Mapping of Flood-Prone Locations Impacted by Cilember River Overflow in Cimahi City Based on Geographic Information System

I. Karnisah¹, Y. Astor², B.S Bambang³, P. A. Suchi⁴, S.S. Rahmah⁵

Polytechnic State of Bandung
*yackobastor@polban.ac.id

Abstract. The high intensity of rainfall in Indonesia has a potential to cause catastrophic flooding in Cimahi City which is geographically located in the valley of basin and causes the overflow of water to the Cimahi City. There are nine flood points in Cimahi City and eight of them are located near Cilember River. This research creates a 2-dimensional map of flood-prone location impacted by Cilember River overflow. The map is integrated by constructing a Geographic Information System (GIS) not only at flood point location, but also at point of the existing survey, point of the river crossing measurement, and river crossing point location at each STA with the information of location coordinates, flood depth, flood solutions, and images. Data processing begin with hydrological analysis that will be used for hydraulic analysis using HEC-RAS software and flood-prone map using ArcGIS software. The map is processed and become GIS that built in ArcGIS software. This research product is a flood-prone map impacted by Cilember River overflow in period of 2, 5, 10, 25, 50, and 100 years based on the GIS. The difference of flood distribution generated in each return period does not appear significantly, but it can be seen at the height of flood in every return period. The benefit of this research is to provide information on the vulnerability of flood area to Cimahi City Government to solve flood problem that occur almost every year in Cimahi City.

1. Introduction

Geographically, Cimahi City is a basin valley that slopes to the south which is the slope of Mount Burangrang and Mount TangkubanPerahu with an altitude in the northern part of ± 1,040 meters above sea level (Cipageran Subdistrict, North Cimahi) and the altitude in the south around ± 685 meters above sea level (Melong, South Cimahi) leads to the Citarum River. The geographical location of the Cimahi City causes water runoff especially to South Cimahi.

There are nine flood points and 25 inundation points in Cimahi City [1]. Eight of the nine flood points are located in Central Cimahi and South Cimahi which are the areas passed by Cilember River. According to the Cilember River Detail Engineering Design (DED) obtained from Cimahi City Government, Cilember River passing Central Cigugur Village in Central Cimahi and also part of Cibeureum Village and part of Melong Village in South Cimahi.

Cited from detik.com, on October 11, 2017, floods inundated South Cimahi and Central Cimahi as high as 0.3 - 1 meter. This result impacts the broken embankment and overflow of water inundating rice fields covering an area of approximately 4 hectares and 30 houses
inhabited by 250 people submerged in water and mud. This causes material losses which are certainly not small.

So far the effort that has been carried out by the Cimahi City Government is to improve drainage around areas affected by Cilember River overflow, but it is only partial. Overcoming the flood problem in Cilember River requires a flood solution as a whole so it must look at the river as a whole as a network that is interconnected. Therefore, a geospatial approach is needed through the Geographic Information System (GIS).

The geospatial approach is a way of looking at an object, which here is a river, as a whole. So that a wider and more complete space information can be obtained. The geospatial approach is carried out using Geographic Information System (GIS) tools.

2. Literature Review and/or Hypothesis Development
Mapping the location of flood-prone in 2-dimensional form caused by the overflow of Cilember River as flood disaster mitigation information for Cimahi City Government in an effort to minimize the impact of flooding in Cimahi City which occurs almost every year in South Cimahi.

3. Methods
This research is mapping flood-prone location around Cilember River in Cimahi City. The methodology used to map flood-prone location in Cilember River shown in Figure 1.

![Figure 1. Flow Chart of Implementation](image-url)
3.1 **Problem Identification and Literature Studies**
Problem identification is based on the problem found in the object being reviewed, namely the Cilember River which often causes flooding problem for the environment around the river. Also survey to the location of the river and analyze data on flood that have occurred in Cimahi City from various media.

3.2 **Primary Data Collection**
Primary data is taken by measuring flood-prone points in Cilember River directly to the field. Primary data includes preliminary survey on the existing conditions of Cilember River along with coordinates and measurements of the elongated and transverse profiles of Cilember River. This data will be processed to become the form of longitudinal and transverse point of the flood-prone point of Cilember River network. This data also includes documentation of Cilember River condition.

3.3 **Secondary Data Collection**
Secondary data is obtained from previous research and any reliable sources. Secondary data used is rainfall data 12 years back from 2005 from Dago Pakar, Cibeureum, and Cipeusing rainfall stations, flood point coordinate data found in Cimahi City, Cilember River cross-sectional dimension from Cimahi City Government in 2014, Map land use in Cilember Sub-watershed of Cimahi City from Cimahi City Government in 2014, 2017 SPOT7 Satellite Imagery data, Cimahi City administration map (2016) and SRTM map.

