Study on the Contribution of Normalization to Reducing Flood Risk in the Ciliwung River, Tebet District, Jakarta

M Yatsrih\(^1\), A N Harman\(^1\), S R Taufik\(^1\), T N A Kesuma\(^2\), D Saputra\(^2\), M S B Kusuma\(^2\), M Farid\(^2\), A A Kuntoro\(^2\)

\(^1\) Water Resource Management Master Program, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Jawa Barat, Indonesia
\(^2\) Water Resources Engineering Research Group, Institut Teknologi Bandung, Jawa Barat, Indonesia

Email: yatsrihplg11@gmail.com

Abstract. Jakarta is the capital city of the State of Indonesia and fast economy and population growth rate. With these, urbanization continues to increase every year. In this study, we analyse the effect of river normalization on reducing flood risk on the MT. Haryono – Manggarai section based on the Hec-RAS hydraulic model. Boundary Condition applied in upstream river is flow hydrograph with a peak discharge of 561.48 m³/s. In the upstream part, a rating curve is applied from the water level measurement data for the Manggarai Sluice Gate. While in the middle, the lateral flow from the urban drainage channel is inserted. The simulation results show that normalizing the channel can increase the drainage capacity as implied by the decrease in the flood water level. However, downstream there is backwater due to the lack of capacity of the Manggarai floodgate.

1. Introduction
Most of the flood management in the urban areas of Indonesia including Ciliwung River facing erosion, sedimentation, and land-use change problems [1-3]. The land-use change in the upper part of the Ciliwung River become settlement tends to increase the extreme discharge rate but also its erosion and sedimentation processes. Several studies demonstrate very well the correlation of land-use change to the increasing extreme discharges [4, 5]. [6] discussed how to enhance Jakarta’s resiliency by reducing the risk of increasing extreme discharges of the Ciliwung River due to climate change and increased flash flood occurrences [18-21]. Meanwhile, the lack of field data on rainfall and discharge distribution remains the main concern to gauge climate change influences on extreme discharge of Ciliwung [7]. Based on neural network methods, [8] demonstrate the application of a mathematical model for river sediment load estimation; however, this model requires a sufficient data that are not available for the Ciliwung River.

Land subsidence is one of the most important parameters that should be addressed in decreasing the flood risk in Jakarta where freshwater availability for the local people is the key solution [9]. Land subsidence is caused by excessive groundwater extraction which makes the soil volume shrink. Furthermore, several reservoirs are developed in the upper part of the Ciliwung river, and one estuary dam is proposed in Jakarta Bay. The upstream reservoir is developed not only to increase the freshwater availability during the dry season but also to reduce the extreme discharges during the wet/rainy season.
[10]. However, [11] concluded that as an archipelago country located on a very active geologic area, Indonesia has a very high probability of earthquake hazard that will generate a high risk of catastrophic dam failure and damage to urbanized areas [10, 12-15].

The current condition along the Ciliwung River, such as physical characteristic, data availability, potential previous research results, and its hydraulic capacity are the basis of this paper’s discussion on the contribution of river normalization as one of the most probable short-term effort to decrease the flood risk in the study area. The analysis is supported by the HEC-RAS 5.0.7 mathematical model.

2. Study Area
The Ciliwung River study location is in the Ciliwung watershed, which covers the provinces of West Java and Jakarta. The river is about 120 km in length. The Ciliwung watershed (393.57 km²) is located between two other large watersheds, namely the Cisadane watershed in the west and the Citarum watershed in the east. The flood analysis focused on six villages on both bank for the river, namely Bidara Cina, Kampung Melayu, Kebon Manggis, Manggarai, Bukit Duri, and Kb (Figure 1).

3. Materials and Methods
3.1. Hydrology Analysis
Hydrological modelling requires data such as daily rainfall, land cover and soil type, and AWLR (Automatic Water Level Recorder) data for MT.Haryono and Manggarai Gate and Digital Elevation Model data. Models allow for a statistical analysis, namely predicting rainfall according to the return period or probability. Here, the 35-year rainfall data series from 1985 – 2019 is the basis for determining the regional rainfall using the Thiessen polygon method [REF needed]. Then, the data is distributed using the Normal, Log-Normal, Pearson III, Pearson III, and Gumbel frequency analysis methods and the distribution tested by Chi-Square and Gumbel tests. The method selected based on the test method was then distributed using the PSA 007 method for 12 hours based on Technical Guideline of Flood Discharge Calculation in Dam form Ministry of Public Works and Housing of Indonesia [23]. The rainfall used to generate the hydrograph is effective rain so that the rain abstraction needs to be calculated.

Figure 1. Study Area in Ciliwung River

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by extracting land-use data into Curve Number. In this study, the SCS-CN method [23] was used to calculate rain infiltration.

