

The use of rapid assessment for flood hazard map development in upper citarum river basin

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Abstract Flood is a natural disaster that can occur at any time and anywhere. The flood disaster causes material and non-material loss, then in order to increase the resilience to disaster, an early warning system is needed. The data is indispensable as a reference to make an early warning system. Unfortunately, flood assessment in purpose to record the data is often conducted much later after the event occurs. Therefore, this research was conducted to do modelling of flood hazard map is quantitatively and validated with observation data as a form of rapid flood assessment. The location of this study is in the Upper Citarum River Basin, around Bandung basin. The model is well done if the result shows the location of the flood as illustrated as the observational data. The result shows fair agreement with observed data where some points of inundated areas are captured and the location of inundated areas from modelling result looks similar to the inundated area from observation data.

1 Introduction

Flood disaster is a natural hazard influenced by many factors including anthropogenic, change in climate, and socio-economic development. Flood frequently occurs in many countries, especially in developing countries [1]. Indonesia with more than 17,000 islands and 5,000 river basins is a country which is well known with a high risk of natural disaster including flood hazard due to its topographic condition and geographical location. Flood has been increasing during the last few years [2]. Climate change might lead to the increase of intensity and potential risk of flood hazard in Indonesia [3]. Flood occurrence will cause a lot of problems such as human activities, health, and economic issues [4] [5]. Furthermore, it also leads to instability slope, building damages, and death victim. It is considered that disaster management is a solution to minimize the risk of a disaster including flood.

Flood is the most frequent disaster in Indonesia. At least there are 8.498 flood events in period 1980-2017 (Figure 1) and overall was happened in Java (BNPB). Which java is the island with the largest population, it means that if a flood happens in Java will cause many losses both material, non-material and a large number of victims. That makes flood disaster management is necessary.

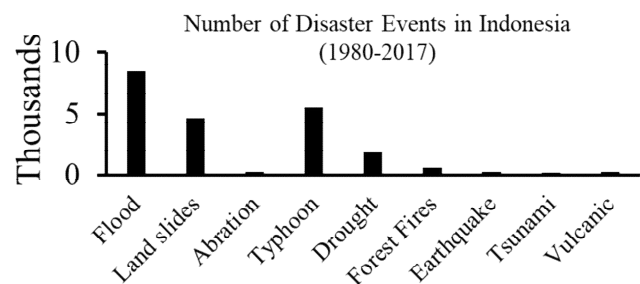


Fig. 1. Number of disaster events in Indonesia (1980-2017)

The Citarum River is one of the main rivers in java which is prone to flood. The flood occurred since the 1980's when massive land conversions occurred. Since then the flood began to hit The Southern Bandung, especially some sub-districts such as Baleendah, Buah Batu, Rancaekek, and surrounding areas. Several measures have been taken to reduce the area of exposure to floods for example by normalization in 1994, but do not eliminate the inundation area thoroughly. Until now the floods are still happening and getting worse due to the problems of garbage and global climate change.

Flood disaster management consists of important information about flood whether it is related to the exposure area or the guideline that is necessary to be done when flooding occurs. Understanding flood

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potency is a key step in managing the impacts and in order to make it easier, historical data of flood disaster event would be very helpful. The problem is that the record is very poor particularly in developing countries like Indonesia. Although there is an action to observe a disaster event, it is often conducted so long after the disaster occurs. That will cause loss of disaster trace or inadequate quality of the recorded data. Thus, the rapid flood assessment is very important. The objective of this study is to model flood hazard map quantitatively and to validate the map with observed data that is obtained by conducting rapid flood assessment.

2 Material and method

This paper studies about the use of rapid flood assessment in supporting the development of flood hazard map by using model simulation. The location of the study is taken in the upper part of Citarum River Basin which includes Bandung City, Bandung Regency, West Bandung Regency, and Cimahi City.

2.1. A case study of upper citarum river basin

Upper Citarum River Basin flows through Bandung District (passing by sub-district of Rancaekek, Sapan, Baleendah, and Dayeuh Kolot) to Saguling Dam. It is located in 6°43'21,8"-7°19'38,1" South and 107°32'2"-107°53'51,6" East. Administratively, it also passes through several cities and districts such as Bandung District, Sumedang, Bandung City, and Cimahi City. The upstream basin is surrounded by mountains and hills. Annual rainfall varies from an average of 1000 mm in the coastal areas and increases to 4000 mm in the mountains, at the top of the watershed [6]. Based on its hydrological characteristic, it is divided into North Bandung Basin and South Bandung Basin. Each basin has its own rainfall variation and different time of concentration.

