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Retention Basin for Flood Mitigation (Case Study: Magetan Regency)

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Abstract: Flooding is a natural event that often occurs in Indonesia. Magetan Regency has several areas drained by various rivers that have the potential to cause flooding problems in the event of high rainfall. Hydrological analysis is needed to determine the various rivers that are potentially unable to accommodate water capacity due to high rainfall, causing flooding problems. Thus, research aims to assess flood mitigation control based on a 25-year return period flood discharge (Q_{25}) using the HSS Snyder method and HEC-HMS software. The flood inundation area due to river runoff is analysed using HEC-RAS 6.4.1 software using a 25-year return period discharge (Q_{25}). This research uses retention basin as one of the efforts in flood mitigation, reducing the amount of flood inundation that occurs by using embankment planning. Retention basin is a water structure that functions to collect rainwater and water runoff to reduce flooding. Retention basin is one of the important steps in the flood inundation that occurred in Magetan Regency using HEC-RAS 6.4.1 software analysis was 3,75 km^2. The largest flood inundation occurred in Kartoharjo District with an area 1,31 km^2. The design of the Kartoharjo Retention Basin in Magetan Regency can reduce the flood inundation area by 22% to 2,94 km^2.

Keywords: Flood, HEC-RAS, HSS Snyder, Retention Basin, River Runoff

Introduction

Flooding is one of the most common problems in cities in Indonesia, especially during the rainy season's high rainfall. Flood are classified as natural disasters that become annual problems and cause large losses. Floods usually occur in areas with wide coverage, causing many victims (Utomo et al., 2019). Magetan Regency in East Java Province is one of the most vulnerable areas to flooding. Magetan Regency is located on the slopes of Mount Lawu and in lowland areas. Areas with varying slopes and soils that do not absorb water well can increase the risk of flooding.

Flood risk in this area may increase with climate change, diverse topography, and high rainfall. Low geographical locations are prone to flooding and inundation. Flooding in low geographic areas occurs due to upstream flows and heavy rainfall. Low geographic locations are prone to flooding and inundation. Flooding in low geographical areas occurs due to upstream submissions and high rainfall. Handling the problem of inundation and flooding is required by planning infrastructure and flood control in order to reduce inundation and flooding points and the impacts caused (Pratiwi & Rahajoeningroem, 2020).

Retention basin planning can use a return of period flood discharge with historical flood event data or with a design rainfall approach. Retention basin planning can be done based on the return period flood discharge and related historical flood data. The 25-year return period discharge (Q_{25}) has a flood approach that has occurred. Using the 25-year return period flood discharge (Q_{25}) is an effective approach for capacity efficiency and avoiding drought problems. Retention basin as a flood mitigation solution in Magetan Regency need to be analysed to determine its potential success.

Retention basin simulation can be optimized to provide a flood mitigation model as an effective protection to reduce the risk of loss. Hydrological characteristics consideration is important to reservoir simulation for broader flood management strategies. Retention basin simulation in the context of modelling for flood mitigation in Magetan Regency lies in its potential as a sustainable solution to reduce the adverse impacts of flooding.

Methodology

Method used in this study are approaches with quantitative descriptive methods. Research begins with data collection activities, then analysing existing data, modelling and then presenting the results of data analysis. As a result of the data analysis, the map of flood potential and mitigation of retention basin installation in Magetan Regency is presented. Secondary data collection was obtained by related agencies in the form of 2004-2023 rainfall data from Jejeruk Rain Station, Ngrambe Rain Station, and Jiwan Rain Station which can be obtained from the Balai Besar Wilayah Sungai (BBWS) Bengawan Solo. Administratie data of Magetan Regency was obtained form the website of the Magetan Regency. DEM map of Magetan Regency from the shapefile map of Magetan Regency obtained on Badan Informasi Geospasial (BIG) website.

Data were analysed using hydrological analysis. Rainfall is analysed for maximum daily rainfall and tested for consistency using the double mass curve method. On average, rainfall from rainfall measurements at several measurement stations can be calculated using the Thiessen polygon method. This method provides a correction to the depth of rainfall as a function of the area considered representative (Sahusilawane et al., 2019). Thiessen coefficient is used to obtain regional rainfall.

