Influence of Ciawi and Sukamahi dam construction on flood early warning system in Katulampa weir

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Abstract. Based on the Comprehensive Flood Management Plan (CFMP), one of the flood control alternatives in the Ciliwung Watershed is using the dry dam construction. Construction of Ciawi dam and Sukamahi dam who are located in Bogor District, are expected to decrease the flood peak and increasing the time concentration in order to reduce the impact caused by a flood in DKI Jakarta due to Ciliwung River. With the construction of Ciawi dam and Sukamahi dam, it is necessary to conduct a research on the effect of both dams construction in Katulampa Weir, one of monitoring point dams on the DKI Jakarta Flood Early Warning System. Hydrological analysis with Win-TR 20 and HEC-RAS was conducted to identify the changes in the flood level of Flood Early Warning System in DKI Jakarta with and without both dams are available. The results of this study indicate that the peak floods decreased by around 2.5% after the implementation of Ciawi dam and Sukamahi dams. The impacts of this reduction will not affect the Flood Early Warning System level at Katulampa Weir significantly.

1 Introduction

Ciliwung River that crossed the DKI Jakarta area often experienced a great flood in the rainy season. The floods that occurred in February 2007 had an economic loss estimated at 8.6 trillion with 60 victims and 263,416 refugees [1]. In the future, large floods will often occur due to the impacts of changes in land use and climate change [2]. Flood early warning for DKI Jakarta area refers to the water level on the Ciliwung River which is observed at Katulampa Weir, Bogor City.

Based on the Comprehensive Flood Management Plan (CFMP) one of the alternatives to flood control in the Ciliwung river is dry dam construction to support runoff on the Ciliwung River [3]. Construction of Ciawi dam and Sukamahi dam located in Bogor Regency is expected to reduce flood peak, prolong the time-concentration and to reduce the impact of flooding in DKI Jakarta due to Ciliwung river runoff being monitored in Katulampa Weir. The purpose of this study was to compare the elevation of the water level at Katulampa Weir for conditions without and with Ciawi dam and Sukamahi dam using WinTR 20 software tools.

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2 Methodology

2.1 Study area and rainfall data

Katulampa Weir, located in Katulampa Village, Bogor City, West Java Province, is an indicator or early warning of the runoff that will flow to the area of DKI Jakarta area.

![Fig. 1. Location of Ciawi and Sukamahi dam.](image1)

Based on the analysis of rainfall, the design is based on the maximum rainfall with a certain repetition period. This design uses the rainfall data at Gadog Station, Gunung Mas Station, Cilember Station, and Katulampa Station. The rainfall is calculated using the Log Pearson Type III method. The rain stations used is determined it depends on the areas that affect the Katulampa Catchment area. The map of Katulampa Sub-watershed and Rain Station in Katulampa watershed can be seen in Fig. 2.

![Fig. 2. Locations of Katulampa subwatershed and rain station locations.](image2)

Katulampa Watershed properties obtained from ArcGIS software with the landcover data based on Spatial Masterplan in 2016 can be seen in Table 1.

CN value on the table above is determined using the Soil Conservation Service-Curve Number (SCS-CN) method developed by the USDA (United States Department of Agriculture) where it is determined based on the characteristics of land use in the Katulampa watershed.
Table 1. Properties of Katulampa watershed.

| Sub-watershed | Area (km²) | CN | Length (m) | Upstream point (m) | Downstream Point (m) | Δh (m) | Slope | Tc (hr) |
|---------------|------------|----|------------|-------------------|---------------------|--------|-------|--------|
| 1             | 87.970     | 69.4 | 20032      | 3000              | 500                 | 2500   | 0.125 | 1.487  |
| 2             | 16.070     | 62.2 | 15091      | 2575              | 563                 | 2013   | 0.133 | 1.165  |
| 3             | 0.360      | 70.2 | 460        | 500               | 488                 | 13     | 0.027 | 0.146  |
| 4             | 0.990      | 75.1 | 1493       | 563               | 525                 | 38     | 0.025 | 0.373  |
| 5             | 26.520     | 68.4 | 14504      | 1638              | 450                 | 1188   | 0.082 | 1.363  |
| 6             | 0.980      | 76.6 | 1416       | 488               | 450                 | 38     | 0.026 | 0.351  |
| 7             | 4.400      | 79.0 | 4390       | 450               | 350                 | 1      | 0.023 | 0.889  |
| 8             | 13.400     | 74.4 | 12695      | 8125              | 350                 | 463    | 0.036 | 1.681  |

The Thiessen method is used to determine the extent of the distribution of rain stations, where the weighted rainfall is calculated based on the extent of rainfall in each station in the Katulampa watershed. Based on the output by ArcGIS software, the percentage of polygon Thiessen area for the Gadog rain station is 23.43%, Gunung Mas rain station is 35.55%, Cilember rain station is 32.73%, and Katulampa rain station is 8.30%.

