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Retention Pool As Alternative For Flood Control Case Study Of Permai Satellite Housing, Sumenep Regency

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A B S T R A C T

Problems with the environment due to development that does not pay attention to the carrying capacity of the environment. To overcome flooding, in this case the city of Sumenep makes a retention pond, which is intended to reduce floods that often occur. The capacity of the retention pond is sufficient, it can be seen from the dimensions of the larger retention pond that the volume of the retention pond capacity when the flood is $6750 m^3 > 6447 m^3$. The retention pond is planned in the downstream area of the residential river with a pool area of 50 x 40 meters and a depth of 4.5 m. The bottom condition of the pond is saturated because it is always inundated by water, so the infiltration rate that occurs in the pond is a constant infiltration rate (fc). The constant infiltration for clayey soil type is 0.5 m/day, the infiltration volume rate that occurs at the bottom of the pond is 179 m^3/hour, the volume is below the threshold 8283.21 m^3, infiltration time is 46 hours.

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1. Introduction

Indonesia is a water country with rivers and hundreds of deep seas. This causes Indonesia to be a country that is very prone to flooding. But basically there are several factors that cause this to happen, namely: natural events, damage to waterways and environmental degradation caused by human activities [1]. The rapid human activity in the Sumenep area has a very positive impact on economic progress. But on the other hand it can cause problems for the environment due to development that does not pay attention to the carrying capacity of the environment. To overcome flooding, in this case the City of Sumenep has created a retention pond, which is intended to reduce frequent flooding. [1] [6]. High rainfall accompanied by river conditions that experience silting due to erosion and sedimentation resulted in the river's capacity to accommodate flood discharge runoff is not optimal. This condition can cause the volume of water to overflow, resulting in a flood inundation area [6][20]. Flooding is a condition where water is not accommodated in the drain channel (times) or the flow of water is obstructed in the drain channel [17]. The hydrological cycle is a continuous process in which water moves from the earth to the atmosphere and then back to the earth again [17][18]. The length of peak flood time becomes the basis for analyzing the volume of the retention pond so that the amount of flowing retention pond discharge can be accommodated with the planned dimensions of the pond volume [1][9][11][16].

2. Literature Review

Flooding is a condition where water is not accommodated in the drain channel (times) or the flow of water is obstructed in the drain channel [17]. The hydrological cycle is a continuous process in which water moves from the earth to the atmosphere and then back to the earth again [18].

Retention pond is a pond that serves to temporarily hold rainwater by providing an opportunity to seep into the ground whose operations can be combined with a pump or sluice. The function of the retention pond is to replace the role of infiltration land which is used as closed land/housing/offices, so the recharge function can be replaced with a retention pond. The function of this pool is to collect direct rainwater and flow from the system to be absorbed into the ground and then can be used for water needs. [1][14].

Flood control is part of water resource management that is more specific to controlling flood discharge generally through flood control dams, or improvement of flood control carrier systems (rivers, drainage) and prevention of potentially damaging things by how to manage land use and flood areas [10].

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Hydrological analysis, parameter testing is needed to test the suitability of the frequency distribution of the data sample to the probability distribution function which is estimated to describe or represent the frequency distribution. Parameter testing that is often used is the chi-square test and the Smirnov-Kolmogorov test [9].

To calculate the intensity of rainfall, several empirical formulas can be used such as the Talbot formula, the Sherman formula, the Ishiguro formula, and the Mononobe formula [9].

In statistics, there are several parameters related to data analysis which include the average, standard deviation, coefficient of variation and coefficient of skewness. Frequency analysis that is often used in the field of hydrology is the normal distribution, log normal distribution, Log Pearson III distribution, and Gumbel distribution [9].

The hydraulic analysis aims to determine the potential for the retention pond discharge which is calculated based on the result of the difference between the return flood discharge and the capacity discharge of each cross section of the river [3].

3. Research Method

3.1 Data Collection Procedure

The study began by analyzing the flood, namely inadequate drainage capacity. This can be done through interviews or interviews with residents.

a. Primary data

Documentation about the location to be studied, and the data from elevation measurements at the location that will be used as research samples.

b. Secondary data

Secondary data in this study is data obtained from certain parties related to the research being conducted. Certain parties, including the developer of Bapetarum Housing in the Marketing Office.