After obtaining regional rainfall to determine the chance distribution of rainfall amount and design flood discharge at a return period of 25 years that occurs is analysed using the Log Pearson Type III distribution. The distribution suitability test is used to determine the suitability of the planned rainfall analysis of vertical and horizontal data deviation with the Smirnov-Kolmogorof suitability test, so that the selected distribution is acceptable or not (Triatmodjo, 2008).

Research stages process in the form of data and information collection, map management, rain data processing, then calculation of return period flood discharge with HSS-Snyder and HEC-HMS Methods. The Snyder Synthetic Unit Hydrograph is a synthetic unit hydrograph where the discharge is expressed as discharge q against peak discharge qp and time t against the rise time of the T_b an T_r (hour) unit hydrographs (Pangemanan et al., 2020). Then modeled the flood inundation area and flood inundation recucrion simulated using HEC-RAS 6.4.1.

Result and Discussion

This research is located in Magetan Regency, which includes eighteen sub-districts namely: West Bendo, Karangrejo, Karas, Kartoharjo, Kawedanan, Lambeyan, Magetan, Maospati, Ngariboyo, Nguntoronadi, Panekan, Parang, Plaosan, Poncol, Sidorejo, Sukomoro, and Takeran.

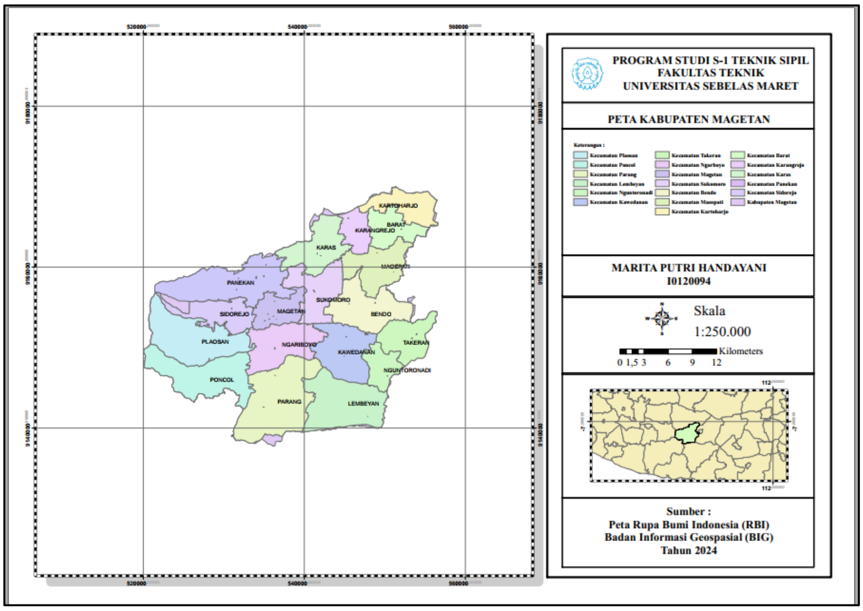

Figure 1. Magetan Regency
Source: image of Districts Magetan Regency

The rivers analysed in this study are Trinil River, Kersikan River, Waduk River, Nganggang River, Ngelang River, Pare River, Gandong River, Dayoah River, Bringin River, Bening River, Tengah River, Pucang River, and Galok River. The Thiessen coefficient representing the influence of each rainfall station (Jiwan, Jejeruk, and Ngrambe) occurs is presented in Table 1 below.

Table 1. Thiessen Coefficient

No	Rain Stations	Thiessen Coefficient (Kr)
1	Jiwan	0.2327
2	Jejeruk	0.6271
3	Ngrambe	0.1402

Source: Calculation Analysis, 2024

The maximum rainfall area that occurs based on the Thiessen coefficient is obtained by multiplying the Thiessen coefficient with the maximum rainfall of each station at the same time. The maximum regional rainfall that occurs is presented in Table 2 below.

