Study on Flood Simulation of Tallo Watershed, Makassar City, South Sulawesi Province

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Abstract. Tallo watershed has a length of 70 km, its area width is 407.00 km², the river upstream or downstream is at an altitude of ± 1,100 m above sea level located on Mount Kaliapolombo in which the overall length of the river in Tallo watershed totaling ± 131.50 km². The research objective was to analyze the effect of five-year flood discharge and tidal changes on the inundation area and flood depth in Tallo watershed. The method of rainfall analysis used the Log Pearson type III method where the flow is considered to be two horizontal dimensions with even velocity at each depth. A five-year period with a discharge value of 127.64 m³/s will statistically reoccur every five years with an estimated chance of occurrence of 0.2 or 20% for each year referred to in a 5-year review cycle. The results of the simulation were then known that the five-year flood discharge resulted in flooding with a depth of 0-3 meters from the maximum tide condition (HWSL), and an inundation area of 31.91 km² inundated the Tallo District, Tamalanrea District, Panakukang District, West Biringkanaya District and northern Manggala District. These areas are located on the left and right of the Tallo River with an altitude between 0 and 2 meters above sea level.

Keywords: Flood, Surface Water Modelling, Tallo River

1. Introduction

As a city where most of its territory is a low-lying area, Makassar is an extremely potential area for flood. Flood hitting Makassar occurred in 1976, 1986, 1998/1999 and 2000; the peak of the flood usually occurred in January - February. For flood in 2000, it inundated an area of 2,535.0 ha with a maximum water level of 1.5 m. Most of the land that was previously an area that functioned as green lines and water pockets has been converted. This development growth has triggered the emergence of new problems, namely ecosystem becomes imbalanced and the water catchment area becomes smaller and decreasing, so that most of the water is flowed directly to the river, especially Tallo River. Tallo Watershed (DPS) based on the Minister of Public Works Regulation No. 39/PRT/1989 concerning the Division of River Basins is included into the part of the River Basin Unit (SWS) 05.17 Jeneberang in which the Tallo River is as the main river which has a length of 70 km, the area is 407.00 km², the river upstream or downstream is at an altitude of ± 1,100 m above sea level located on Mount
Kaliapolompo with the overall length of the river in Tallo Watershed totaling ± 131.50 km² [1]. The damage caused by flood depends on factors that determine the important characteristics of the flood such as the magnitude of the flood discharge, the rate of the flow, and the duration of the flood. The occurrence of flood with the increasing intensity every year requires us to make greater efforts to anticipate it so that the losses incurred can be minimized. Flood is generally caused by three main factors, namely: natural conditions (static) in the form of geography, topography, and river flow geometry; natural events (dynamic) in the form of high rainfall, dam, subsidence and silting of the soil; human activities (dynamic) in the form of inappropriate spatial planning/designation of floodplain areas and so forth. Flood is also caused by rising water levels in river as a result of sea tides and rising sea waves due to storms. The flood is called river overflow flood which is mostly seasonal or annual and can last for days or weeks [2]. The Tallo Watershed System is the main cause in the formation of flood-prone areas in Makassar City, so that when the rain comes with an average of 592.54 mm/month, the Makassar City area which is included in the Watershed system forms flood, especially around the left and right sides of Tallo river [3]. This study aimed to make a simulation in determining the inundation area and flood depth along the Tallo Watershed in Makassar City by using the Surface Water Modeling System (SMS) program. It is a particular research that studies the characteristics of flood including the area of inundation and the depth of the flood and a simulation is made to see the possibility of these factors so that it can be used as a reference for flood control and development planning, especially in the riverside of the Tallo Watershed.

2. Theoretical Basis

2.1. Definition of River

River, according to the geological concept, is water that flows in channels (troughs, valleys) that it makes itself. According to this concept, "flowing water" is seen as a geological force that can change the shape, structure and position/location of rocks; therefore, it is regarding the change in lithology. According to the geomorphological concept, river is a trough or valley created by flowing water. According to this concept, the subject matter is the formation of troughs and/or valleys; namely concerning morphological and topographical changes [4]. The river has the function of collecting rainfall in a certain area and flowing it into the sea. It can also be used for various aspects such as electricity generation, shipping, tourism, fisheries, and others. In agriculture, it functions as an important water source for irrigation [5]. The longitudinal profile of a river, seen from the velocity of flow, erosion, deposition, and its morphological or topographic forms can be divided into three parts: Upstream (top); Middle part; Downstream (bottom). Drainage Basin (DPS) or Watershed (DAS) or catchment, basin, watershed is an area where all the water flows into a river. These areas are generally bounded by topographical boundaries, which means that they are defined based on surface water flows [5]. A watershed is an area where the precipitation concentrates into a river [6]. The adjacent watershed boundaries are called watershed boundaries. The area of the drainage is estimated by measuring the area on a topographic map. Watershed, topography, vegetation and geology have an effect on flood discharge, flood pattern, basic drainage discharge and so forth.