Flood in Citarum Basin started to occur from a long time ago. In 1810, the capital city of Bandung District was moved from Krapyak (now: Dayeuh Kolot) to Central Bandung due to flood event which always occurs in wet season [7]. Nowadays the problems which cause flood are more complex. Besides of high rainfall intensity and inadequate channel capacity, the population growth provides an excessive charge to the environment, especially in absorbing and storing rainfall. Furthermore, human activities in managing environment cause decreasing carrying capacity of the environment such as deforestation, land conversion, livestock breeding, unequal farming, household waste, irregular groundwater use, and industry which make a flood that happened in Citarum River Basin is getting worse. Within the last few decades, environmental conditions of Citarum River Basin decrease significantly. The rapid urbanization causes flood threat many areas in this region. In the upstream, there is about a 45% decrease of forest cover, from about 35,000 ha to about 19,000 ha [8]. Flood in the upstream of Citarum River Basin which is known as Bandung Basin is affected by geological and

topographical factors. The flat area in the centre part of the basin and the mountainous area surrounding has caused the prolonged flood in this region. For example, Inundation in Dayeuh Kolot is hard to be drained. It is considered to be caused by the topographic condition which is lowland as can be seen in Figure 2.

Several major flood events which inundated large area occurred in this region in 1986 (about 7,100 acres of inundation area), 1995 (about 6,000 ha), 2002 (7,800 ha), and 2010 (9,180 ha) [8] [9]. In some events, heavy rains in Upper Citarum River Basin also resulted in a landslide with hundreds of victims [10]. Several studies have been done by government, universities, and any institutions to solve the flood problem. However, studies which observe the causes of flood quantitatively are rarely to be found. Some studies have predicted the flood-prone maps but they generated the inundation information based on return period flow from frequency analysis which is not from eventual based and actual information (rainfall or inundated area) of a flood event. Therefore, an adequate dataset for input into a flood model is needed in order to represent the real condition of the flood event and to obtain good accuracy in the simulation.

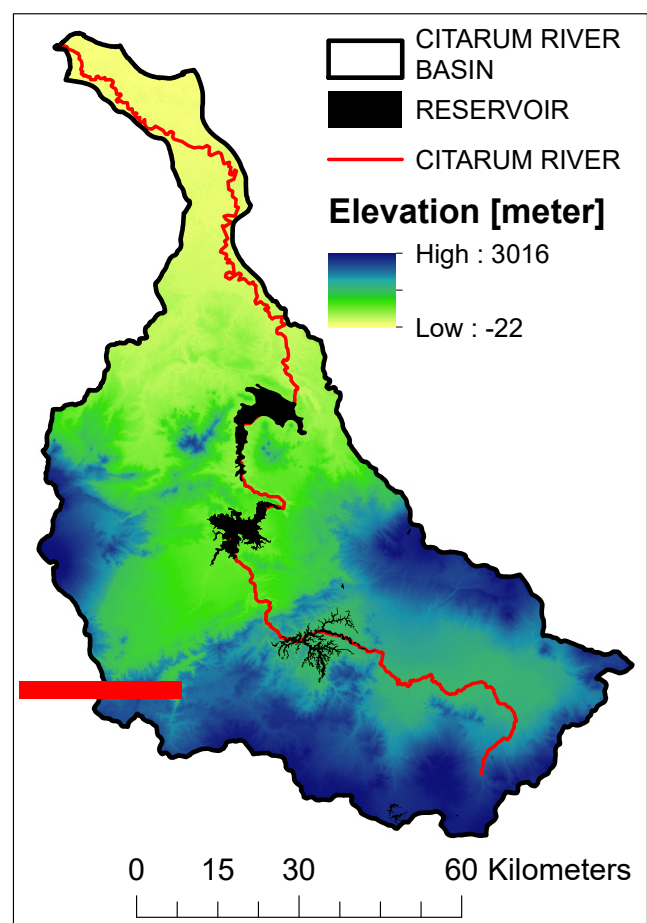


Fig. 2. The topographical condition of the Citarum River Basin

The aim of this study is to conduct an observation for a flood event, to build a quantitative flood model for a flood event, and to create a flood-prone map from a physical model flood event in Upper Citarum Basin.