Table 2. Maximum regional rainfall

Year	Maximum Rainfall (mm)
2004	67.77
2005	64.38
2006	59.09
2007	130.42
2008	84.13
2009	96.14
2010	96.95
2011	85.09
2012	83.46
2013	127.25
2014	92.45
2015	64.12
2016	72.72
2017	108.97
2018	54.6
2019	74.39
2020	108.9
2021	77.75
2022	60.01
2023	46.92

Source: Calculation Analysis, 2024

Based on the watershed map from the result of the analysis that has been done using the Magetan Regency Administration Map and DEM MAP with HSS Snyder and HEC-HMS Methods, the 25-year return period flood discharge of each sub-basin is obtained according to Table 3 below.

Table 3. Flood Discharge Plan Analysis Result

No	Subbasin	River	HSS Snyder (m^3/dt)	Hec-HMS (m^3/dt)	Difference Value
1	Subbasin 1	Trinil	99.86	99.3	0.6%
2	Subbasin 2	Kersikan	31.08	30.2	2.8%
3	Subbasin 3	Waduk	79.71	78.7	1.3%
4	Subbasin 4	Nganggang	54.56	54.5	0.1%
5	Subbasin 5	Ngelang	366.76	352.7	3.8%
6	Subbasin 6	Pare	131.21	126.4	3.7%
7	Subbasin 7	Gandong	128.26	126.3	1.5%
8	Subbasin 8	Dayah	95.02	94.3	0.8%
9	Subbasin 9	Bringin	170.61	168.6	1.2%
10	Subbasin 10	Bening	170.61	168.6	1.2%
11	Subbasin 11	Tengah	174.70	174.7	0.0%
12	Subbasin 12	Kali Pucang	100.67	100.5	0.2%
13	Subbasin 13	Kali Galok	71.95	72.6	0.9%

Source: Calculation Analysis, 2024

Modelling of flood inundation areas based on 25-year return period discharge was conducted using HEC-RAS 6.4.1 software. The results of the analysis can be seen in Table 4 and Figure 2 below.

Table 4. 25-year Return Flood Inundation Area

No.	Sub-district	Flood Inundation Area km^2
1	Barat	0.83
2	Bendo	0.19
3	Karangrejo	0.07
4	Karas	0.09
5	Kartoharjo	1.31
6	Kawedanan	0.07
7	Lambeyan	0.17
8	Magetan	0.02
9	Maospati	0.02
10	Ngariboyo	0.05
11	Nguntoronadi	0.07
12	Panekan	0.04
13	Parang	0.13
14	Plaosan	0.07
15	Poncol	0.05
16	Sidorejo	0.05
17	Sukomoro	0.06
18	Takeran	0.45
	Total	3.74

Source: Calculation Analysis, 2024

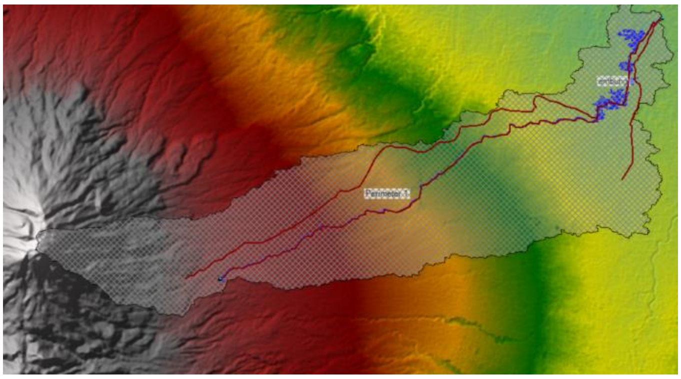

Figure 2. 25-Year Flood Discharge Running Results

Source: Image of running HEC-RAS software

The placement of the reservoir is simulated in the area with the highest flood inundation area in Kartoharjo Sub-district, so the location of the reservoir is in Kartoharjo. The amount of reservoir storage was obtained using HEC-RAS software with a storage volume of 419.405 m^3. The results of the analysis can be seen in Table 5 and Figure 3 below.

