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Reservoir Capacity for Maximum Flood Discharge From The Flow of Rainfall Entering Through the Karang Mumus River in the Samarinda City, East Kalimantan

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Abstract:- It is hoped that the Benanga Reservoir in Samarinda City can function as irrigation for the surrounding community's rice fields, as a flood buffer or controller, and also as a Local water company (PDAM) raw water, and in the future it can become a water tourism area for the people of Samarinda, as well as residents outside Samarinda. The main problem facing the current is the reservoir not being able to function as needed due to the insufficient capacity of the reservoir due to the large amount of sedimentation and the surface is filled with wild water hyacinth plants. The current condition of the existing reservoir has an area of 108 hectares and the volume of the reservoir that does not fulfill it is only 3.24 x 106 m^3. To find out the reservoir capacity of the Benanga Reservoir, it is necessary to carry out an analysis of inflow and outflow calculations and an analysis of the reservoir capacity. The study aimed to determine the water holding capacity of the Benanga Reservoir, Samarinda. The research was conducted at the Benanga Reservoir, Samarinda City from April to May 2023. Primary data were collected, namely the depth of the reservoir and the volume of the reservoir, secondary data, namely the area of the reservoir, from the Department of Public Works and Public Housing (PUPR) Office of East Kalimantan. Data analysis, namely: analysis of tracking floods through the reservoir using the Muskingum method, analysis of reservoir capacity (inflow and outflow), analysis of sediment deposition in the reservoir, analysis of sediment that settles in the reservoir, and maximum flood discharge. The results of the research show that: (1) The results of the analysis of flood tracing through the Benanga Reservoir obtained that the flood discharge entering the reservoir (Qinflow) was 706.4578 m^3/second and the flood discharge that was leaving the reservoir (Qoutflow) was 443.930 m^3/second, so that the Benanga Reservoir can reduce flood discharge by 262.528 m^3/second; and (2) by using the mass arch method, the capacity of the Benanga Reservoir is 27.145 x 106 m^3, while the actual water holding capacity of the Benanga Reservoir is 3.240 x106 m^3.

Keywords:- *Reservoir Capacity, Flood Discharge, Reservoir Volume, Benanga Reservoir*

I. INTRODUCTION

The Samarinda City flood control program is being carried out by the Samarinda City Government, the Provincial Government of East Kalimantan, and the Central Government. The target achieved from the program's efforts is to control floods in Samarinda City. Floods are affected by the presence of relatively large surface water runoff and the rate at which soil erodes as sediment in rivers originating from the water catchment area. Biophysical conditions greatly affect the occurrence of floods and waterlogging. The problem of flooding that often occurs in every rainy season, the city area is always inundated by overflowing water from the river (Asdak, 1995).

Flood control along the Karang Mumus River channel such as the Benanga Reservoir as a temporary flood storage location is not yet optimal in reducing future floods. From the flood events that have occurred almost every year in the City area, it is always inundated by overflowing water from the Karang Mumus River. Flood control on the Karang Mumus River and rivers in Samarinda City with a very dense population and most of the people living on the banks of the river, so the river drainage area becomes very slow. The condition of the river is winding and narrowing in the downstream area resulting in flooding and during the rainy season and the river's watershed often floods occur because the river channel is unable to accommodate the overflowing flood water (Hadisusanto, 2004).

Changes in land use patterns affect decreasing the potential of the area caused by the increasingly widespread use of land for residential and industrial buildings around the Samarinda City area which causes a reduction in water catchment areas (Siswoko, 2007) or flooding because rainfall falls to the ground surface and cannot enter the area. Because the water channels are blocked by buildings and high topographic conditions, the roadside channels which are supposed to catch rainwater do not function properly so it will interfere with transportation and can damage the road body (Hadisusanto, 2011).

