The influence of aquatic buffer characteristic of Ciliwung River from the Katulampa Weir to Manggarai Water Gate on hydrograph characteristics of design flood

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Abstract. Increasing population in Jakarta leads to increased needs of settlements and their supporting facilities. To compensate, various methods are being undertaken, from utilization of open area to the riparian, especially in the Ciliwung River. This utilization results in the loss of riparian natural ability, which changes the river's hydraulic condition. These riparian changes will significantly affect the roughness coefficient. The roughness coefficient is a value that is affected by channel irregularity, variation of cross-section, effects of obstructions, vegetation, and degree of meandering. Changes of the roughness coefficient will influence the velocity of the stream. The purpose of this research is to determine the effect of riparian characteristics to the roughness coefficient that affects the stream velocity, which has impact on the peak time of the hydrograph. The peak time shift can be seen in the flood hydrograph characteristics of the Ciliwung River from the Katulampa Weir to the Manggarai sluice gate. Identification of Ciliwung riparian conditions at that segment is conducted by river routing. HEC-RAS 4.1.0 [1] application is used to obtain a design flood hydrograph at Manggarai Water Gate. To know the influence of riparian characteristics to roughness coefficient, HEC-RAS 4.1.0 simulation is done using existing and natural condition to compare the hydrographs between those two conditions. It obtains a lower peak discharge and extended duration of the hydrograph.

1 Introduction

The urbanization rate in Indonesia is regarded as high, at 53.3% in 2015 [1], after which the population in Jakarta increased to 10,192,886 people [2]. The increase of population in Jakarta causes increased settlements and required complementary facilities. This creates changes in land cover from open space to construct. Another aspect affected by population growth is uncontrolled constructions. An example of uncontrolled construction is the conversion of river banks for settlements, especially at the Ciliwung River. Riverbanks utilization causes a deprivation of its natural aspects, consequently changing its hydrologic conditions. These changes will influence the flow rates and change the flood peak times.

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In this research, the characteristic mapping of the river border from Katulampa Weir to Manggarai Water Gate was performed to understand the changes in peak flood time and discharge due to the change in the river bank characteristics.

2 Research methodology

The research was carried out at Ciliwung River, specifically the Katulampa Weir-Manggarai Water Gate segment. Data used in this research are river lengths, cross-sections, streamflow discharges, and embankment conditions. Cross-sections data were obtained from "Studi Penataan Ulang Sempadan Sungai Ciliwung Tahap II" image data [3]. Stream flows were obtained from hydrographs corresponding to the event which occurred on February 5th, 2018. The chosen date was attributed to the big flood which occurred in Jakarta. The flow discharge from the flood is required to verify whether the Ciliwung River can withstand the flow discharge, preventing flooding from occurring in Jakarta. River border conditions data were obtained from direct observations using field measurements.

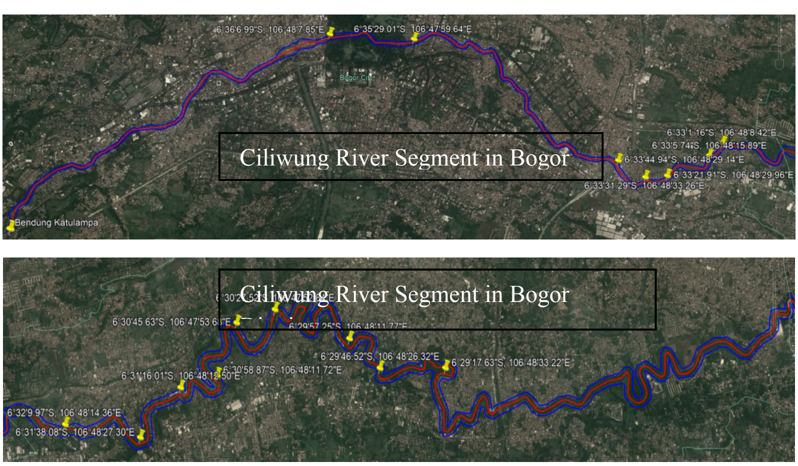
Roughness was determined through conversion of bank conditions to Manning roughness coefficient [4] using the formula:

$$n = (nb + n1 + n2 + n3 + n4) \times m \tag{1}$$

All data were then applied to HEC-RAS 4.1.0 for simulation. The results were presented with a downstream flood hydrograph. Two flood hydrographs, with existing and natural river border condition, were obtained in the research. From the two results, the differences in peak time and peak discharge were observed. Thus, the magnitude of influence from river bank conditions was obtained.