The rainfall data used is started from 1999 to 2017 where the linear regression method was done to complete the missing data, the completed rainfall data used in Katulampa watershed can be seen as follow.

Table 2. Rainfall data at Katulampa watershed.

| Year | Station rainfall (mm) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------|-----------------------|------|------|------|------|------|------|------|------|------|------|
|      | Gadog                 | 118  | 121* | 125  | 127  | 161  | 97   | 121* | 122* | 121* | 156  |
|      | Gunung Mas            | 151* | 148* | 146* | 143* | 118  | 138* | 157  | 127  | 156  | 105  |
|      | Cilember              | 93*  | 91*  | 89*  | 87*  | 110  | 70   | 80*  | 78*  | 76*  | 74*  |
|      | Katulampa             | 101  | 79   | 102  | 154  | 129  | 109  | 111  | 71   | 172  | 166  |
|      | Weight rainfall (mm)  | 120  | 117  | 119  | 122  | 126  | 104  | 120  | 105  | 123  | 112  |

The construction of the Ciawi dam and Sukamahi dam is located in the upper Ciliwung watershed area, administratively located in Bogor Regency, West Java Province. Based on the geographical location of the Ciawi dam is on 106º52'20" E 06º39'28" S and Sukamahi dam is on 106º52'20" E 06º40'12" S. Ciawi dam is located on the upper Ciliwung river with several major tributaries namely the Cibogo River and the Cisarua River. Sukamahi dam is located on the Cisakabirus River which is a tributary of the Ciliwung River.

2.2 Hydrological model WinTR-20

The WinTR-20 model is a storm event surface hydrologic water model applied at a watershed scale. The model assists the hydrologic evaluation of flood events for use in the
analysis of water resource projects. It can be used to analyze current watershed conditions using SCS-CN model as well as assess the impact of proposed changes made within the watershed. Multiple storms (or rainfall frequencies) can be analyzed within one model run. Direct runoff is computed from watershed land areas resulting from synthetic or natural rain events. The runoff is routed through channels and impoundments to the watershed outlet [4].

2.3 Hydrological model Hec-Ras

Hydrologic Engineering System-River Analysis System (HEC-RAS) is a software that allows performing one-dimensional steady flow to river hydraulics calculations, quasi-unsteady and full unsteady flow of sediment transport, water temperature analysis, and the general water quality modelling [5]. The most important element in the use of HEC-RAS is the availability of cross-sectional geometry of longitudinal sections and transversal sections following existing conditions.

3 Results and discussion

3.1 Analysis before the existence of dams

WinTR 20 analysis is needed to determine the rain hydrograph before and after the construction of Ciawi dam and Sukamahi dam. After obtaining the data of Watershed Properties, Maximum Annual Rainfall, and Rain Distribution. The data is used as input on WinTR 20 as the basis of hydrograph before the construction of Ciawi dam and Sukamahi dam and can be seen as follow.

![Hydrograph](image)

**Fig. 3.** Hydrograph of Katulampa watershed before the existence of dams.

The peak discharge value based on the results of the WinTR 20 on a 50-year annual rainfall return period with the conditions before the construction of the Ciawi dam and Sukamahi dam is 531.2 m$^3$/s, but to determine the accuracy of these values, it will be tested by calibrating these results against the Automatic Water Level Recorder (AWLR) data observed in the Katulampa Weir.

Based on the hydrograph comparison above, the discharge will be adjusted to the Rating Curve before the existence of Ciawi and Sukamahi dam to get the water level based on the
discharge. The peak discharge was obtained from the WinTR 20 is 137.1 m$^3$/s. If it is projected with a Rating Curve, then it is obtained a water level at 1,905 m, while based on AWLR data, it is obtained a water level at 1,930 m. The difference of the result is 0.025 m or 2.5 cm, so it is assumed that the WinTR 20 modeling of the Katulampa watershed is corresponding with the existing conditions.

![Hydrograph comparison between WinTR 20 and AWLR.](image)

**Fig. 4.** Hydrograph comparison between WinTR 20 and AWLR.

### 3.2 Analysis after the presence of dams

The calculation of WinTR 20 in the presence of dams aims to find hydrograph after the construction of Ciawi and Sukamahi dam. The inputs to calculate the hydrograph after the presence of dams using WinTR 20 is the same as before, the difference of inputs only adds Structure based on the previous calculation where the flood hydrograph will consider the runoff discharge and the area of inundation area of Ciawi and Sukamahi dam. Schematic of both Ciawi and Sukamahi dam can be seen in Fig. 5.