Lately, floods have often occurred, thus disrupting residents' activities. The various efforts that have been made have turned out to be not optimal in overcoming the problem of flooding. These efforts are in the Benanga Reservoir, Samarinda

II. RESEARCH METHODOLOGY

➢ *Location and Time of Research*

The research was conducted at the Benanga Reservoir, Samarinda City from April to May 2023, which included literature study activities, data collection, processing, and data analysis.

➢ *Research Object*

The research object of the Benanga Reservoir, Samarinda City, East Kalimantan Province, Indonesia.

➢ *Tools*

The tools used are meter and stationery.

➢ *Data Collection*

Primary data collection is the depth of the reservoir and the volume of the reservoir, secondary data is the area of the reservoir from the Office of Public Works and Public Housing of the Province of East Kalimantan.

➢ *Data Analysis*

Data analysis is as follows:

- Analysis of tracing floods through the reservoir using the Muskingum method (Triatmojo, 2010).
- Analysis of reservoir capacity (inflow and outflow) using the mass arch method (Soemarto, 1986).
- Analysis of sediment deposition in the reservoir was carried out using the Reduction Area method (Soemarto, 1986).
- Analysis of the sediment that settles in the reservoir is calculated using the Reservoir Capacity Reduction approach (Soemarto, 1986).
- Maximum Flood Discharge using the Nakayasu hydrograph method (Hadisusanto, 2011).

III. RESULTS AND DISCUSSION

➢ *Analysis of Tracing Floods Through Reservoirs*

To analyze the search for flooding through the reservoir using the Muskingum method (Triatmojo, 2010), namely the following steps:

- Determine the holding constant K;
- Determine the flow time of the flood wave in the channel section Δt;
- Determine the price of X between 0–0.5 (the steeper the slope of the river, the greater the value of X);
- Calculating constants;
- Calculating the constant C1 = C0 ;
- Calculating constants;
- Calculating the price of C0+C1+C2 = 1 ;
- Calculate the flood discharge at the outflow of O2 = C0I2 + C1I1 + C2O1.

Information :

I1 = inflow at the beginning of time t; I2 = inflow at the end of time t; O1 = outflow at the beginning of time t; O2 = outflow at the end of time t; Δt = time interval; C0, C1, C2 are constants K = holding constant, the value is approximately the same as the time of flood displacement in that section of the river and X = between 0–0.5, the steeper the slope of a river, the greater the value of X.

The results of the flood tracing analysis through the reservoir in the Karang Mumus sub-watershed (Table 1), are as follows:

K = 5 (holding constant)
Δt = 1 hour (time the flood wave flows in its channel section)
X = 0.3 (between 0–0.5)
C0,C1,C2 = constants

$$C_0 = \frac{\Delta t/K}{2+(\Delta t/K)} = \frac{1/5}{2+1/5} = \frac{0{,}2}{2{,}2} = 0{,}0909$$

$C_1 = C_0$

$$C_2 = \frac{2-\Delta t/K}{2+(\Delta t/K)} = \frac{2\ -\ 1/5}{2+1/5} = \frac{1{,}8}{2{,}2} = 0{,}8182$$

$C_0 + C_1 + C_2 = 0{,}0909 + 0{,}0909 + 0{,}8182 = 1$

$O_2 = C_0I_2 + C_1I_1 + C_2O_1$

Table 1 Tracing Floods Through Reservoirs

Time t (Hours)	Discharge inflow (m³/s)	C0.I2	C1.II	C2.OI	Debit *outflow* (m³/dt)
		0,0909	0,0909	0,8182	
0	0,0000	0,0000	0,0000	0,0000	0,0000
1	24,6759	2,2430	0,0000	0,0000	2,2430
2	136,6618	12,4226	2,2430	1,8353	16,5009
3	383,0428	34,8186	12,4226	13,5010	60,7421
4	702,5186	63,8589	34,8186	49,6992	148,3768

