The Integration of Retention Pond and Composite Sluice in Flood Prevention in Makassar City

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Abstract. In 2018, Badan Pengkajian dan Penerapan Teknologi (BPPT) has developed composite sluice for controlling flood goals. The integration of retention pond and composite sluice deemed necessary to be analyzed as the integrated system as a flood disaster mitigation effort. This study aims to give a brief overview of the suitable retention pond capacity, which is integrating with composite sluice as a flood prevention effort. The retention pond designed in this study requires rainfall data, land use data and topography map. This study method uses empirical formulation based on statistical parametric on hydrology analyze and hydraulic analyze as a basis of retention pond capacity calculation and composite sluice as flood controller. The result of this study are; the maximum flood discharge in 10 years return period is 103,28 m³/s, while the riverbed discharge capacity with 8 meters width is 68,29 m³/s. To prevent flooding the retention pond volume with capacity volume in 1,117,214,24 m³ has required. In sluice practical width calculation for the retention pond, the resulting amount is 28,70 meters. It takes 32 units of composite sluice if the current needs to be maintained. The side composite sluice width has obtained 1 meter while the total composite sluice building width with four units for the retention pond is 6,4 meters.

1. Introduction

The tidal flood that hit the city of Makassar in the earlier 2019 in Bung Permai Housing Tamalanrea districts has caused around 400 families to flee. The wave was the worst since the last 20 years and inundated hundreds of home in the housing. As the flood control efforts in Makassar City, canals have been built that divide the city from Paotere in North to Mariso in west and branch in the middle to Tallo River through Pampang River. The most critical flood mitigation facility in Makassar City is the existence of two large rivers, namely Tallo River which empties in the north of the city, and Jeneberang River which leaves in the west of the town. The problem that seen nowadays is when the dry season comes, Tallo River is classified shallow and contains brackish water that feels around the PLTU.

Conversely, when the rainy season begins, the water tends to be turbid containing erosion deposits (Arifuddin et al., 2013). Tamalanrea District includes in the Medium Inundation Zone (Rudyanto et al., 2015). Based on the leading causes of flooding, retention ponds are deeming necessary to be built to temporarily accommodate flood water then streamed back to the sea after flood peak has passed. At the same time, the composite sluice is considered useful in dealing with the tidal flood that enters the river in the study area. Composite sluice system that can self-open when receding and self-close when the tide has flooding overcome occurs. In 2018, Badan Pengkajian dan Penerapan Teknologi (BPPT) had developed composite sluice for tidal flood controlling in Pekalongan City. The formulation of the problem in this study is the suitable retention pond capacity to accommodate potential flooding in the ponded area by integrating the composite sluice into the pond to give a brief description of the...
requirement for the function and width of the composite sluice. This study aims to provide a brief overview of the suitable retention pond capacity, which is integrating with composite sluice as a flood prevention effort. The limitation of the problem in this study is: (a). The rainfall data used is from the office of Balai Besar Wilayah Sungai Jeneberang, in the form of rainfall data from 1997 to 2016 with a data length of 20 years, (b). The area of the research site is limited to the catchment area with affected flooding Bung Permai housing and its surrounding in the research. It is namely Sub-DAS Bung Permai. Then, the pattern of analysis is reviewing into terms of hydrology and hydraulics (the geometry of the building) without a review of the embankment strength of the soil structure, economic aspect. It also only a trapezoid-shaped cross-section of simplifying the calculation.

