Hydrological analysis of moveable weir planning for tidal flood handling in Cilacap, Central Java

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Abstract. Global warming resulting in climate change has become a new disaster in the world. One of the changes in climate is the rise of sea water to land surface, which causes tidal flooding. One area that experienced tidal flooding was Kawunganten District, Cilacap, Central Java Province. The area is traversed by the Parit River with the river estuary located in Ujungmanik Village. The problem of tidal flooding in Kawunganten District can be overcome by constructing a moveable weir in the estuary of the Parit River. In planning on the moveable weir, a hydrological analysis is needed to determine the flood discharge plan. Rainfall data used as a basis for calculation of flood discharge at the study site is rainfall data from 3 observation stations namely Cilacap Station, Majenang Station and Ujungbarang Station with the recording period from 2009 to 2018. Calculation of rainfall plan is done using the Pearson Log Method III with a value of $T_{100} = 165.463$ mm. The results of the calculation of the flood discharge plan with the hapers method $Q_{100} = 280.989$ m$^3$/sec, while the weduwen method $Q_{100} = 132.804$ m$^3$/sec and the HSS Nakayasu method $Q_{100} = 102.444$. Furthermore, an analysis of tides on the coast of Cilacap Regency with the results of MWL (Mean Water Level) = 110 cm, LWL (Low Water Level) = 20 cm, HWL (High Water Level) = 220 cm.

1. Introduction
Global warming followed by climate change has become a new disaster in the world. One of the impact of climate change is the rise of sea water to land surface [1]. Cilacap Regency is one of the regions in Central Java, which is located in the southern coastal region bordering the Indonesian Ocean. The topography of Cilacap Regency has caused frequent flooding due to tidal flooding [2]. One of the areas that experienced flooding in Cilacap Regency was Kawunganten District. Most areas in Kawunganten Regency are dominated by lowlands, which results in frequent flooding. Floods that occur due to sea level rise. Tidal floods occur in areas directly adjacent to mangrove forests and are still affected by tides with intensity of 2-3 times a month. The floods occurred because of the high discharge and abundant water supply from the upstream of the Cibereum River and the Kawunganten River which empties into the Parit River with the river estuary located in Ujungmanik village. Parit River has a length of approximately 7 km from the downstream of Segoro Anakan, which is one of the rivers that are prone to flooding in Cilacap Regency. In early 2017, floods in the Parit river occurred several times which resulted in a flood retaining embankment bursting so that the water overflowed to the residents' housing which caused considerable losses to the people living around the Parit river.
The problem of tidal flooding in Kawunganten District can be overcome by constructing a moveable weir in the estuary of the Parit River. A moveable weir is a weir construction with a gate that can be moved to contain and drain the air, so as to minimize the increase in flooding [3]. The availability of the moveable weir is expected to reduce flooding in the Kawunganten District and surrounding areas. Tidal flood control planning in a watershed can be done well if the flood discharge plan is known [4]. Therefore, a hydrological analysis is needed for the study of the planned flood discharge in the watershed area and an analysis of the capacity of the Parit river [5]. Where the river hydraulics analysis is intended to analyze the profile of flood water levels in the Parit river with various times from the planned flood discharge.

![Figure 1. Map of Ujungmanik village (Google Earth, 2019)](image1)

This research was conducted at the estuary of the Grugu river and the Parit river sub-watershed Cikonde and Sapuragel watershed in Ujungmanik Village, Kawunganten District, Cilacap Regency, Central Java, with a coordinate position of 070 38' 48.9912" S and 1080 57' 2.0124" E. To go to the study site reached by land. It takes about 1 hour as far as ± 26 Km from Cilacap City to get to the project site by 2 or 4 wheeled vehicles. Whereas from Kawunganten District it can be reached for 15 minutes as far as ± 7.3 km or from the Kubangkangkung highway entering as far as + 3, 0 km to the south up to Ujungmanik Village.

![Figure 2. Inventory map of the drainage and irrigation river network (Google Earth, 2019)](image2)
2. Literature review

2.1. Hydrological analysis
Hydrological data is a collection of information or facts about hydrological phenomena, such as the amount: rainfall, temperature, evaporation, duration of solar radiation, wind speed, river discharge, river water level, flow velocity, river sediment concentration will always change with respect to time [6].

2.2. Watershed (DAS)
The watershed is determined based on the topography of the area, where the watershed is an area bounded by ridges between two rivers to the river being observed [7]. On the topographic map, it can be determined how to make imaginary lines connecting the points that have the highest contour elevation on the left and right of the river being observed. To determine the area of a watershed a planimeter can be used [8].

