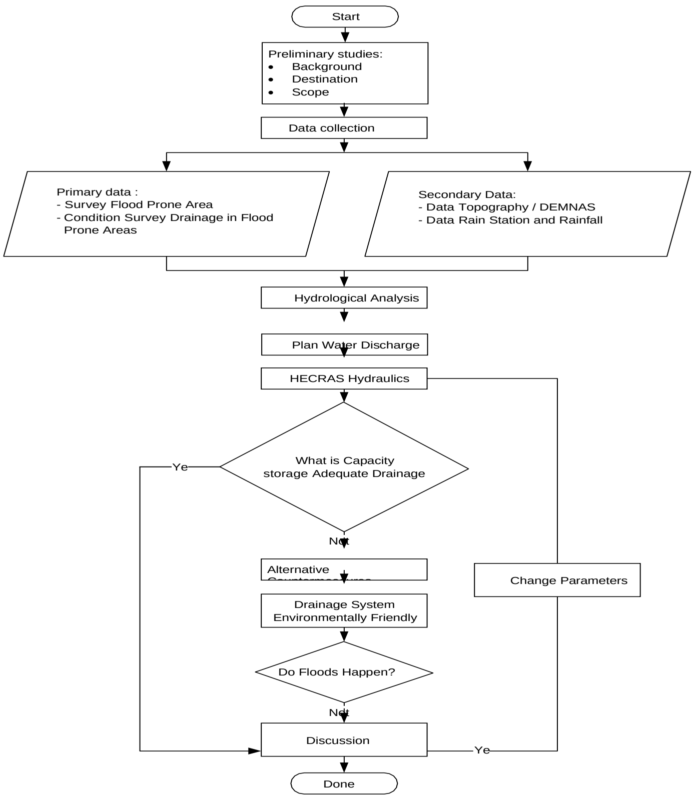

Figure 1. Flow Chart of Research and Methodology

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III. Results and Discussion

A. Hydrological Analysis

The rainfall data stations which affected on the study area are the Senre and Tamangapa Kassi stations. The recapitulation of the average rainfall data can be seen in Table 1 and Table 2.

Table 1. Maximum Rainfall of Tallo Sub-watershed

Year	Annual Maximum Daily Rainfall (mm)		Total
	Tamangapa Kassi	Senre	
	0.3700	0.6300	
1995	78.4331	49.7726	128.21
1996	73.9935	89.4646	163.46
1997	37.3667	42.8422	80.21
1998	36.2568	41.5821	77.84
1999	38.8466	68.0435	106.89
2000	123.9392	121.5962	245.54
2001	53.6453	77.4940	131.14
2002	63.6344	115.2959	178.93
2003	39.5865	86.9445	126.53
2004	34.4070	78.7540	113.16
2005	36.2568	69.3036	105.56
2006	39.5865	190.8998	230.49
2007	44.3961	141.7573	186.15
2008	50.6856	119.7061	170.39
2009	33.2971	113.4058	146.70
2010	29.5974	77.4940	107.09
2011	44.3961	56.7029	101.10
2012	43.6562	74.3438	118.00
2013	36.2568	127.8966	164.15
2014	28.8575	72.4537	101.31
2015	52.5354	106.4755	159.01
2016	33.2971	71.8237	105.12
2017	53.6453	100.8052	154.45
2018	58.7014	121.5962	180.30
2019	58.0436	149.3177	207.36

Table 2. Maximum Rainfall of Mangalarang Sub-watershed

Year	Annual Maximum Daily Rainfall (mm)		Total
	Tamangapa Kassi	Senre	
	0.0558	0.9442	
1995	11.8356	74.5896	86.43
1996	11.1657	134.0724	145.24
1997	5.6387	64.2037	69.84
1998	5.4712	62.3153	67.79
1999	5.8620	101.9705	107.83
2000	18.7025	182.2251	200.93
2001	8.0951	116.1331	124.23
2002	9.6025	172.7834	182.39
2003	5.9736	130.2957	136.27
2004	5.1920	118.0215	123.21
2005	5.4712	103.8589	109.33
2006	5.9736	286.0840	292.06
2007	6.6994	212.4386	219.14
2008	7.6485	179.3926	187.04
2009	5.0246	169.9509	174.98
2010	4.4663	116.1331	120.60
2011	6.6994	84.9754	91.67
2012	6.5878	111.4122	118.00
2013	5.4712	191.6668	197.14
2014	4.3546	108.5797	112.93
2015	7.9276	159.5650	167.49
2016	5.0246	107.6356	112.66
2017	8.0951	151.0675	159.16
2018	8.8581	182.2251	191.08
2019	8.7588	223.7687	232.53

