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Modeling of Flood Prone Areas In The Kelara Watershed

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Modeling of Flood Prone Areas In The Kelara Watershed

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Abstract. One of the efforts to minimize the negative impacts of flooding in the Kelara Watershed is to make model flood-prone areas that can be used as an initial reference for flood disaster mitigation. The analytical method used is hydraulic analysis using 2D HECRAS numerical simulations to determine areas affected by flooding based on flood discharge at a return period of 2 - 100 years. Based on the simulation results, it is found that the discovery area for Q2 is 331.42 Ha, Q5 is 547.21 Ha, Q10 is 798.76 Ha, Q20 is 925.11 Ha, Q25 is 925.79 Ha, Q50 is 1048.48 Ha, and Q100 is 1146.71 Ha. From the results of the flood depth verification, it was also known that the flood that occurred on January 22, 2019 was approaching the 100 year return period flood and June 12, 2020, was approaching the 20 year return period flood. So from the results of mapping and field verification, it is known that the 4 affected districts are Binamu District, Kelara District, Turatea District, and Biringbulu District with the location of the worst flooding occurred in Sapanang Village, Binamu District.

1. Introduction

Floods are natural disasters that often happen all over the world and affect an average of 70 million people. Likewise in Indonesia, one of the natural disasters that often occurs is flooding. Flooding in Indonesia has enormous potential, considering the topography of lowlands, basins and most of the region is the ocean. Aside from the topographical conditions, Indonesia is also one of the countries with extreme rainfall. Extreme rainfall is divided into two, namely extreme high rainfall and extreme low rainfall. Extremely low rainfall is often associated with drought while extreme high rainfall is often associated with landslides and floods [1].

Flooding is also a problem that can cause considerable losses such as loss of property and loss of life. In line with the rate of development of the community, especially those who live and work around floodplains, the problems caused by flooding are increasing and need attention and efforts to overcome them properly [2].

To reduce the risk of damage and losses due to flooding, flood disaster management efforts are needed that can be immediately realized in the field. Flood management can be carried out effectively if a study of the existing condition of the river and its flood characteristics is carried out to determine the sections of the river that are prone to flooding in order to determine the optimal plan based on hydraulic feasibility [3].

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Kelara watershed is geographically located between 05°32'71" - 05°70'06" south latitude and 119°72'96"- 119°89'07" east longitude. Administratively, the Kelara watershed covers two regencies, namely Gowa Regency (Bontolempangan, Bongaya, Tompobulu, and Biringbulu Subdistricts) and Jeneponto Regency (Rumbia, Kelara, Turatea, and Binamu Subdistricts) with the upstream part located in Gowa Regency and the downstream part located in Jeneponto Regency, so that the total area of the Kelara watershed is around 39,112 Ha.

The large number of land conversions from forest to residential and agricultural land (especially rice fields) in the Kelara watershed causes changes in the condition of the catchmen area and can cause surface runoff. This greatly affects the river water discharge in the Kelara watershed [4]. This is in line with the results of previous research in the Karalloe watershed (Upstream Kelara Watershed) which showed that there was a tendency to increase the surface runoff coefficient (C) in 2009 of 0.166 and in 2018 of 0.173 which led to an increase in flood discharge of 7 - 8% [5].

According to historical data on disaster events for the last 10 years obtained from the National Disaster Management Agency through the Indonesian Disaster Information Data (DIBI) website, floods occurred in Jeneponto Regency in 2010, 2015, 2018, 2019, and 2020. On January 22, 2019, Kabupaten Jeneponto was hit by floods with a height range of 50-600 cm. There were 11 sub-districts flooded with 15 people dead, 1 person missing, 937 houses damaged and 48 public facilities damaged. Then on June 12, 2020, there were 8 sub-districts that were flooded with 4 people dead and 136 houses damaged. Floods that occurred in 2019 and 2020 were caused by high rainfall intensity, namely 107.7 mm and 97.2 mm, causing rivers in Jeneponto Regency to overflow, one of which is the Kelara River [6].

One of the efforts to minimize the effects of flood disasters is to model flood-prone areas that can be used as a reference in the Flood Early Warning System. In addition, modeling of flood-prone areas is also very much needed by the government in supporting infrastructure planning, transportation facilities, and other planning including planning an area by developers to determine insurance and flood insurance from buildings, houses, offices, etc [7].

