Impact evaluation of Cilember River normalisation to PURBALEUNYI Toll Road using two dimensional model HEC-RAS

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Abstract. Cilember River flows from North to South of Cimahi and crosses PURBALEUNYI Toll road in downstream. Therefore normalization of Cilember River Cimahi can impact the PURBALEUNYI Toll road. Hydraulic simulation carried out to determine the impact and formulate the mitigations alternatives. The study was conducted based on Detail Engineering Design Data for Cilember Normalisation Program prepared by Citarum River Authority as a base data. Two-dimensional HEC-RAS model was used to simulate the impact of the river normalization program. The model also used to evaluate the alternatives (detention pond, diversion of flows) to minimize the impact of the Cilember normalization program to PURBALEUNYI Toll road. Applying 10 year return period and HEC-RAS simulation, with an existing condition, 26 505 sqm area is inundated mostly in the North area of Toll Roads. After the normalization program, the inundation area shifts to the south area, including Toll road. The further simulation shows that normalization of the river can reduce inundation area to 7 993 sqm. Simulation of combination between detention pond and diverting the excess flow of Cilember to Kali Malang inundated area occurs, but it does not affect the toll road.

1. Introduction

Flood is identified as a significant hazard to transportation infrastructure [1]. The impact of flood to transportation infrastructure can vary from traffic disturbance to the disclosure of road. The level of the impacts depends on the high of the water on the road, and the road is closed if traffic safety cannot be guaranteed. Disclosure if the road will socially and economically impact society.

The PURBALEUNYI Toll Road located in a southern part of Cimahi city and cross Cilember River. Since the position of the toll road is at the downstream area of the Cilember River, the risk of flood considered high [2]. On 10th November 2017, the toll road was closed due to flood caused by the Cilember river overflows [3]. In the last 10 years, the Cilember river flow has been significantly increased due to land-use change in the upstream area. With the increase of the Cilember river flow, both frequency and flood areas are increasing, which includes residential and industrial areas.

To anticipate a further increase of Cilember flow and to improve the existing condition (Figure 1), The Government of Cimahi City has a plan to normalize the Cilember River. The normalization program increases the river capacity, and runoff from the upstream area flows to the downstream area more quickly. On the other hand, the increase of the flow from upstream to the downstream area increases the...
risk to PURBALEUNYI toll road; therefore, the impact of river normalization on the PURBALEUNYI toll road has to be considered during the planning stage.

This study is aimed to minimize the risk of Cilembe river normalization to PURBALEUNYI toll road by simulating the hydraulic behaviour of both existing and planned river conditions. The hydraulic simulation was done using HEC-RAS software. The HEC-RAS (Hydrologic Engineering Center-River Analysis System) software is a free hydraulic simulation modelling software released by the US Army Corps of Engineering [4,5]. The simulation shows the behaviour of the Cibeureum River, the water level, and the velocity in both steady and unsteady conditions [6].

Figure 1. Map and existing condition of Cilember River.

2. Methods
As the effectiveness of the normalization program and the impact on the toll-road tested using the two dimensional HEC-RAS simulation, the first step is to prepared all relevant input data. Through an understanding of specific flood phenomena in the study area, type, and priority of relevant data can be screened so that the study can be conducted efficiently. As shown in figure 2, this step is mentioned as “problem Identification”. In this study, the deductive approach was adopted to define all factors and variables which are involved in the flooding process, which then blended as the conceptual model. The literature study is aimed to get more understanding of flood phenomena within the study area, collect related data and methods of analysis. The output of this literature study is the collection of references that are relevant approach and methodology for the study.

Data Collection, two types of data have been collected, which include premier and secondary data. Primary data consist of topographical measurement results for existing river conditions and field documentation [7]. Secondary data includes rainfall data, river cross-section; SRTM; river and land use map; satellite images [8].
Figure 2. Flow chart method.

Hydrological, hydrological calculations, and hydraulic analysis, start with rainfall data analysis, watershed delineation, and hydrograph analysis. The hydrological analysis conducted by applying the Nakayasu method. River discharge used for one-dimensional simulation, whereas the hydrograph is used as an input for two-dimensional simulation of the Cilember River.

Verification of simulation result for existing river conditions made through comparison of simulation result with actual flood condition. The actual flood data is based on an interview with local residence and secondary data from a related agency. In the case of the simulation result not meet the actual condition, some adjustments have to be made the manning coefficient values can be changed until the simulation approaches the actual flood condition [9,10].

Based on the verified model, the simulation continued using planed river normalization. The second simulation is aimed to check the flood condition after normalization and the impact on the toll road. The result then used as a basis for further recommendation to optimize the normalization program.

3. Results and discussion

Based on watersheds delineation, rainfall analysis, watersheds, and time concentration, a unit hydrograph, as shown in Figure 3, is calculated applying the Nakayasu method. The diagram in Figure 3 shows that the maximum river discharge occurs at a duration of rain 3 hours. During the early period of the rain, the diagram presents the discharge increase until at the peak of about 3 hours. After 3 hours of rain, the discharge starts to decrease.

The simulation results are used as the basis to develop a physical model for Cilember normalization design. Some initial steps have been taken to collect and process data to be used as HEC-RAS input. Rainfall data collection has been carried out as a basis for analysis to determine flood discharge plans.
Figure 3. Nakayasu HSS method of flood discharge chart for each period.

From the results of simulations carried out using the HEC-RAS software with topographical conditions taken from DEMNAS, a map of the flood situation that occurred around the study site was produced. Research simulations were carried out for 3 rainfall return periods 2, 5, 10 years. The simulation results presented in Figure 4.

Figure 4. HEC-RAS Cilember River existing 2D flood simulation.

Inundation area for 2 years, 5 years, 10 years return periods are respectively 6675.752sqm, 18785.29 sqm, and 26505.2 sqm.
From Figure 5 it can be seen that the significant reduction of the inundation area. In the simulation after normalizing the river, inundation area for 2 years, 5 years, 10 years return periods are respectively 1600.489 sqm, 5031.22 sqm, 7993.228 sqm.

4. Conclusion

- Existing river capacity is unable to accommodate runoff, which continues to increase rainfall annually.
- Before normalization, the flood inundation area is 26,505.2 sqm after normalization the inundation area reduces to 7,993.228 sqm for the ten year return periods, resulting in a reduction of flood area inundation by 18,511.912 sqm.
- After normalization, flooding still occurs but does not affect the toll road.

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