2.3. Tide water resources management
Tides are periodic sea level rise and fall caused by the attraction of celestial bodies, especially the moon and the sun against the mass of water on earth in a certain time. Management of water resources is an effort to deal with securing coastal areas due to global climate change [9].

3. Research method
This study uses a quantitative research methodology with detailed, systematic, structured calculations. The data in this study include primary data and secondary data. Primary data obtained by surveys and observations that include bathymetry surveys, tidal measurement surveys, river flow velocity measurements and sedimentation surveys. Secondary data was obtained from the BBWS agency (Balai Besar Sungai Serayu Region) that include rainfall data, evapotranspiration, temperature, wind speed, air humidity, topographic maps, geological maps. Based on these data, a hydrological analysis is then performed which covers: the determination of the Watershed (DAS) and the determination of the rain gauge station using the Thiessen Polygon Method. Then calculating the maximum rainfall, analyzing the return period of the T rainfall year plan and calculating the flood discharge plan based on the amount rainfall plan, calculation of flood discharge and rainfall intensity.

The steps to be taken in the hydrological analysis of the design of Parit river movable Weir are:
1. Hydrological analysis of the calculation of the rainfall plan and flood discharge plan for the tides.
2. Hydraulic analysis simulation using the HEC-RAS program to obtain flood water levels and tides.

Based on the background description, the formulation of the problems that will be discussed in this study are as follows:
1. Hydrological analysis uses maximum daily rainfall data for 10 years.
2. Time period at Q5, Q10, Q50, Q100 years.
3. Simulation of hydraulic analysis using the HEC-RAS program to obtain flood water levels.

4. Results and discussion

4.1. Watershed (DAS) calculation
The Watershed (DAS) is an area where all water flows into the destination river. Calculation of the area of influence of rain stations on watersheds (DAS) consists of three stations, namely Cilacap Station, Majenang Station, Ujungbarang Station.
The following table are the results of calculations using the Thiessen Polygon Method on the Topographic map of the Parit River rain station which has an influence on the Sapuregel and DAS Cikonde Sub Watershed.

**Table 1. Extent of rain station influence on watershed**

| No | Rainfall Station | Percentage (%) | DAS Area (km²) |
|----|------------------|----------------|---------------|
| A1 | Sta Cilacap      | 25.54%         | 7             |
| A2 | Sta Majenang     | 21.89%         | 6             |
| A3 | Sta Ujungbarang  | 52.55%         | 14.4          |
|    | Total            | 100%           | 27.4          |

4.2. Hydrology

4.2.1. Calculation of rainfall plan.
For the calculation of rainfall plans use 3 stations, namely: Cilacap station, Majenang Station, and Ujung Barang Station. After proven by the Thiessen Polygon Method on the topographic map of the Parit River, the station estuary which influences the Cikonde Sub-basin and Sapuregel Sub-basin.

The Parit River is the estuary of the Cibereum River and the Kawunganten River Cikonde and Sapuregel Sub-watersheds, which are affected by tides in Segoro Anakan, the length of the Parit River is approximately 7 km from the downstream of Segoro Anakan.

**Table 2. Maximum rainfall**

| Year | Cilacap Sta (mm) | Majenang Sta (mm) | Ujungbarang Sta (mm) |
|------|------------------|-------------------|----------------------|
| 2009 | 166              | 124               | 90                   |
| 2010 | 135              | 172               | 113                  |
| 2011 | 135              | 44                | 96                   |
| 2012 | 124              | 49                | 90                   |
| 2013 | 97               | 48                | 87                   |
| 2014 | 194              | 78                | 104                  |
| 2015 | 132              | 91                | 145                  |
| 2016 | 181              | 99                | 110                  |
| 2017 | 180              | 118               | 123                  |
| 2018 | 173              | 148               | 128                  |
Calculation of rainfall plans using probability distribution namely Gumbel Probability Distribution, Log Normal Probability Distribution and Log Person Type III Probability Distribution.