Considering the huge impact of the Kelara River flood on the damage to public facilities,, rice fields, gardens, residential areas, loss of life and implementation of development in Jeneponto Regency, it is necessary to model flood-prone areas on the Kelara River to reduce and minimize the impact of flooding in Jeneponto Regency.

Research on modeling flood-prone areas has been carried out by other researchers with a scoring system on natural factors (parameters) that affect flooding, including meteorological factors (rain intensity, distribution of rainfall, frequency and duration of rain) and characteristics of watersheds (land slope/slope, land height, soil texture and land use) which is then analyzed overlay (map overlay) to see the distribution of flood-prone areas with the help of ArcGIS application [8–15]. In addition, there is also a flood simulation with a certain return period using the HEC-RAS application to see the distribution of floods and flood hazard maps obtained from the results of the analysis using the ArcGIS application [16–19]. This method is similar to the one used, but in this study combines the data from the river cross-section measurement and DEMNAS then corrects the DEMNAS elevation to match the measurement results, and uses the Diffision Wafe method for 1 second calculation intervals in the 2D HEC-RAS numeric simulation so that the results are more similar to events what happens in the field.

2. Materials and Methods

The Kelara River in the middle stream area towards the down stream (estuary) along ± 35 km which is geogradically located at 3°52'49.82"LS and 120°0'32.07"E to 3°56'18.85"LS and 119°57' 29.81"BT is the main location for modeling research on flood-prone areas because the area is affected by floods almost every year.

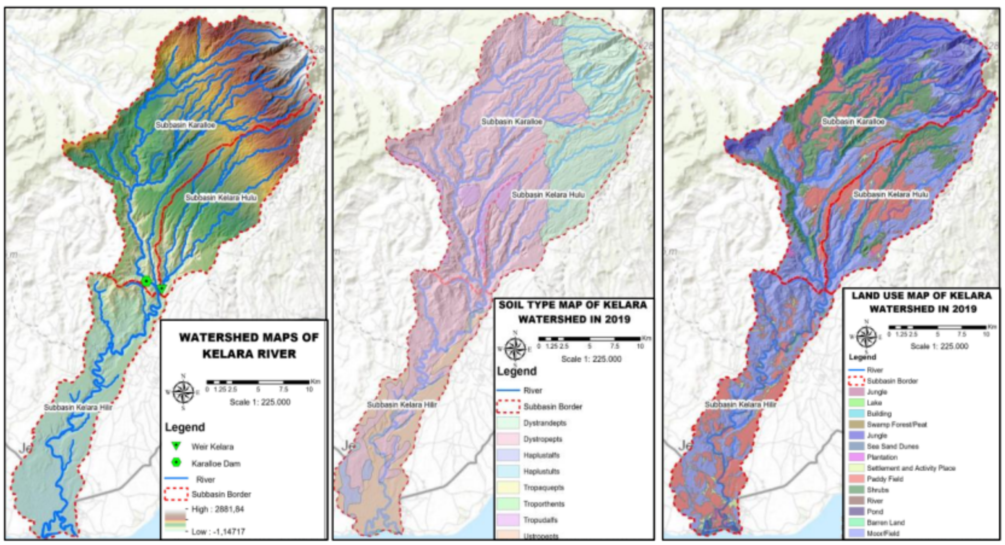
The data used in this study include land use data, soil type data, river topography, and TRMM (Tropical Rainfall Measuring Mission) rainfall data. Research related to the accuracy of TRMM has been studied and shows that of the many satellite rainfall data, the TRMM data has good performance for the Indonesian region and has a correlation with the daily rainfall observation data on average around 0.90 [20].

In this study, hydrological analysis was carried out using the HSS SCS method with the help of HEC-HMS 4.8 software by calculating the flood discharge reduced by the Karalloe Dam and hydraulics analysis with 2D flood simulation using the HEC-RAS 6.1.0 software. In the simulation, the equation used is Diffusion Wave so that the simulation runs stably [21]. The results of the flood simulation will be mapped using AricGis 10.8 software to determine flood-prone areas classified by depth. Depth < 0.76 m is a low danger grade, a depth of 0.76 – 1.5 m is a medium danger grade, and a depth > 1.5 m is a high danger grade [22].

