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FLOOD CONTROL STRATEGY IN SAMPANG CITY, EAST JAVA, INDONESIA

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ABSTRACT: Flood always hits Sampang City every year and it causes the transportation disruption in Madura Island. The flood in Sampang City is caused by four main factors: the watershed (DAS) quality, the drainage system, the river capacity, and the tide. The flood control strategies that have been done are: the reduction of flood discharge peak and increasing the river capacity. However, these strategies have not achieved the significant results yet. Thus a new strategy is needed to solve the problem. The result of hydrography analysis shows that the discharge is dominated by the surface runoff, thus it indicates that the quality of DAS is very poor. Further, the land usage in DAS is dominated by the agricultural land such as the farms and the rice fields. Based on these observations, a new flood control strategy by controlling the surface runoff on agricultural land is proposed. The strategy is described as the technical activities in the form of utilization of the farmland partition as the temporary storage facilities. To achieve the maximum result, it should be followed by the following activities: a) increasing the capacity of interception and infiltration by the land conservation; b) increasing the capacity of the water reservoir on the land by raising the embankment design from 30 cm to 50 cm; c) shortening the water puddle time by constructing the absorption wells. The result of the hydrological analysis shows that the new strategy is able to reduce the flood discharge peak of 20% to 67%.

Keywords: Flood control, Surface runoff, Agricultural land

1. INTRODUCTION

Flood is one of the dominant natural disasters in Indonesia, followed by the landslide disaster [1]. In last three decades, flood disaster in Indonesia is at fourth rank (190 events) after the United States (388 events), China (344 events) and India (225 events) [2]. While flood disaster in East Java Province is at the second rank in Indonesia [1].

The flood always hits Sampang City, Madura Island, Indonesia every year that causes the transportation disruption, especially in the inner city transportation and along sub-districts in the Madura Island. It becomes one of the main focuses of flood disaster news in Indonesia.

The area of Sampang City is located in the estuary of the Kemuning River, which is hydraulically affected by the tide [3]. The flood is caused by four main factors, i.e. the watershed (DAS) quality, the city drainage system, the river capacity, and the tide. Several flood control strategies have been done such as [3]-[5]: a) the reduction of flood discharge peak by making the basin retarding and reservoir, and b) increasing the river capacity by river flow normalization, which consumes the high cost [6]. However, these efforts have not yielded the significant results. Therefore the new strategy should be proposed to overcome such problems. The right strategy might be achieved when a thorough analysis of the discharge raising is done and their alternative solutions are provided [7].

The rest of paper is organized as follows. Section 2 presents the analysis of flood control strategy. Section 3 discusses the development strategy. The results and discussion are presented in Section 4. The conclusion is covered in Section 5.

2. ANALYSIS OF THE FLOOD CONTROL STRATEGY

2.1 The River Capacity Enhancement

The hydrological analysis result shows that the capacity of Kemuning River is 50.13 m^3/s. While the flood discharge in two years return periods is 622 m^3/s. The flow normalization by widening the riverbed to 40 m should be done to discharge the flood [8]. However, it is difficult to be done due to the fact that the river in the urban area of Sampang City experiences the narrowing to become 15 m only.

2.2 The Flood Discharge Peak Reduction

The reduction of flood discharge peak in the Kemuning River by making the retarding basin is able to reduce the flood recharge of 260 m^3/s [4].