3.4 **Hydrological Analysis**
Hydrological analysis is carried out by calculating the flood discharge plan of Cilember River with a return period of 2, 5, 10, 25, 50, and 100 years. The stages of hydrological analysis and the method used shown in Figure 2.

![Figure 2. Hydrological Flow Chart](image-url)
The results obtained from this hydrological analysis are flood discharge plans at 2, 5, 10, 25, 50, and 100 years which are calculated using the Nakayasu-Cytetic Unit (HSS) Hydrograph method with the results in Table 1.

| No | Time (t) [hour] | Qt [m³/det] | Flood Discharge Plan [m³/det] |
|----|----------------|-------------|-------------------------------|
|    |                |             | Q₂th | Q₅th | Q₁₀th | Q₂₅th | Q₅₀th | Q₁₀₀th |
| 1  | 0              | 0.000       | 1.193 | 1.193 | 1.193 | 1.193 | 1.193 | 1.193  |
| 2  | 1              | 1.754       | 14.126 | 18.006 | 20.192 | 22.624 | 24.243 | 25.717  |
| 3  | 1.232          | 2.895       | 92.545 | 119.952 | 135.394 | 152.573 | 164.007 | 174.420  |
| 4  | 2              | 1.589       | 61.301 | 79.334 | 89.494 | 100.798 | 108.321 | 115.173  |
| 5  | 2.772          | 0.869       | 37.106 | 47.880 | 53.951 | 60.704 | 65.199 | 69.293  |
| 6  | 3              | 0.771       | 35.087 | 45.255 | 50.985 | 57.359 | 61.001 | 65.464  |
| 7  | 4              | 0.458       | 21.321 | 27.359 | 30.761 | 34.547 | 37.066 | 39.360  |
| 8  | 5              | 0.269       | 13.018 | 16.565 | 18.564 | 20.788 | 22.268 | 23.616  |
| 9  | 5,083          | 0.261       | 12.642 | 16.076 | 18.012 | 20.165 | 21.598 | 22.903  |
| 10 | 6              | 0.182       | 9.192 | 11.592 | 12.944 | 14.448 | 15.449 | 16.361  |
| 11 | 7              | 0.123       | 6.604 | 8.227 | 9.142 | 10.160 | 10.837 | 11.454  |
| 12 | 8              | 0.083       | 4.853 | 5.952 | 6.570 | 7.259 | 7.717 | 8.134  |
| 13 | 9              | 0.056       | 3.669 | 4.412 | 4.831 | 5.296 | 5.606 | 5.888  |
| 14 | 10             | 0.038       | 2.868 | 3.370 | 3.654 | 3.969 | 4.178 | 4.369  |
| 15 | 11             | 0.026       | 2.326 | 2.666 | 2.857 | 3.071 | 3.212 | 3.342  |
| 16 | 12             | 0.017       | 1.959 | 2.189 | 2.319 | 2.463 | 2.559 | 2.646  |
| 17 | 13             | 0.012       | 1.711 | 1.867 | 1.954 | 2.052 | 2.117 | 2.176  |
| 18 | 14             | 0.008       | 1.543 | 1.649 | 1.708 | 1.774 | 1.818 | 1.858  |
| 19 | 15             | 0.005       | 1.430 | 1.501 | 1.541 | 1.586 | 1.616 | 1.643  |
| 20 | 16             | 0.004       | 1.353 | 1.401 | 1.428 | 1.459 | 1.479 | 1.497  |
| 21 | 17             | 0.002       | 1.301 | 1.334 | 1.352 | 1.373 | 1.386 | 1.399  |
| 22 | 18             | 0.002       | 1.266 | 1.288 | 1.301 | 1.314 | 1.324 | 1.332  |
| 23 | 19             | 0.001       | 1.242 | 1.257 | 1.266 | 1.275 | 1.281 | 1.287  |
| 24 | 20             | 0.001       | 1.226 | 1.236 | 1.242 | 1.248 | 1.253 | 1.256  |
| 25 | 21             | 0.001       | 1.215 | 1.222 | 1.226 | 1.230 | 1.233 | 1.236  |
| 26 | 22             | 0.000       | 1.208 | 1.213 | 1.215 | 1.218 | 1.220 | 1.222  |
| 27 | 23             | 0.000       | 1.203 | 1.206 | 1.208 | 1.210 | 1.211 | 1.212  |
| 28 | 24             | 0.000       | 1.200 | 1.202 | 1.203 | 1.204 | 1.205 | 1.206  |
| Maximum flood discharge | 92,545 | 119,952 | 135,394 | 152,573 | 164,007 | 174,420  |