### Table 1. Thiessen Area for each Raingage.

| Raingage          | Thiessen Area (km²) | Percentage (%) |
|-------------------|---------------------|----------------|
| Citeko            | 92.17               | 28             |
| Gadog             | 22.03               | 7              |
| Cawang            | 5.21                | 2              |
| Pasir jaya        | 5.17                | 2              |
| Gunung Mas        | 56.24               | 17             |
| Bogor             | 32.11               | 10             |
| Cibinong          | 65.20               | 20             |
| Kampus UI         | 33.31               | 10             |
| Halim Perdana Kusuma | 16.29            | 5              |
| **Total**         | **327.72**          | **100**        |

The hydrological model was calibrated with AWLR measurement data from the MT Haryono station on 5-6 June 2017. Based on the calibrated model, hydrographs were simulated by the synthetic unit hydrograph method using several methods, namely: Snyder, SCS, Nakayasu, ITB 1a, ITB 1b, ITB 2a, and ITB 2b (Figure 2) [22]. Based on calibration and optimization, the selected method is ITB 1a because it has the smallest Root Mean Square Error (RMSE) and the largest Nash Sutcliff Efficiency (NSE) (Table 1).
Table 2. RMSE and NSE Value

| Method   | RMSE  | NSE  |
|----------|-------|------|
| SCS      | 0.367 | 0.859|
| Nakayasu | 0.689 | 0.532|
| ITB 1    | 0.226 | 0.949|
| ITB 2    | 0.549 | 0.669|
| Snyder   | 0.798 | 0.363|

Model verification was then carried out on another date, July 17, 2016, and still showed the similar results. The output of the hydrograph is shown in Figure 3. The ITB 1a method calibration results were used with a peak discharge of 561,480 m³/s of 100 years.

![Figure 3. Hydrograph of each Unit Synthetic Hydrograph Method](image)

3.2. Existing Hydraulic Model

A hydraulic analysis with a 1D model was carried out to determine the flood water level on the river cross-section. The modelling was carried out with Hec-RAS 5.0.7 software. The return period discharge calibrated by comparing model with water level at MT Haryono on January 1, 2020, with a peak discharge of 308.69 m³/s. In this incident, the water level was 7.80 m based on observation data. The modelling time step was 4 seconds and the Manning value was 0.035. With these parameters, the simulated water level is 7.39 m.

The boundary condition were set in the Unsteady Flow Data menu. For the upstream boundary conditions, a Flow Hydrograph is applied, namely by entering the hydrograph data. While in the downstream part of Manggarai a rating curve was applied. In addition, Lateral Flow was defined for the
MT segment sub-section. Haryono – PA Manggarai based on PHB DKI Jakarta data in Tebet and Jatinegara Districts.

3.3. Normalized Hydraulic Model
Normalization in the river increases the capacity of the river by dredging the riverbed so that the channel capacity increases. River normalization is often applied to meandering rivers. Normalization activities typically include river reinforcement structures, such as sheet piles and cribs, to protect from water scouring. Normalization activities are carried out from MT. Haryono to P.A Manggarai. The following is an example of normalization (Figure 4).

4. Result and Discussion
Based on the modelling with the existing condition, most of the cross-sections still flooded, including the existing embankment. The Manggarai sluice gate overtopped due to insufficient capacity.

After normalizing the river segment, the long section is not change because the slope channel is kept unchanged and water level decreases, especially in the Kebon Baru, Bidara Cina, Kampung Melayu, and Bukit Duri sections shown in Figure 5. Meanwhile, in the Manggarai and Kebon Manggis sub-districts, there is no drastic change, this is due to backwater due to lack of capacity of Manggarai floodgates with a return period of 100 years.

The normalization simulation on the hydraulic model was carried out by dredging a river cliff without deepening the river. This is done so that the basic slope of the Existing River does not decrease. If the river base slope decreases, the flow speed will decrease which causes the channel capacity to decrease.
5. Conclusion
Based on the simulation results, normalization of the river channel can increase channel capacity and reduce floods in the upstream area of hydraulic modelling domain, especially in Kebon Baru, Bidara Cina, Kampung Melayu, and Bukit Duri. Normalization, however, cannot overcome backwater due to insufficient capacity of Manggarai sluice gates. The addition of a door at the Manggarai Gate is not recommended because it will increase the discharge load on the West Flood Canal. Therefore, it is recommended to reduce the flow on the channel by diverting river flow, which can be accomplished by routing the flow from the Sodetan River/channel? to the Cipinang River or by using the Old Ciliwung Gate. In areas that are still experiencing flooding after normalization, it is recommended to install embankments.

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Figure 5. Modelling Result for Existing and Normalized Scenario
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