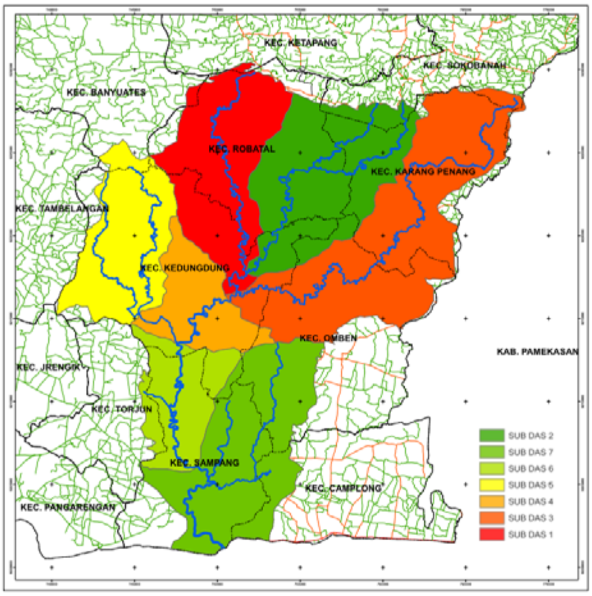

Fig.1 The sub-DAS in the Kemuning River

When we use the two years return period of 622 m^3/s, this effort is able to reduce the flood discharge peak of 42%. However, this analysis does not indicate the precise location.

3. DEVELOPMENT STRATEGY

3.1 The Evaluation of DAS Quality

Based on the evaluation of the strategy and the results of flood control that have been done, and from the experiences of authors and previous researchers, the new strategy is proposed as presented in the following section.

To increase the accuracy of the analysis result and the convenience in the implementation, the DAS is divided into 7 (seven) sub-DAS as given in Table 1 and Fig.1.

Table 1 The area of sub-DAS in the DAS of Kemuning River

No	Name of sub-DAS	Area (Km^2)
1	Sub-DAS 1	62.52
2	Sub-DAS 2	70.73
3	Sub-DAS 3	103.22
4	Sub-DAS 4	30.14
5	Sub-DAS 5	47.83
6	Sub-DAS 6	33.15
7	Sub-DAS 7	72.65
The total area of DAS		420.24

Source: Analysis result

To monitor and evaluate the DAS management, several indicators may be used such as [9]: the Flow Regime Coefficient (KRA), the annual flow coefficient, the sediment load, the flood and water usage index. Since this research is focused on the control of surface runoff, the KRA indicator is selected to classify the DAS quality. The KRA value is defined as the ratio of maximum discharge (Q_{max}) to minimum discharge (Q_{min}) in the DAS. Based on the KRA value, the DAS is classified as given in Table 2, where the higher class denotes the lower quality of DAS.

Due to limited discharge monitoring data in each sub-DAS, the measurement of flood discharge and minimum discharge is obtained analytically. There are 2 (two) options in the flood analysis, namely using the lumped model and the distributed model.

Since the uncertainty in the flood discharge analysis is very high, the combination of historical data and the usage of the proper model may reduce this uncertainty [10].

Table 2 The classification of watershed based-on KRA

No	KRA value	Class
1	$KRA \leq 20$	Very low
2	$20 < KRA \leq 50$	Low
3	$50 < KRA \leq 80$	Medium
4	$80 < KRA \leq 110$	High
5	$KRA > 110$	Very High

Source: Minister of Forestry of Republic Indonesia, 2014.

Table 3 The KRA value and Quality Class in the DAS of Kemuning River

No	Name of Sub-DAS	Q_{max} (m^3/s)	Q_{min} (m^3/s)	KRA (Q_{max}/Q_{min})	Class
1	Sub-DAS 1	173.86	0.0021	82790.48	Very high
2	Sub-DAS 2	162.51	0.0007	232157.14	Very high
3	Sub-DAS 3	162.25	0.0092	17635.87	Very high
4	Sub-DAS 4	242.93	0.0021	115680.95	Very high
5	Sub-DAS 5	181.06	0.0352	5143.75	Very high
6	Sub-DAS 6	242.11	0.0097	24959.79	Very high
7	Sub-DAS 7	253.53	0.0105	24145.71	Very high

Source: Analysis Results

The distributed model without calibration can be used to analyze the flood discharge when the discharge data is limited [11]. This model requires the availability of the spatial data with good quality. Since the Nakayasu-Hydrograph Unit Synthetic (HUS) is very precise for the discharge analysis on the DAS of 10 Km^2 up to 1000 Km^2 [12], it is employed in this research.

