Study on Morphological Change due to Flood in the Tuntang River

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Abtsrak. The Tuntang River is located in the Jratunseluna River Region in Central Java Province. At the present morphological condition of the river have been experiencing aggregation and degradation. Aggregation is caused by the large amount of soil granular material carried by the river flow due to the landslide of the existing embankment. The degradation is caused by the erosion of the riverbed in the upstream. The purpose of this study is to examine the parameters of river morphology changes in conditions before and after normalization for the 2-year return period (Q2) and 50-year return period (Q50) design flood discharge with models using the analysis method HEC-RAS 1D software for quasi unsteady flow. In the HEC-RAS 1D quasi unsteady modeling Q2 and Q50 the geometry is used from terrestrial measurements with boundary condition types in the upstream form of flow hydrograph with actual unit hydrograph and boundary sediment with rating curve, boundary condition types downstream in the form of stage hydrograph of tides, and bed gradation grain size as many as 15 points spread from upstream to downstream. On the results of the simulation analysis of river morphology during Q2 of 259.50 m3/s after normalization there was a decrease in the average flow velocity (V) from 0.97 m/s to 0.86 m/s by 11.57%, an increase the average channel bed slope (S) from 0.000385 m/m to 0.000427 m/m by 10.91%, the increase in the average channel bed shear stress (τ) from 2.02 pa to 2.36 pa by 16.65%, the maximum decrease in the height of the aggradation from 2.04 m to 0.68 m by 66.78%, and the maximum depth of degradation by 2.00 m. On the results of the simulation analysis of river morphology at the time of Q50 of 259.50 m3/s after normalization there was a decrease in the average flow velocity (V) from 1.28 m/s to 1.17 m/s of 8.46%, an increase in the average channel bed slope (S) from 0.000346 m/m to 0.000491 m/m by 12.48%, the increase in the average channel bed shear stress (τ) from 3.25 pa to 4.33 pa by 33.27%, the maximum decrease in the height of the degradation from 4.37 m to 3.95 m by 9.50%, and the maximum depth of degradation of 2.00 m.

Keywords: River Morphology, Tuntang River, Design Flood, Normalization, HEC-RAS

1. Introduction

The Tuntang River is under the authority of the Pemali Juana River Basin Center located in the administrative area regency of Grobogan, Semarang, Demak, and Salatiga city. Geographically, the Tuntang Watershed is located at 10° 15' 50" East Longitude - 110° 33' 20" East Longitude and 06° 51' 25" South Latitude - 07° 26' 40" South Latitude with a main time length of 108.8 km. The total area watershed of the Tuntang River is 1038.90 km^2. The upstream area is in Semarang Regency, the middle area is in Salatiga City and Grobogan Regency, and the downstream area is in Demak Regency which empties into the Java Sea. Morphological conditions of the Tuntang River at the riverbed, the upstream starting point is located at an altitude of +454 m to a height of +0 m downstream with an average slope (0.6%, -0.3%) with a maximum slope (8.5%, -1 ,6%). The condition of the Tuntang River has a meander with many extreme river bends and natural river embankments with expansive soil characteristics so that if there is a large discharge flow or flooding will result in river embankment erosion which will cause sedimentation (gradation and degradation pattern) resulting in scouring and sedimentation forming braided on the Stream. The condition of the upstream to midstream channel of the Tuntang River has a steep height difference, but the condition of the midstream to downstream channel with relatively sloping floodplain conditions. The Tuntang River caused flooding in Trimulyo Village, Guntur District, Demak Regency. Often during the rainy season the embankment on the Tuntang River in Trimulyo Village is unable to withstand the discharge, silting of the river channel occurs, and embankment settlements so that the embankment bursts and causes flooding[8]. One of the villages that often floods in Kab. Demak is Pulosari Village. Pulosari village has an area of 2 km² and a population of 2151 people in December 2014. The condition of the Tuntang River which is experiencing narrowing of the channel and silting causes a reduction in the cross-sectional capacity of the river to drain flood discharge. The design flood discharge used in analyzing the cross section uses a 25 years return period Q25 = 270,032 m^3/s. The analysis of the existing section and the design section was carried out using the HEC-RAS software. The problem of flooding in the Tuntang River was overcome in various ways, namely by improving the cross section, planning the embankment, and raising the existing embankment[10]. The purpose of this study was to study the morphological changes of the Tuntang River by analyzing the river morphology parameters at the design flood discharge of the 2-year return period (Q2) and the design flood discharge of the 50-year return period (Q50).