2.2 Data and methodology approach

The model was developed from flood event data on February 25th, 2018. Some inundated villages near Citarum River are Bojongsoang, Dayeuh Kolot, Bale Endah, Citeureup, Andir, Pasawahan, Suka Maju, Majasetra, Majakerta, and Sukamanah.

From field observation at some village, a height of water that inundates in the exposure area is around 80 cm and from the Regional Disaster Management Agency for Bandung District (BPBD Kab. Bandung), the height of inundation water in other villages reached 120 cm. This kind of observed data will be used in this study for the model consideration.

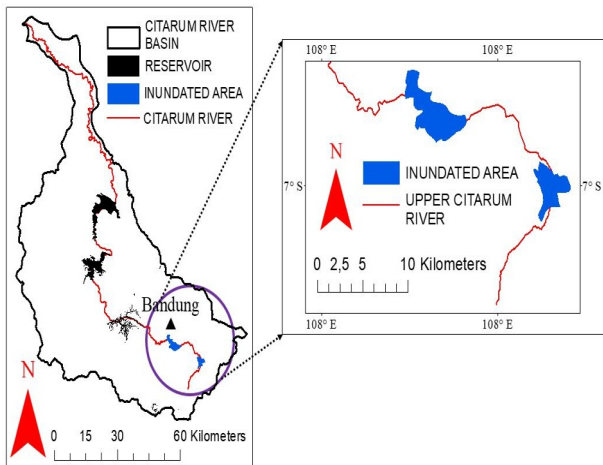


Fig. 3. The inundated area in upper Citarum basin

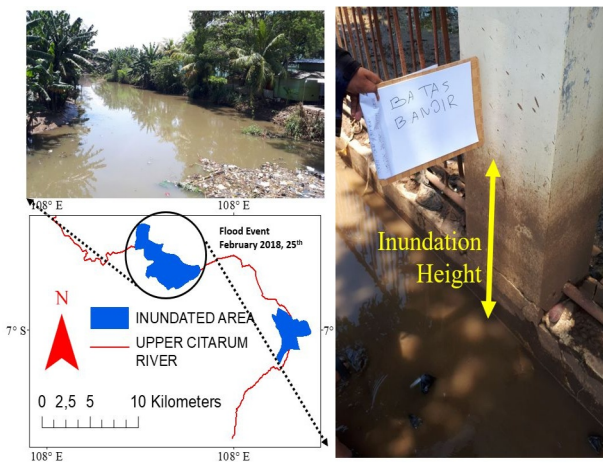


Fig. 4. Flood mark in several areas

The rainfall data for this model is derived from 5 (five) ground stations that record daily rainfall data. The rain gauge was scattered at several locations in Upper Citarum Basin as can be seen in Figure 5. The rain gauge stations are Kertasari, Jatiroke, Dayeuh Kolot, Paseh, and Sapan. Those rain gauges have a record of rainfall data at flood event on February 25th, 2018. Rainfall data that will be used and will be analyzed in this study is those on February 21st – 25th, 2018. The rainfall data will be analyzed spatially to observe the distribution of rainfall that occurs. It also will be compared temporally per day.