Basic flow discharge is calculated using the FJ Mock model. This model has been used to analyze the low discharge flow in the DAS of Tirtomoyo, Wonogiri (area of 204.7 Km^2) with the daily periods of 5, 10, and 15 [13]-[14]. The result shows that the model achieves a high degree of matching. Thus in this research, we employ the same method (FJ Mock model) to analyze the low discharge flow. The results of the two discharge analyses are then used to calculate the KRA in 7 (seven) sub-DAS as given in Table 3.

3.2 The Evaluation of River Quality

The width and the depth of Kemuning River in urban area decrease due to the riverside utilization and sedimentation. This condition causes the reduction of river capacity and the reverse water that potentially produces the overflow.

The capacity of river discharge is calculated by comparing the flood discharge to the discharge capacity on a control point. The control point in this study is selected at the upstream of an urban area where the automatic water level record (AWLR) exists. The flood discharge (Q_k) is calculated using the following equation:

$$Q_k = A \times V \ (m^3/s) \quad (1)$$

where
A = Area of wet section of the river (m^2)
V = Flow velocity (m/s)

The area of the wet section of the river view is the function of the height of the water that is recorded from the AWLR. Meanwhile, the topographic parameters, i.e. the longitudinal and transverse pieces are measured directly using the Total station (TS). The result of discharge analysis (Q_k) for each water level (H) is given in Table 4 and Fig. 2.

Table 4 The capacity of River Discharge

H (m)	Q (m^3/s)
1	3.68
2	11.79
3	22.62
4	38.29
5	55.63
6	79.35
7	93.50

The flood discharge at the AWLR location (Q) is calculated based on the DAS parameter using Nakayasu-HUS method for various return periods. The result is given in Table 5.

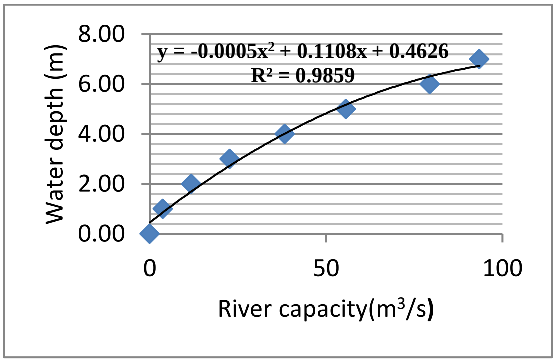

Fig.2 Graph of the Capacity of River Discharge

Table 5 Result of Flood Discharge at AWLR 1 Control Point

Return Period (year)	2	5	10	25	50
Q (m^3/s)	160.9	216.5	253.1	299.0	332.8

The comparison of the flood discharges in various return periods and the river discharge capacity are given in Table 6. The comparison results of Q/Q_k indicate that the capacity of river discharge is able to flow the flood discharge at the return period less than two years only. This result is validated by the real information where the Kemuning River overflows at the urban area of Sampang City in every year, even though there is no tide.

Table 6 The comparison of the flood discharge and the river discharge capacity

Return Period (year)	2	5	10	25	50
Q (m^3/s)	160.9	216.5	253.1	299.0	332.8
Q_k (m^3/s)	93.50	93.50	93.50	93.50	93.50
Q/Q_k	1.72	2.32	2.71	3.20	3.56

3.3 The Effect of Tide

The tide affects highly the drainage system of Sampang City which can be identified from the facts that the boats of the fishermen may sail close to the city even though there is no flood. Besides that when the flood and the tide occur simultaneously, the reverse water in the downstream of Kemuning River flows to an urban area.

3.4 The Proposed Strategy

Based on the evaluation of the DAS condition, the river flow, and the side effect, we propose a new strategy, i.e. controlling the surface runoff water on the farmland. This strategy is implemented into technical activities by utilizing the farmland as the temporary storage. To maximize the result, the following activities should be done:

- Land conservation: The combination of vegetative and mechanical methods for increasing the capacity of interception and infiltration.
- Raising the embankment design from 30 cm to 50 cm to increase the capacity of water storage on the land.
- Construction of absorption well: The absorption well is constructed on each land partitioning for shortening the water puddle time.