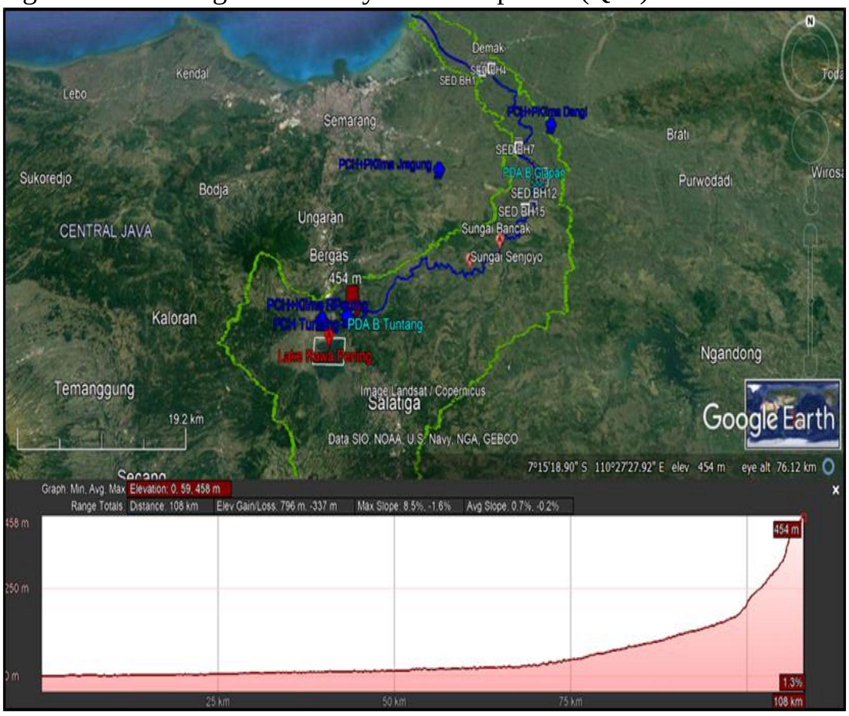

Figure 1. Tuntang River Morphological


Figure 2. Downstream


Figure 3. Midstream


Figure 4. Upstream

2. Materials and Methods

2.1 Data Collection

Data collection is as follows:

Table 1. Data Collection

No	Data	Information	Source
1	Watershed Characteristics Data	Digital Elevation Model	http://tides.big.go.id/DEMNAS
2	Rainfall Data	Rainfall Dangi 2004 sd 2019 Rainfall Jragung 2004 sd 2019 Rainfall Rawapening 2004 sd 2019 Rainfall Tuntang 2004 sd 2019	Department of Public Works and Spatial Planning, Province of Central Java
3	AWLR Data	Rating Curve AWLR Glapan Weir	Pemali Juana River Basin Organization
4	Tidal Data	Tidal Data 2004-2019	http://tides.big.go.id/pasut/index.html
5	Bed Load Sediment Data	Sediment 15 Points 2016	Pemali Juana River Basin Organization
6	Suspended Load Sediment Data	Sediment 2017-2021	Pemali Juana River Basin Organization
7	River Geometry Data	Terrestrial Measurement	Pemali Juana River Basin Organization

2.2 Watershed Characteristics Analysis

Data for the analysis of watershed characteristics can be downloaded through open sources from the proprietary digital elevation model data page http://tides.big.go.id/DEMNAS. The digital elevation model data is processed by delineating the watershed through software based on the Geographic Information System.