Table 3. Tallo Hulu Sub-watershed Distribution Test Recapitulation

No.	Year	Distribution Method		Information
		Gumbel	Log Person III	
1	Smirnov Kolmogorov	0.1475	0.1282	Critical Value = 0.27
2	Chi Square	6.44	6.44	Critical Value = 7.815

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Table 4. Mangalarang Sub-watershed Distribution Test Recapitulation

No.	Test	Distribution Method		Information
		Gumbel	Log Pearson III	
1	Smirnov Kolmogorov	0.1465	0.1282	Critical Value = 0.27
2	Chi Square	1.64	12.68	Critical Value = 7.815

Tables 3 and 4 show that the rainfall plans on sub watershed upstream Tallo was calculated using distribution Log Pearson III and the subzone Mangalarang using Gumbel distribution. The runoff coefficient C in the Upper Tallo sub-watershed and the Mangalarang sub-watershed is 0.7. The value of effective rainfall for each sub-watershed can be seen in table 5 and table 6.

Table 5. The effective rainfall of Tallo Subwatershed

t (hour)	C	5	10	20	25	50	100	1000
1	0.7	68.48	78.66	86.87	91.29	100.55	109.74	140.54
2	0.7	17.80	20.45	22.58	23.73	26.14	28.52	36.53
3	0.7	12.49	14.34	15.84	16.64	18.33	20.01	25.62
4	0.7	9.94	11.42	12.61	13.25	14.60	15.93	20.40
5	0.7	8.39	9.64	10.65	11.19	12.33	13.45	17.23
6	0.7	7.34	8.43	9.31	9.78	10.77	11.76	15.06

Table 6. The Effective Rainfall of Mangalarang Subwatershed

t (hour)	C	5	10	20	25	50	100	1000
1	0.7	76.21	90.71	104.63	109.04	122.64	136.14	180.74
2	0.7	19.81	23.58	27.20	28.34	31.88	35.39	46.98
3	0.7	13.89	16.54	19.08	19.88	22.36	24.82	32.95
4	0.7	11.06	13.17	15.19	15.83	17.80	19.76	26.23
5	0.7	9.34	11.12	12.82	13.37	15.03	16.69	22.15
6	0.7	8.17	9.72	11.21	11.68	13.14	14.59	19.37

The amount of the discharge design is determined based on the amount of planned rainfall and the characteristics of the watershed. The design flood discharge for fhe upper Tallo Sub-watershed is:

Watershed area (A) = 70.85 km^2
Main River Length (L) = 18.53 km
Coefficient (α) = 2
Delay Time (tg) = 1.47 hours
Peak Time (Tp) = 2.36 hours
Rain Duration (Tr) = 1.11 hours
Time When Discharge 0.3 times peak discharge ($t_{0.3}$) = 2.95 hours
Peak Flood Discharge Q_p = 5.38 m^3/s
$t_p + t_{0.3}$ = 5.31 hours
$t_p + t_{0.3} + 1.5 + t_{0.3}$ = 9.73 hours
$0.5\ t_{0.3}$ = 1.47 hours
$1.5\ t_{0.3}$ = 4.42 hours
$2\ t_{0.3}$ = 5.90 hours