5	**706,4578**	64,2170	63,8589	121,4019	249,4778
6	673,7353	61,2425	64,2170	204,1227	329,5823
7	626,2023	56,9218	61,2425	269,6642	387,8286
8	565,6540	51,4179	56,9218	317,3213	425,6611
9	486,6468	44,2362	51,4179	348,2759	**443,9300**
10	398,8803	36,2582	44,2362	363,2236	443,7180
11	332,0539	30,1837	36,2582	363,0500	429,4920
12	279,0484	25,3655	30,1837	351,4103	406,9595
13	236,5210	21,4998	25,3655	332,9743	379,8395
14	210,1993	19,1071	21,4998	310,7847	351,3916
15	176,1658	16,0135	19,1071	287,5086	322,6292
16	151,6579	13,7857	16,0135	263,9752	293,7744
17	130,7527	11,8854	13,7857	240,3662	266,0373
18	113,9080	10,3542	11,8854	217,6717	239,9114
19	100,2563	9,1133	10,3542	196,2955	215,7630
20	87,8845	7,9887	9,1133	176,5373	193,6393
21	78,0203	7,0920	7,9887	158,4357	173,5164
22	69,5145	6,3189	7,0920	141,9711	155,3821
23	62,1513	5,6496	6,3189	127,1336	139,1020
24	55,6412	5,0578	5,6496	113,8133	124,5206
25	49,8117	4,5279	5,0578	101,8828	111,4684
26	44,5936	4,0536	4,5279	91,2035	99,7849
27	39,9227	3,6290	4,0536	81,6440	89,3265
28	35,7418	3,2489	3,6290	73,0870	79,9649
29	31,9970	2,9085	3,2489	65,4273	71,5847
30	28,6460	2,6039	2,9085	58,5706	64,0831

Source: Data Processed Results (2023)

Flood discharge at inflow (I) Q25 = 706.4578 m^3/second which occurs at hour 5. Flood discharge at outflow (O) Q = 443.9300 m3/second which occurs at hour 9. Flood tracing through the reservoir cutting discharge of Q25 = 706.4578 m^3/second - 443.9300 m^3/second = 262.5278 m^3/second this is the meaning of controlling floods by using reservoirs. The reduced peak discharge is due to the discharge being accommodated in the reservoir.

➢ *Mass Bend Analysis and Reservoir Capacity*

The mass curve is used to determine the capacity/volume of the reservoir needed to fulfill a certain function, the river discharge that enters the reservoir. The mass curve can be used to determine the reservoir capacity/reservoir volume required to fulfill a certain function. River discharge that enters the reservoir with Q1.2 after t = t1 is equal to Q1.2 to t1.2. The capacity of the reservoir is required to regulate the expenditure of a constant discharge Q0 which is equal to the average price of the incoming discharge between t = 0 to t = t2 (Soemarto, 1986).

The results of the analysis to calculate the dam capacity using the mass arch method are presented in Table 2.

Table 2 Mass Curve for Dam Volume

Time t (Hours	***Inflow***	***Outflow***	**Δt**	**Volume (10^6 m^3)**				***Residual***	***Required capacity***
				I	**O**	**AI**	**AO**		
1	2	3	4	5	6	7	8	9	10
0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	27,1454
1	24,6759	6,1690	3600	0,0888	0,0222	0,0888	0,0222	0,0666	27,2120
2	136,6618	39,1253	7200	0,9840	0,2817	1,0728	0,3039	0,7689	27,9809
3	383,0428	126,5528	10800	4,1369	1,3668	5,2097	1,6707	3,5390	31,5199
4	702,5186	273,2520	14400	10,1163	3,9348	15,3259	5,6055	9,7204	41,2403
5	706,4578	383,2276	18000	12,7162	6,8981	28,0422	12,5036	15,5386	56,7789
6	673,7353	448,8627	21600	14,5527	9,6954	42,5949	22,1990	20,3958	77,1747
7	626,2023	479,8587	25200	15,7803	12,0924	58,3751	34,2915	24,0837	101,2584
8	565,6540	483,8966	28800	16,2908	13,9362	74,6660	48,2277	26,4383	127,6966
9	486,6468	464,8218	32400	15,7674	15,0602	90,4333	63,2879	**27,1454**	154,8420
10	398,8803	427,4534	36000	14,3597	15,3883	104,7930	78,6763	26,1168	180,9588
11	332,0539	382,7697	39600	13,1493	15,1577	117,9424	93,8339	24,1084	205,0673