2.3 Hydrological Analysis of Design Rainfall

Analysis begins with analysis of design rainfall by sorting daily rainfall data. Analysis of the consistency test using the double mass curve method to find out if there are deviations in the relationship between each rain station post and other rain station posts around the post using manual calculations. The consistency test using the double mass curve method is said to be consistent if the slope angle of the trend line on the graph is $\alpha = 45^o$ or the slope of the slope line S = 1. The data tolerance can still be considered consistent in the range of values $42^o < \alpha < 48^o$ (repository.ub.ac.id). Analysis of regional rainfall to map the observations of the coordinates of the rainfall post on the influence of area using the Thiessen polygon method. Rain frequency analysis using the Normal distribution method, Gumbel, Log Normal and Log Pearson III was compared with software calculations. The analysis of the rain distribution suitability test using the Chi Square and Smirnov Kolmogorov method (Triatmodjo, 2009). The selected rainfall is validated with an isohyet map (Directorate General of Water Resources, Ministry of Public Works and Housing).

2.4 Hydrological Analysis of Design Floods

Analysis of design flood discharge was carried out to obtain the value of the design return period flood discharge, both the number of frequencies per unit time and the return period with manual calculations. This design flood discharge analysis uses an empirical method in the form of a unit hydrograph method which in this method needs to be considered effective rain, base flow, and runoff hydrograph. In determining the amount of flooding with a unit hydrograph, hourly rain data is needed. In this analysis, the procedure for making unit hydrographs from actual observation data of hydrograph units is calculated manually (SNI 2415-2016):

$$\mathrm{heff} = \frac{\Sigma \mathrm{Qnet}\ \Delta \mathrm{t}}{\mathrm{A}} = \frac{\mathrm{Qnet}.60.60.\Delta \mathrm{t}}{\mathrm{A}}$$

Furthermore, the design rain data is distributed into hourly rain using the PSA 007 Distribution with the duration of the rain used is 24 hours (Technical Instructions for Calculation of Flood Discharge on Dams, 2017).

2.5 Hydraulic Analysis of River Morphology

Analysis of the design flood river used with HEC-RAS software for quasi-unsteady flow 1D flow type both in the geometry conditions before and after normalization. The analysis was used to measure river morphology parameters at the time of discharge of the 2-year return period (Q2) and discharge of the 50-year return period (Q50) (HEC-RAS Sediment Transport).

$$(1 - \lambda \mathrm{p})\mathrm{B}\,\frac{\delta \mathrm{n}}{\delta \mathrm{t}} = -\frac{\delta \mathrm{Qs}}{\delta \mathrm{x}}$$

Steps and conditions for analyzing the morphology of the planned flood river with software HEC-RAS quasi flow unsteady flow 1D discharge Q2 and discharge Q50 with geometry conditions before and after the normalization of the Tuntang River:

- The measurement data of cross section the Tuntang River on the geometry of the conditions before and after normalization for Q2 and Q50 of the Tuntang River are in the form of normalization along 55 km.
- The table of values of manning's roughness coefficient n (Chow, 1959) is taken from the Book of Sediment Transport, Theory and Practice, Chie Ted. Glapan Dam overflow discharge curve rating field. The value of the Manning roughness coefficient (n) both in the conditions before and after river normalization is in accordance with the field and theory.
- Boundry data condition types in the form upstream of flow hydrograph of hydrograph unit from observed data (actual unit hydrograph) discharge Q2 and Q50 with simulation time hours for 2 days.
- Boundary data condition types downstream of the river in the form of a stage hydrograph of the tides http://tides.big.go.id/pasut/index.html by selecting the highest tides and lows with an hour simulation time of 2 days.
- Bed gradation grain size of secondary data Tuntang River as much as 15 points spread from the upstream to the downstream, and suspended load data is in the upstream.
- Boundary sediment data upstream in the form of approach rating curve from flow discharge Q (m^3/s) and suspended load concentration C (mg/l) obtained a value of $R^2 = 0.71$ (Figure 5).