3. Result and Discusion

3.1. Hydrological Analysis

In hydrological analysis in addition to rainfall data, watershed characteristics are also important because they greatly affect rainwater which will become surface runoff. The watershed characteristics needed in the analysis using the HSS SCS method are processed using the arcGIS application to obtain watersheds, river length, time lag, initial abstraction, curve number, and impervious. The results of the analysis using ArcGIS software as well as input material from the HEC-HMS software are shown in Figure 1 and Table 1.



(a) (b) (c)

Figure 1. a) Kelara Watershed Map, (b) Soil Type Map, and (c) Land Use Pattern Map

Table 1. HEC HMS Input Material Parameters

No.	Physical Parameters	Sub Basin		
		Karalloe	Kelara Hulu	Kelara Hilir
1	Watershed Area (km^2)	195,23	86,89	104,65
2	Inital Abstraction (mm)	23.40	16,33	20,924
3	Curve Number (CN)	68	76	71
4	Impervious (%)	0,58	0,93	1,59
5	Time Lag (minutes)	124,17	53,89	345,12

Figure 1 and Table 1 show that each sub-watershed has its own characteristics so that a hydrological analysis should be carried out for each sub-watershed so that the flood discharge obtained is closer to the original conditions in the field. The characteristic data of each sub-watershed is then input into the HEC-HMS software to determine the amount of flood discharge from the Kelara watershed with the results which can be seen in Figure 2.

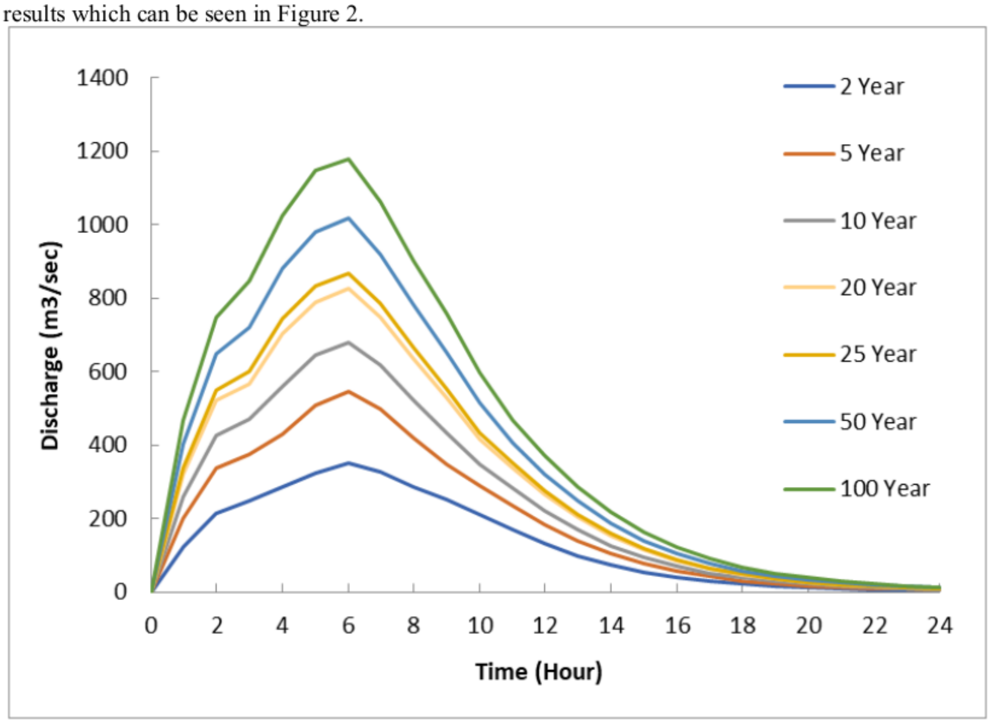


Figure 2. Kelara Watershed Flood Hydrograph

Figure 2 shows that the Kelara watershed flood discharge in Q2 max is 351 m^3/s, Q5 max is 545.2 m^3/s, Q10 max is 680.1 m^3/s, Q20 max is 824.9 m^3/s, Q25 max is 866.4 m^3/s, Q50 max of 1017.4 m^3/s and Q100 max of 1179.6 m^3/s. The results of this flood discharge include the reduction of the flood discharge reduced by the Karalloe Dam in the Karalloe sub-watershed. Furthermore, the flood discharge will be used in the HEC-RAS 2D flood simulation to determine the flood distribution due to overflow of the Kelara River.

