Study of the Effect of River Basin Morphology Change on Threshold Parameters in Cimahi Flood Early Warning System

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Abstract. Flood early warning systems are used for flood disaster preparedness to reduce disaster risks. The problem is damage of water level sensor due to aggradation which also results in river capacity reduced. The purpose of this research is to determine the effect of river basin morphology change on threshold parameters in flood early warning system. Measured hydraulic parameters are flow depth, flow velocity, and riverbed slope. Land cover was conducted using Cimahi river basin land use map to determine runoff coefficient. Rainfall-runoff model used is the Deconvolution Software program to determine unit hydrographs. Results of this study indicate that morphological changes of watershed significantly influence threshold parameters. A 0.5 m rise in river bed can reduce river capacity by 41.8% and narrowing of 16 m-wide river border dropped river capacity from 730 m³/s to 95.2 m³/s. An increase of 17 % runoff coefficient, increased direct runoff by 17%. Reducing this river capacity makes threshold parameters in flood early warning system invalid causing flood events cannot be detected earlier by the system.

1. Introduction
Flood early warning systems are used for flood disaster preparedness to reduce disaster risks. The system uses threshold parameters to provide flood information quickly to communities and stakeholders via telemetry networks [1]. The commonly used threshold parameter is the river water level [2]. In Cimahi flood early warning system, there are two parameters of threshold those are river water level and rainfall. The problem that happened was flooding but the warning alarm did not ring. Based on field observations, this occurs because the change in threshold parameters where the water level that causes the flood is lower than the threshold water level that has been set in the system. Similarly, for threshold rainfall parameters, floods occur before the precipitation reaches the threshold limit [3].

Morphology characteristics analysis is essential to any hydrological study, so the determination of stream networks behavior and their interrelation with each other is of great importance in many water resources studies[4]. Parameters of basin morphology such as riverbed slope, flow depth, flow velocity, river border and also land cover affect river capacity or discharge. Based on the study, it is
known that there is a logarithmic relationship between land use and the number of abstractions. In the dry season, the amount of abstraction is 16% greater than in the rainy season. For the same watershed slope, abstraction is greater if the amount of forest and gardens are larger. In addition, the abstraction is also influenced by the watershed area with logarithmic relationships, where the abstraction is greater with the increase in the area but in the area above 1000 km$^2$, the addition is slow or asymptote [5].

River morphology is changing from its natural channel due to human activities, such as sand excavation from the bed, agricultural activity, disposal of municipal waste and construction on the river. The environment of the river should be maintained and would not be extremely disturbed by human activity [6]. River is important part of human being which is continually changing from its evolutions. The river slope, velocity and nature of river are responsible parameters for changing the river shape and size. Throughout study at Pravara River showing that river stream changes owing to various natural and manmade phenomena [7].

The purpose of this research is to determine the influence of river basin morphology change on threshold parameters in flood early warning system. The river morphology parameters reviewed are bed river elevation, land cover, and river border. Change of bed river elevation affect on river water level measurement while land cover affect the magnitude of runoff coefficient. Changes in river borders occur in urban areas that use river banks for construction and activities. The relationship between changes in river basin morphology parameters to the change of threshold parameters can also be used as a guide in river management and flood control.

2. Methods of The Study

This research was conducted by field data analysis using mathematical model to get correlation between morphology parameters of watershed and threshold parameters of flood early warning system. There are 15 cross-sections of the river that are used scattered in the upstream, midstream and downstream areas of Cimahi river basin, and then one of the cross-section of the river is determined as a threshold. The measured hydraulic parameters are the flow depth, flow velocity and the slope of the river bed. The land cover analysis was conducted using the Cimahi river basin land use map to determine the runoff coefficient. Water level of the river on the threshold cross section and the rainfall threshold are determined using the rainfall-runoff model where the direct runoff discharge is determined by the convolution method which is the function of effective rainfall and unit hydrograph.

Discrete convolution equation for the linear system used is shown in equation 1,

$$Q_n = \sum_{m=1}^{n-1} P_m U_{n-m+1}$$

(1)

Where $Q$ is direct runoff discharge, $P$ is effective rainfall and $U$ is unit hydrograph ordinate.

Landuse of a watershed shows the type of surface or land cover of the watershed. The land surface affects the amount of water infiltrated into the soil, so the type of land surface becomes the determining variable of the flow coefficient or runoff coefficient [8][9]. If $\sum_{m=1}^{M} R_m$ is the total rainfall and $r_d$ is the runoff depth, then the runoff coefficient can be defined as:

$$C = \frac{r_d}{\sum_{m=1}^{M} R_m}$$

(2)

In actual case, uniform flow is practically parallel flow. Gradually varied flow may also be regarded as parallel flow, since the change in depth of flow is so mild that the streamlines have neither appreciable curvature nor divergence, that is, the curvature and divergence are so small that the effect of the acceleration components in the cross-sectional plane is negligible [10].

The continuity equation for steady flow with constant $\rho$ is,
\[ \iiint_{\mathcal{V}} \nabla \cdot \mathbf{V} \, dA = 0 \]  

(3)

3. Results and Discussion

3.1. Study Area
Cimahi river basin is located in West Bandung Regency in the upstream, Cimahi City in the midstream and Bandung Regency in the downstream. The upstream of Cimahi river is located in a geographical position of 06°46'20'' south latitude and 107°34'42'' east longitude at an elevation of 1,482 m mean sea level and downstream at the geographical position of 06°57'37'' south latitude and 107°32'38'' east longitude at an elevation of 678 m mean sea level. Cimahi river is 30.6 km length and watershed area of 72.2 km². Cimahi river basin map is shown in Figure 1 below.