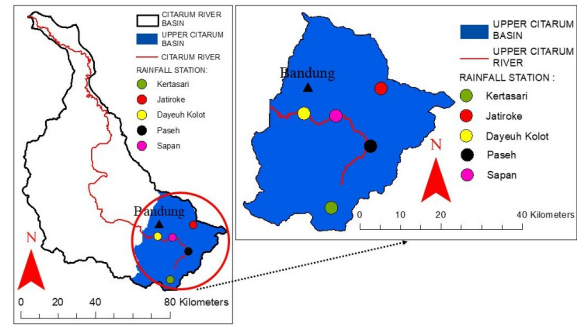


Fig. 5. Observed rainfall station

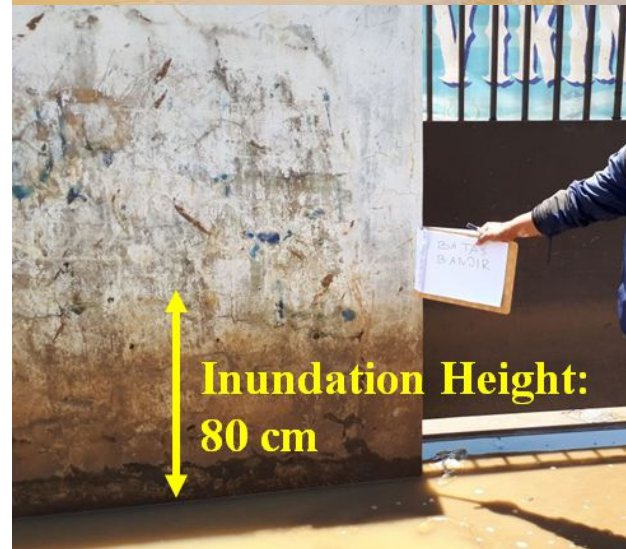


Fig. 6. The water level of the inundated area

Flood modeling in this study was computed by using integrated modeling package in MIKE Zero, between MIKE 21 and MIKE Flood. And for hydrologic analysis to get the runoff is using MIKE 11. The model enables to model many flood problems that involve river, floodplains, drainage network, dam break or breaches, or any combinations of those cases. 2D model has been considered as the best way to simulate flood inundation due to its effectiveness and efficiency [11]. The calculation process in MIKE 21 is based on a numerical calculation of two/three-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to assumptions of Bussines and hydrostatic pressure. Thus, the calculation equation consists of continuity,

momentum, temperature, salinity and density equations and it is closed by a turbulent closure scheme. The density only depends on two parameters. Those are temperature and salinity. More detail information about the model can be seen as in [12]

The governing equations are presented using Cartesian coordinates. The local continuity equation is written as below.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = S \quad (1)$$

And the two horizontal momentum equations for the x- and y- component is written respectively as below.

$$\frac{\partial u}{\partial t} + \frac{\partial u^2}{\partial x} + \frac{\partial vu}{\partial y} + \frac{\partial wu}{\partial z} = fv - g \frac{\partial \eta}{\partial x} - \frac{1}{\rho_0} \frac{\partial p_a}{\partial x} - \frac{g}{\rho_0} \int_z^\eta \frac{\partial \rho}{\partial x} dz + F_u + \frac{\partial}{\partial z} \left(\nu_t \frac{\partial u}{\partial z} \right) + u_s S \quad (2)$$

$$\frac{\partial v}{\partial t} + \frac{\partial v^2}{\partial y} + \frac{\partial uv}{\partial x} + \frac{\partial wv}{\partial z} = fu - g \frac{\partial \eta}{\partial y} - \frac{1}{\rho_0} \frac{\partial p_a}{\partial y} - \frac{g}{\rho_0} \int_z^\eta \frac{\partial \rho}{\partial y} dz + F_v + \frac{\partial}{\partial z} \left(\nu_t \frac{\partial v}{\partial z} \right) + v_s S \quad (3)$$

Where:

- t = time
- x, y, z = Cartesian coordinates
- u, v, w = flow velocity components
- s = magnitude of discharge due to point sources
- η = water level elevation to water depth
- g = gravitational acceleration
- f = Coriolis parameter

3 Results and discussions

The flood that occurred on February 25th, 2018 hit at least 10 villages, it can be seen in Figure 7 with the range of inundation height is around 80 cm – 120 cm. In this study, the inundated area determined is based on observation data and some information are from Disaster Management Agencies with an assumption that the inundated area is for whole villages.

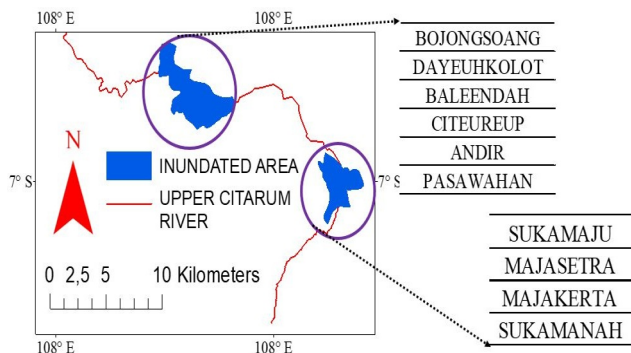


Fig. 7. Inundated area in several villages

Rainfall data was analyzed spatially by using isohyet method. The result of the isohyet method for daily rainfall data is shown in Figure 7.