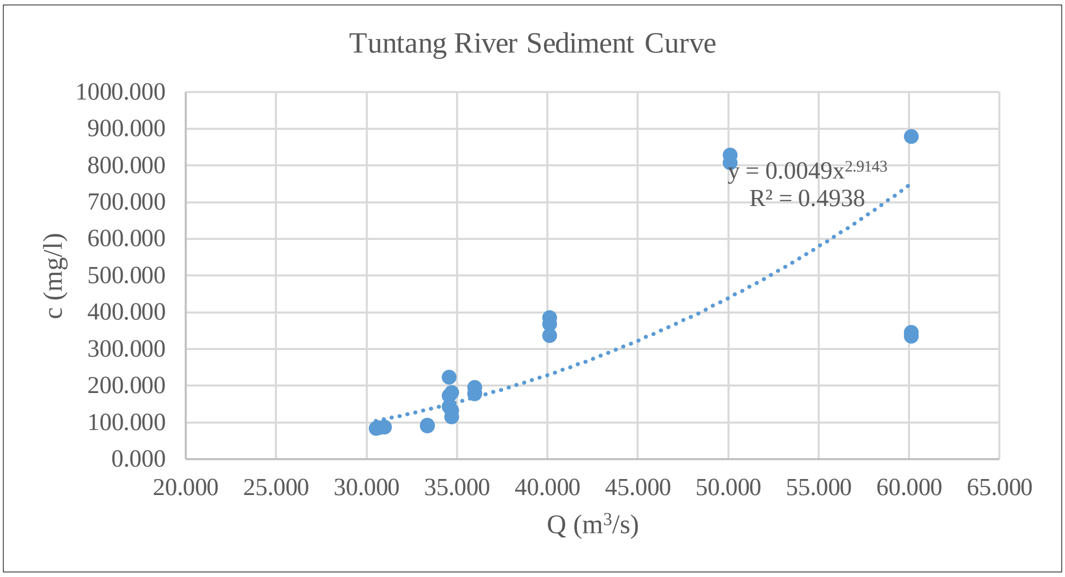

Figure 5. Gradation Curve Sediment Suspended Load Sungai Tuntang

- Data Initial conditions and transport parameters for transport function using Toffaleti, sorting method using Thomas (Ex5), and fall velocity method using Rubey. The Toffaleti sediment transport function was chosen because the bed load diameter in the Tuntang River was 15 points between 0-2 mm in diameter (Table 2).

Table 2. Range of input values for sediment transport functions (HECRAS Sediment Transport)

Function	d	d_m	s	V	D	S	W	T
Ackers-White (*flume*)	0.04 - 7.0	NA	1.0 - 2.7	0.07 - 7.1	0.01 - 1.4	0.00006 - 0.037	0.23 - 4.0	46 - 89
Englund-Hansen (*flume*)	NA	0.19 - 0.93	NA	0.65 – 6.34	0.19 – 1.33	0.000055 – 0.019	NA	45 - 93
Laursen (*field*)	NA	0.08– 0.7	NA	0.068 – 7.8	0.67 – 54	0.0000021 – 0.0018	63 – 3640	32 - 93
Laursen (*flume*)	NA	0.011 -29	NA	0.7 - 9.4	0.03 – 3.6	0.00025 – 0.025	0.25 – 6.6	46 - 83
Meyer-Peter Muller (*flume*)	0.4 – 29	NA	1.25 – 4.0	1.2 – 9.4	0.03 – 3.9	0.0004 – 0.02	0.5 – 6.6	NA
Tofaletti (*field*)	0.062 – 4.0	0.095 – 0.76	NA	0.7 - 7.8	0.07 – 56.7 (R)	0.000002 – 0.0011	63 - 3640	32 – 93
Tofaletti (*flume*)	0.062 – 4.0	0.45 – 0.91	NA	0.7 - 6.3	0.07 – 1.1 (R)	0.00014 – 0.019	0.8 – 8	40 - 93
Yang (*field-sand*)	0.15 – 1.7	NA	NA	0.8 - 6.4	0.04 – 50	0.000043 – 0.028	0.44 – 1750	32 - 94
Yang (*field-gravel*)	2.5 – 7.0	NA	NA	1.4 - 5.1	0.08 – 0.72	0.0012 – 0.029	0.44 – 1750	32 - 94

- Simulation analysis was carried out on the geometry of conditions before (Figure 6) and after normalization (Figure 7) for river morphology conditions with Q2 and Q50.