Table 5. Flood Inundation Area of 25-year Return Period after Embankment Laying

No.	Sub-district	Flood Inundation Area km^2
1	Barat	0.64
2	Bendo	0.19
3	Karangrejo	0.03
4	Karas	0.02
5	Kartoharjo	0.82
6	Kawedanan	0.07
7	Lambeyan	0.17
8	Magetan	0.02
9	Maospati	0.02
10	Ngariboyo	0.05
11	Nguntoronadi	0.07
12	Panekan	0.03
13	Parang	0.13
14	Plaosan	0.07
15	Poncol	0.05
16	Sidorejo	0.05
17	Sukomoro	0.05
18	Takeran	0.45
	Total	2.94
	Reduksi	0.22
		22%

Source: Calculation Analysis 2024

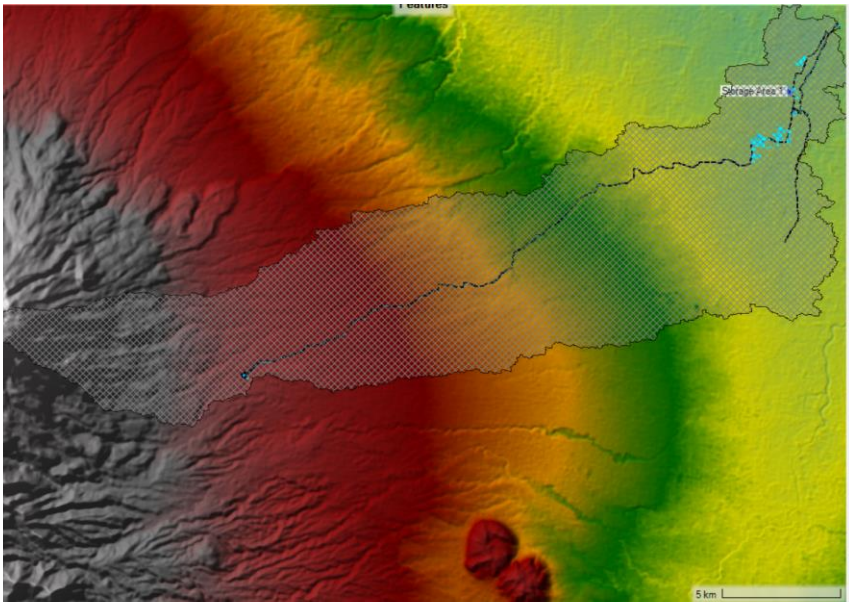

Figure 3. Kartoharjo Sub-district Retention Basin Simulation Running Results

Source: HEC-RAS software running image

In the Figure 3 shows that the reduces largest flood inundation occurred in Magetan Regency. Retention basin simulation can be optimised to provide a flood mitigation model as an effective protection to reduce flood inundation. Simulation retention basin in Magetan Regency with a storage capacity of 419.405 m^3 can reduce the flood inundation area by 22%. Retention basin simulation modeling for flood mitigation in Magetan Regency has the potential to be a sustainable solution to reduce the adverse impacts of flooding.

Conclusion

Based on the results of the research that has been done, it can be concluded that: the value of the 25-year return period flood discharge of the Trinil watershed is 99.86 m3/s, the Nganggang River watershed is 99.86 m3/s, the Kersikan River watershed is 31.08 m3/s, the Waduk River watershed is 54.56 m3/s, the Pare River watershed is 131.21 m3/s, the Gandong River watershed is 128.26 m3/s, Dayah River watershed 95.02 m3/s, Bringin River watershed 170.61 m3/s, Benin River watershed 174.70 m3/s, Tengah River watershed 100.67 m3/s, the Pucang River watershed 71.95 m3/s, and Galok River watershed 105.24 m3/s. The result of the analysis for the most inundated area is in Kartoharjo District, which is an area that experiences high prone runoff. The value of the inundation area of Magetan Regency is 3.74 km^2. With the analysis of reservoir planning simulations aimed at flood disaster mitigation through the Kartoharjo Retention Basin, which has a storage capacity of 419.405 m^3 , the flood inundation area has been reduced by 22% to 2.94 km^2.

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