Mapping of flood-prone-zone and puddle-prone-zone in Cimahi city, West Java province

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Abstract. Climate change and advanced urbanization level followed by the changing function of an area affect to the amount of water absorption area. It causes puddle and flood in city, include Cimahi, West Java, which is in the last 10 years has been surrounded by flood and puddle. To avoid the flood case in Cimahi, the re-identification and flood-factor inventory are needed. The identification and inventory are using the simplest method (literary study from any source), start from discussing session with Cimahi government, interviewing and filling questioner to the citizen who live in flood and puddle area, measuring river and drainage profile, counting the capacity of river and drainage, until simulating the 2-dimension and 3-dimension of flood and puddle. The result of the identification and inventory is shown in Flood-Prone-Zone Map and Puddle-Prone-Zone Map. According to Cimahi’s Flood-Prone-Zone Map, it shows that the flood-safe area is about 110,747 ha (2.70%), the not-flood-prone area is about 494,233 ha (12.05%), the flood-prone area is about 2016,474 ha (49.18%), and the very-flood-prone area is about 1478,799 ha (36.07%). According to Cimahi’s Puddle-Prone-Zone Map, it shows that the puddle-safe area is about 128,616 ha (3.14%), the not-puddle-prone area is about 551,246 ha (13.44%), the puddle prone area is about 2702,826 ha (65.92%), and the very-puddle prone area is about 717,556 ha (17.50%). The Flood-Prone-Zone Map and the Puddle-Prone-Zone Map can be used as a reference for the Cimahi Government in formulating the policy of regional development.

1. Introduction
Cimahi City West Java Province is one of the urban areas that often occur flood. Geographically Cimahi City is basin valley that slopes to the south with altitude in the north 900-1025 meters above sea level (Cipageran Urban District North Cimahi). This valley is the slope of Mount Burangrang and Mount Tangkuban Perahu, while the altitude in the south is about 850-900 meters above sea level (partly in Cibeber and Leuwi Gajah Urban District South Cimahi) leading to the Citarum River [1]. This topography condition that causes South Cimahi more often affected by floods compared with North Cimahi.

Based on the location of administration in Figure 1, Cimahi City is a buffer city of Bandung. Cimahi city is bordered directly with West Bandung regency and Bandung City [2]. The flood that occurred in South Cimahi is a more complex problem (Figure 2) than in North and Central Cimahi, it is caused by the flood location located in the border area so to solve the flood problem it is need to cross local government involving West Bandung Regency, Bandung and West Java Provincial Government [3].
In addition, the population in South Cimahi is higher than the population in North and Central Cimahi [4] (Table 1) causing the need for residential and garbage produced increase. This condition causes the Watershed (DAS) in South Cimahi shallow and no longer functioning properly.

Many efforts have been done by the Cimahi City Government independently or in cooperation with the Government of Bandung, West Bandung Regency and West Java Provincial to handle the problem of this flood, which is by doing short and medium term solutions, including the normalization of the river and non-structural solution through community empowerment. Meanwhile, to overcome the problem of flood in the long term, it is necessary to conduct a comprehensive study related to the management of water resources in an integrated manner through flood engineering and management.

The definition of city flood engineering and management is the application of scientific and mathematics principles for the purpose of practical (engineering) integrated process to achieve the goal of overcoming flood problem systematically, effectively and efficiently in cities or urban areas [5]. Referring to the definition, that to conduct a comprehensive and integrated process is needed an accurate and actual data and information as input to build a flood management model in accordance with the characteristics of Cimahi City. Therefore, it is necessary a flood-prone-zone and puddle-
prone-zone mapping model that can display the data as a whole and actual, which able to visualize flood phenomenon that occurred in Cimahi City, West Java Province.

This research builds zonation map model of flood prone-zone and puddle-prone-zone in an effort to overcome the problem of flood and puddle in Cimahi City, West Java Province. Zonation map model of flood-prone-zone and puddle-prone-zone is built based on a comprehensive study on the problem of flood and puddle in the City of Cimahi using textual and geographical data conditions of the Cimahi City.