![Figure 1. Research Site (Sub-WS Bung Permai)](image)

2. Research Method

Based on the Makassar City watershed (WS) maps (source: website Geoportal Bappeda Kota Makassar). WS Tallo located between WS Jongaya and WS Bone Tanjore. Bung Permai housing located in di Tamalanrea District, included in WS Tallo. Sub-WS is determined based on UU No. 7 of 2004, which states that a watershed is a land area. It is an integral part of the river and its tributaries. And also, serves to store and drain water that comes from rainfall into lakes or the sea naturally, the boundary on land is the topographic separator and the limit in the sea to the waters that are still affected by land activities. Sub-WS which includes Bung Permai Housing can see on the following map with a scale of 1:500 shown by the yellow line with an area of 6,07 km2, and the length of the main river through which is 6,9 km. Rainfall data used in this study is the data of the maximum hourly rainfall obtained from the BBWS Pompengan Jeneberang Panakkukang Station from the year 1997 to 2016 (20 years). Makassar's topography around the Sub-WS generally shows a dark green colour which is located at an altitude of 0 to 10 meters above the sea (source: topography map of Makassar City, RBI Bakosurtanal, 1999).

3. Results and Discussion

**Calculates the maximum average rainfall**

The Maximum average rainfall are calculating by using Maximum Annual Series Method. Maximum annual series method calculation processed by taking one maximum data each year from the average of rain gauge.
Frequency analysis and the suitable distribution method selection.

After frequency analysis, a suitable distribution is chosen and the following frequency analysis is the result of determination of distribution type. From table below, then the Gumbel type I and Pearson Log type III Distribution Method are chosen before it tested on the Chi Square Method.

### Table I. The Maximum Average Rainfall

| Year | Daily Rainfall (mm) | Year | Daily Rainfall (mm) |
|------|---------------------|------|---------------------|
| 1997 | 91                  | 2007 | 97                  |
| 1998 | 103                 | 2008 | 181                 |
| 1999 | 235                 | 2009 | 113                 |
| 2000 | 376                 | 2010 | 91                  |
| 2001 | 200                 | 2011 | 217                 |
| 2002 | 161                 | 2012 | 115                 |
| 2003 | 210                 | 2013 | 193                 |
| 2004 | 128                 | 2014 | 135                 |
| 2005 | 141                 | 2015 | 139                 |
| 2006 | 110                 | 2016 | 142                 |
| MAX AVERAGE RAINFALL | 175.5               |

### Table II. Distribution Selection Requirements

| No. | DISTRIBUTION | REQUIREMENTS | CALCULATION RESULTS | INFORMATION |
|-----|--------------|--------------|---------------------|-------------|
| 1   | NORMAL LOG   | CS = 0.00    | CS = 0.735          | UNFULFILL   |
|     |              | CK = 3.00    | CK = 0.416          | UNFULFILL   |
| 2   | NORMAL       | CS = CV3 + 3CV | CS = 1,823       | UNFULFILL   |
|     |              | CK = CV8 + 6CV6 + 15CV4 + 16CV2 + 3 | CK = 4,521 | UNFULFILL   |
| 3   | GUMBEL type I| CS = 1.396   | CS = 1.823          | FULFILL     |
|     |              | CK = 5,4002  | CK = 4,521          | FULFILL     |
| 4   | Pearson Log type III | CS = 0.000 | CS = 0,735          | FULFILL     |

**Source:** Triatmodjo, 2008

Chi Square for selecting the suitable distribution

In Chi-Square Test previously determined the number of classes, which is $C = 5,32 \approx 5$. Degree of Freedom (DF) is 4. The Expected Value (Ei) for 20 years is 4, and the interval class is 0.12. The requirement for acceptable distribution is Chi Square Calculation ($X_h^2$) < Critical Chi Square ($X_h^2_{cr}$). From the distribution match test, Gumbel Method did not meet the requirement so that the Pearson Log type III was chosen.
From the table III the Chi Square Value is obtained in 6.50. On Degree of Freedom (DF) 4, Critical Chi Square value at the 5% significance level is 9.49. Thus the Pearson Log type III distribution can be accepted.