Table 3. Calculation results of rainfall plans

| No. | Periode Repeated (Year) | Gumbel I (mm) | Log Normal (mm) | Log Pearson Tipe III (mm) |
|-----|------------------------|---------------|-----------------|--------------------------|
| 1   | 2                      | 1,141,657     | 1,123,572       | 117,959                  |
| 2   | 5                      | 1,397,087     | 1,307,634       | 140,090                  |
| 3   | 10                     | 1,566,204     | 1,440,330       | 149,801                  |
| 4   | 20                     | 1,728,425     | 1,575,166       | 157,227                  |
| 5   | 25                     | 1,779,884     | 1,620,111       | 158,756                  |
| 6   | 50                     | 1,938,403     | 1,759,227       | 162,821                  |
| 7   | 100                    | 2,095,753     | 1,885,502       | 165,463                  |

4.2.2. Calculation of flood discharge plan

Plan flood discharge is the maximum flood discharge from a river or channel whose amount is based on a certain return period [10]. Flood discharge plan, used as a basis in planning a hydraulic building with the aim that the planned building is able to receive the amount of flooding that is likely to occur in the planned return period. In analyzing the flood discharge the plan will use 3 methods namely Haspers Method, Weduwen Method, and Nakayasu Synthetic Unit Hydrograph Method.

Table 4. Recapitulation of flood discharge plans

| Design Flood Discharge (m³/d) | Hasper | Weduwen | Nakayasu |
|-------------------------------|--------|---------|----------|
| Q 2 Th                        | 200,317| 83,727  | 61,603   |
| Q 5 Th                        | 237,900| 105,917 | 80,413   |
| Q 10 Th                       | 254,392| 115,975 | 88,892   |
| Q 20 Th                       | 267,002| 123,908 | 95,458   |
| Q 25 Th                       | 269,599| 125,606 | 96,818   |
| Q 50 Th                       | 279,502| 129,999 | 100,444  |
| Q 100 Th                      | 280,989| 132,804 | 102,817  |
4.2.3. Tidal of sea water analysis
Calculation of tidal phenomena using tide data belonging to PT (Pelindo III) Tanjung Intan Indonesia III Port Cilacap, Central Java. The mixed tidal type tends to a single daily (Mix Tide Prevailing Semidiurnal), with an average height of sea level ranging from 110 cm, the lowest tide of 20 cm and the highest tide of 220 cm.

4.3. Analysis of HEC-RAS water flooding weir
Depend on the trials using the Hec-Ras software to calculate flood simulations of the tidal plan with the Synthetic Unit Hydrograph (HSS) method of Nakayasu Q100 = 102,817 m³/s. Tidal flood simulations using the HEC-RAS program obtained Flood Water level (MAB) +4.35 m, Normal Water Level (MAN) elevation +2.20, Low Water Level (MAR) +0.20. Then obtained the water level in the downstream of the weir + 4.55 m.

Figure 4. Flood hydrograph syintetic unit nakayasu (HSS nakayasu)

Figure 5. Long profile of HEC-RAS analysis result
5. Conclusions and recommendations

5.1. Conclusions
Based on the results of the analysis, it can be concluded as follows:
1. The results of the hydrological analysis of the planned rainfall as the basis for tidal flood treatment are used in the Repeat Period with the Gumbel Method $T_{100} = 2,095,753\text{ mm}$, the Normal Log Method $T_{100} = 1,885,502\text{ mm}$, the Pearson III Log Method $T_{100} = 165,463\text{ mm}$. Calculation of rainfall plan is done using the Pearson Log Method III with a value of $T_{100} = 165.463\text{ mm}$. Calculation of flood discharge plan as a basis for handling flood tides using a 100 year return period.
   - The method used is the hapers method, the Wesuwen method and the Nakayasu HSS method. The results of the calculation of the flood discharge plan with the hapers method $Q_{100} = 280.989\text{ m}^3/\text{sec}$, while the weduwen method $Q_{100} = 132.804\text{ m}^3/\text{sec}$ and the HSS Nakayasu method $Q_{100} = 102.444$.
   - From the three calculation results, the chosen flood discharge plan using the Nakayasu HSS method is the most appropriate for the conditions at the study site.
2. The results of tidal analysis on the coast of Cilacap Regency are included in the type of tidal mixture leaning to a single daily (Mix Tide Prevailing Semiidiurnal), the results of MWL (Mean Water Level) = 110 cm, LWL (Low Water Level) = 20 cm, HWL (High Water Level) = 220 cm.
3. Tidal flood simulation using the Hec-Ras program is obtained by the surface water flood (MAB) +4.35 m elvation and the normal water surface elevation (MAN) +2.20

5.2. Recommendations
The recommendations that can be submitted are as follows:
1. Need to build a dike with a suitable height to deal with flooding in the river.
2. Routine maintenance needs to be done on the river such as cleaning grass and dredging the bottom of the channel because it can affect the storage capacity.

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