3.4.1 Land conservation

The vegetative conservation is done in the medium critical land and the high critical land. The land area according to the DAS condition is given in Table 7. Since the vegetative conservation covers the medium critical land and the high critical land, the total area is 2355 ha (1233+1122=2355).

Table 7 Land area according to the DAS condition

Land area (Ha)				
Good	Normal	Low critical	Medium critical	High critical
6550	7	34354	1233	1122

Source: Analysis Results

The conservation plant is selected based on the analysis of land conformity. The plants with the high conformity are the water apple, the mango, the cashew fruit, and the elephant grass. By selecting the high conformity plants, it is expected that the peoples will participate actively. Further, the planting will increase the capacity of interception and infiltration.

The proposed mechanical conservation is by constructing the bench terrace and the embankment in the garden and the field. To increase the capacity of the rainwater storage, the height of the embankment is set to be 50 cm. Thus it is expected that the height of water storage will be 40 cm.

3.4.2 Absorption well construction

The absorption well is constructed on the farm field partition, the garden and the field. To avoid the landslide, the absorption well is constructed on the land with the natural topography slope less than 30% [16]. The absorption well is intended for shortening the duration of water puddle time so that it does not disturb the quality of life and the productivity of the plant. By maximizing the absorption of rainwater into the farmland, it is expected that the flood discharge peak on the river can be controlled. This effort also impacts on increasing the availability of ground water in the growing media layer of the plant and in the aquifer.

3.4.3 Analysis of controlled surface runoff

To examine the amount of surface runoff discharge that can be controlled, two conditions are analyzed, i.e. before treatment and after treatment. The difference of discharge in those conditions is called as DQ and represents the indicator of flood discharge peak control. The analysis results of 7 (seven) sub-DAS are given in Table 8.

Table 8 Percentage of the discharge control

Sub-DAS	1	2	3	4	5	6	7
DQ(%)	55	51	50	20	67	58	56

4. RESULTS AND DISCUSSION

The results of the hydrological and hydraulic analysis show that the flood in Sampang City is affected by several factors as follows (written according to the level of influence): a) The DAS quality; b) Effect of the tide; c) The narrowing of the river; d) The quality of city drainage system.

The existing flood control strategy, i.e. the construction of retarding basin and reservoir, and the river channel normalization, tend to handle the water when they have been collected in the riverbed only. However, it does not yield the significant result. Therefore a new strategy is needed.

The new strategy is proposed by considering the condition of the water when they are still on the surface runoff. This strategy provides two advantages: a) reducing the flood discharge; b) increasing the groundwater reserve.

The effort to control flood in the area of Batu City, East Java Province by constructing 450 absorption wells was proposed by [15]. According to authors, this effort is difficult to be implemented due to a large number of absorption wells that requires the large land areas. Therefore in this research, the absorption well is modified so that it has a dual function, i.e. as the water runoff control and as the irrigation water wells. By providing this dual function, it is highly expected that the effort will be supported by the community.

The new strategy is implemented by the land conservation, raising the embankment, and the absorption well construction. The vegetative conservation is intended to increase the evaporation and land infiltration. The embankment is raised from 30 cm to 50 cm in order to increase the capacity of water catchment on the land. The aim of absorption well construction is to shorten the duration of a water puddle so that it does not disturb the plant life.

From the hydrological analysis, it is obtained that the proposed strategy is able to reduce the flood discharge peak from 20% to 67%. The reduction of flood discharge peak depends on the land condition of each sub-DAS. This strategy should be accompanied by the effort to maintain the area and composition of land utilization. It complies with the recommendation in [17].

5. CONCLUSION

From the above discussions, we may conclude as follows:

- The flood in Sampang City is caused by several factors such as the DAS quality, the river capacity, and the tide.
- The existing flood control strategy tends to handle the condition when the water has been collected in the waterbed. Thus it does not yield the significant effect of the flood control.
- The new flood control strategy is proposed by controlling the surface runoff water in the farmland using the land conservation that focuses on the utilization of the farmland partition as the water reserve. This new strategy may reduce the flood discharge peak by 20% to 67%.

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