### Table III. Chi Square Method

| NO | Px  | E1  | O1 | O1 - E1 | (O1 - E1)^2 / E1 |
|----|-----|-----|----|---------|------------------|
| 1  | 1.96 - 2.08 | 4.00 | 7.00 | 3.00 | 9.00 | 2.25 |
| 2  | 2.08 - 2.20 | 4.00 | 6.00 | 2.00 | 4.00 | 1.00 |
| 3  | 2.20 - 2.32 | 4.00 | 4.00 | 0.00 | 0.00 | 0.00 |
| 4  | 2.32 - 2.44 | 4.00 | 2.00 | -2.00 | 4.00 | 1.00 |
| 5  | 2.44 - 2.56 | 4.00 | 1.00 | -3.00 | 9.00 | 2.25 |
|    | 20.00 | 20.00 | 0.00 | 26.00 | 6.50 |

### Table IV. Rain Plan based on the return period

| T  | GT | YR | R plan |
|----|----|----|--------|
| 2  | 0.195 | 2.14 | 137.78 |
| 5  | 0.732 | 2.29 | 194.21 |
| 10 | 1.340 | 2.39 | 243.26 |
| 25 | 2.087 | 2.51 | 320.78 |
| 50 | 2.626 | 2.59 | 391.65 |
| 100 | 0.149 | 2.19 | 156.50 |

### Rainfall Intensity Calculation

Rain intensity analysis calculation uses the Mononobe Method with a 5 hour rain duration. The equation used is:

\[ I = \frac{R_{24}}{24} \times \left( \frac{R_{24}}{t} \right)^{\frac{2}{3}} \]

which; \( I \) = rainfall intensity (mm/hr), \( t \) = rainfall time (hours) and \( R_{24} \) = daily maximum rainfall for 24 hours (mm).

### Table V. Rainfall Intensity Intensitas 5 hr duration

| DURATION (hr) | MAXIMUM RAINFALL 24 HR (R24) |
|---------------|-------------------------------|
|               | 2 5 10 25 50 100             |
| 1             | 137.78 194.21 243.26 320.78 391.65 156.50 |
| 2             | 80.57 113.58 142.26 187.59 229.04 91.52 |
| 3             | 50.76 71.55 89.62 118.18 118.18 57.65 |
| 4             | 38.74 54.60 68.39 90.18 110.11 44.00 |
| 5             | 31.98 45.07 56.45 74.45 90.89 36.32 |

Figure 2. Rainfall Intensity (return period)
Calculation of flood discharge plan using the Nakayasu Method

Concentration Time (tc) Calculation using Kirpich Method:

\[ t_c = \frac{0.06628L^{0.77}}{S^{0.385}} \]

which; \( L \) = is the length of watercourse which is 6.9 Km, \( S \) = the mean slope of the riverbed which is 0.322%. The result of Concentration Time calculation is 92,628 minutes.

Hydrograph Theory

As known before, Sub-WS area of Bung Permai Housing are 6.07 km². Because river cross length (L)< 15 km, it is known that \( T_g = 0.21 \times L^{0.7} \) shows 0.81 hr. \( T_r = (0.5 - 1)T_g = 0.41 \) hr. \( T_p = T_g + 0.8 T_r = 1.14 \) hr. \( T_{0.3} = \alpha T_g = 2.44 \) hr. \( R_o = 1 \) hr. \( Q_p = A.R_o/3.6/(0.3 T_p + T_{0.3}) = 0.61 \) m³/s. Because the hydrograph section rises fast but decreases slowly, then \( \alpha = 3 \). Thus hydrograph description is as follows:

![Figure 3. Synthetic Hydrograph Units(Nakayasu)](image)

After obtaining rainfall intensity data from the area rainfall, the flood discharge plan of WS can be known using gamma 1 method. Here are the result of processing the rainfall intensity data into the flood discharge plan using Nakayasu Method.

| Table 6. River Capacity Calculation |
Figure 4. Total Hydrograph Discharge

Retention Pond Volume Calculation
River capacity of the downstream river in the planned reservoir has been calculated, in this case is the river cross sectional capacity of the study area.

