Study of Hydraulic and Sediment of River Sunter in Flood Management

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Abstract. Sunter River flows through East Jakarta City with its upstream in Cimpaeun District, Depok City and downstream of the Sunter River cut by the KBT (Kanal Banjir Timur) and flows directly into the sea. Cipinang Melayu Village, East Jakarta City is one of the villages in the lower reaches of the Sunter River which often floods. This study aims to obtain a proposed cross-section of the Sunter River with a planned flood discharge of 25 years and the morphological changes that occur in the Sunter River with respect to daily discharge and daily discharge without high rainfall. Analysis of planned flood discharge using Hec-HMS software. Meanwhile, the daily flood discharge used is from PDA Pondok Gede in 2013. For flood discharge without high rainfall, discharge is used from PDA Pondok Gede with a maximum value of 10% probability percentage. River morphology analysis using Hec-Ras 1D software. The conclusion of this study is that a cross section of the proposed management of the Sunter River is obtained with a width of 20 meters and a height of 4.5 meters. As well as the existing sedimentation trend as well as the proposed normalization of daily discharge and daily discharge without high rainfall which are relatively the same. And the amount of existing sediment of the Sunter River at daily discharge without high rainfall is 95% greater than the amount of sediment that enters the daily discharge.

1. Introduction

The problem of flooding in Jakarta has existed since the colonial era, but until currently, the flood has gotten bigger, both in intensity, frequency and distribution. In the last ten years, the worst floods occurred in early 2020 in the Krukut, Ciliwung, Cakung and Sunter watersheds. Based on the studies [1] that have been conducted, it can be concluded that the basic principle used in flood control in Jakarta is to drain river water that enters Jakarta through the outskirts of the city and directly into the sea so as not to enter the downtown area of Jakarta. Jakarta floods are channeled through the Kanal Banjir Barat (KBB) and Cengkareng Drain in the west and in the east through the Kanal Banjir Timur (KBT) and Cakung Drain [5]. In addition to the canal, several rivers and lakes in DKI Jakarta are also normalized to reduce the impact of the flooding that will occur. The normalization that has been carried out by the

DKI Jakarta Provincial Government and the Ministry of Public Works and Housing has not been fully realized due to limited land. In addition, flooding also occurs due to reduced river capacity caused by sedimentation build up.

2. Problem Identification

The downstream Sunter River include changes in land use in the upstream from green open spaces to residential and open land. The normalization of the Sunter River has not been fully carried out, there are still some natural sections of the Sunter River with river walls made of soil, resulting in a lot of material entering the river. In addition, the topography of the downstream Sunter River is relatively sloping with very fine grains of sedimentary material. As a result, the flow velocity at the downstream of the Sunter River is relatively small and sediment from the upper reaches of the Sunter River settles in the downstream area. The reduced capacity of the downstream Sunter River can cause flooding. Problems that occur in this study is how the trend of sediment transport towards daily discharge and daily discharge without heavy rainfall.

3. Overview of the Study

Based on the Ministry of Public Works and Housing Decree No. 4 of 2015, the Sunter watershed has 2 main rivers, namely the Sunter River and the Cipinang River. The upstream of the Sunter River is in Cimpaeun District, Depok City and the lower reaches of the Sunter River is cut by the KBT (Kanal Banjir Timur). The focus of this study is on the downstream of the Sunter River in the Cipinang Melayu sub-district, East Jakarta City along 3.5 km from the Jakarta-Cikampek toll road to the KBT (Kanal Banjir Timur). The focus of the research location can be seen in figure 1.

Figure 1. Focus of the research location

4. Research Method

In order to obtain the necessary information for numerical modelling, topographical data such as Digital Elevation Model (DEM), land cover and Harmonized World Soil Database (HWSD) maps were collected. Furthermore, hydrological data such as rainfall data collected from 4 rain stations for 12 years. Topographic and hydrological data were analyzed to obtain a river hydrograph [2].
Field data such as instantaneous discharge, bed material, and suspended solid concentration was also collected [6]. Numerical model for hydraulic and sediment transport analysis uses hydrograph as the upper boundary, river geometry data is obtained from shop drawing and the field data that was collected is used to model the river bed gradation and sediment rating curve.

5. Result

5.1. Topographic Analysis

Topographic data obtained in the form of DEM data from BIG and *Orthophoto* from BBWS Ciliwung Cisadane and land cover data from the Ministry of Environment and Forestry. Topographic analysis was carried out to determine the parameters of the Sunter watershed. To obtain watershed parameters, Sunter watershed delineation analysis was performed using GIS-based software. The area of the watershed is 75,7255 km^2 and the length of the river is 38.23 km. The coefficients for the Thiessen rainfall area method is presented in the table 1.