12	279,0484	337,3416	43200	12,0549	14,5732	129,9973	108,4071	21,5902	226,6574
13	236,5210	294,4973	46800	11,0692	13,7825	141,0664	122,1896	18,8769	245,5343
14	210,1993	257,7864	50400	10,5940	12,9924	151,6605	135,1820	16,4785	262,0128
15	176,1658	223,8000	54000	9,5130	12,0852	161,1734	147,2672	13,9062	275,9190
16	151,6579	193,7621	57600	8,7355	11,1607	169,9089	158,4279	11,4810	287,4001
17	130,7527	167,5893	61200	8,0021	10,2565	177,9110	168,6844	9,2266	296,6267
18	113,9080	145,1420	64800	7,3812	9,4052	185,2922	178,0896	7,2027	303,8294
19	100,2563	126,1252	68400	6,8575	8,6270	192,1498	186,7165	5,4332	309,2626
20	87,8845	109,8336	72000	6,3277	7,9080	198,4775	194,6245	3,8529	313,1155
21	78,0203	96,0377	75600	5,8983	7,2604	204,3758	201,8850	2,4908	315,6063
22	69,5145	84,3376	79200	5,5055	6,6795	209,8813	208,5645	1,3168	316,9231
23	62,1513	74,3727	82800	5,1461	6,1581	215,0275	214,7226	0,3049	317,2280
24	55,6412	65,8221	86400	4,8074	5,6870	219,8349	220,4096	-0,5748	316,6532
25	49,8117	58,4177	90000	4,4831	5,2576	224,3179	225,6672	-1,3493	315,3039
26	44,5936	51,9570	93600	4,1740	4,8632	228,4919	230,5304	-2,0385	313,2654
27	39,9227	46,2857	97200	3,8805	4,4990	232,3724	235,0294	-2,6570	310,6084
28	35,7418	41,2843	100800	3,6028	4,1615	235,9751	239,1908	-3,2157	307,3927
29	31,9970	36,8571	104400	3,3405	3,8479	239,3156	243,0387	-3,7231	303,6697
30	28,6460	32,9276	108000	3,0938	3,5562	242,4094	246,5949	-4,1855	299,4842

Source: Data Processed Results (2023)

The result of the calculation is that the volume of the reservoir with an inundated area = 108 ha (1,080,000 m^2), and the height of the dam = 3 m is 1,080,000 x 3 = 3.24 x 106 m^3. The planned storage volume that occurs during the incoming 9 hours = 27.1454 x 106 m^3, so the recommended storage volume is = 27.1454 x 106 m^3 > the actual reservoir volume is = 3.24 x 106 m^3, so the Benanga reservoir is no longer able to accommodate rainfall.

➢ *Analysis of Sediment Entering the Reservoir*

It is estimated that the sedimentation rate in this study will be useful for knowing the sedimentation rate in the Benanga Reservoir and also estimating erosion in the upstream area of the Benanga Reservoir. The problems of erosion and sedimentation are two interrelated problems, most of the erosion is caused by the water factor, although other factors such as wind can cause erosion.

Sedimentation can be defined as the transport, drift, or settling of fragmental materials by water. Sedimentation is the result of an erosion process and can usually have a greater impact. Ideally, to obtain accurate information, it is necessary to measure the sedimentation rate at the location. The approach method used in this analysis is Smith and Weishcmer whose general equation can be described by Soemarto (1986) as follows:

S-pot = E-Akt * SDR

$$SDR = \frac{S\,(1 - 0{,}8683 \times A^{-0{,}2018})}{2 \times (S + 50 \times n)} + 0{,}8683 \times A^{-0{,}2018}$$