Figure 5. The Planned retention pond behind the housing

Figure 6. River Cross Sectional

Capacity calculation of the location being reviewed uses the following Manning Method:

\[ Q = \frac{1}{n} \times S^{1/2} \times R^{2/3} \times A \]

Which:  
- \( Q \) = Discharge capacity (m³/s)  
- \( n \) = Manning Roughness Coefficient  
- \( n_{\text{base channel}} = 0.030 \) (ground)  
- \( n_{\text{channel wall}} = 0.025 \) (installed bricks)
To know the amount of water volume, which required to store in the retention pond, the comparison between flow discharge and river capacity is needed.

Planned by the retention pond without a pump then the maximum water level of the pool = maximum water level in the channel so that the depth (H) of the retention pond is taken in 2 meters. The retention pond area is adjusted to the needs of the storage volume. Storage pool dimension has sloping wall in 1:2. then the planned pool area has predicted by land plotted on the location map.

![Figure 7. River capacity calculation in ponded area and air level](image)

![Figure 8. Flow discharge vs river capacity](image)

![Figure 9. Planned Location of Retention Pond](image)
The planned pool capacity can be determined by comparing the relationship between water level (H) and cumulative storage (Scum).

![Figure 10](image)

**Figure 10.** (a) H vs Scum, (b) Relationship of H-Scum

**Composite Sluice Width Requirement Analysis**

One of the advantages of composite sluice is being customized, which means that the sluice's width can be adjusted into the retention pond requirements. This research uses Romijn Sluice Formulation as the basis to make the calculation and adjusted by the maximum discharge which has flown into the retention pond. The maximum discharge is 68.29 m³/s. To determine the dimensions of the sluice previously estimate the width of the right flood divide building. The Effective Width of Romijn Sluice (Kriteria Perencanaan, (KP-08), 2013) is:

\[
Q = Cd \times Cv \times \left(\frac{2}{3}\sqrt{\frac{2}{3g}}\right) \times B \times h1^{1.5}
\]

Where:
- \( Q \) = Flood discharge = 68.29 m³/s
- \( Cd = 0.958 \) (Aditya Prihantoko, et al, 2015)
- \( Cv = \) Inlet Velocity Coefficient = \( Cd \times A'/A1 = Cd \times \left(\frac{B \times h1}{B \times (h1+0.5)}\right) = Cd \times \frac{h1}{h1+0.5} \)
- \( g = \) Acceleration of Gravity = 9.81 m²/s²
- \( B = \) Sluice Effective Width (m)
- \( h1 = \) Table Energy Height (m)
- \( h1 = \) Upstream Table Energy Height (m) = \( H1 - \frac{V12}{2g} \)

The result \( B = 28.70 \) m.