3 Results and discussion

This research was done using two river boundary conditions. The first was the existing condition, while the second corresponds to the natural condition. It was assumed that the stream entering the channel only from Katulampa Weir is open. For existing condition, data were obtained from field measurements at Ciliwung River. Sampling locations are presented in Fig. 1.



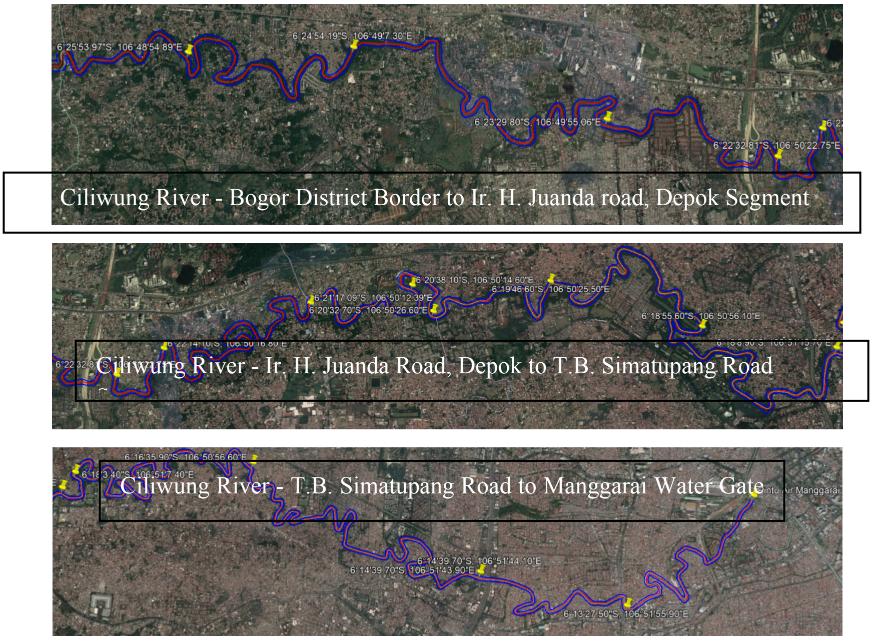


Fig. 1. Ciliwung River segmentation from Katulampa Weir until Manggarai Water Gate.

From the figure above, the field measurements area is shown in yellow pins. There are 36 points reviewed for field measurements. These points are scattered in Bogor City, Bogor Regency Depok City, and Jakarta City with the following coordinates in Table 1.

Table 1. Coordinat of the location of field measurements

Point	Location	Point	Location	Point	Location
1	6°38'0.43"S, 106°50'13.52"E	13	6°31'16.01"S, 106°48'12.50"E	25	6°21'17.09"S, 106°50'12.39"E
2	6°37'45.37"S, 106°49'36.41"E	14	6°30'58.87"S, 106°48'11.72"E	26	6°20'38.10"S, 106°50'14.60"E
3	6°36'6.99"S, 106°48'7.85"E	15	6°30'45.63"S, 106°47'53.68"E	27	6°20'32.70"S, 106°50'26.60"E
4	6°35'29.01"S, 106°47'59.64"E	16	6°30'27.52"S, 106°47'52.64"E	28	6°19'46.60"S, 106°50'25.50"E
5	6°33'44.94"S, 106°48'29.14"E	17	6°29'57.25"S, 106°48'11.77"E	29	6°18'55.60"S, 106°50'56.10"E
6	6°33'31.29"S, 106°48'33.26"E	18	6°29'46.52"S, 106°48'26.32"E	30	6°18'8.90"S, 106°51'15.70"E
7	6°33'21.91"S, 106°48'29.96"E	19	6°29'17.63"S, 106°48'33.22"E	31	6°18'3.40"S, 106°51'7.40"E
8	6°33'5.74"S, 106°48'15.89"E	20	6°25'53.97"S, 106°48'54.89"E	32	6°16'35.90"S, 106°50'56.60"E