![Cimahi River Basin Map](image)

**Figure 1.** Cimahi River Basin Map

Runoff coefficient of Cimahi city increased from 0.57 in 2011 to 0.63 in 2017 with the highest percentage increase in residential and industrial areas which reduced the area of gardens and agriculture.

3.2. Observed Cross Section of Cimahi River
Five cross sections in the upstream region show the top width is about 48 m with an average channel elevation of 1450 mean sea level with an average slope of 17%. One of those cross sections is shown in figure 2 below,
Five cross sections in the midstream region show the top width is about 12 m with an average channel elevation of 768 mean sea level with an average slope of 10.6%. One of those cross sections is shown in figure 3 below,

![Midstream Cross Section](image1.png)

**Figure 3. Midstream Cimahi River Cross Section**

Five cross sections in the downstream region show the top width is about 19 m with an average channel elevation of 674 mean sea level with an average slope of 2.31%. One of those cross sections is shown in figure 4 below,

![Downstream Cross Section](image2.png)

**Figure 4. Downstream Cimahi River Cross Section**
3.3 The Effect of Changes in River Morphology to Threshold Parameters

3.3.1 Change of River Border. Narrowing of the border on the cross-section of the Cimahi river is very heavy. The top width upstream is 48 m, narrowing in the middle to 12 m and downstream to 19 m. The narrowing of the border makes the cross-sectional capacity of the Cimahi river upstream of 730 m$^3$/s decrease to 95.2 m$^3$/s in the middle and 59.4 m$^3$/s in the downstream. The capacity of the river due to the narrowing of this border resulted in the Cimahi river not being able to accommodate a number of design discharge. With Rational method, using the effective rainfall threshold in the middle which is determined based on the cross-sectional capacity of 29 mm with a duration of 1 hour, design discharge load for the downstream section is 332 m$^3$/s, very much greater than its capacity of 59.4 m$^3$/s. Change of river border is shown in Table 1.

Table 1. Change of River Border and The Effect to River Capacity

| Cross Section | Top Width (m) | Maximum Area (m$^2$) | $Q_{\text{cap}}$ (m$^3$/s) | $Q_{\text{load}}$ (m$^3$/s); $I_{\text{eff}} = 29$ mm/h |
|---------------|--------------|----------------------|-----------------------------|-----------------------------------------------------|
| Upstream      | 48           | 890                  | 730                         | 55                                                  |
| Midstream     | 12           | 18.5                 | 95.2                        | 184                                                 |
| Downstream    | 18           | 18.02                | 59.4                        | 332                                                 |

3.3.2 Change of Runoff Coefficient. Change in runoff coefficient is directly proportional to runoff volume. If the runoff coefficient increases, the runoff volume will also increase, resulting in greater discharge load. The rainfall threshold in the downstream area is based on river hydraulic and land use data in 2011 with a runoff coefficient of 0.57 is 29 mm with a discharge capacity of 59.4 m$^3$/s, produce design discharge of 332 m$^3$/s. By using the rational $Q = CIA$ equation, the increase in $c$ by 0.63 will increase the design discharge becomes 367 m$^3$/s.

3.3.3 Change of River Bed Elevation. Aggradation caused by sedimentation can reduce river capacity. This happens a lot in tropical countries like Indonesia. As shown in Table 2, downstream section of the Cimahi river which is the threshold location of the Cimahi flood early warning system, rise in the elevation of the river bed as high as 10 cm can reduce river capacity by 7.3% and rise in river bed by 50 cm can reduce river capacity by 41.8%. To overcome this aggradation, threshold of the flood early warning system must be periodically updated.

Table 2. Change of River Bed at Threshold Location

| Depth (m) | Discharge capacity, $Q_{\text{cap}}$ (m$^3$/s) |
|-----------|-----------------------------------------------|
| 0.8       | 34.6                                          |
| **1.3**   | **59.4**                                      |
| 1.52      | 71.12                                         |
| 1.62      | 76.6                                          |
| 1.72      | 82.17                                         |
| 2.00      | 98.3                                          |
| 2.2       | 110.3                                         |
| 2.5       | 129.1                                         |
| 3.5       | 197.9                                         |

the effect of rise in river bed on the river capacity is shown in the regression equation in the following figure 5,
Figure 5. Correlation between Rise in River Bed and Discharge Capacity at Downstream Cross Section

The curve above is exponential curve but its limited by maximum discharge of the river at the cross-section. \( R^2 \) of 0.95 is good enough for good correlation because it's close to one.

4. Conclusion
Changes in morphology and land cover have a very significant effect on the hydraulic parameters of the watershed ie river capacity and depth. Rise in runoff coefficient, increase the load on the river so that the risk of flooding is higher. Narrowing of the river border and the elevation of the river bed, significantly reduce the river capacity. Narrowing the width of the river from 48 m to 18 m, decreasing the discharge capacity from 730 m\(^3\)/s to 95.2 m\(^3\)/s, and increasing the elevation of river bed as high as 50 cm can reduce river capacity by 41.8%. Reducing this river capacity makes threshold parameters in flood early warning system invalid causing flood events cannot be detected early by the system.

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