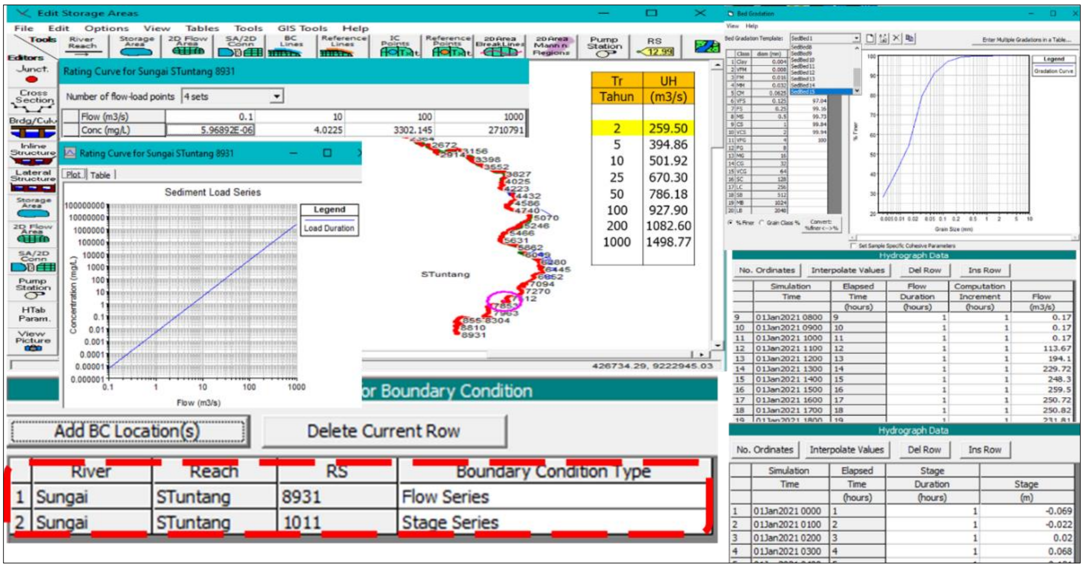

Figure 6. Boundary Condition Layout Quasi Unsteady Flow 1D Q2 River Morphology

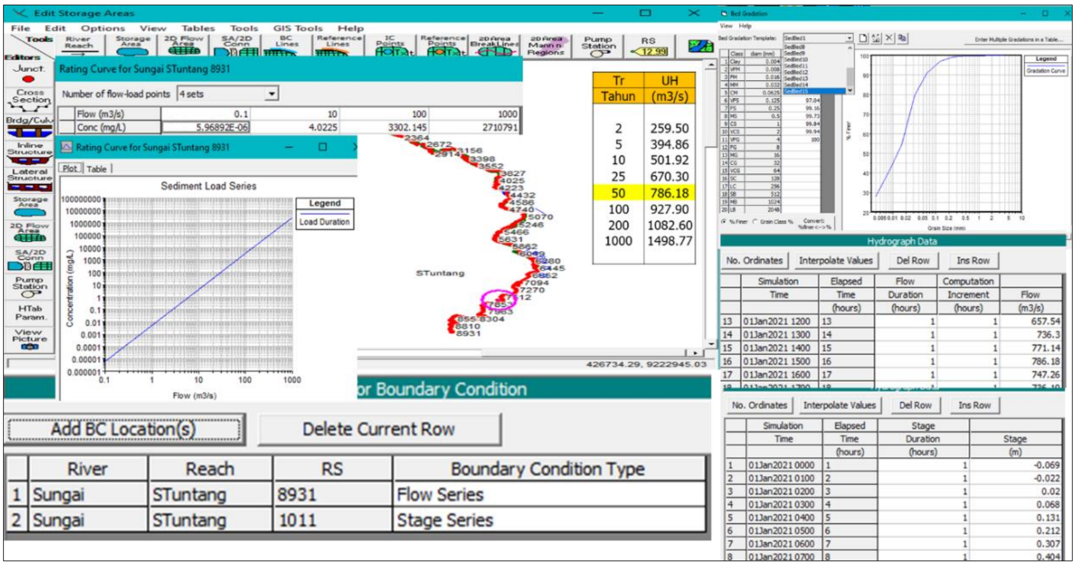

Figure 7. Boundary Condition Quasi Unsteady Flow 1D Q50 River Morphology

3. Results and Discussion

3.1 Watershed Characteristics Analysis

Results of the watershed characteristics analysis obtained watershed area of 1038.90 km^2 with a river length of 108.80 km (Figure 8) (Table 3).