3.2. Flood Prone Area Model

The flood inundation simulation in this study used HEC-RAS 2D which was carried out with Usteady Flow Analysis with the Diffision Wafe calculation interval of 1 second to obtain detailed results related to flood inundation for each return period. The simulation results will be exported in raster form and then processed using the ArcGIS application to determine the classification of areas including flood-prone areas. The results of the simulation and mapping of flood-prone areas are shown in Figure 3.

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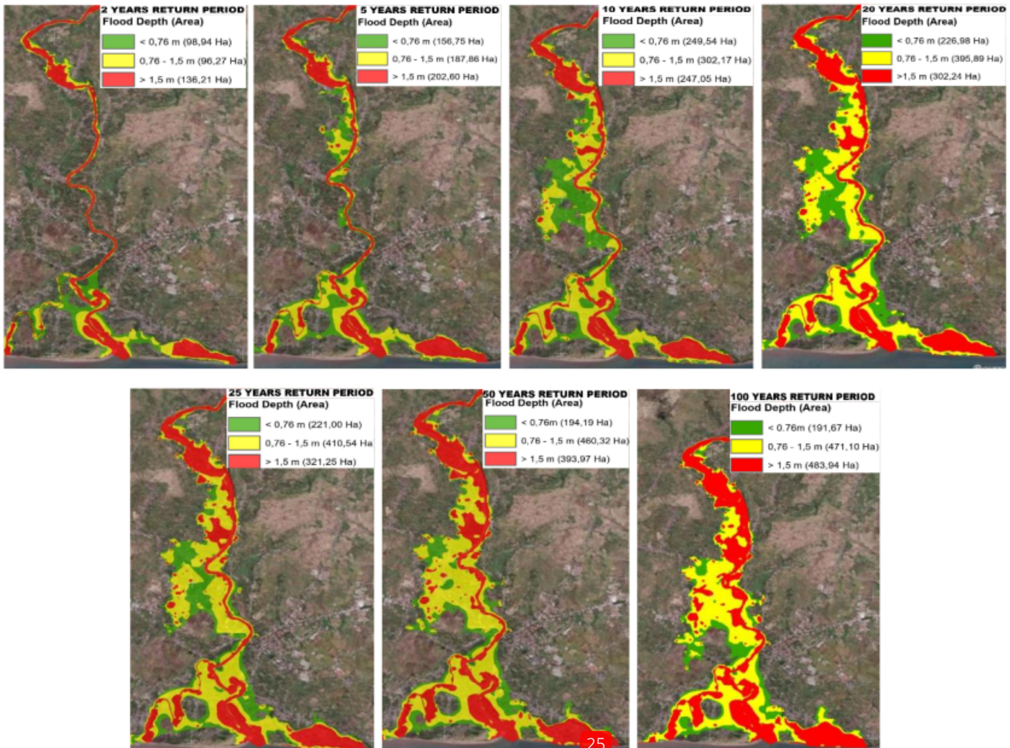
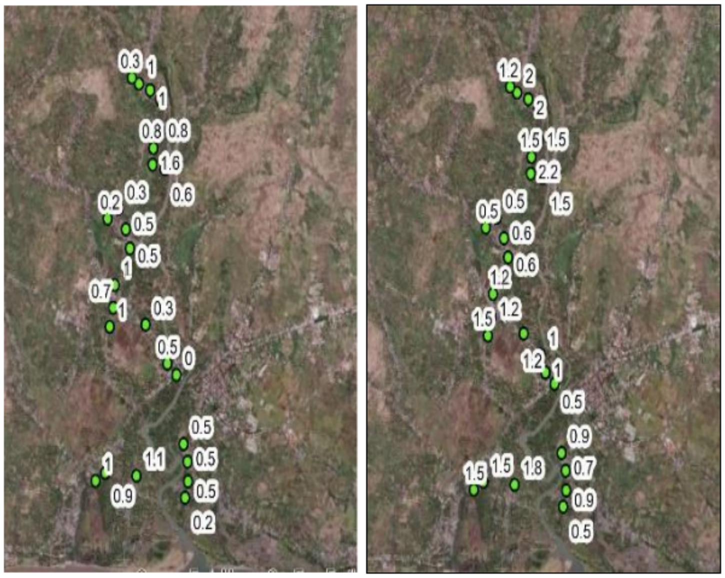