2. Research methodology

Figure 3 is the research methodology that used in building a Model of flood-prone-zone and puddle-prone zone in Cimahi City:

Identify the elements that causing flood and puddle, also impacts and losses caused by flood and puddle that occur in the City of Cimahi. Identification is done through literature study to find information of flood and puddle that ever happened in Cimahi City so that obtained information of location of flood and puddle, time of incident, and reason of flood and puddle occur. Information searching is done through printed mass media, electronic, and other references such as official government accounts and agencies in Cimahi City, as well as amateur photos and videos from Cimahi City residents displayed through social media. In addition to the literature study, also conducted presentations and discussions with the Cimahi City Government discussing the definition of flood and puddle, as well as effort to overcome the flood and puddle that has been done by the Cimahi City Government. Flood is defined as the condition of the increasing water volume in the river that causes the water which is not accommodated and then it flows into the surrounding land. Meanwhile the puddle is a condition of the water that is not accommodated in the drainage channel so it flows out the drainage channel or wets the surrounding area. Based on the results of identification from various sources, it obtains 6 points of flood and 27 points of puddles in Cimahi City.
Inventory of necessary data, including prevailing laws and local government policies related to flood prevention in Cimahi City. Primary data obtain directly from the field such as measurement data and survey data. Secondary data are obtained from related agencies such as rainfall data, Satellite Imagery, Earth Rising Map, Digital Elevation Model (DEM), Watershed Map, River Network Map, Land Use Map, and other data.

Survey at flood-prone-zone and puddle-prone-zone. Measure the situation and cross-section of the river to obtain information of existing conditions (Figure 4). Observe the high frequent of flood and puddle that often occur (Figure 5) and direct interviews and questionnaires that has been given to flood victims and local government.

Based on observation and measurement of the 4 rivers in Cimahi, which are CIlembre River, Cisangkan River, Cibereum River and Cimahi River, the cause of flood in Cimahi City is dominant due to the narrowing and shallowing of river channel [6]. Based on the result of observation and measurement of drainage channel cross-section in the location of puddle in Cimahi City, the cause of puddle in Cimahi City is dominant due to the condition of drainage channel that covered by garbage and the drainage channel dimension that is not in accordance with guidelines and planning.

Calculation of river capacity (Figure 6) and drainage (Figure 7) at flood and puddle area in Cimahi City. Calculations are performed using HEC RAS software for modelling the flow.
Flood modeling in 3 dimensions (Figure 8). Conducted to get a visualization of the flood and puddle phenomenon in the Cimahi City, so the location that affected by flood is known and the area of flood can be calculated. The modeling results are obtained information that the change of flood and puddle high in Cimahi City does not significantly affect the area of flood and puddle, it because Cimahi City is basin valley.

Making the Map of Flood-prone-zone and Puddle prone-zone in Cimahi City. The parameters, that is used in the manufacture, are slope, land use, rainfall, soil type, river buffer and puddle point. Each parameter will be given the weight, the greater the effect of parameters on flood and puddle the higher weights used. Each parameter consists of classes, each class has given a score based on the class's influence on the flood and puddle. Flow chart that shows the Map of Flood-prone zone and Puddle-prone-zone making process in Cimahi City is showed in attachment section.

2.1. Making of slope map
The slope is a factor that has a great effect on the flood prone. The more sloping the slope the runoff flow will be slower that can cause flood prone. Conversely, the steeper the slope the runoff will be faster, so the water that falls to the ground will flow quickly. Based on RTRW Cimahi City Year of 2012-2032, the most slope in Cimahi City is at 0-8% (Table 2) [1].
Table 2. Slope in Cimahi city based on districts.

| District     | Slope (Ha) | Total   |
|--------------|------------|---------|
|              | 0-8%      | 8-15%   | 15-25%  | 25-40%  |
| South Cimahi | 1483,07   | 13,60   | 68,69   | 68,69   | 1.654,30 |
| Central Cimahi | 977,44  | -       | 6,44    | 5,74    | 989,62   |
| North Cimahi  | 1288,71   | 22,30   | 80,11   | 17,84   | 1.408,96 |
| Total        | 3749,22   | 35,90   | 175,49  | 92,26   | 4.052,88 |

Source: RTWR Cimahi city year of 2012-2032

Table 3. Score of land slope classes.

| Num. | Class                | Score |
|------|----------------------|-------|
| 1    | Flat (0-3%)          | 9     |
| 2    | Ramps (3-8%)         | 7     |
| 3    | Slant (8-15%)        | 5     |
| 4    | Steep (15-30%)       | 3     |
| 5    | Very steep (30-45%)  | 1     |