E-Akt = E-pot x CP
E-pot = R x K x LS x A
LS = (L/100) x (0,0139 x S^2 + 0,0965 x S + 0,0136)
R = -8.79 + 7.01 Hb

Information :

SDR = Sediment release ratio, where 0 < SDR < 1; R = Erosivity of rain; Hb = monthly rainfall (cm); LS = length factor and slope; L = slope length; S = Slope; E-pot = Erosion potential (tons/year); K = Erodibility of soil; A = DPS area (ha); E-Akt = actual erosion in DPS (tonnes/year); E-pot = Erosion potential (tons/year); CP = Crop factor and soil preservation; S slope mean DPS surface slope (%); and n = Coefficient of roughness by Manning.

Erosion calculations are carried out for each land use in a Sub Watershed (DAS). Meanwhile, the calculation of the sediment discharge ratio (SDR) is carried out for each sub-watershed, and the sedimentation rate of the Karang Mumus watershed to the Benanga Reservoir is the sum of the sedimentation rates from all the Karang Mumus sub-watershed to the Benanga Reservoir. The results of sedimentation calculations in the Karang Mumus watershed up to the Benanga Reservoir with a watershed area of 194.5 km2 is 0.299 mm/year or 55,220.22 m^3/year or 99,369.93 tons/year.

➢ *Sedimentation Entering Reservoir*

Analysis of sediment deposition in the reservoir was carried out using the Reduction Area method. This method states that the distribution of sediment deposits depends on several factors, namely:

- *Reservoir Shape*

The shape of the reservoir can be determined by finding the value of m as the inverse of the slope of the relationship between the water depth of the reservoir as the ordinate and the capacity of the reservoir as the abscissa, where the values of both are plotted on a logarithmic scale. Based on the m value, the shape of the reservoir is divided into four types, namely:

Type I (Like Type) m = 3,5 - 4,5
Type II (Flood Plain Type) m = 2,5 - 3,5
Type III (Hill Type) m = 2,5 - 1,5
Type IV (George Type) m = 1,5 - 1

Based on the criteria for the shape of the reservoir, the Benenna Reservoir has a Type II shape, so it is assumed that the price is m = 2.55

- *Density of Sediment Deposits*

Sediment density which is affected by the duration of the deposition process and the type of reservoir operation is calculated by the following formula:

W T = W 1 + 0.4343 K (T/T-1) {(ln T) -1}

Information:

W T = Sediment density after T years; W 1 = Initial density; K = constant that depends on the type of reservoir operation and the percentage of sediment particles.

The initial density of sediment deposits is calculated by the following formula:

W 1 = Wc Pc + Wm Pm + Ws Ps

Information:

W 1 = Initial sediment density (m3/second); Wc, Wm, Ws = Coefficients of clay, silt, sand, depending on the type of reservoir operation, and Pc, Pm, Ps = Percentage of clay, silt, sand, respectively.

Classification of reservoir operating types

Type 1 = always submerged or nearly submerged sediment
Type 2 = low water level in medium to large reservoirs
Type 3 = reservoir is usually empty
Type 4 = River bottom sediment

Prices of Wc, Wm, Ws for various Reservoir Operations and Prices of Kc, Km, Ks for various Reservoir Operations Prices of Kc, Km, Ks for various Reservoir Operations are presented in Table 3 and Table 4.

Table 3 Prices of Wc, Wm, and Ws for Various Reservoir Operations

Operation Type Reservoir	Wc	Wm	Ws
1	416	1120	1550
2	561	1140	1550
3	641	1150	1550
4	961	1170	1550

Table 4 Prices of Kc, Km, and Ks for various Reservoir Operations

Operation Type Reservoir	Kc	Km	Ks
1	0	91	256
2	0	29	135
3	0	0	0
4	0	0	0

The sediment density is calculated by first calculating the initial density and the K factor which depends on the type of reservoir operation and the percentage of grain gradation. It is assumed that the gradation of sediment grains entering the Benanga Reservoir consists of 10% clay, 20% silt, and 70% sand. The operational type of the Benanga Reservoir is type 1, where the sediment is always submerged or almost submerged.