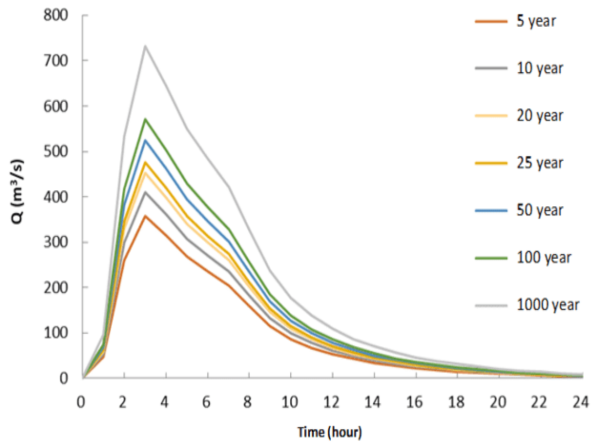

Figure 2. Flood Hydrograph of Upper Tallo Sub-watershed using Nakayasu Method

The design flood discharge for the Mangalarang sub-watershed is:

Watershed area (A) =168.29 m^2
Main River Length (L) = 49.25 km
Coefficient (α) = 2
Delay Time (tg) = 3.26 hours
Peak Time (Tp) = 5.21 hours
Rain Duration (Tr) = 2.44 hours
Time When Discharge is equal to 0.3 times peak discharge ($t_{0.3}$) = 6.51 hours
Peak Flood Discharge Q_p = 5.79 m3/s
$t_p + t_{0.3}$ = 11.72 hours
$t_p + t_{0.3} + 1.5 + t_{0.3}$ = 21.49 hours
$0.5\ t_{0.3}$ = 3.26 hours
$1.5\ t_{0.3}$ = 9.77 hours
$2\ t_{0.3}$ = 13.03 hours

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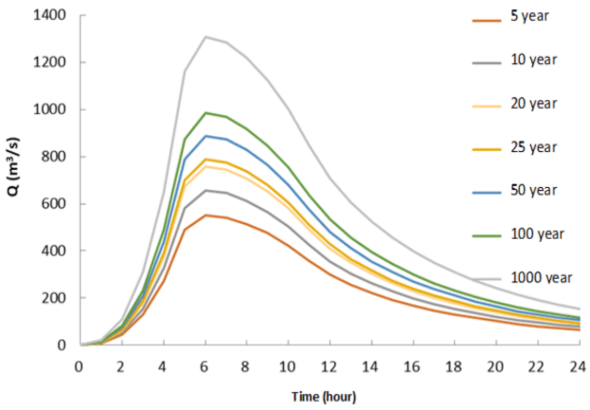

Figure 3. Mangalarang Sub-watershed Flood Hydrograph with Nakayasu Method

B. Performance of the Existing Condition of the Tallo . River

Hydraulics analysis uses a 2D non-permanent flow model with the help of the HEC–RAS application. The Tallo River is located in an urban area where the design flood discharge requirements used are Q_{20} – Q_{50} , so that in this study the flood simulation uses a flood with a return period of 50 years. The following is a map of the simulation results of the Tallo River flood, as seen in fig.4

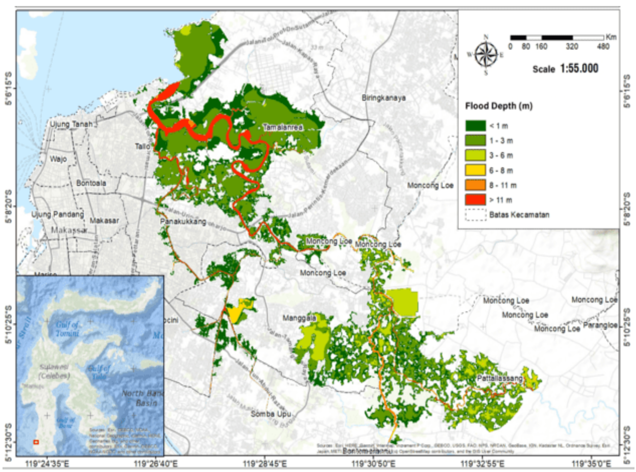

Figure 4. Tallo River Flood Area Map

Based on the results of mapping the flood-prone areas of Makassar City, from the simulation results above, it can be seen the performance of the existing conditions of the Tallo River. The flood area which affected based on sub-districts in Makassar can be seen in the Table 7.