2.2. Making of land use map

Land use is classified into two which are built and non-built land use. Land use consists of industrial facilities, health, commercial, sports, education, communications, offices and community services, defense and security, places of worship, tourist attractions and habitation. The non-constructed land use consists of rice fields, parks, shrubs, vacant lots, gardens, cemeteries, landfills, water bodies, and fields [7]. Based on the Land Use Data in Cimahi City in 2012 the largest land use is habitation, followed by the use of rice fields [1]. The correlation of land cover types to flood-prone and puddle-prone level is that the land use can reduce rainwater absorption.

Making of Slope Map using Digital Elevation Model (DEM) from Shuttle Radar Topography Mission (SRTM) 30 m accuracy. Scores used in each class show in Table 3. Making of Land Use Map is using Cimahi City Satellite Imagery data, visual interpretation method and digitization process. Land use in Cimahi City consists of settlements, factories, rice fields, vegetation, plantations and open land. Scores used in each class are (Table 4):

Table 4. Score of land use classes.

| Num. | Class     | Score |
|------|-----------|-------|
| 1    | Factory   | 5     |
| 2    | Habitation| 3,5   |
| 3    | Open field| 3     |
| 4    | Vegetation| 2     |
| 5    | Plantation| 1,5   |
| 6    | Rice field| 1     |

2.3. Making of rainfall map

Rainfall is the most influencing factor of flood and puddle. Rainfall data that is used is annual rainfall data from BBWS Citarum and Irrigation Agency in 2004-2016. The stations that are used are Cidadap-Montaya station, Dago Pakar-Bengkok, Cisondari, Cipaku-Ciparay and Cicalengka. Based on RTRW Cimahi City Year of 2012-2032, Cimahi City has low rainfall. Meanwhile, according BMKG July and November Year of 2014, the Cimahi City has a medium rainfall that is 151-200mm but sometimes it
raises into 201-300 mm. Making of rainfall maps includes calculating the average annual rainfall for each station. Interpolation of Inverse Distance Weighted (IDW) method is performed. Scores used in each class show in Table 5:

| Num | Class | Score |
|-----|-------|-------|
| 1   | >3000mm (Very wet) | 9     |
| 2   | 2501-3000mm (Wet) | 7     |
| 3   | 2001mm-2500mm (Moist) | 5     |
| 4   | 1501mm-2000mm (Dry) | 3     |
| 5   | <1500mm (Very Dry) | 1     |

2.4. Making of soil type map
Soil type is very influential on infiltration process (soil absorption). If the capacity of the rainwater that goes down directly to the ground does not exceed or less than the infiltration capacity, the infiltration rate can be said to be equal to the rain intensity. Based on data from the Center of Groundwater and Environmental Geology year of 1996, the extent of land type in Cimahi City is mostly Tufaan clay and silty-clay which has a very low rate of infiltration compared with other soil types (Table 6) [8].

| District      | Soil type (Ha) | Total   |
|---------------|---------------|---------|
| South Cimahi  | 290,44        | 1,654,30|
| Central Cimahi| 24,72         | 989,62  |
| North Cimahi  | 0             | 1,408,96|
| Total         | 315,16        | 4,052,88|

Description: 1 = Andesite, 2 = Clay and sandy-clay, 3 = Sandstone, conglomerate and tufaan sandstone, 4 = Tufaan clay and silty-clay. Scores used in each class show in Table 7:

| Num | Class                                         | Score |
|-----|----------------------------------------------|-------|
| 1   | Tufaan clay and silt clay                     | 4     |
| 2   | Clay and sandy-clay                           | 3     |
| 3   | Andesite                                     | 2     |
| 4   | Sandstone, conglomerate and tufaan sandstone  | 1     |

2.5. Making of puddle and river buffer map
Distance from the river and drainage is one of the factors that influence the level of flood and puddle. The closer to the river and drainage channels the more likely to be affected by flood and puddle. The distance from the river and drainage is determined based on the existing condition in the field. The puddle and river buffer maps are made using the Buffer method and the Multiple Ring Buffer tools. Scores used in each river buffer class show in Table 8:

| Num | Class             | Distance of buffer | Score |
|-----|------------------|--------------------|-------|
| 1   | Very prone       | 0-25m              | 7     |
| 2   | Prone            | >25m-100m          | 5     |
| 3   | Somewhat prone   | >100m-250m         | 3     |
Table 9. Score of puddle buffer classes.