The calculation of sediment density for 10 years (Soemarto, 1986) is as follows:

W 1 = 416 x (0,1) + 1120 x (0,2) + 1550 x (0,7)
W 1 = 1.350,60 kg/m^3
K = 0 x (0,1) + 91 (0,2) + 256 (0,7) = 197,4
W T = 1350,6 + 0,4343 (197,4) (10/9) (ln 10^{-1})
W T = 1.560,4 kg/m^3 = 1,5604 tons/m^3

- *Sediments that Settle in Reservoirs*

Sediment that settles in the Benanga Reservoir is calculated using the Reservoir Capacity Reduction approach. Based on erosion analysis in the upper Karang Mumus sub-watershed which is the water catchment area of the Benanga Reservoir, the potential value of the sediment entering the Benanga Reservoir is assumed to be floating sediments which enter the Benanga Reservoir through several tributaries of the Karang Mumus river to the Benanga Reservoir. Meanwhile, to calculate the total potential volume of sediment entering the reservoir, it is necessary to add the bed load potential. Because there was never any data on bottom sediment in the Karang Mumus watershed, it was assumed that the amount of bottom sediment that entered the Benanga Reservoir was 25% of the floating sediment. Assuming that the sediment catchment coefficient in the reservoir is 70% and the specific gravity of the sediment material is based on a calculation of 1.5604 tons/m^3, the sediment that will enter the Benanga Reservoir can be calculated. Based on the assumption that the entire capacity of the Benanga Reservoir will be fulfilled or the final elevation of the sediment in the Reservoir is at an elevation of +7.20, based on the calculation results, it shows that the required time is approximately 11.11 years.

Changes in the volume or removal of the volume of this reservoir will affect the level of flood reduction in the Benanga Reservoir and will directly affect the current existence of the Reservoir. Reservoir reduction will be smaller and the threat/danger of runoff above the top of the dam will be greater. A complete analysis of runoff/flood tracing through the reservoir with various alternatives and the planned flood return period can be seen in the dam body planning chapter (Triatmojo, 2010).

➢ *Maximum Flood Discharge*

Based on the results of the flood hydrograph analysis, the design flood discharge was obtained, from the sediment transport analysis based on each fractionation percent and grain diameter of the sediment transport using the Einstein formula. The design flood return period is used for the Q25 year anniversary period. In the Karang Mumus sub-watershed, the planned flood discharge is Q25 = 706.4578 m^3/s, sediment transport is QB = 0.2198 m^3/s, the maximum flood discharge in the Q25 year return period is Q25 = 706.4578 m^3/s + 0,2198 m^3/s = 706.6776 m^3/s. The recommended capacity of the river is Q25 = 1,228.7797 m3/s > the maximum flood discharge is Q25 = 706.6776 m^3/s, the water holding capacity of the river is sufficient, safe.

IV. CONCLUSIONS AND RECOMMENDATIONS

➢ *Conclusion*

- The results of the analysis of flood tracing through the Benin Reservoir obtained a flood discharge that entered the reservoir (Qinflow) of 706.4578 m^3/second and a flood discharge out of the reservoir (Qoutflow) of 443.930 m^3/second so that the Benanga flow can reduce flood discharge by 262.528 m^3/second;
- By using the mass arch method, the capacity of the Benanga Reservoir is 27.145 x 106 m^3, while the actual water holding capacity of the Yamba Reservoir is 3.240 x106 m^3.

➢ *Recommendations*

Considering that the flood discharge capacity of the Benanga Reservoir from the results of calculations using the Mass Arch of 27.145 x 106 m^3 is greater than the actual water holding capacity of the Berliana Reservoir of 3.240 x 106 m^3, the reservoir capacity needs to be enlarged proportionally so that it can accommodate the flood discharge, Among other things, this can be done by dredging mud and cleaning water hyacinth weeds in the reservoir.

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