Tabel 7. The Affected Area based on subdictricts in Makassar

No.	Sub-Districts	Total Area (km^2) (km^2)
1	Mangala	6.48
2	Rappocini	0.31
3	Panakukang	4.24
4	Tallo	3.37
5	Tamalanrea	11.59
6	Biringkanaya	0.01
Total		26.00

C. Environmentally Friendly Drainage System to Overcome Makassar City Flood

By mel lhat s results urvey field and the simulation result of flooding can be concluded that the tide is very influential on benjir occurring downstream Tallo River. Thus, it is necessary to revitalize the Tallo River by means of ecodrain, namely a retention pond. K olam ret ensi expected to reduce the flood water to slow the tide with a meeting between the flood discharge of the river from upstream. Figure 5 shows the results of the flood simulation before the retention pond.

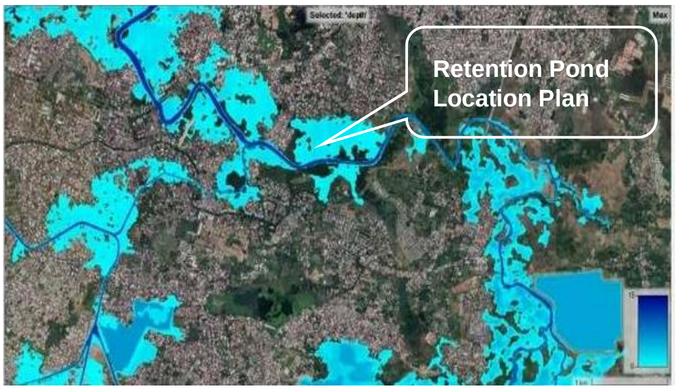

Figure 5. The location of Retention Pond Plan

The planning for retention pond in the downstream of Tallo River can be seen in Figure 6 which is in District Tamalanrea at coordinates 5 ° 10'3,13" latitude and 119 ˚ 31'10,93" BT, plan dimensions as follows:

Retention Pool Area	: 353783.47m^2
Pool Base Elevation	: - 7.00 m
Spillway Elevation	: + 0.00 m
Spillway Length	: 58.5 m
Pool Embankment Height	: + 8.00
River Embankment Height	: + 8.0 0
Normal Storage Volume	: 2.48 million m^3

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Maximum Storage Volume : 5.31 million m^3

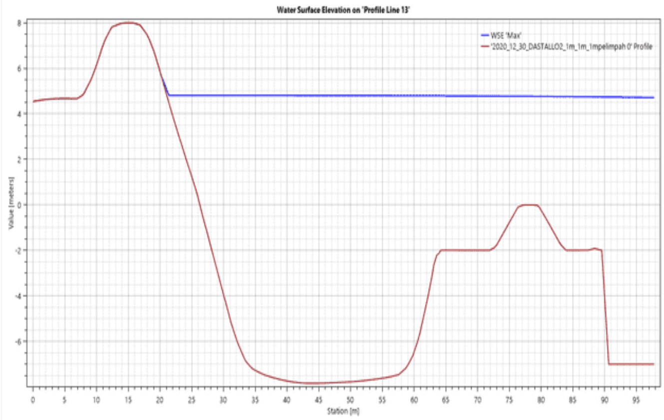
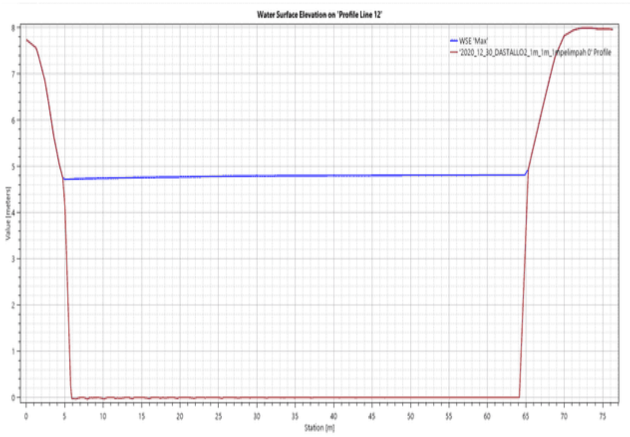