| Num | Class          | Distance of buffer | Score |
|-----|----------------|--------------------|-------|
| 1   | Very prone     | 0-100m             | 7     |
| 2   | Prone          | >100m-300m         | 5     |
| 3   | Somewhat prone | >300m              | 1     |

After the scoring for each parameter is done, the next thing is to determine the score of flood-prone-zone and the puddle-prone-zone parameters (Table 10 and Table 11), as follows:

Table 10. Score of flood-prone-zone.

| Num | Parameter | Score |
|-----|-----------|-------|
| 1   | Slope     | 0,3   |
| 2   | Soil type | 0,25  |
| 3   | River buffer | 0,2 |
| 4   | Land use  | 0,15  |
| 5   | Rainfall  | 0,1   |

Table 11. Score of puddle-prone-zone.

| Num | Parameter       | Score |
|-----|----------------|-------|
| 1   | Slope          | 0,3   |
| 2   | Land use       | 0,25  |
| 3   | Soil type      | 0,2   |
| 4   | Puddle buffer  | 0,15  |
| 5   | Rainfall       | 0,1   |

Flood and puddle values are determined from the total sum of scores of all parameters affecting floods and puddles. The prone value is determined by the following equation [9]:

\[ K = \sum_{i=1}^{n} (W_i \times X_i) \]

Information:
- \( K = \) Value of Prone
- \( W_i = \) Score for the i-th parameter
- \( X_i = \) Score Class for the i-th parameter

The interval width of each class is done by dividing the same number of values obtained by the number of class intervals specified by the following equation:

\[ i = \frac{R}{n} \]

\( i = \) Width of Interval
\( R = \) Difference in maximum and minimum scores
\( n = \) Number of flood prone classes

Table 12. Score of flood prone level.

| Num | Flood prone level | Score       |
|-----|------------------|-------------|
| 1   | Very prone       | 6.75-5.487  |
| 2   | Prone            | 5.487-4.225 |
| 3   | Not prone        | 4225-2962   |
| 4   | Secure           | 2.962-1.7   |
Each class of flood and puddle prone has characteristics based on frequency, duration and depth.

| Num | Class of prone | Frequency (year) | Duration (days) | Depth (m) |
|-----|----------------|-----------------|----------------|----------|
| 1   | Secure         | Never           | -              | -        |
| 2   | Not prone      | 1-2             | -              | -        |
| 3   | Prone          | 1-2             | 1-2            | 0,5-1,0  |
| 4   | Very prone     | Annually        | 2-15           | 0,5-3,0  |

3. Result and discussion

There are 2 main outputs of this research which are Flood-prone-zone and Puddle-prone-zone Map. In contrast to previous similar research, the Flood-prone-zone and Puddle-prone-zone Map from this research has more value which lies in better data reliability, because the process of identification and inventory of flood and puddle elements is done using several methods, ranging from the simplest method (literature study from various sources), discussions with Cimahi City government, interviews and questionnaires to residents in flood and puddle locations, up to river and drainage cross-sectional measurement, calculation of river capacity and drainage, and simulation of flood and puddle 2 dimensions and 3 dimensions.

3.1. Flood-prone-zone map

Flood-prone-zone map is displayed in 2 formats which are vector and raster (figure 9 and figure 10), as follows:

Figure 9. Flood-prone-zone in vector and raster format.

Figure 10. Puddle-prone-zone in vector and raster format.
Based on flood-prone-zone map above, calculate the area of each flood-prone-zone of Cimahi City area. In this study there are differences of the area of Cimahi City, based on Map of Administrative Boundary of the Earth Rising Map of Indonesia which is downloaded from Geospatial Information Agency Portal it obtains the area of 4,100,244 ha. Meanwhile, according to RTRW Cimahi City Year of 2012-2031 it obtains information that the area is 4,052.88 ha, and according to Book of Cimahi in Year of 2015 it obtains information that the area is 40.2 km2.

The result of calculating flood-prone-zone of Cimahi City taken from Rupa Bumi Indonesia map, obtained information that the secure area of flood is 110,747 ha (2.70%), not flooding is 494,233 ha (12.05%), prone to flood is 2016,474 ha (49.18%), and very vulnerable is 1478,799 ha (36.07%).