Table 1. Flood discharge plan for each period

3.5 Hydraulics Analysis

Hydraulics analysis is carried out using HEC-RAS 5.0.3 water flow modeling software when it has obtained a flood discharge plan from the results of hydrological analysis. The results includes water level of Cilember River at return periods 2, 5, 10, 25, 50, and 100 years. Based on result from HEC-RAS analysis, dimensions in longitudinal and cross section shown in Figure 3 and Figure 4.
3.6. Mapping of Flood-Prone Location
Mapping of flood-prone locations using the HEC-RAS 5.0.3 software is assisted by Global Mapper software. The method used to simulate flow in the 2-dimensional HEC-RAS is the unsteady flow method. This method requires a data flow hydograph for each return period which is obtained from hydrological analysis and river slope numbers. This 2-dimensional HEC-RAS analysis also requires contour data in SRTM format and combined with the Cilember River terrain data. The results of mapping the location of flood-prone using 2-dimensional HEC-RAS in the form of flood distribution shown in Figure 5, and the distribution of flood can be changed in the form of raster data so it can be read in ArcGIS software for map making and GIS.

3.7 Geographic Information System of Flood-Prone Location
Geographical information system development displays flood points in Cimahi City for reviewing Cilember River and also displaying flood height of the hydraulics analysis results at each STA on Cilember River. Data are needed to create flood-prone map due to Cilember River overflow and to create Geographic Information Systems (GIS) of flood-prone location due to Cilember River overflow in ArcGIS 10.6 software, namely SPOT 7 Satellite Image, Cimahi City administrative boundary map, Cilember River map, contour map (from the RBI map), Cilember River watershed data and also the map of the flood distribution that has been changed in raster format. To support GIS, data were added in the form of 9 flood location points, 10 existing survey location points, 12 cross-sectional locations, and 128 river crossing points for each STA, where attribute data was added such as point coordinates, location, depth of floods, solutions and drawings on the location of flood, existing survey location, river crossing measurement and river crossing point at each STA.
4. Discussion

a. Map of Flood-Prone Location

Map of flood-prone locations impacted by Cilember River overflow was made to provide information on the spread of river water to certain locations at each time period that had been planned in advance. The following is a map of flood-prone location impacted by Cilember River overflow made in ArcGIS software shown in Figure 5 and Figure 6.

![Figure 5. Map of Cilember River Overflow in 2 Years Flood Discharge Plan](image1)

![Figure 6. Map of Cilember River Overflow in 100 Years Flood Discharge Plan](image2)

The blue color found around the location of Cilember River on a map of flood-prone locations indicates that when the blue color is getting darker, the greater the depth value of overflow water occurs in the area. At the flood discharge, the 2-year plan also contained flood caused by Cilember River. Then when observed, the flood conditions caused by the flood discharge plan in the 5, 10, 25, 50 and 100 time periods did not look significant.

The difference between the distribution of overflow water and the depth of flood in the area around Cilember River is not significant for each time period. Floods are seen to only inundate certain locations for each period of time, the distribution of water is seen only widened gradually and not significant. The difference that can be seen directly is the height of the flood in the location that was affected by the flood. The depth of flood continues to increase along
with the increasing flood discharge plan that has been calculated in each period of time, even though the value is not significantly different considering to the 2-dimensional display that water flows from high elevation to lower elevation.

This can be happening due to the cross-sectional input based on secondary data that is not too long in the riverbank area, with a length ranging from 1.5 to 5 meters. So the visualization shown on the map of the flood overflow distribution does not reflect the difference significantly. The distribution results will be better if the cross-sectional input in the riverbank area is more expanded, so that the resulting river terrain describes the actual river condition better.

Also, this can be happening due to the geographical area of Cimahi City which is a region with a basin elevation state. So, in the event of a flood, the event is only centered on a particular location that does have a lower elevation compared to the others, and if it not handled properly, the flood will be higher in every year.

b. Geographic Information System (GIS) Flood-Prone Location

GIS is made to provide information on a map of flood-prone locations related to locations affected by Cilember River overflow. The following is a flood-prone GIS where the final results of the Cilember River overflow map were made in ArcGIS software shown in Figure 7 and Figure 8.