Table 1. Thiessen coefficient for Sunter watershed

Station	Thiessen Polygon Area (km^2)	Thiessen Coefficient
Cibinong	16.982	0.22
UI	22.680	0.3
Halim Perdanakusuma	31.626	0.42
Cawang	4.437	0.06

5.2. Hydrologic Analysis

Using rainfall data from 4 (four) stations around the watershed and the results of topographical analysis. The hydrological calibration uses actual discharge data from PDA Pondok Gede. Flood hydrograph analysis using HEC-HMS software with SCS unit hydrograph method with abstraction using curve number (CN). The hydrograph for various return period is presented in the figure 2:

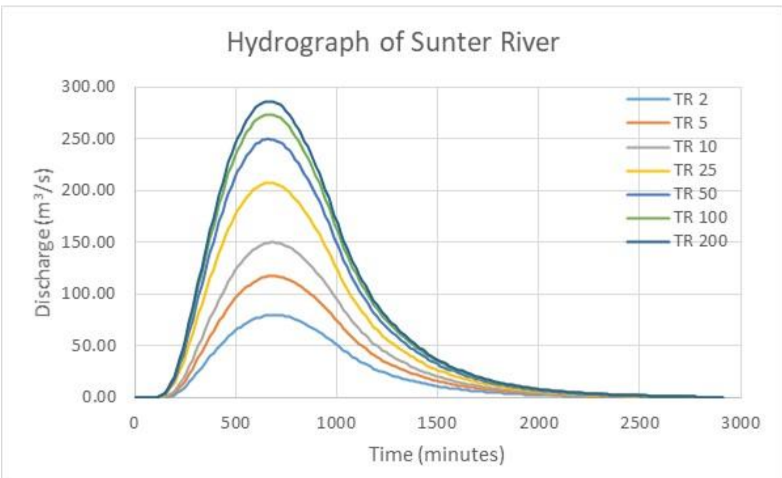

Figure 2. Hydrograph Sunter River

For daily discharge data is used from PDA Pondok Gede 2013. Meanwhile, for daily discharge without heavy rainfall, the Weibull method is used to determine the high discharge to be issued. The Weibull distribution chosen is 10% because it is very rare. The daily discharge is shown in Figure 3. and the daily discharge without heavy rainfall is shown in Figure 4.

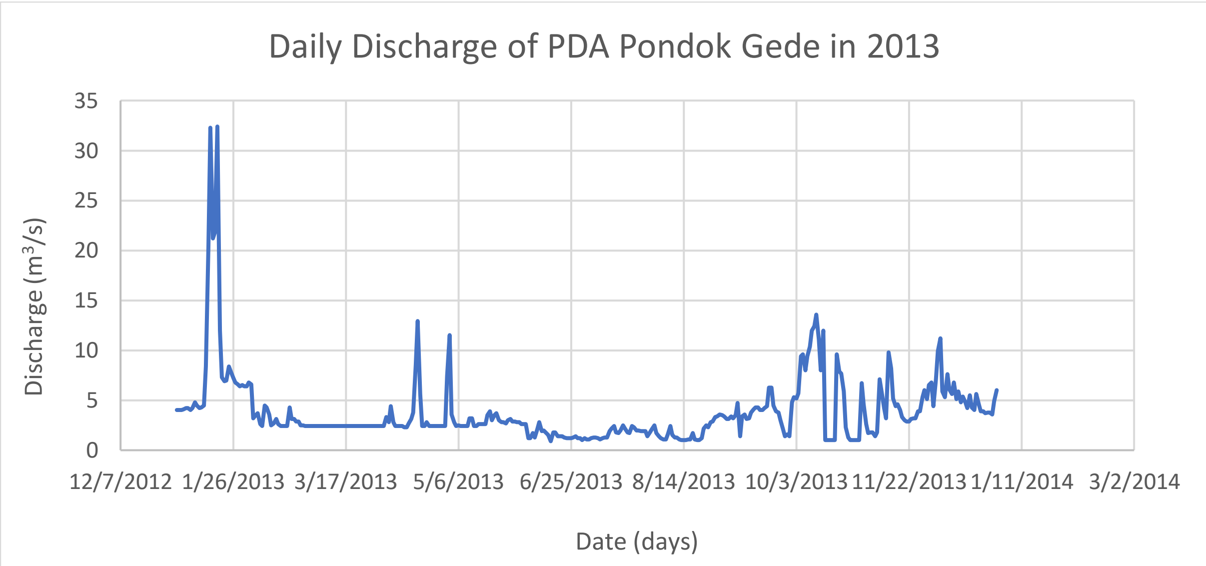

Figure 3. Daily Discharge.