3.2 Technical Data Analysis

1. Planned Rain Analysis

a. Gumbel Distribution Method

$$R_r = \frac{\sum Ri}{n}$$

Where :

R_r = Average Rain

R_i = Rainfall

n = Amount of data

b. Pearson Type III Log Method

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Calculate the logarithm of the planned rain with the selected return time, with the formula:

LogRI=LogR+K.Sx

Where :

R = area average rain height

K = Pearson log frequency factor type III

Sx = standard deviation

2. Rainfall Intensity

$$Ii = \frac{R_t}{24} \text{ x } \left(\frac{24}{t}\right)^{2/3}$$

Where :

Rt = plan rain (mm)

t = concentration time (hour)

It =Rain intensity (mm)

3. Flood discharge analysis

a. Rational Method

Qt=0,278.C.I.A

Where :

Qt = flood discharge (m^3/sec)

C = flow coefficient

I =rain intensity (mm/hour)

A = area of flow (km^2)

b. Rational modification method

Qt = 0,278C.Cs.I.A

Where :

Qt = flood discharge (m^3/sec)

C =flow coefficient

Cs = deviation coefficient

I = rain intensity (mm/hour)

A = an area (km^2)

4. Retention pool capacity :

$$V = \frac{1}{2} \text{ X } (A_1 + A_2).\text{H}$$

Where :

V = storage pool volume (m3)

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A1 = bottom area (m)

A2 = top area (m)

H = storage pool height

4. Results and Discussions

4.1 Planned Rain Analysis

a. Gumbel Distribution

1. Ranking daily rainfall data max.

Table 1. Order CHH Max

NO	CHH Max (Ri)
1	189.07
2	177.04
3	165.2
4	127.70
5	120.7
6	103.33
7	102.85
8	99.71
9	91.30
10	66.72
Total	1243.62
Lots of Data	10

Source:*Research result (2021)*

2. Determining the Average Rain Value.

   $Rr = \frac{\sum Ri}{n} = \frac{1243.64}{10} = 124.40$

3. Determine the difference between the maximum rainfall and the average rain.

   (Ri – Rr) = (189.07 – 124.40) = 64.74

4. Determine the difference between the maximum rainfall and the average rain.

   $(Ri\text{-}Rr)^2 = (189.07\text{-}124.40)^2 = 4182.20$

5. Determine the difference between the maximum rainfall and the average rain.

   $(Ri\text{-}Rr)^3 = (189.07\text{-}124.40)^3 = 270463.45$

6. So by following steps number 2,3, and 4 for the following sequence, the following results are obtained.

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Table 2. Gumbel Distribution Calculation

No	CHHMax (Ri)	Ri-Raverage	(Ri-Raverage)^2	(Ri-Raverage)^3
1	189.07	64.67	4182.20	270463.45
2	177.04	52.64	2770.97	145863.84
3	165.2	40.80	1664.64	67917.312
4	127.70	3.30	10.89	35.937
5	120.7	-3.70	13.69	-50.653
6	103.33	-21.07	443.9449	-9353.919
7	102.85	-21.55	464.4025	-10007.87
8	99.71	-24.69	609.5961	-15050.93
9	91.30	-33.10	1095.61	-36264.69
10	66.72	-57.68	3326.982	-191900.3
Jumlah	1243.62	-0.38	14582.93	221652.13

Source :*Research result (2021)*

7. Determining the Standard Deviation (Sx) :

$$Sx = \sqrt{\frac{\sum(Ri-R)^2}{n-1}} = \sqrt{\frac{14582.93}{9}} = 40.25$$

8. Calculating the Asymmetry Coefficient (C_2)

$$(C_2) = \frac{n.\sum(R_i-R_{rata})^3}{(n-1)(n-2){s_x}^3} = \frac{10\ x\ 221652.13}{9\ x\ 8\ x\ (\ 40.25)^3} = 0.47$$

Table 3. Gumbel Distribution Calculation

Kala Ulang	**Yt**	**Kt**	**Rt (mm)**
2	0.367	-0.097	148
5	1.500	1.096	222
10	2.250	1.750	194
25	3.199	2.885	332
50	3.902	3.626	378
100	4.600	4.361	423

