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Sigeleng River Capacity Analysis, Kec. Brebes with HEC-RAS 4.1.0

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Abstract

The purpose of this study was to determine the cross-sectional capacity of the Sigulung river, Kec. Brebes based on hydrological and hydraulic analysis using the HEC-RAS 4.1.0 program. Hydrological calculations were carried out using rain data obtained from the Water Resources Management Office (PSDA) and Spatial Planning of Brebes Regency from 2009-2018. After calculating with several kinds of distribution methods, it is concluded that the appropriate distribution method used in this research is the log normal distribution. Then from the results of the distribution calculation, the distribution of rainfall at the return period is 2 years, 5 years, 10 years, 25 years, 50 years, and 100 years. There are several calculation methods in calculating the planned debit. The rational method was chosen because it produces the highest discharge compared to other calculation methods. This discharge will be input for hydrological analysis into the channel model in the HEC-RAS program which is then observed so that the output of the model obtains a cross-sectional and longitudinal cross-sectional view of the flow in the channel model and it is known at what time the channel discharge causes flooding. Based on the results of this study, it can be concluded that at the 25-year return period, the distribution of rainfall reaches 377.97 mm/hour with a planned discharge of 31.29 m3/second. And on this 25th anniversary, the cross-sectional capacity of the river can still accommodate it.

Keywords
cross-sectional capacity; hydrology; design discharge; normal log; HEC-RAS 4.1.0

I. Introduction

Rivers/seas or waterways that provide easy living for the surrounding community can also make the community at risk of annual disasters due to flooding. Floods can occur due to rising water levels due to above normal rainfall, changes in temperature, dams/dams that burst, obstruction of water flow in other places.

The high rate of sedimentation faced by rivers in Indonesia generally occurs as a result of the increased rate of surface erosion and cliff erosion in the upstream areas. The conservation aspect in the upstream watershed area which is neglected during land management is also a factor in increasing the rate of erosion. Education and skills are the main keys in gaining social status in community life (Lubis *et al*, 2019). That is why we need to know knowledge about erosion.

Erosion not only reduces soil fertility due to loss of topsoil in eroded areas, but also has a negative impact in downstream areas, namely the emergence of sedimentation problems that can harm certain places such as silting of rivers, reservoirs, beaches and river estuaries as well as flooding in the downstream area.

Sediment control efforts start from the catchment area along the river as a producer of sediment material.

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Likewise, the Sigulung River flows from the Upper in the South Brebes area, crossing several areas in two sub-districts, Jatibarang and Brebes to the North Coast of Java. The Sigulung River, especially in the estuary area, has serious problems that must be addressed, one of the problems that almost every year always hits the surrounding community is flooding. When the rainy season arrives, people around the estuary are made restless due to the possibility of flooding due to overflowing of river water into residential areas. This was allegedly caused by the local community as a result of the blockage of the mouth of the Sigulung River by piles of sediment material, causing the water flow at the mouth of the river to be not smooth and tend not to move (silent), while the water discharge continues to increase along with the arrival of the rainy season.

To overcome these problems, a study is needed concerning the problem of estuary sedimentation, both caused by river sediment transport and coastal sediments.

II. Research Method

2.1 Rainfall Data

Estimates of planned rainfall are carried out by frequency analysis of annual maximum daily rainfall data with an observation period of 20 years in a row. The rain data used in the hydrological analysis is selected from the nearest rain station and has the potential to be distributed centrally to the location under review.

2.2 Calculation of the planned flood discharge

The calculation of the planned flood discharge is divided into two, namely:

a. Planned Flood Discharge based on Rainfall The
   The amount of river flood discharge is determined by the amount of rainfall, the time of rain, the area of the watershed and the characteristics of the watershed. To calculate the planned flood discharge based on rainfall, the Java Sumatra, Rasional, Melchior, and Weduwen FSR methods can be used.
b. Planned Flood Discharge Based on Discharge Data The
   The amount of river flood discharge is determined by the amount of discharge, the time of rain, and the area of the river watershed. To calculate the planned flood discharge based on the discharge, the Unit Hydrograph and Passing Capacity Methods can be used.

2.3 Frequency Distribution for Flood Discharge Data Analysis

In statistics, there are several kinds of frequency distribution, four types of distribution that are widely used in the field of hydrology are:

a. Normal Distribution
b. Normal Log Distribution
c. Log-Person III Distribution
d. Gumbel Distribution

2.4 Analysis of the Initial River Capacity (existing) with HEC-RAS

In calculating the hydraulics analysis of the Sigulung River in this study, the Hydrologic Engineering Center-River Analysis System (HEC-RAS) software version 4.1.0 was developed by the Hydrologic Engineering Center owned by the US. Army Corps of Engineers. The HEC-RAS system has 3 components of a one-dimensional hydraulic analysis for:

a. Calculation of the constant flow water surface profile.
b. Simulation of non-fixed flow.
c. Calculation of sediment transport.

a. Primary

Primary data is obtained directly from the location of the development plan and survey results which can be directly used as a source in research. Primary data is used if the secondary data obtained is incomplete.