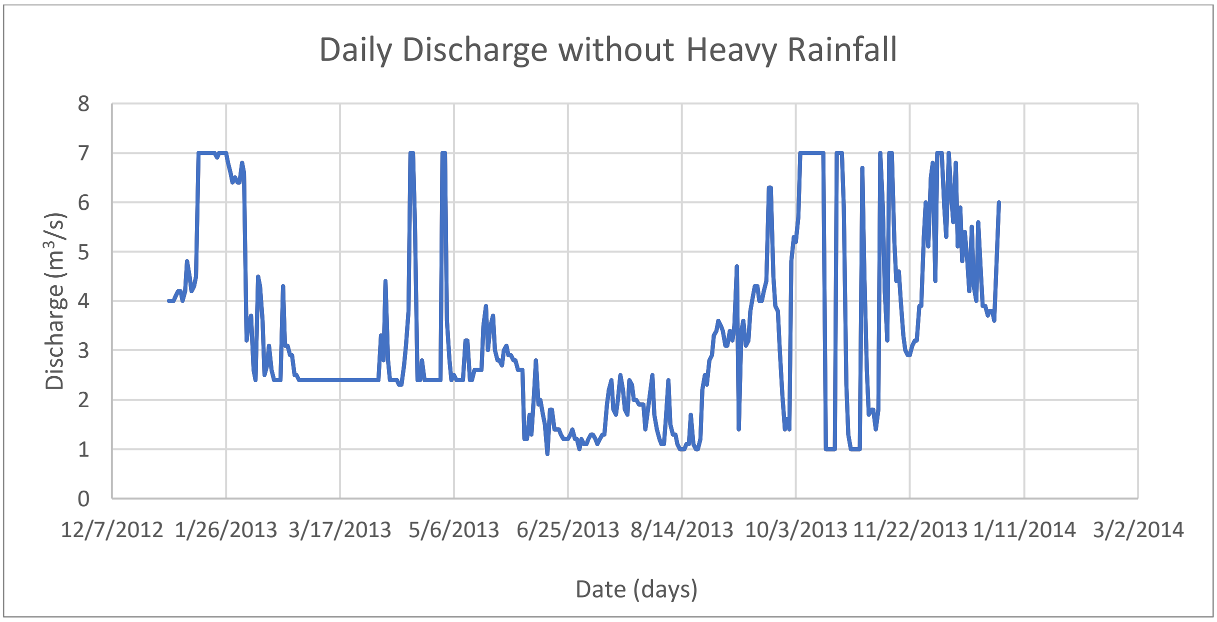

Figure 4. Daily Discharge without Heavy Rainfall

5.3. Sediment Transport Analysis

Sediment analysis was carried out to find out how much sediment transport occurred in the Sunter River. The relationship between discharge and sediment concentration will later be used as a boundary in the sediment transport analysis carried out using HecRas software. *quasi-unsteady flow.* Calculation of the relationship between discharge and sediment concentration using the Engelund Hansen equation. [3]

5.4. Simulation 1 – Eksisting Geometry

HecRas 1D hydrodynamic model of the Sunter River in the existing conditions with the constant *variable* geometry of the existing river and *variables* the changing, namely normal daily discharge and daily discharge without high rainfall events [4]. The purpose of this simulation is to obtain changes and differences in morphology of the Sunter river as a result of normal daily discharge with sediment transport and daily discharge without high rainfall with sediment transport.

The HecRas 1D simulation uses a quasi *-unsteady flow* with *boundary,* an upstreamnamely a *flow hydrograph,* namely daily discharge and daily discharge without high rainfall events. And at *boundary* the downstreamused *normal depth is.* With *boundary sediment transport, transport function :* MPM-Toffaleti, *sorting method* : Thomas (Ex5), *fall velocity method* : Toffaleti.