2.2 River Density

River density is an index that shows the number of tributaries in a watershed.

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\text{River density} = \frac{\text{Total length of main rivers and tributaries (km)}}{\text{Area of watershed (km}^2)}
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Usually, this value is in the range of 0.30 to 0.50 and is considered an index indicating the topography and the geology of the drainage area. The river density is small in permeable rock, on mountains and on slopes, but large for areas having a lot of rainfall.
2.3 Longitudinal River Gradients and Cross Section Patterns (Shape)

The curve showing the relation between the distance and the riverbed surface measured along a river starting from the estuary is called river profile. This profile gradually changes to a stable profile after erosion and sedimentation occurs in accordance with the influence of the river flow. The profile which has become stable in such a way is called balanced profile. The cross-sectional shape of the river varies according to the characteristics of the river bed rock, flow velocity, and so forth. In the upstream of mountainous areas, the riverbed is usually extremely steep and its cross section becomes a valley in V shape. In the middle stream of the river, the valley section is in U shape. In the alluvial zone of the river downstream, the cross section becomes a trapezoid in the straight and triangular in the bend. Generally, the cross-sectional shape of the river is rectangular and triangular.

2.4 Definition of Flood

The river water flow exceeding the normal water level that overflows from the riverbed causes inundation on the low land on the side of the river. The runoff is getting higher, flowing and overflowing the ground surface which is usually not passed through by waterflow [2]. For tropical countries, based on their water sources, the excess water can be categorized into three categories:
- Flood caused by heavy rain that exceeds the distribution capacity of the water drainage system consisting of a natural river system and a man-made drainage system;
- Flood caused by rising water levels in river as a result of high tides or rising sea waves due to storms;
- Flood caused by failure of man-made water structures such as dams, embankments, and flood control structures;
- Flood caused by failure of natural dams or blockage of river flow due to river bank collapse or landslide.

The occurring process of flood is caused by three factors, namely:
- Natural event factor (dynamic), which includes: high rainfall intensity, dam (from sea/tide and from main river), land subsidence and river silting.
- Natural condition factor (static), which includes; geographical condition, topography, river geometry (slope, sedimentation, natural overlay).
- Human activity factor (dynamic) such as: development in the floodplain, inappropriate spatial planning in the floodplain, spatial planning/land use in the watershed, settlements on riverbanks, garbage, limited flood control infrastructure, community misperception on flood. [2].

Flood area modeling is carried out with a computerized system for horizontal two-dimensional analysis of river hydraulics. This such system has also been carried out by the U.S. Army Corps of Engineers as a module of the TABS 2 model system, while for this study, the RMA-2 module was used which is part of the BOSS Surface Water Modeling System version 8.0 (SMS) [7]. This hydrodynamic program will calculate the water level elevation and water velocity for flow problems in shallow water, and also support steady state and dynamic flow. Several modifications have been done by the researchers from the Waterway Experiment Station (WES). RMA-2 is a two-dimensional modeling, evenly distributed, free surface, finite element program to solve hydrodynamic problems. The RMA-2 can be used to calculate water level elevation and flow velocity at nodal points in a finite element mesh, representing water bodies such as rivers, estuaries or harbors. RMA-2 supports both steady state and dynamic flow. In other words the boundary conditions (discharge, water level) can vary with time and
the solution can be determined in a number of time steps. The core program of the hydrodynamics software is suitable for the construction of large and complex meshes (numerical computation grids) (up to several thousand elements) which have arbitrary shapes. Simulation result data that contains water level elevation, flow velocity, at each node of the mesh can be read in this program for vector plots, color contour plots, time-changing curve plots, and dynamic animation.

3. Research Methodology
The research method used includes data collection, data processing, data analysis, and interpretation.

3.1 Data Collection
Data collection techniques done include: Literature study and field observations: river gradient measurements were carried out manually by using measuring tanks on the left and right banks and the middle of the river where the position of each measurement was obtained by using the Global Positioning System (GPS) then it was plotted on a base map. Current velocity measurements were carried out by using the buoy method on the left, right and middle of the river.

3.2 Data Processing
3.2.1 Primary Data. Primary data from field measurements in the form of gradient and current velocity were processed to determine the measured discharge value. The river gradient data collection points were then plotted on the base map with the gradient values of each data collection point then they were compared with topographic contours and contour intervals of 1 meter.