![Schematic with and without the dam.](image)

**Fig. 5.** Schematic with and without the dam.

Based on the hydrograph results after the presence of the dams, the peak discharge at the outlet with a 50-year annual rainfall return period is 460 m$^3$/s with the peak flood time occurring at 16.57 hours, the discharge had decreased from the previous condition before the Ciawi dam and Sukamahi dam which the peak discharge was 516.70 m$^3$/s with the peak flood time occurring at 16.9 hours. The discharge had decreased by 56.7 m$^3$/s and the peak flood time changes were 0.33 hours. The comparison hydrograph without and with the existence of the Ciawi dam and Sukamahi dam can be seen as follows.
Based on the hydrograph results, after the existence of both dams, it shows that the peak discharge at the outlet within a 50-year annual rainfall period of 460 m$^3$/s with the peak flood time occurring at 16.57 hours. This debit decreases from previous discharge before the Ciawi and Sukamahi dam where the prior discharge of the dam is 516.70 m$^3$/s with the peak flood time at 16.9 hours. The discharge has decreased by 56.7 m$^3$/s, and the flood peak change is 0.33 hours.

### 3.3 Analysis after the presence of dams using HEC-RAS software

Analysis using HEC-RAS software is being held to determine the number of Rating Curve after Ciawi and Sukamahi dam considering a cross-section of the river and runoff discharge based on WinTR 20 software. Analysis with HEC-RAS software using Steady Flow runoff discharge data, due to this research only looking for the influence of Ciawi and Sukamahi dam to the height of water level observed at Katulampa Weir. The water level obtained based on the use of HEC-RAS software is as follows.

The water level in the 5-year period has an elevation at 350.11 meters, while for the 10th year period is at the elevation of 350.18 meters, and for the 50th year period is at the elevation of 350.32 meters.

The comparison of water level in Katulampa Weir was made by comparing the result between the elevation obtained from Rating Curve with the discharge from WinTR 20 and the water level obtained from HEC-RAS software with discharge data from WinTR 20 of Ciawi and Sukamahi dam. The comparison table can be seen as follows (Table 3 and 4).
Table 3. Katulampa dam discharge comparison.

| Return period (Years) | 2    | 5    | 10   | 25   | 50   | 100  |
|-----------------------|------|------|------|------|------|------|
| Without Ciawi and Sukamahi Dams | 404.8 | 460  | 484.2 | 505.4 | 516.7 | 525.5 |
| With Ciawi and Sukamahi Dams | 379.6 | 424.7 | 439.3 | 452.6 | 460.0 | 457.5 |
| Difference (m)        | 25.20 | 35.30 | 44.90 | 52.80 | 56.70 | 58.00 |
| Reduction percentage  | 6.2%  | 7.7%  | 9.3%  | 10.4% | 11.0% | 11.0% |

Table 4. Katulampa dam water level comparison.

| Return period (Years) | 2    | 5    | 10   | 25   | 50   | 100  |
|-----------------------|------|------|------|------|------|------|
| Without Ciawi and Sukamahi Dams | 3.19  | 3.39  | 3.47  | 3.54  | 3.59  | 3.61  |
| With Ciawi and Sukamahi Dams | 3.09  | 3.32  | 3.39  | 3.45  | 3.49  | 3.57  |
| Difference (m)        | 0.10  | 0.07  | 0.08  | 0.09  | 0.10  | 0.04  |
| Reduction percentage  | 3.1%  | 2.1%  | 2.3%  | 2.5%  | 2.8%  | 1.1%  |

Based on Table 4, the water level is obtained without the Ciawi and the Sukamahi dam is 3.59 m while the water level with the Ciawi and Sukamahi dam is 3.49 m or has a difference of 10 cm and has just change of 2.8%.

4 Conclusions

This study purposed to analyze the effect of Ciawi and Sukamahi dam construction towards the Early Warning System due to the changes made on the water level of Katulampa Weir. Compare the elevation of the water level at Katulampa Weir for conditions without and with Ciawi and Sukamahi dam using WinTR 20 software tools.

Before the existence of both dams, the highest peak flow with a 100-year annual rainfall return period is 525.5 m³/s, and after the existence, the highest peak flow becomes 467.5 m³/s. Thus, the reduction percentage is only 11%. For the 50th year period, the reduction percentage is also about 11% for the peak flow. The highest reduction percentage of water level after the both of dams exist 3.1% with 2-year annual rainfall return period, but it is not common to calculate the design for the massive structure with the short return period. The next highest reduction percentage is 2.8%. Therefore, the construction of Ciawi dam and
Sukamahi did not have a significant effect to decrease the water level of the Flood Early Warning System in Katulampa Weir.

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References

1. Y. Hasanah, M. Herlina, H. Zaikarina, Proc. of the 3rd International Conference on Sustainable Future for Human Security (2012)
2. H. Takagi, M. Esteban, T. Minami, Projection of coastal floods in 2050 Jakarta urban climate (2016)
3. JICA & Yachiyo Engineering Co, The project for capacity development of Jakarta comprehensive flood management in Indonesia (2013)
4. USDA, WinTR-20 Project formulation hydrology, Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/null?cid=stelprdb1042793 (2017)
5. G.W. Brunner, HEC-RAS 5.0 River analysis system applications guide (US Army Corps of Engineers, California, 2016)