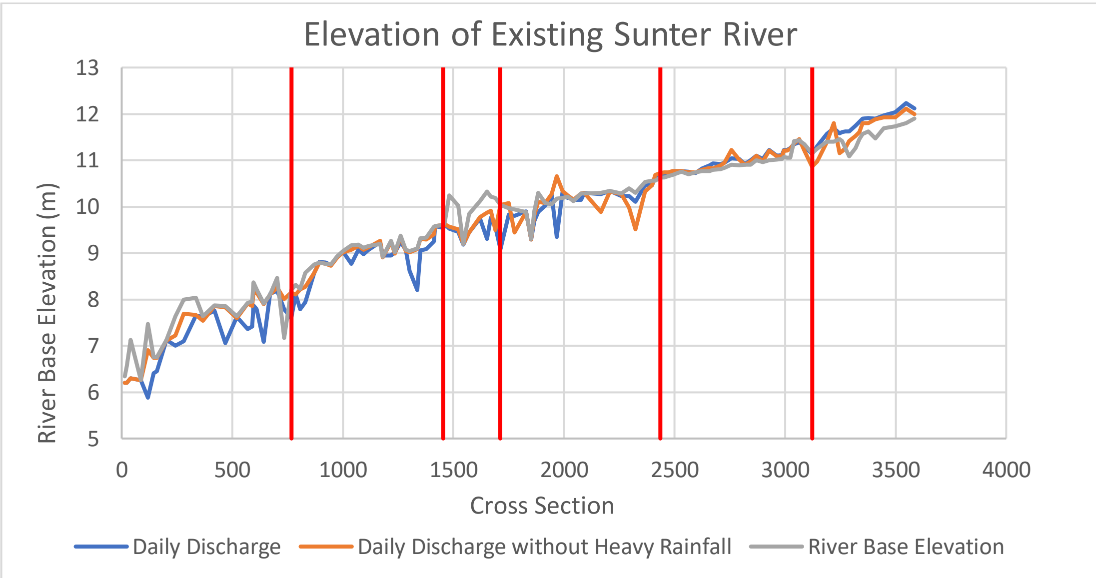

Figure 5. Base elevation of existing Sunter River against normal daily discharge and daily discharge without high rainfall

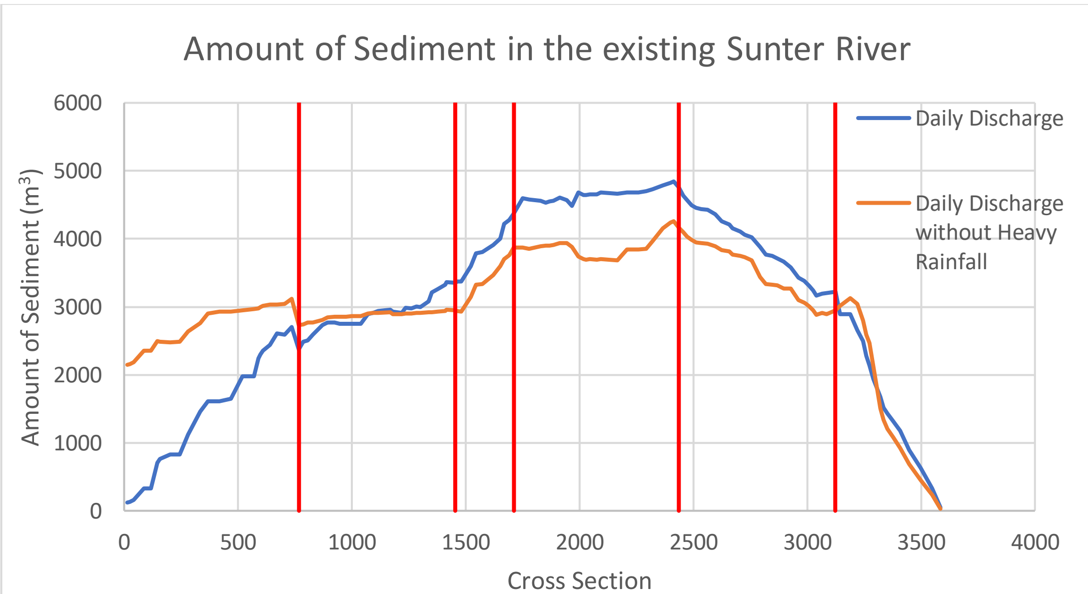

Figure 6. Amount of Sediment in the existing Sunter River against daily discharge and daily discharge without high rainfall

5.5. Simulation 2 – Normalization Geometry

HecRas 1D hydrodynamic model of the Sunter River for the geometry of the proposed treatment with a river width of 20 meters and a height of 4.5 meters. The constant variable is the geometry of the proposed river for handling and the variable that changes is the normal daily discharge and the daily discharge without the occurrence of high rainfall. The purpose of this simulation is to obtain changes and differences in morphology of the Sunter river as a result of normal daily discharge with sediment transport and daily discharge without high rainfall with sediment transport.