Source : *Research result (2021)*

9. Determine the value of Yn and Sn that depends on n

N = 10 $\longrightarrow$ Yn = 0.5070

N = 10 $\longrightarrow$ Sn = 0.9971

10. Determining the variation of the rephrase functionY_t

Function of variation for return periods 10 years $\longrightarrow Y_t$ = 2.25

11. Determine the frequency factor (K)

$$K = \frac{Y_t-Y_n}{S_n} = \frac{2.25-0.5070}{0.9971} = 1.750$$

12. Determine the planned rainfall with the selected return time :

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$R_t = R_r + (KxS_x)$

$R_{10th} = 124.40 + (1.750 \text{ x } 40.25) = 194.8$

b. Distribution of Log Person Type III

Table 4. Calculation of the Pearson Type III Log Distribution

No	CHHMax (Ri)	Log Ri	Log Ri - Log R	(Log Ri - Log R)	(Log Ri - Log R)
1	189.07	2.277	0.221	0.253	0.056
2	177.04	2.248	0.192	0.037	0.007
3	165.2	2.218	0.162	0.026	0.004
4	127.70	2.106	0.050	0.003	0.000
5	120.7	2.082	0.026	0.001	0.000
6	103.33	2.014	-0.042	0.002	0.000
7	102.85	2.012	-0.044	0.002	0.000
8	99.71	1.999	-0.057	0.003	0.000
9	91.30	1.960	-0.096	0.009	-0.001
10	66.72	1.824	-0.232	0.054	-0.012
Total	1243.62	20.56	0.18	0.389	0.054

Source : *Research result (2021)*

1. Transform the maximum daily rainfall data to its logarithmic depth.

   LogRi = Log(189.07) = 2.277
2. Calculating the middle price (Log R)

   LogR = $\frac{\sum LogRi}{n} = \frac{20.56}{10}$ = 2.056
3. Log Ri – Log R = 2.277 – 2.056 = 0.221
4. (Log R – Log R)^2 = (0.221)^2 = 0.253
5. (Log R – Log R)^3 = (0.221)^3 = 0.056
6. So that in a tabular manner by following steps numbers 2 to 6 for the next data, the results are as follows:
7. Calculating Standard Deviation (Sx)

   Sx = $\sqrt{\frac{\sum(LogRi-LogRi)^2}{n-1}} = \sqrt{\frac{0.389}{10-1}}$ = 0.207
8. Calculating the Asymmetry Coefficient (C_s)

   $C_s = \frac{n.\ \sum(LogRi-LogR)^3}{(n-1)(n-2){s_x}^3} = \frac{10\ x\ (0.054)}{9\ x\ 8\ x\ (0.207)^3}$ = 0.919
9. Determining the frequency factor K

   With data K = 0.919 and when return periods 10 years , then return periods 10 years is K =1.339
10. Determining the rain of the plan for the return (Rt)

    LogR_1 = LogR + K.Sx

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$\text{Log}R_2$ = 2.056 + (1.339 x 0.207) =2.333

R_2 =$10^{2.333}$= 215 mm

11. So that in a tabular manner by following steps numbers 3 to 8, the results are as follows:

Table5. Planned Rainfall for Log Pearson Type III Distribution

Kala Ulang	Log R	K	Log Rt	Rt(mm)
2	2.065	-0.148	2.034	108
5	2.065	0.769	2.224	168
10	2.065	1.339	2.333	215
25	2.065	2.018	2.483	304
50	2.065	2.498	2.582	382
100	2.065	2.957	2.677	475

Source : *Research result (2021)*

4.2 Rain Intensity Analysis

Table6. Gumbel Distribution Rain Resume andLog Pearson Type III Distribution

Rain Station	Analysis method	Plan Rain (mm/Day) With Return Periods					
		2 Years	5 Years	10 Years	25 Years	50 Years	100 Years
3 Station	Log Pearson III	108	168	215	304	384	475
	Gumbel	148	222	194	332	378	423

Source : *Research result (2021)*

Calculating Rain Intensity (It) Using the results of the Pearson Log method which is close to the value of Cs = 0.919, Analysis of rain intensity with various return periods.

With intervals of 2,5,10,25,50,100 years, the planned rainfall for various return periods is 108,168,215,304,384,475 mm/day. So for time t = 10 minutes, the rainfall intensity is:

a. Rain intensity at intervals of 25 years

$$\text{It} = \frac{R_t}{24} \text{ x } \left(\frac{24}{t}\right)^{2/3}$$

$$\text{It} = \frac{304}{24} \text{ x } \left(\frac{24 \, x \, 60}{10}\right)^{2/3}$$

= 347 mm/hour

b. Rain intensity at intervals of 50 years

$$\text{It} = \frac{R_t}{24} \text{ x } \left(\frac{24}{t}\right)^{2/3}$$

$$\text{It} = \frac{382}{24} \text{ x } \left(\frac{24 \, x \, 60}{10}\right)^{2/3}$$

= 347 mm/hour

c. Rain intensity at intervals of 100 years

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$$\text{It} = \frac{R_t}{24} \times \left(\frac{24}{t}\right)^{2/3}$$

$$\text{It} = \frac{475}{24} \times \left(\frac{24 \times 60}{10}\right)^{2/3}$$

$$= 543 \text{ mm/hour}$$

Table7. Rain Intensity Analysis (mm/hour)