The primary data needed include:

1. Direct field observations with the aim of knowing the current conditions of the research area.
2. Interviews with local communities.
3. Taking pictures and documenting the current state of the Sigulung River.

b. Secondary

Data Secondary data is data resulting from recording, measuring, research/investigation as well as activities carried out by other parties, including research reports or activity reports from a study or existing agency or data collected from sources the second includes the collection of literature on hydrology, hydraulics, and modeling using the HEC-RAS program. Field data needed for research materials include:

1. Hydrological data for the Sigulung watershed.
2. Geometric Data of the Sigulung River.
3. Data Profile of Sigulung River Water Level.
4. Data on General Condition of Study Location.

After the data has been collected, the next step is to process the data needed for hydraulics analysis using the HEC-RAS 4.1.0 software. The data needed in this hydraulics analysis is river condition data in the form of river geometry data, and river flow data in the form of planned flood discharge data. The planned flood discharge used in this study is a return period of 25 years. Of course, this planned flood discharge is obtained from the results of hydrological calculations, namely from extreme rainfall for 10 years (2008-2018).

The hydraulics analysis of the Sigulung River is intended to analyze the profile of the flood water level in the Sigulung River with a 25-year planned flood discharge return period. The hydraulics analysis will calculate how far the influence of three structural flood controls, namely the existence of a Retention Pond, River Normalization, and Embankment on the flood water level and the flood overflow that occurs.

To find out the total capacity of the river in carrying the volume of flood discharge in the initial conditions, a Simulation Modeling of the Sigulung River was carried out. The conditions that will be reviewed include river capacity, flood inundation area, and the effect of three flood mitigation analyzes.

The first step to determine the capacity of the Silent River is to determine the amount of water that enters the river. In this case, the authors determine the amount of the design discharge, with the discharge used is flood discharge with a return period of 25 years resulting from the calculation of hydrological analysis.

To evaluate the cross-sectional capacity of the Sigulung River, the author uses the HEC-RAS 4.1.0 program. This program is used to perform one-dimensional hydraulic analysis. In the case study of the Sigulung River, a steady flow cross-sectional calculation is used.

III. Results and Discussion

The Sigulung River has a straight trend with shallow depths and a gentle slope of the riverbed. The width of the cross-section remains or varies regularly, getting wider upstream. Types of river flow include relatively uniform flow and *steady (steady flow)*.

More detailed technical data on the Sigulung river are as follows:

1. Watershed area : 2,289 km^2
2. slope : 0.00015-0.00025
3. River Depth : 1.20 – 1.80 m
4. Average river width: 16 m
5. River slope : 45^o until upright

The flow pattern on the Sigulung river is a flow pattern starting from upstream (Jatibarang / Krasak Pemaron Secondary Channel) to downstream (Muara Sigulung). More details on the flow pattern of the Sigulung river can be seen in Figure 4.1 Map of the Sigulung River Basin

Hydrological
Analysis Rainfall

In performing calculations to determine the amount of rain intensity to share the return period, first an analysis of the maximum rainfall data obtained from the rainfall station in around Brebes.

The rainfall data used is the maximum daily rainfall for 10 years, namely from 2009-2018, which was obtained from the Department of Resource Management Water Resources (PSDA) and Spatial Planning of Brebes Regency.

Determining the Distribution Method Used

a. Normal Distribution

No	Year	R max	Xi –Xbar	$(Xi\text{-}Xbar)^2$	$(Xi - Xbar)^3$	$(Xi - Xbar)^4$
1	2009	185	-60.70	3684.49	-223648.54	13575466.56
2	2010	209	-36.70	1346.89	-49430.86	1814112.67
3	2011	229	-16.70	278.89	-4657.46	77779.63
4	2012	228	-17.70	313.29	-5545.23	98150.62
5	2013	232	-13.70	187.69	-2571.35	35227.54
6	2014	189	-56.70	3214.89	-182284.26	10335517.71
7	2015	129.2976	_	241.71	.	_
_	_	_	_	_	2352.64	31290.07
9	2017	330	84.30	7106.49	599077.11	50502200.12
10	2018	408	162.30	26341.29	4275191.37	693863558.86
Total		2457	0	45980.10	4216383.36	781417475.70
R average		245.7				