The HecRas 1D simulation uses a quasi -*unsteady flow* with *boundary,* an upstream namely a *flow hydrograph,* namely daily discharge and daily discharge without high rainfall events. And at *boundary* the downstream used *normal depth is.* With *boundary sediment transport, transport function :* MPM-Toffaleti, *sorting method* : Thomas (Ex5), *fall velocity method* : Toffaleti.

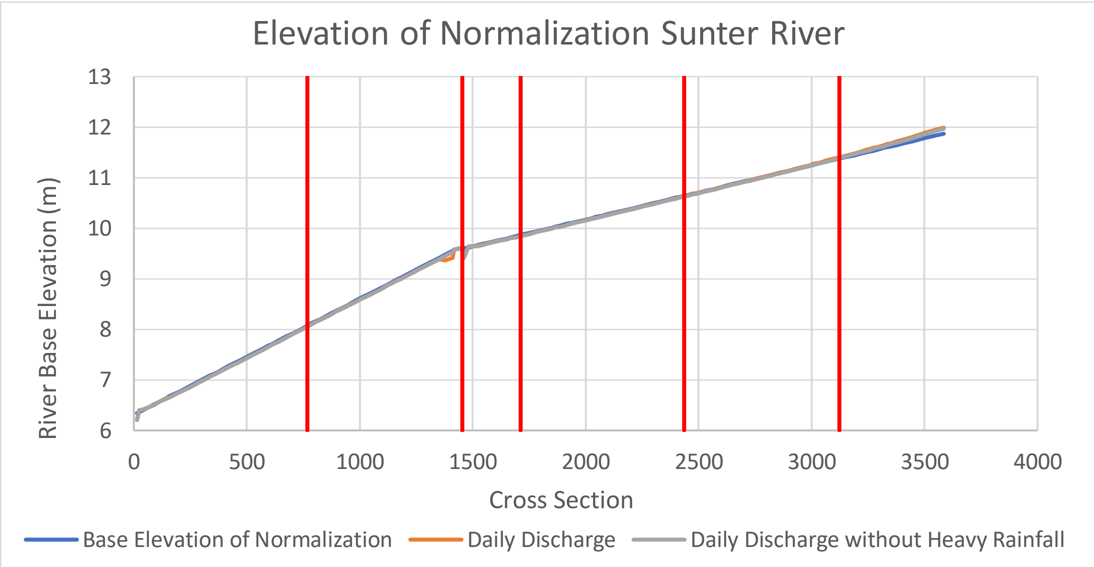

Figure 7. Base elevation of normalization Sunter River against normal daily discharge and daily discharge without high rainfall