Point	**Location**	**Point**	**Location**	**Point**	**Location**
9	6°33'1.16"S, 106°48'8.42"E	21	6°24'54.19"S, 106°49'7.30"E	33	6°14'39.70"S, 106°51'44.10"E
10	6°33'0.91"S, 106°48'7.04"E	22	6°23'29.80"S, 106°49'55.06"E	34	6°13'27.50"S, 106°51'55.90"E
11	6°32'9.97"S, 106°48'14.36"E	23	6°22'32.81"S, 106°50'22.75"E	35	6°12'26.97"S, 106°50'56.70"E
12	6°31'38.08"S, 106°48'27.30"E	24	6°22'14.10"S, 106°50'16.80"E		

Table 2. Channel and aquatic buffer correction values

Channel	
Conditions	n
n-Base	
Firm Soil	0.025
Surface Irregularity (n1)	
Smooth	0
Minor	0.003
Moderate	0.007
Severe	0.012
Variation (n2)	
Gradual	0
Alternating Occasionally	0.003
Alternating Frequently	0.012
Obstruction (n3)	
Negligible	0.002
Minor	0.009
Appreciable	0.025
Severe	0.045
Vegetation (n4)	

Aquatic Buffer	
Conditions	n
n-Base	
Firm Soil	0.025
Surface Irregularity (n1)	
Smooth	0
Minor	0.003
moderate	0.007
severe	0.012
Variation (n2)	
none	0
Obstruction (n3)	
Negligible	0.002
Minor	0.009
Appreciable	0.025
Vegetation (n4)	
Small	0.005
Medium	0.018
Large	0.035

Channel	
Conditions	n
n-Base	
Small	0.006
Medium	0.018
Large	0.035
Very Large	0.07
Meandering (m)	
Minor	1
Appreciable	1.15
Severe	1.3

Aquatic Buffer	
Conditions	n
n-Base	
Very Large	0.07
Extreme	0.15
Meandering (m)	
none	1

The observed conditions for each location are soil conditions, slope, and its vegetation height. Determination of above values is based on the manning value in a book "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains" [4]. The correction values used are in Table 2.

Riverbank conditions from each sampling location were converted as Manning coefficients using formula (1) in Table 3. The observed conditions from each location are soil conditions, slope, and its vegetation height.

Table 3. Manning Roughness Coefficient Observation Results

Segment	LOB	Channel	ROB
Natural			
All Segments	0.102	0.041	0.102
Existing			
Point 1-2	0.05	0.035	0.05
Point 2-3	0.015	0.035	0.015
Point 3-4	0.102	0.035	0.102
Point 4-5	0.019	0.035	0.019
Point 5-6	0.102	0.035	0.01
Point 6-7	0.029	0.055	0.029
Point 7-8	0.037	0.053	0.054
Point 8-9	0.054	0.038	0.054

Segment	LOB	Channel	ROB
Point 17-18	0.102	0.037	0.072
Point 18-19	0.098	0.05	0.102
Point 19-20	0.024	0.053	0.054
Point 20-21	0.098	0.037	0.085
Point 21-22	0.098	0.037	0.098
Point 22-23	0.098	0.037	0.102
Point 23-24	0.037	0.037	0.102
Point 24-25	0.05	0.037	0.05
Point 25-26	0.033	0.031	0.102
Point 26-27	0.046	0.041	0.02
Point 27-28	0.0298	0.031	0.05

Segment	LOB	Channel	ROB
Point 9-10	0.042	0.055	0.072
Point 10-11	0.02	0.035	0.02
Point 11-12	0.05	0.041	0.067
Point 12-13	0.023	0.041	0.023
Point 13-14	0.054	0.041	0.037
Point 14-15	0.02	0.037	0.059
Point 15-16	0.102	0.066	0.102
Point 16-17	0.102	0.05	0.102

Segment	LOB	Channel	ROB
Point 28-29	0.067	0.035	0.033
Point 29-30	0.033	0.035	0.046
Point 30-31	0.024	0.031	0.024
Point 31-32	0.024	0.031	0.031
Point 32-33	0.024	0.031	0.026
Point 33-34	0.02	0.018	0.02
Point 34-35	0.019	0.018	0.019

Stream flow discharge data used for the simulation were obtained from previous research that indicated the maximum peak value at February 5, 2018 are presented in Table 4. On February 5, 2018, there was a high intensity of rain in Bogor City and Jakarta City, causing high floading in the Jakarta City. The election on February 5, 2018, aims to find out how much the flow changes in these extreme conditions.