**Table 7. Composite sluice effective width calculation**

| \( V \) | \( VV2/g \) | \( g \) | \( H1 \) | \( h1 \) | \( Cd \) | \( Cv \) | \( B \) | \( Q \) |
|------|----------|------|------|------|------|------|------|------|
| 2.85 | 0.41     | 9.81 | 2.00 | 1.59 | 0.96 | 0.73 | 28.70 | 118.29|
| 2.60 | 0.35     | 9.81 | 1.75 | 1.40 | 0.96 | 0.71 | 28.70 | 95.48 |
| 2.35 | 0.28     | 9.81 | 1.50 | 1.22 | 0.96 | 0.68 | 28.70 | 74.20 |
| 2.08 | 0.22     | 9.81 | 1.25 | 1.03 | 0.96 | 0.64 | 28.70 | 54.67 |
| 1.79 | 0.16     | 9.81 | 1.00 | 0.84 | 0.96 | 0.60 | 28.70 | 37.21 |
| 1.48 | 0.11     | 9.81 | 0.75 | 0.64 | 0.96 | 0.54 | 28.70 | 22.24 |
| 1.13 | 0.07     | 9.81 | 0.50 | 0.43 | 0.96 | 0.45 | 28.70 | 10.38 |
| 0.71 | 0.03     | 9.81 | 0.25 | 0.22 | 0.96 | 0.30 | 28.70 | 2.56  |
| 0.00 | 0.00     | 9.81 | 0.00 | 0.00 | 0.958| 0.00 | 28.70 | 0.00  |
Total Width of composite sluice
The composite sluice has installed in Pekalongan City and has 90 cm width (0.9 m), and assumed in this research as the effective of sluice width. By the 5 meter of river width, the total installed of composite sluices are 2 units (2 x 0.9 = 1.8 meter). For B = 28.70 meter, then total installed of composite sluices should be 32 units. This is ineffective. That is why all the composite sluices must be calculated at the same time:
1. The planned of each composite sluice width:
   \[bp = Be + (Kp + Ka)\]
   \[H_{max}\], which:
   \[Be = 0.9 m; Kp = 0.01; Ka = Abutment coefficient = 0.1; H_{max} = 2 m; \]
   \[bp = 0.9 + (0.01 + 0.1) \times 2 = 1.12 m; \]
   \[taken \ bp = 1.0 m. \]
   From the width of each sluice's calculation, \(br = 1.0 m\) is taken.

2. Total Composite Sluice Building's Width:
   \[Br = N \times br + \Sigma t + \Sigma b\]
   \[Br = Total Composite Sluice Building's Width; N = amount of sluice = 4 units; bp = each\]
   composite sluice width = 1.0 m; \(\Sigma t = Pillar width = 0.8 m; \Sigma b = Abutment width = 2 \times 0.8 = 1.6 m; \]
   \[then: \ Bb = N \times br + \Sigma t + \Sigma b = 4 \times 1.0 + 0.8 + 1.6 = 6.4 m\]

4. Conclusion

Conclusion
Based on the analyses and discussion about the integration of recognition pond and composite sluice in flood prevention in Makassar City's results, the following conclusions will explain as follow with:
1. capacity with 8 meters width is 68,29 m³/s. To prevent flooding the retention pond volume with function around 1.117.214,24 m³ has required.
2. The composite conduit is customized (can be adjusted with the retention pond building condition).
   The existing composite sluice made in 90 centimeters width. In sluice practical width calculation for the retention pond, the resulting amount is 28,70 m, so it takes 32 units of composite sluice if the existing composite sluice needs to maintain.
3. The side composite sluice width has obtained 1 m while the total composite sluice building width with four units for the retention pond is 6.4 m.

Suggestion
Based on the conclusions of planned retention pond which the composite sluice has been integrated inside, some suggestions to be put forward are:
1. By the sluice effective 28,70 meters and the available land are quite enough, the proper retention pond to be installed is the type of riverside pond. This type advantages are there will be no disruption to the existing flow systems, easy in operational and maintenance.
2. To keep the capacity volume at 1.117.214,24 m³, redesign of width and the length of the retention pool needs to be considered to store the 10 years return period flooding.
3. The installed composite sluice into retention pond can be calculated as an inlet or outlet.
4. To keep the effective of composite sluice width in 28,70 m, the breakthrough design for the model is required by further calculating the building strength and aesthetic to be able to give the value-added for the existence of the retention pond, in addition to its effectiveness and efficiency in flood prevention. The value-added maybe from the tourism aspects which can increase the local community's economy.
5. Further calculation still requires to analyze the stability of retention pond slope, the wall reinforcement, horizontal and vertical forces and moments, gravity wall test (rolling and sliding), sluice design, sluice horizontal-vertical profile design, total sluice weight, pillar and abutment design, review to the rolling-sliding-eccentricity-soil bearing capacity, pillar dimension control and calculation of the other supporting construction such as riverside spillway, access road to the retention pond, low threshold in front of outlet sluice, trash filter and sediment catcher pool.
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