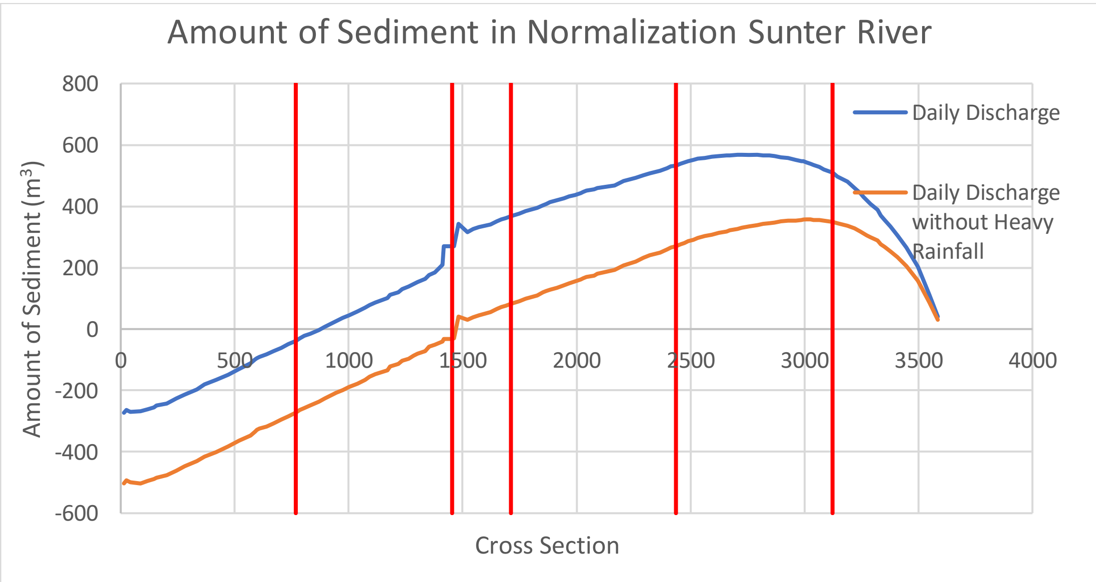

Figure 8. Amount of Sediment in the normalization Sunter River against daily discharge and daily discharge without high rainfall

6. Result of River Morphology

River morphology that will be discussed is river slope, velocity, amount of sediment and degradation and aggradation which are summarized in the table 2.

Table 2. Conclusion of River Morphology

No	Parameter	Existing Section with Daily Discharge	Existing Section with Daily Discharge without Heavy Rainfall	Normalization Section with Daily Discharge	Normalization Section with Daily Discharge without Heavy Rainfall
Cross Section 3585 – 3123					
1	Slope	Mild	Mild	Mild	Mild
2	Velocity (m/s)	0.62 – 1.36	0.40 – 0.89	1.22 – 1.27	0.68 – 0.72
3	Amount of Sediment (m^3/year)	3173	2916	469	317
4	Description	Aggradation	Aggradation	Aggradation	Aggradation
Cross Section 3123 – 2436					
1	Slope	Mild	Mild	Mild	Mild
2	Velocity (m/s)	0.60 – 0.88	0.32 – 0.8	1.22 – 1.23	0.67 – 0.69
3	Amount of Sediment (m^3/year)	1539	1220	24	78
4	Description	Aggradation	Aggradation	Aggradation	Aggradation
Cross Section 2436 – 1712					
1	Slope	Mild	Mild	Mild	Mild
2	Velocity (m/s)	0.60 – 1.22	0.30 – 0.97	1.22 – 1.29	0.69 – 0.67
3	Amount of Sediment (m^3/year)	393	294	165	188
4	Description	Stable	Stable	Aggradation	Aggradation
Cross Section 1712 – 1454					
1	Slope	Mild	Mild	Mild	Mild
2	Velocity (m/s)	0.60 – 1.17	0.40 – 1.00	1.10 – 1.30	0.69 – 0.62
3	Amount of Sediment (m^3/year)	1014	923	97	51
4	Description	Degradation is starting	Degradation is starting	Degradation is starting	Degradation is starting
Cross Section 1454 – 768					
1	Slope	Mild	Mild	Steep	Steep
2	Velocity (m/s)	1.00 – 1.40	0.90 – 1.08	1.54 – 1.55	0.85 – 0.87
3	Amount of Sediment (m^3/year)	980	218	232	-241
4	Description	Degradation is starting	Stable	Degradation is starting	Degradation
Cross Section 768 – 14					
1	Slope	Steep	Steep	Steep	Steep
2	Velocity (m/s)	1.10 – 2.00	0.70 – 1.20	1.48 – 1.54	0.85 – 1.00
3	Amount of Sediment (m^3/year)	2252	580	-234	-231
4	Description	Degradation is starting	Degradation is starting	Degradation	Degradation

According to Table 2 can be concluded :

1. The velocity at the daily discharge is higher than the daily discharge without high rainfall in the existing geometry conditions and the normalization geometry.
2. High velocities result in greater sediment carried. And it can be seen that the amount of sediment at daily discharge is greater than the amount of sediment at daily discharge without high rainfall.

3. The trend of sedimentation in the existing geometry and normalization is almost the same, which can be shown by the daily flow chart for the existing geometry conditions and the normalization conditions is always above the daily flow chart without high rainfall in the existing geometry conditions or the normalization conditions.
4. The amount of sediment in the existing conditions is greater than the amount of sediment in the normalization conditions, because in the normalization conditions the slope and manning have been arranged so that the velocity that occurs is mostly uniform.

7. Conclusion

The result of this study is the trend of sediment transport to the daily discharge and daily discharge without heavy rainfall for a year is relatively the same.

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Acknowledgments

Authors wishing to acknowledge assistance or encouragement from graduate advisors Mr. Indratmo Soekarno and Mr. Nugroho Eka Oktariyanto, colleagues, special work by staff of Water Resources Engineering and Management Program and financial support from Ministry of Public Works and Housing.