3.2. Puddle-prone-zone map

Puddle-prone-zone map is displayed in 2 formats which are vector and raster, as follows: The results of the calculating puddle-prone-zone of Cimahi City taken from the Rupa Bumi Indonesia Map, obtained information that the secure area of puddle is 128,616 ha (3.14%), not puddle is 551,246 ha (13.44%), puddle is 2702,826 ha (65.92%), and very vulnerable to puddle is 717,556 ha (17.50%). After the location of flood and puddle along with its extent, place each flood and puddle location in Cimahi City Spatial Pattern Map sourced from Spatial Plan of Cimahi City Region year of 2012-20132 (Figure 11). The compatibility of spatial pattern on flood-prone-zone and puddle-prone-zone is showed in figure 12 and table 14.

Figure 11. Cimahi city spatial pattern map year of 2012-2032.
Figure 12. Flowchart of flood-prone-zone and puddle-prone-zone map making process.

Table 14. Compatibility of spatial pattern on flood-prone-zone and inundation-prone-zone.

| Num | Spatial Pattern        | Location                  | Flood-prone-zone Map | Inundation-prone-zone Map |
|-----|------------------------|---------------------------|----------------------|----------------------------|
|     |                        |                           | VP       | NP | S | VP | NP | S |
| 1   | RTH                    | Kel. Melong               | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibeureum            | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cigugur              | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Padasuka             | 1        | 1  | 1 | 1  |    |    |
| 2   | Socio-cultural         | Kel. Padasuka             | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibeber              | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Baros                | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Leuwisjiah           | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cipageran            | 1        | 1  | 1 | 1  |    |    |
| 3   | Low Density Habitation | Kel. Tjepangeran          | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Citereup             | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cimahi               | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibabat              | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Pasirikilik          | 1        | 1   | 1 |    |    |    |
|     |                        | Kel. Setiamanah           | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibeber              | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Leuwisjiah           | 1        | 1  | 1 | 1  |    |    |
| 4   | Medium Density         | Kel. Leuwisjiah           | 1        | 1  | 1 | 1  |    |    |
|     | Habituation            | Kel. Ummi                 | 1        | 1  | 1 | 1  |    |    |
| 5   | Office or Institution  | Kel. Leuwisjiah           | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibeber              | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Baros                | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Setiamanah           | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Karang Mekar         | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cipageran            | 1        | 1  | 1 | 1  |    |    |
| 6   | Modern Trade           | Kel. Baros                | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cipageran            | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cimahi               | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Setiamanah           | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Karang Mekar         | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibabat              | 1        | 1  | 1 | 1  |    |    |
| 7   | Tours                  | Kel. Tjepangeran          | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Citereup             | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibabat              | 1        | 1  | 1 | 1  |    |    |
| 8   | Military               | Kel. Ummi                 | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibeureum            | 1        | 1  | 1 | 1  |    |    |
| 9   | Industry               | Kel. Melong               | 1        | 1  | 1 | 1  |    |    |
|     |                        | Kel. Cibeber              | 1        | 1  | 1 | 1  |    |    |
Description:
VP = Very Prone,
P = Prone,
NP = Not Prone,
S = Safe.

4. Conclusion

- It provides 6 points of floods and 27 points of puddles in Cimahi City.
- The cause of floods in Cimahi City is dominant due to the narrowing and shallowing of river channels. Meanwhile, the cause of puddles in Cimahi City is dominant due to the condition of drainage channels that is covered with garbage and drainage channel dimensions that are not in accordance with guidelines and planning.
- Change of the flood water and puddle height in Cimahi City did not significantly affect the area of flood and puddle.
- It provides information that the area of secure flood is 110,747 ha (2.70%), not flooding is 494,233 ha (12.05%), prone is 2016,474ha (49.18%), and very prone is 1478,799 ha (36.07%).
As for the puddle, it was found that the secure area of puddle is 128,616 ha (3.14%), not prone is 551,246 ha (13.44%), prone is 2702,826 ha (65.92%), and very prone is 717,556 ha (17.50%).
- Nine types of spatial patterns in the City of Cimahi mostly located in the zone that is very prone and prone to flooding and puddles.

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