T	It 2 Years	It 5 Years	It 10 Years	It 25 Years	It 50 Years	It 100 Years
Minute	108	168	215	304	382	475
10	123	192	246	347	437	543
20	77	121	155	219	276	342
30	60	92	121	167	211	261
40	50	76	99	138	174	215
50	42	65	86	119	150	185
60	37	58	80	105	133	164
70	33	52	68	95	120	148
80	30	48	62	86	109	135
90	28	44	58	80	101	125
100	26	41	54	74	94	117
110	24	38	50	70	88	109
120	23	36	48	66	83	109
130	22	34	45	62	79	98
140	21	33	43	59	75	93
150	20	31	41	57	72	89
160	19	30	39	54	62	85
170	18	29	38	52	66	82
180	18	28	36	50	64	79
190	17	27	35	48	61	76
200	16	26	34	47	59	73
210	16	25	33	45	57	71
220	15	24	32	44	55	69
230	15	23	31	43	54	67
240	14	23	30	41	52	65

Source : *Research result (2021)*

The table above is the result of the calculation of rainfall intensity analysis with intervals of 2 years to 100 years.

4.3 Flood Discharge Analysis

Flood Hydrograph Rational Modification Method

A 10-year return period of 10-year return period flood discharge analysis is used with the following planning data:

1) Size of the catchment area (A) = 16,19 ha = 0,1619 km^2
2) Flow Coefficient (C) = 0,40
3) Start time (t_o) = 10 minute

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4) Channel Length (L) = 1430 m

5) Rain plans on return periods 10 years (R_t) = 215 mm/day

6) The difference between the upstream altitude and the study location (ΔH) = 0,6 mm

Calculation:

a). Average flow rate:

$$V = 72\left(\frac{\Delta H}{L}\right)^{0,6} = 72\left(\frac{0,6}{1.430}\right)^{0,6} = 0.67 \text{ m/sec}$$

b). Flow time along the river:

$$t_d = \frac{L}{60V} = \frac{1.430}{60 \times 0,67} = 35 \text{ minute}$$

c). Concentration Time

$$t_c = t_o + t_d = 10 + 35 = 45 \text{ minute}$$

d). Deviation coefficient

$$C_s = \frac{2t_c}{2\,t_c + t_d} = \frac{2 \times 45}{(2 \times 45) + 35} = 0,72$$

e). Deviation coefficient:

$$I_t = \frac{R_t}{24} \times \left(\frac{24}{t}\right)^{2/3} = \frac{215}{24} \times \left(\frac{24 \times 60}{45}\right)^{2/3} = 90 \text{ mm/hour}$$

f). Incoming water discharge

$$Q_{in} = 0,278 \times C \times C_s \times I_t \times A$$

$$= 0,278 \times 0,40 \times 0,72 \times 90 \times 0,1619 = 1,16 m/\text{sec}$$

1. Calculation of retention pond volume and pump capacity:
   a. Flow time along the river (t_d) = 35 minute
   b. Concentration time (t_c) = 45 minute
   c. Rain plan for 10 year return period (R_t) = 215 mm/day
   d. Rain intensity (I) = 137 mm/hour
   e. Incoming water discharge (Q_{in}) = 1,16 m^3/sec
2. The cumulative inflow volume calculation from the graph above is as follows:

Table 8. Cumulative Flow Q_{in} Dimensions t_c

Cumulative time(minute)	Inflow (m^3/sec)	AverageInflow (m^3/sec)	At	Volume (m3)	Cumulative volume 1 (m^3)
10	0.31	0.16	600	93	93
20	0.55	0.43	600	258	351
30	0.81	0.68	600	408	759
40	1.1	0.96	600	573	1332
45	1.23	1.17	600	699	2031
50	1.15	1.19	600	714	2745
60	0.99	1.07	600	642	3387
70	0.79	0.89	600	534	3921

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80	0.71	0.75	600	450	4371
90	0.51	0.61	600	366	4737
100	0.29	0.40	600	240	4977
110	0.21	0.25	600	150	5127
120	0	0.11	600	63	5190
130	0	0.00	600	0	5190

Source : *Research result (2021)*

Example Calculation table above:

a. Data taken from 45 minutes

rInflow $= \frac{Inflow + Inflow}{2} = \frac{1.10 + 1.23}{2}$ = 1.17 m^3/sec

b. V = r inflow x At

= 1.17 x 600 = 699 m^3

c. KV = KV + V

= 1332+ 699 = 2031 m^3

3. Calculation of critical inflow capacity by trying (trial & error) hydrograph model of critical retention pond conditions t_e>t_c

Tired : return periods 10 yearswitht_c = 60 minutes, i = 80 mm/hour.