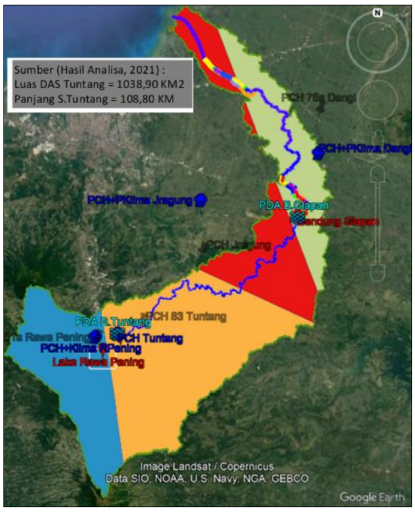

Figure 8. Delineation Watershed

Table 3. Area Polygon Thiessen

NO	Observation Station	Total Area (km^2)	(%)
1	Rainfall Post Rawa Pening	221.25	21.30%
2	Rainfall Post Jragung	203.21	19.56%
3	Rainfall Post Tuntang	425.03	40.91%
4	Rainfall Post Dangi	189.40	18.23%
	Total	**1038.90**	**100%**

3.2 Hydrological Analysis of Design Rainfall

Results of the hydrological analysis of the design consistency test using the double mass curve method obtained that the slope angle of the trend line on the graph falls within $42^o < \alpha < 48^o$. Analysis of regional rainfall to map the observations of the coordinates of the rainfall post on the analysis of rainfall frequency manually compared with the calculation of the software obtained Log Pearson III with a 2-year return period of 96.73 mm of rainfall and a 50-year return period of 160.87 mm (Table 4) and verified against the fit test (Table 5) with isohyet map validation with a maximum return period of 100 years (Figure 9).

Table 4. Recapitulation Analysis of Rainfall Plan

Period	Normal	Hydrognomon (Normal)	Log Normal	Hydrognomon (Log Normal)	Pearson III	Hydrognomon (Pearson III)	Log Pearson III	Hydrognomon (Log Pearson III)	Gumbel	Hydrognomon (Gumbel)
1000	167.44	167.23	180.83	188.67	170.90	216.15	173.86	231.14	248.61	206.61
200	155.50	156.26	162.33	169.51	168.59	186.59	171.04	191.30	214.26	179.81
100	150.73	150.94	155.49	160.93	165.70	173.70	167.58	175.70	199.42	168.24
50	144.78	145.13	147.35	152.06	159.91	160.68	160.87	160.88	184.54	156.63
25	137.82	138.67	138.36	142.76	148.35	147.49	148.24	146.74	169.54	144.93
10	126.92	128.66	125.39	129.48	129.17	129.66	128.77	128.78	149.32	129.17
5	115.84	119.28	113.43	118.15	116.09	115.70	115.41	115.42	133.32	116.68
2	101.34	101.34	99.50	99.17	95.93	95.89	96.73	96.73	109.15	97.83

Table 5. Recapitulation Analysis of Rainfall Distribution Suitability

No	Type	Match Test Distribution Type Rain												
		Parameter			Smirnov Kolmogorov				Chi Square				Smirnov Kol Hydrognomon	Chi Square Hydrognomon
		koef	Analysis		D_n<D_{kritis}			Analysis	$X^2_{hitungan} < X^2_{tabel}$			Analysis		
1	Gumbel	Cs ≈ 1.1396 Ck ≈ 5.4002	Cs = 1.6 Ck ≈ 3.7	OK	0.388	<	0.330	Not Accrepted	3.375	<	9.488	Accrepted	Accrepted	Not Accrepted
2	Normal	Cs ≈ 0 Ck ≈ 3	Cs = 1.6 Ck ≈ 3.7	NOT	0.939	<	0.330	Not Accrepted	14.625	<	9.488	Not Accrepted	Accrepted	Accrepted
3	Log Normal	Cs ≈ 3 (+) Cs = 3 Cv	Cs = 1.6 Ck ≈ 3.7 Cs = 3*Cv 1.52 ≠ 3*3.7	NOT	0.876	<	0.330	Not Accrepted	9.625	<	9.488	Not Accrepted	Accrepted	Accrepted
4	**Log Pearson III**	**Other than valude above**	**Not Special Properties**	**OK**	**0.139**	<	**0.330**	**Diterima**	**9.175**	<	**9.488**	Accrepted	Accrepted	Accrepted