Figure 3. Map of the Kelara River Flood Prone Area

Figure 3 shows that the inundation area has increased in accordance with the increase in the return flood, namely for Q2 covering an area of 331.42 Ha, Q5 covering an area of 547.21 Ha, Q10 covering an area of 798.76 Ha, Q20 covering an area of 925.11 Ha, Q25 covering an area of 925.79 Ha, Q50 covering an area of 1048.48 Ha, and Q100 covering an area of 1146.71 Ha. Then there are 4 affected districts is Binamu District, Kelara District, Turatea District, and Biringbulu District with the location of the worst flooding occurred in Sapanang Village, Binamu District, which is located in the middle stream.

3.3. Historical Flood Verification

Based on the results of surveys and interviews conducted, several historical flood depths have occurred. The data is then used to determine the return period of floods that have occurred, especially floods on January 22, 2019 and June 12, 2020. Data on the depth of floods that have occurred and comparisons of simulation data and historical floods are shown in Figures 4 and 5



(a) (b)

Figure 4. Inventory of Kelara River Flood Height (a) 12 June 2020 and (b) 22 January 2019

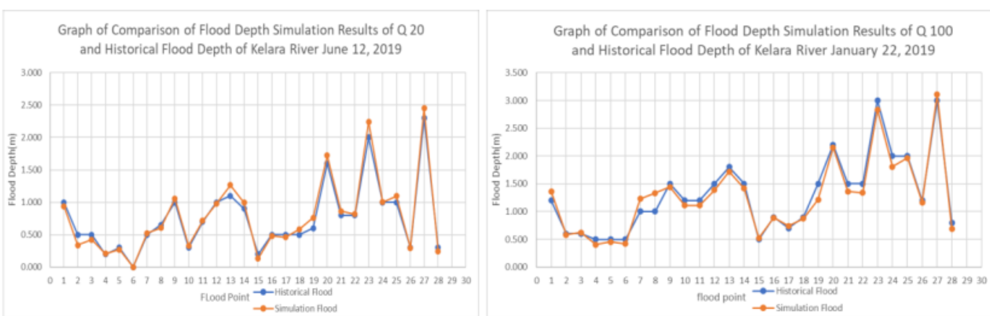


Figure 5. Comparison of Simulation Results and Hitroris Flood (a) 12 June 2020 and (b) 22 January 2019

Figure 5 shows that the difference between simulated flood heights and historical flood heights is not much different, this is possible due to the use of topographic data from measurements according to the original conditions in the field and the corrected DEMNAS. This is evidenced by the Mean Absolute Percentage Error (MAPE) approach, the percentage error value between the flood data from the Q20 simulation and the historical flood of 12 June 2020 is 9.907% and the flood data from the Q100 simulation and the historical flood of 22 June 2019 is 8.208%. Based on the interpretation of the MAPE approach, with a value of <10%, the simulation model ability is very good [23]. So it can be seen that the flood that occurred on June 12, 2020 was a flood with a 20 year return period and January 22, 2019 was a flood with a 100 year return period.

4. Conclusion

- Design flood discharge in the Kelara watershed using the HSS SCS (HEC-HMS) method obtained a maximum Q2 flood discharge of 351 m^3/s, Q5 max of 545.2 m^3/s, Q10 max of 680.1 m^3/s, Q20 max of 824.9 m^3/s, Q25 max of 866.4 m^3/s, Q50 max of 1017.4 m^3/s and Q100 max of 1179.6 m^3/s.
- Based on the results of the 2D HEC-RAS numerical simulation and mapping of flood-prone areas, it is known that the area of inundation at each return period is for Q2 an area of 331.42 Ha, Q5 an area of 547.21 Ha, Q10 an area of 798.76 Ha, Q20 an area of 925.11 Ha, Q25 is 925.79 Ha, Q50 is 1048.48 Ha, and Q100 is 1146.71 Ha. There are 4 districts that are affected, namely Binamu District, Kelara District, Turatea District, and Biringbulu District with the location of the worst flooding occurred in Sapanang Village, Binamu District.
- Based on the results of flood verification, it is known that the flood that occurred on June 12, 2020 was a flood with a 20 year return period and January 22, 2019 was a flood with a 100 year return period.

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