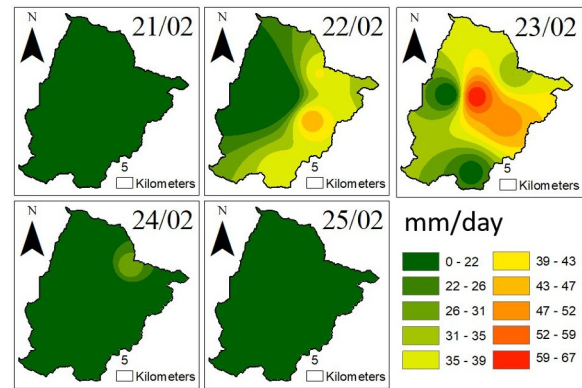


Fig. 8. Spatial distribution of rainfall on February 21st – 25th, 2018

From Figure 8, it can be seen that the maximum rainfall occurred on February 23th, 2018, with a maximum rainfall, is about 67 mm. It shows that the distribution of rainfall that occurs in central is around the midpoint of the basin. Following the rainfall criteria from Geophysics, Climatology, and Meteorology Agency are shown in Table 1 [13], the rainfall event on February 23th, 2018 is in the category of heavy rain. And as can be seen in Figure 7, the rainfall is occurred 2-3 days before the flood event on February 25th, 2018. Therefore, it can be considered that flood on February 25th, 2018 comes from the accumulation of some sub-basin around Upper Citarum River Basin. And also it can be considered that the flood occurred due to the rainfall mostly occurred evenly across the Upper Citarum River Basin.

The result of the hydrologic model was created by using MIKE 11 with rainfall data from February 21th – 25th, 2018 and hydrodynamic model uses MIKE 21 with the similar time interval between flood modeling and rainfall data. The result of the modeling process can be seen in Figure 8. The inundated area was marked by yellow point.

Table 1. Rainfall category

Category	Description
Small	1-5 mm/hour; or 5-20 mm/day
Medium	5-10 mm/hour; or 20-50 mm/day
High	10-20 mm/hour; or 50-100 mm/day
Very High	>20 mm/hour; or >100 mm/day

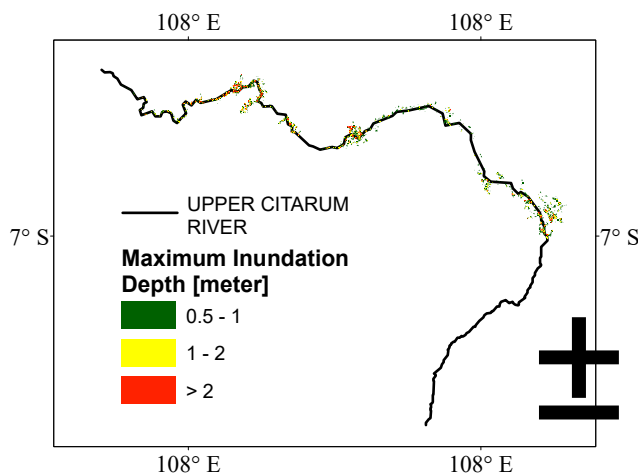


Fig. 9. Flood inundation modelling result

Based on the result, it can be seen that the model shows fair agreement with the observed data shown in Figure 10. From the figure, some point of result which shows the location of the inundation is quite similar to the existing field observation data. However, the area of observation data is wider compared to the simulation result. It is caused by the assumption of inundation area where the inundated area is evenly distributed in all sub-districts.

Table 2 and 3 shows the infrastructure and the total people affected due to flood event from February 21th – 25th, 2018 in Upper Citarum Basin.

Table 2. The Impacted object of flood

Category	Description
House	6000
Worship Building	35
School Building	8

Table 3. Impacted human of flood

Category	Description
People	3500
Children	301
Old People	328

4 Conclusion

The result of flood modeling process shows a fair result compared to observed data. Even though ground stations of rainfall data used in this study are 5 stations for a whole basin with a wide area, some points of floodplain area were detected as shown as observation data.

Further development of this study can be done by adding some rainfall station points in Citarum River Basin to detect an event and more accurate flood. More detail or upscaling topographic data on floodplain area can also improve the model. If the development on flood modeling process can be improved, it will give much

better result and more accurate information about floodplain area so that preventive measures can be taken to handle future flood events and any adverse impacts.