1. Total data (n) 10

$$Xi = Xi \frac{Standard}{n}$$

= 245.7

2. Deviation (sd)

$$Sd = \sqrt{\frac{(Xi - Xbar)^2}{n - 1}}$$

$$Sd = \sqrt{\frac{45980.1}{9}} = 71.48$$

3. The coefficient of variation (Cv) is calculated by the equation:

$$Cv = \frac{sd}{X}$$

$$Cv = \frac{71.48}{142.73} = 0.5$$

4. The Skewness coefficient (Cs) is calculated by the equation:

$$Cs = \frac{n.(\sum X - Xbar)^3}{(n-1)(n-2)S^3}$$

$$Cs = \frac{10x4216383.36}{9.8.(71.43)^3} = 1.60$$

5. Peak/curtosis coefficient (Ck) :

$$Ck = \frac{n^2.(\sum X - Xbar)^2}{(n-1)(n-2)(n-3)S^4}$$

$$Ck = \frac{10^2.45980{,}10}{9.8.7.(71.43)^4} = 5.94$$

b. Log Normal and Log Pearson III

No	year	X	Log X	Log Xi - Log Xrt	(Log Xi - Log Xrt)^2	(Log Xi - Log Xrt)^3	(Log Xi - Log Xrt)^4
1	2009	185	2.2672	-0.1092	0.0119	-0.0013	0.0001
2	2010	209	2.3201	-0.0562	0.0032	-0.0002	0.0000
3	2011	229	2.3598	-0.0165	0.0003	0.0000	0.0000
4	2012	228	2.3579	-0.0184	0.0003	0.0000	0.0000
5	2013	232	2.3655	-0.0109	0.0001	_	0.00000
6	2014	10.089	2.2765	-0.0999	0.0100	-0.0010	0.0001
7	2015	188	2.2742	-0.1022	0.0104	-0.0011	0.0001
8	2016	259	2.4133	0.0369	0.0014	0.0001	0.0000
9	2017	330	2.5185	0.1421	0.0202	0.0029	0.0004
10	2018	408	2.6107	0.2343	0.0549	0.00129	0.002738
Total		_	24	_	0.012	0.10.00	_
_245.7		-average	2.3764				

Determining the Type of Distribution Used

No.	Type	of Condition	Calculation Results	Information
1	Normal Distribution	Cs ~ 0	1.6037	Not Approaching
		Ck ~ 3	5.9402	Not Approaching
2	Gumbel Distribution Type I	Cs 1.1396	1.6037	Not Approaching
		Ck 5,4002	5.9402	Not Approaching
3	Log Distribution Pearson Type III	Cs 0, Cv = 0.3	1.2118	Not Approaching
		Ck ~ 1.5Cs(In X)^2 +3 = 3.25	4.7881	Not Approaching
4	Log Normal Distribution	Cv ~ 0	0.0471	Approaching
		Cs ~ 3Cv+Cv^3= 0.4675	1.2118	Approaching

Hydraulic Analysis with HEC-RAS Modeling 4.1.0

The analysis was carried out using the HEC-RAS 4.1.0 numerical modeling program. HEC-RAS is a steady and unsteady one-dimensional flow model. HEC-RAS has four components of a one-dimensional model including: (1) Calculation of the permanent/fixed flow water level profile; (2) Simulation of impermanent / non-permanent flow; (3) Calculation of sediment transport; (4) Calculation of water quality (temperature).

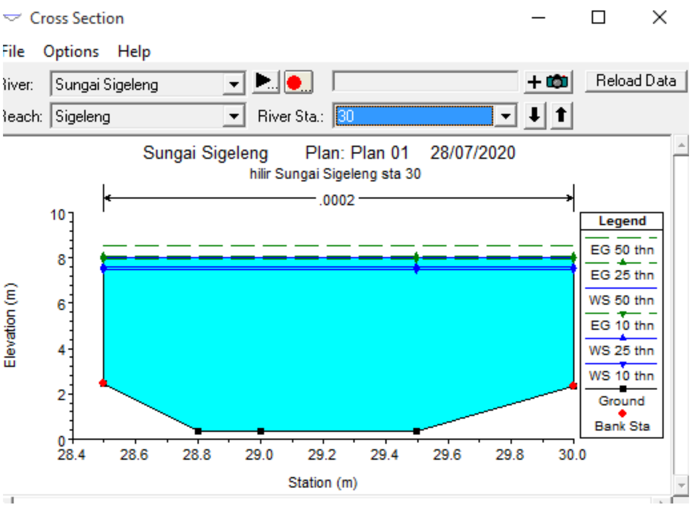
In this study, the analysis is carried out using a permanent flow or steady flow, including an analysis of the ability of existing and planned channels to drain the planned flood discharge. The research location is the Sigulung river, Kec. Brebes with a STA span limit of G.25+00 to G.30+00.