3.2.2 Secondary Data. 1) Rainfall; this rainfall data was processed to obtain flood discharge plans for 5 and 10 years by using statistical calculations with the Log Pearson type III method. The steps for processing rainfall data were as follows. The maximum daily rainfall data from each station used for further analysis were recapitulated, as were blank data (not recorded). In this case, a recapitulation was carried out for the maximum at one station as a reference and on the same day, then, the daily rainfall was sought for each station around it. 2) Tidal; It was used to determine the value of the highest tide (HWSL), the average tide (MLWS), the lowest tide (LWSL) and the highest and lowest tidal hoses (tidal range).

3.3 Data Analysis and Data Interpretation
After the required data coverage has been completed, then it was proceeded with the analysis of the inundation simulation model by using the Surface Water Modeling (SMS 8.0) program to determine fluctuations in water level changes during floods including inundation area, flood depth, and the relationship between 5 and 10 year flood discharge to tidal changes.

4. Results and Discussion
The Tallo Watershed based on the Minister of Public Works Regulation No. 39/PRT/1989 concerning the Division of River Basins including part of the River Basin Unit (SWS) 05.17 Jeneberang, in which the Tallo River as the main river having a length of 70 km, the area is 407.00 km$^2$, the river upstream or downstream is at an altitude of ± 1,100 m above sea level located on Mount Kaliapolombo with the overall length of the river in the Tallo Watershed totalling ± 131.50 km$^2$. Geographically, Tallo Watershed located at coordinates 5°0 6' - 5°0 16' South Latitude and 119°3' - 119°46' East Longitude is strongly influenced by tropical climates as in other areas in Indonesia. The air temperature is extremely high with small variations throughout the year and it has significantly small difference between the dry season and the rainy season in a year (Virama Karya, 2004).

Based on the recapitulation of the planned discharge calculation, a 5-year period with a discharge value of 127.64 m$^3$/s is statistically repeated once every five years with an estimated chance of occurrence of 0.2 or 20% for each year referred to in a 5-year review cycle. A 10-year period with a
discharge of 150 m$^3$/s will statistically re-occur every ten years with an estimated probability of occurrence of 0.1 or 10% for each year that is included in one 10-year review cycle. The tidal conditions used come from Makassar port observation station by using the formula according to Okto. S. R. Ongkosonongo and Suyarso, 1982. It is known that the highest tide value (HWSL) is 1.86 m, the lowest tide value (LWSL) is 0.647 m, the average tide value (MWSL) is 0.6065 m, and the tidal range is 1.213 m. Flood modeling uses the Surface Water Modeling System 8.0 (SMS 8.0) program for the 5-year design flood discharge where the input data are 1). Five (5) annual design flood discharge data obtained from the calculation of rainfall; 2). Maximum tidal data; and 3) Topographic data. The results of the simulation showed that the five-year flood discharge resulted in flooding with a depth of 0-3 meters from the maximum tide condition (HWSL), and an inundation area of 31.91 km$^2$ inundated the Tallo District, Tamalanrea District, Panakukang District, West Biringkanaya District and northern Manggala District. These areas are located on the left and right of the Tallo River with an altitude between 0 and 2 meters above sea level.

5. **Conclusion**

Five-year flood discharge resulted in flooding with a depth of 0-3 m from HWSL, and an inundation area of 31.91 km$^2$ inundated the Tallo District, Tamalanrea District, Panakukang District, Western Biringkanaya District and northern Manggala District.

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**References**

[1] Asdak, C. 2004. *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. Gadjah Mada University. Press, Jogjakarta.

[2] BR, Sri Harto. 1993. *Analisis Hidrologi*. Jakarta : Gramedia Pustaka Utama

[3] Eko, T. Paripurno 2006. *Geohazard Zone, Tentang Riset & Manajemen Bencana Geologi*, (Online), (http :// www.geohazard-zone.or.id, accessed on August 8$^{th}$, 2019).

[4] Environmental Modeling Research Laboratory. 2002. *Tutorials Surface Water Modeling System version 8.0*. Brigham Young University, USA.

[5] Maulana, Adi. *Tinjauan Bencana Banjir Di Kota Makassar Berdasarkan Analisis Data Geologi*, (Online), (http :// www.maulana.multiply.com, accessed on July 12$^{nd}$, 2019)

[6] PT. Virama Karya. 2004. *Laporan Hidrologi Dan Hidrolika*, Direktorat Jendral Sumber Daya Air, Makassar.

[7] Prasad, Halaf Hanafi. 2004. *Geomorfologi : Sungai dan Pantai*, Geografi Universitas Negeri Makassar, Makassar

[8] Sosrodarsono., Takeda. 2003. *Hidrologi Untuk Pengairan*, PT Pradnya Paramita, Jakarta.