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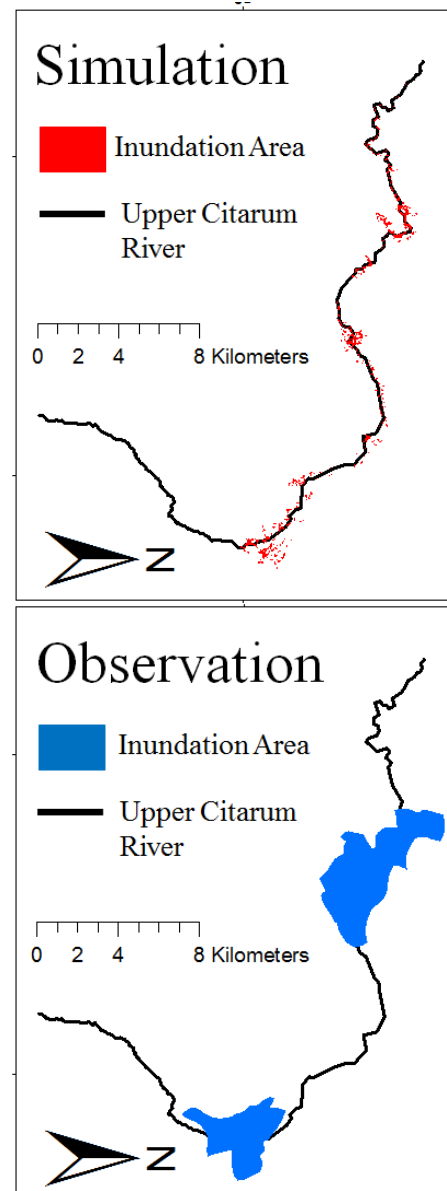


Fig. 10. Observation data and simulations result comparison

References

1. I. K. Hadihardaja, A.A. Kuntoro, and M. Farid, "Flood Resilience for Risk Management: Case Study River Basin in Indonesia", *Global Aspect*, vol. 3(4), pp. 16-19, Dec. 2013.
2. I. R. Moe, S. Kure, M. Farid, K. Udo, S. Kazama, and S. Koshimura, Numerical Simulation of Flooding in Jakarta and Evaluation of a Counter Measure to Mitigate Flood Damage, *Journal of*

- Japan Society of Civil Engineers Ser. G (Environmental Research), vol. 71(5), pp. 29-35, Apr. 2015.
3. M.S.B. Kusuma, A.A. Kuntoro, and R. Silasari, "Preparedness Effort toward Climate Change Adaptation in Upper Citarum River Basin, West Java, Indonesia", *Internet Journal of Society for Social Management Systems*, vol. 7(1), 7198, Sept. 2011.
 4. M. Farid, A. Mano, and K. Udo, "Urban Flood Inundation Model for High-Density Building Area", *Journal of Disaster Research*, vol. 7(5), pp. 554-559, Oct. 2012.
 5. S. Kure, M. Farid, Y. Fukutani, A. Muhari, J. D. Bricker, K. Udo, and A. Mano, "Several Social Factors Contributing to Floods and Characteristics of the January 2013 Flood in Jakarta, Indonesia", *Journal of Japan Society of Civil Engineers Ser. G (Environmental Research)*, vol. 70(5), pp. 211-217, Dec. 2014.
 6. R. I. Siregar, M. S. B. Kusuma, and M. Farid, "Assessment of the Contribution of the Flood Hydrograph of Cirasea, Cidurian and Ciwidey River in Affecting Flood Index in Bandung Basin", in *Proc. of the Second International Conference on Sustainable Infrastructure and Built Environment 2013*, vol. 3, pp. 234-245.
 7. www.citarum.org.
 8. Information Map of Citarum, Citarum River Basin Organization, 2011
 9. Upper Citarum Basin Flood Management, Volume 1, Deltares, 2011
 10. Apip, K. Takara, Y. Yamashiki, and A. B. Ibrahim, "Study on Early Warning System for Shallow Landslides in the Upper Citarum River catchment, Indonesia", *Annuals of Disas. Prev. Res. Inst., Kyoto Univ.*, No. 52B, pp. 9-17, 2009.
 11. M. Farid, A. Marlina, and M. S. B. Kusuma, "Flood Hazard Mapping of Palembang City by using 2D Model", *AIP Conference Proceedings*, vol. 1903(1), 100009, Nov. 2017.
 12. DHI: MIKE 21 & MIKE 3 Flow Model FM Hydrodynamic and Transport Module Scientific Documentation, MIKE DHI, 2017.
 13. BMKG, Press Release: Extreme and Climate Weather Conditions year 2010-2011, BMKG, Jakarta, Indonesia, 2010.