$C_s = \frac{2t_c}{2\,t_c + t_d} = \frac{2 \, x \, 60}{(2 \, x \, 60) + 35}$ = 0,77

$Q_{in'}$ = 0,278 C.C_s.i.A

= 0,278 x 0,40 x 0,77 x 80 x 0,1619 = 1,10m^3/sec

The cumulative calculation of the inlet volume from the graph above is as follows :

Table 9. Cumulative Inflow Volume Q_{in}dimensionst_cCritical

Cumulative Time (Minute)	Inflow (m3/Sec)	Average inflow (m3/Sec)	At	Volume (m3)	Cumulative volume 1 (m3)
0	0				
10	0.29	0.15	600	87	87
20	0.5	0.40	600	237	324
30	0.72	0.61	600	366	690
40	1.01	0.87	600	519	1209
45	1.1	1.06	600	633	1842
50	1.12	1.11	600	666	2508
60	1.1	1.11	600	666	3174
70	0.99	1.05	600	627	3801
80	0.94	0.97	600	579	4380
90	0.8	0.87	600	522	4902
100	0.68	0.74	600	444	5346
110	0.65	0.67	600	399	5745
120	0.4	0.53	600	315	6060
130	0.31	0.36	600	213	6273

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140	0.21	0.26	600	156	6429
150	0.1	0.16	600	93	6522
155	0	0.05	600	30	6552
160	0	0.00	600	0	6552

Source : *Research result (2021)*

Example Calculation table above:

d. Data taken from 45 minutes

rinflow = $\frac{inflow + inflow}{2}$ = $\frac{1.10 + 1.01}{2}$ = 1.06 m^3/sec

a. V = r inflow x At

= 1.06 x 600 = 633 m^3

b. KV = KV + V

= 1209+ 633 = 1842 m^3

4.4 Pool Infiltration Capacity

1. Retention Pool Volume

The dimensions of the retention pond are planned as follows:

A1 = 2000 m

A2 = 1000 m

H = 4,5

From the data above, the dimensions of the retention pool will be calculated:

V $= \frac{1}{2}$ x $(A_1 + A_2)$. H

V $= \frac{1}{2}$ x (2000 + 1000). 4,5 = 6750 m^3

So the capacity of the retention pond is sufficient because the dimensions of the retention pond are larger than the volume of the retention pond capacity when the flood is 6750m^3>6447m^3

2. Infiltration

The retention pond is planned in the downstream area of the residential river with a pool area of 50 x 40 meters and a depth of 4.5 m. The bottom condition of the pond is saturated because it is always inundated by water, so the infiltration rate that occurs in the pond is a constant infiltration rate (fc). Infiltration constant for loamy clay is 0.5 m/day

Fc = 0,5 m/day = $\frac{0,5}{24}$ = 0,02083 m/hour

The rate of infiltration volume that occurs at the bottom of the pond:

V = fc x A pool

V = 0,02083 x 8631,4695 = 179 $m^3/hour$

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Volume below threshold:

V $= \frac{1}{2}$ x $(A_1 + A_2)$. H. pool length

V $= \frac{1}{2}$ x (39,1128 + 34,5158)x 4,5 x 50 = 8283,21m^3

Infiltration Time:

V = v x t

T = v/v

= 8283,21 /179 = 46 hour

Within 46 hours the water from the retention pond has seeped into the ground.

5. Conclusion and Suggestion

5.1 Conclusion

The capacity of the retention pond is sufficient, it can be seen from the dimensions of the larger retention pond that the volume of the retention pond capacity when the flood is 6750m^3>6447m^3. The retention pond is planned in the downstream area of the residential river with a pool area of 50 x 40 meters and a depth of 4.5 m. The bottom condition of the pond is saturated because it is always inundated by water, so the infiltration rate that occurs in the pond is a constant infiltration rate (fc). The constant infiltration for clayey soil type is 0.5 m/day, the infiltration volume rate that occurs at the bottom of the pond is 179 m^3/hour, the volume is below the threshold 8283.21 m^3, infiltration time is 46 hours.

5.2 Suggestion

Some suggestions that can be submitted after this research is carried out are:

1. There needs to be serious handling of conditions where the main channel at the location is smaller than the discharge that must be accepted.
2. It takes awareness to protect the environment from local residents. One of them is not to throw garbage in channels that should be crossed by water.

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