The Results of the Hydraulic

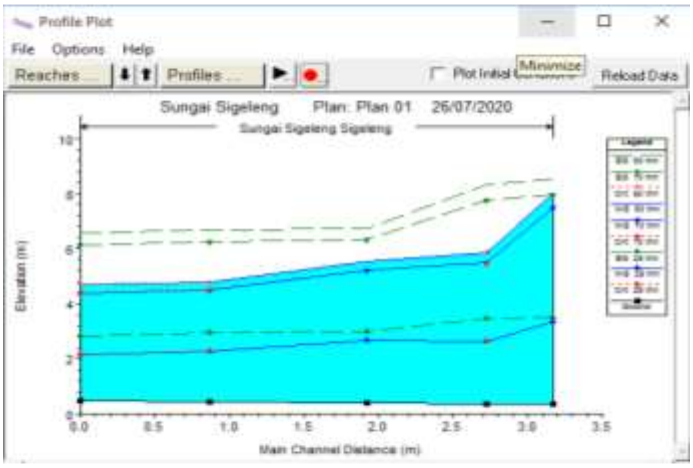
Analysis of the Sigulung River STA 25+00 s/d 30+00 with the HEC-RAS 4.1.0 program modeling can be concluded as follows:

1. Sigulung River which has a steady or permanent flow, the running steady mode is used in the analysis flow and uses constant flow data as input discharge.

2. In the HEC-RAS application, the use of the running steady flow mode depends on the confidence of the modeling person. Some experienced modelers, based on their intuition and river morphology data, can tell that the use of running steady flow mode in HEC-RAS will result in significantly different river water levels or not.
3. Below are the results of the cross section of the Sigulung river after entering the river morphology data.



4. The results of the Profiles Plot can be seen in Figure.



5. Below is a detailed table of hydraulics analysis using HEC-RAS 4.1.0.

Table Profile Output Table Hydrological Analysis of Sigulung River discharge at the 25-year return period

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Sigeleng	30	50 thn	34.30	0.34	8.01		8.53	0.000001	3.21	10.67	1.50	0.38
Sigeleng	30	25 thn	31.30	0.34	7.59		8.09	0.000001	3.12	10.05	1.50	0.38
Sigeleng	30	10 thn	30.50	0.34	7.48		7.96	0.000001	3.09	9.88	1.50	0.38
Sigeleng	28	50 thn	34.30	0.37	5.87	5.87	8.34	0.000006	6.96	4.93	1.00	1.00
Sigeleng	28	25 thn	31.30	0.37	5.58	5.58	7.90	0.000006	6.75	4.64	1.00	1.00
Sigeleng	28	10 thn	30.50	0.37	5.50	5.50	7.78	0.000006	6.69	4.56	1.00	1.00
Sigeleng	27	50 thn	34.30	0.39	5.54		6.75	0.000002	4.87	7.05	1.50	0.72
Sigeleng	27	25 thn	31.30	0.39	5.30		6.42	0.000002	4.69	6.68	1.50	0.71
Sigeleng	27	10 thn	30.50	0.39	5.23		6.32	0.000002	4.64	6.57	1.50	0.71
Sigeleng	26	50 thn	34.30	0.45	4.80	4.80	6.68	0.000003	6.08	5.64	1.50	1.00
Sigeleng	26	25 thn	31.30	0.45	4.58	4.58	6.35	0.000003	5.90	5.31	1.50	1.00
Sigeleng	26	10 thn	30.50	0.45	4.52	4.52	6.26	0.000003	5.85	5.22	1.50	1.00
Sigeleng	25	50 thn	34.30	0.47	4.68	4.68	6.56	0.000003	6.08	5.64	1.50	1.00
Sigeleng	25	25 thn	31.30	0.47	4.46	4.46	6.23	0.000003	5.90	5.31	1.50	1.00
Sigeleng	25	10 thn	30.50	0.47	4.40	4.40	6.14	0.000003	5.84	5.22	1.50	1.00

IV. Conclusion

Conclusions that can be drawn from the hydrological analysis of the Sigulung River, Kec. Brebes is as follows:

1. From the 10-year rainfall data, 2009-2018, obtained from the Water Resources Management Service (PSDA) and Spatial Planning of the Brebes Regency, the average rainfall was 245.7 mm.
2. Statistical parameter calculations are performed to determine the distribution method used. From these calculations, it can be concluded that the distribution method used is the Log Normal Distribution. Because it is close to the normal log distribution requirements, namely Cv = 0.0471 and Cs = 1.2118.
3. With n = 10 and an error rate of 2.5%, the critical value for the Chi Square distribution is 7.3780. After that, the results obtained are $Xh^2 < Xh^2$ cr, then the log Normal distribution can be accepted
4. The flood discharge at the 25 year return period is 31.29 m^3/s.
5. According to table 4.14 Recapitulation of Planned Flood Discharge, it can be concluded that the method used is the Rational method. The Rational method was chosen because the calculation shows the highest debit value.

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