Figure 7. Examples of GIS on Flood-Prone Points and Location of Existing River Survey Points

Figure 8. Examples of GIS on the location of measurement points for cross sectional dimension and river dimension in each STA

Based on the system that has been made, it can be seen that the information contains the coordinate point, location, depth of flood, solution and image on the location of the flood point,
the point of the existing survey location, the location point of the river crossing, and the river crossing point at each STA. The geographical information system found on this flood-prone location map is more informative and efficient for the wider community, because it can display the information needed in a system just by clicking on the desired point.

c. Alternative Flood Management Solution

Based on the results that have been explained, the flood caused by the overflowing of Cilember River has a major impact on the surrounding area. Flood that occur can impacted by many factors, including the narrowing of river sections, river banks that are used as settlements, sedimentation, the conversion of land functions that are supposed to be areas of water uptake, to the lack of public awareness of the cleanliness of Cilember River.

An alternative solution is needed to reduce the impact when a flood occurs so losses in material and non-material matter can be minimized. Flood mitigation that always occurs in Melong area has actually become a top priority for Cimahi City Government. The following are alternative solutions that can be used.

1. River Normalization

The reduced capacity in the cross-section of Cilember River has an impact on the lack of rainwater being collected. This can be caused by the silting of sediments and/or river bodies that are narrowed due to both natural factors and human intervention factors. Riverbanks that switch function to houses are common things.

Normalization of Cilember River has actually been recommended by Cimahi City Government because drainage repairs that applied continuously around flooded areas are still not enough to overcome the flood that occur in rainy season. By normalizing Cilember River, it is expected that the capacity of rainwater in the river can be greater, so the flood can be overcome.

2. Making Embung

Embung is a building that functions to store rainwater in a pool and operated during dry season for various needs of a village, namely: residents, animals and gardens [2].

Cited from jabarekspress.com, responding to the problem of flood that occurred in Melong, Cimahi City Government will make puddles and embung. The reservoir will be made in three points, namely in Pasir Kaliki, North Cimahi, Central Cigugur, Central Cimahi, and Melong, South Cimahi. This certainly requires a large enough area which means that land acquisition must be applied.

Making embung is an alternative solution that can be applied to reduce flood. Embung can accommodate excess rainwater that comes from river which overflows during rainy season. In addition, the collected water can be used by local residents to distribute and guarantee the availability of water supply in dry or rainy season.

3. Planting Trees in Cilember Watershed

The ability of trees to regulate rainwater is one of the causes of water balance in an area. Water balance is a manifestation of the function of hydrological system and means that all ecosystem components are in a complete hydrological system performance [3].

With the presence of trees, the rate of infiltration will be faster. Infiltration is the event of water movement into the soil until it reaches the root layer, following lateral water flow and percolation or drainage [3]. Infiltration rate can be defined as the volume of water flowing into the soil profile per unit of land surface area. If the rate of infiltration is faster it will reduce the risk of flooding and inundation in the area. Alternative trees that can be planted in flood areas because they have good infiltration values are Pine with infiltration rate of 26.59 cm/hour, Surian with infiltration rate of 1.73 cm/hour, Mahonid with infiltration rate of 18.13 cm/hour, Teak with infiltration rate of 0.17 cm/hour, Avocado with an infiltration rate of 3.57 cm/hour, Clove with an infiltration rate of 2.16 cm/hour, Durian with an infiltration rate of 7.80 cm/hour,
Duku with an infiltration rate of 3.49 cm/hour, and Rambutan with an infiltration rate of 0.27 cm/hour.

Planting trees can be an alternative solution to overcome flood of Cilember River, especially in the downstream river area, namely Melong, South Cimahi, considering there is always flooding in this area due to water overflow from Cilember River. Awareness in the surrounding community about the importance of planting trees is needed to reduce the problem of flood.

References
[1] M. F. A. Pratama and S. R. J. Sari. (2017).“Identifikasi dan Inventarisasi Unsur-unsur Penyebab Banjir dan Genangan di Wilayah Kota Cimahi Provinsi Jawa Barat”, Politeknik Negeri Bandung Publisher, Bandung.
[2] Kamaludin. (2018). “Demi Kurangi Banjir Melong, Pemkot Cimahi Terpaksa Ambil Opsi Membuat Embung” in Tribun Jabar.id. http://jabar.tribunnews.com/2018/02/13/demi-kurangi-banjir-melong-pemkot-cimahi-terpaksa-ambil-opsi-membuat-embung (19 July 2018).
[3] L. N Ayni. (2010).“Pengaruh Karakter Individu Pohon Terhadap Laju Infiltrasi dan Permeabilitas Tanah di Sub DAS Samin, DAS Bengawan Solo Hulu, Kabupaten Karanganyar”, Fakultas Pertanian Publisher, Surakarta.