Figure 6. Cross Section of the Retention Pond Spillway Elevation Plan Retensi



Gambar 7. Longitudinal Piece of Retention Pond Spillway

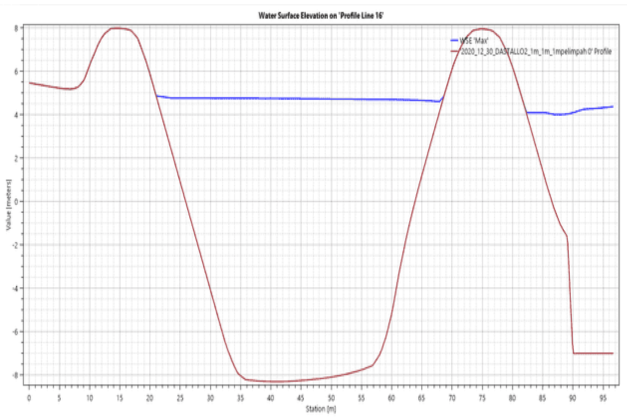


Figure 8. Cross Section of Pond Embankment and River Embankment

Figure 9 shows the condition of the simulated flooded area after the downstream retention pond

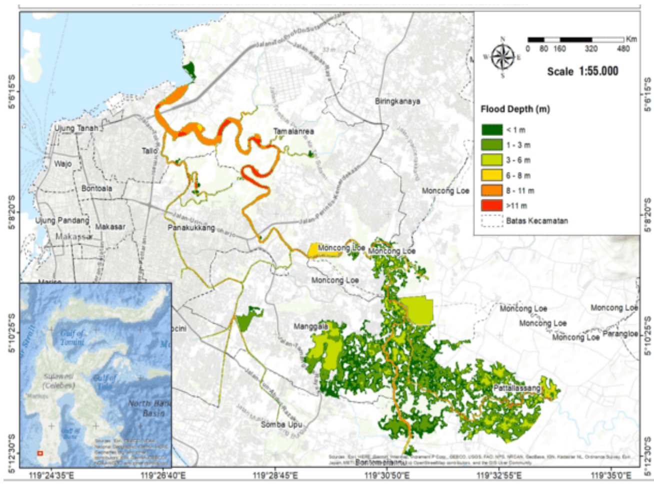


Figure 9. Map of the Areas Affected by the Flood of the Tallo River after the Downstream Retention Pond

Based on Figures 4 and 9, it can be seen that the difference in flood-affected areas before and after the downstream retention pond is established, for more details, see the following table 8.

Table 8. Area of Tallo River Flood Affected Before and After the Downstream Retention Pond

No.	Districts	Area of Flood Affected Before Downstream Retention Pond (km^2)	Area of Flood Affected After Downstream Retention Pond (km^2)	Difference (km^2)
1	Mangala	6.48	4.94	1.54
2	Rappocini	0.31	0.05	0.26
3	Panakukang	4.24	0.61	3.63
4	Tallo	3.37	0.92	2.45
5	Tamalanrea	11.59	1.77	9.82
6	Biringkanaya	0.01	0.01	0.00
Total		26.00	8.30	17.70

Based on the table above, the total area of inundation that can be reduced from the presence of a downstream retention pond is 17.70 km^2

Conclusion

Based on the results of the research conducted, the following conclusions can be drawn:

1. Dischage flooding upstream into the river Tallo is divided into two sub-watershed is subzone subzone Tallo Hulu and flood discharge

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Mangalarang with Q_{50} = 523.76 m^3/sec and Q_{50} = 886.82 m^3/sec.

2. The flood of the Tallo River caused 6 sub-districts to be affected by flooding, namely Manggala (6.48 km^2), Rappocini (0.31 km^2), Panakukang (4.24 km^2), Tallo (3.37 km^2), Tamalanrea (11.59 km^2) and Biringkanaya (0.01 km^2). So the total area affected is 26 km^2
3. The solution to cope with the flood Tallo River drainage system that is environmentally sound development plan retention ponds downstream with a total catchment normal volume of 2.48 million m^3 and a maximum capacity of 5.31 million m^3 can reduce about 17.7 km^2 area affected by flood

Acknowledgement

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