Table 4. Flow discharge in Katulampa Weir

Time (h)	**Flow discharge (m^3/s)**
0	39.1
1	110.3
2	163.2
3	168.6
4	133.8
5	93.1
6	81.7
7	121.8
8	214
9	451.1
10	727.5
11	634.2
12	600.4

Time (h)	**Flow discharge (m^3/s)**
13	545.9
14	508.4
15	432.6
16	359.7
17	242.2
18	178.7
19	133.5
20	89.4
21	51.4
22	26.6
23	13.3
24	6.5

Data were simulated using HEC-RAS 4.1.0. The simulation was done under two possible scenarios, which are natural and existing conditions. The results from both simulations are presented with a downstream flood hydrograph.

The following is the simulation results obtained using HEC-RAS 4.1.0 (Table 5).

Table 5. Flood discharge via HEC-RAS 4.1.0 simulation.

Time (h)	Existing (m^3/s)	Natural (m^3/s)
0	39.1	38.5
1	39.03	38.39
2	39.15	38.49
3	39.3	38.59
4	39.36	38.69
5	38.99	38.71
6	38.31	38.65
7	37.64	38.54
8	37.17	38.39
9	36.68	38.07
10	35.8	37.43
11	34.27	36.39
12	33.42	34.95
13	32.68	33.21
14	31.44	31.03
15	29.27	28.74
16	26.59	26.33
17	24.07	25.06
18	21.79	24.24
19	19.69	22.85
20	17.75	20.67
21	15.98	18.67
22	14.26	16.38
23	12.46	14.36
24	10.73	12.43

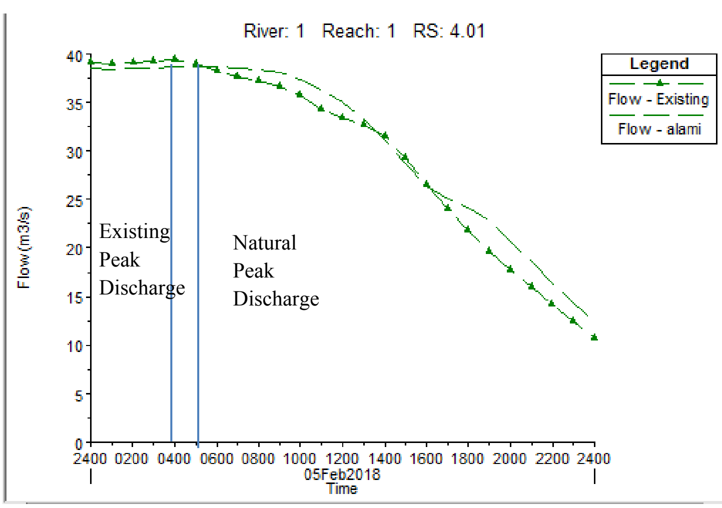


Fig. 2. Hydrograph for both river conditions.

Table 5 and Fig. 2 are the simulation results of HEC-RAS 4.1.0. In the above results, there are changes in the hydrograph between natural and existing condition are observed. The change takes place in peak flood time, which takes one hour longer in natural condition compared with existing condition. The shift in peak discharge was also obtained in which the degradation occurred from 39.36m^3/s in the existing condition to 38.71m^3/s in natural condition.

4 Conclusions

Based on HEC-RAS 4.1.0 simulation results, it can be concluded that the condition of the river banks can affect the streamflow of the river. The natural condition of the river reduces the discharge value of the flood. The river bank changes also prolong the peak flood time. This can be used as an early warning for incoming floods whenever high flows occur.

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References

1. N.S. Auliya, *Urbanisasi: Dilema pemerataan pembangunan* (Lembaga Administrasi Negara, Jakarta, 2017)
2. Jakarta Open Data. *Data jumlah penduduk Provinsi DKI Jakarta berdasarkan kelompok usia per kelurahan*. Available at: http://data.jakarta.go.id/dataset/data-jumlah-penduduk-provinsi-dki-jakarta-berdasarkan-kelompok-usia-per-kelurahan (2017)
3. Balai Besar Wilayah Sungai Ciliwung-Cisadane, *Studi penataan ulang sempadan Sungai Ciliwung Tahap II* (Balai Besar Wilayah Sungai Ciliwung-Cisadane, Jakarta, 2013)
4. G.J. Arcement, V.R. Schneider, *Guide for selecting manning's roughness coefficients for natural channels and flood plains* (United States Government Printing Office, Denver, 1989)