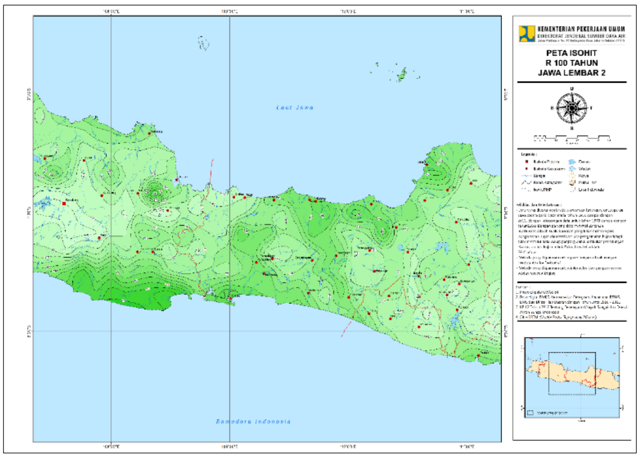

Figure 9. Map Isohyet R100 Year 200 mm

3.3 Hydrological Analysis of Design Floods

Design flood hydrology analysis results with unit hydrograph calculation of actual observation data distribution unit hydrograph with 007 PSA obtained design flood return period of Q2 amounted to 259.50 m^3/ s and Q50 of 786.18 m^3/ s (Figure 10) (Table 6).

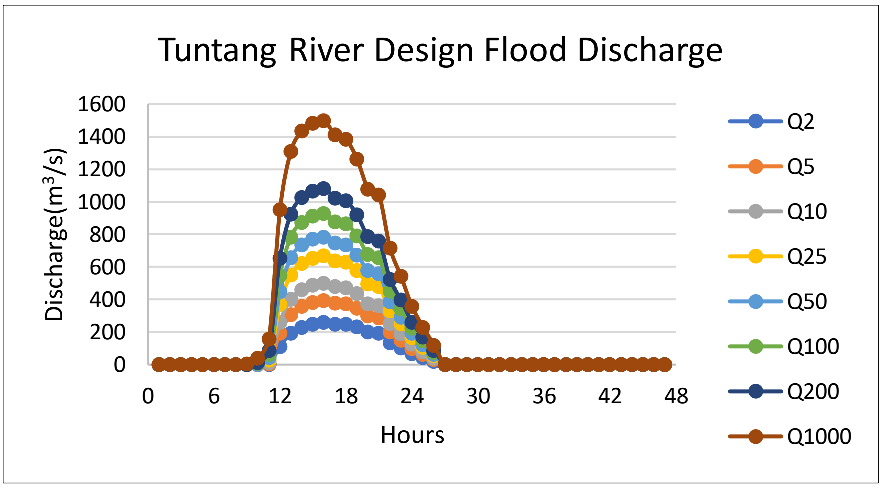

Figure 10. Tuntang River Design Flood Discharge

Table 6. Q2-Q1000

Tr	UH
Year	(m^3/s)
2	259.50
5	394.86
10	501.92
25	670.30
50	786.18
100	927.90
200	1082.60
1000	1498.77

3.4 Hydraulic Analysis of River Morphology

Analysis of the design flood river used with software HEC-RAS quasi unsteady flow 1D discharge Q2 and Q50 with the geometry of conditions before and after normalization as follows:

- In simulating river morphology during the design flood Q2 on the geometry of conditions before and after normalization Tuntang river with maximum discharge Q2 259.50 m^3/s were examined from hydraulics river decrease average flow velocity (V) from 0.97 m/s to 0.86 m/s by 11.57%, an increase in the mean the average channel bed slope (S) from 0.000385 m/m to 0.000427 m/m by 10.91%, and an increase in the average channel bed shear stress (τ) from 2.02 pa to 2.36 pa by 16.65% (Figure 11) (Table 7).
- In the simulation of river morphology during the design flood Q2 on the geometry of the condition before and after normalization Tuntang River with maximum discharge Q2 259.50 m^3/s were examined from bed changes in channel decreased aggregation maximum heights of 2.04 m to 0.68 m by 66.78% with a maximum degradation height of 2.00 m (Figure 11) (Table 7).
- In the simulation of river morphology during the design flood Q50 on the geometry of the condition before and after normalization Tuntang River with maximum discharge Q50 786.18 m^3/s were examined from hydraulics river decrease average flow velocity (V) from 1.28 m/s to 1,17 m/s by 8.46%, there was an increase in the average channel bed slope (S) from 0.000436 m/m to 0.000491 m/m by 12.48%, and an increase in the average channel bed shear stress (τ) from 3.25 pa to 4.33 pa by 33.27% (Figure 12) (Table 8).
- In the simulation of river morphology during the design flood Q50 on the geometry of the conditions before and after normalization Tuntang River with a maximum discharge Q50 786.18 m3/s were examined from bed changes in channel decreased aggregation maximum heights of height from 4.37 m to 3.95 m. by 9.50% with a maximum degradation height of 2.00 m (Figure 12) (Table 8).

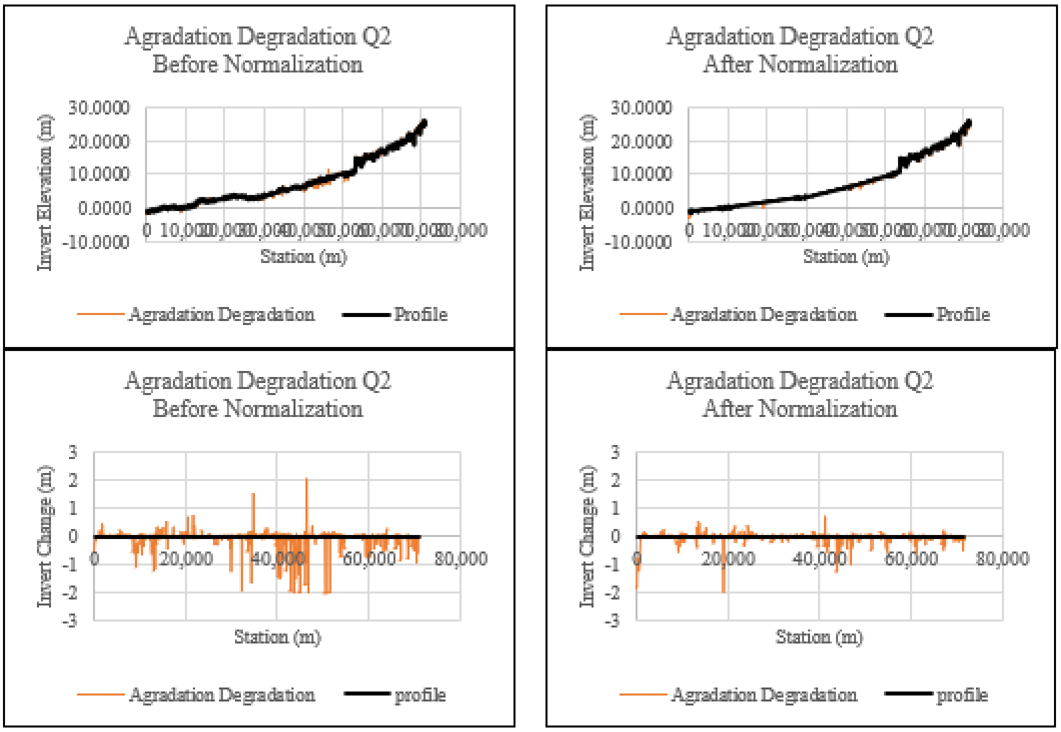

Table 7. At The River Morphology Parameter Design Flood Q2

No	Description	River Morphology Design Flood Q2 Bed Change Before Normalization (m)	River Morphology Design Flood Q2 Bed Change After Normalization (m)
A	Maximum Aggregation	2.04	0.68
B	Maximum Degradation	-2.00	-2.00

No	Description	River Morphology Design Flood Q2 River Hydraulics Before Normalization (Average)	River Morphology Design Flood Q2 River Hydraulics After Normalization (Average)
A	Flow Q (m^3/s)	259.50	259.50
B	Velocity V (m/s)	0.97	0.86
C	Slope S (m/m)	0.000385	0.000427
D	Shear Stress τ (pa)	2.02	2.36

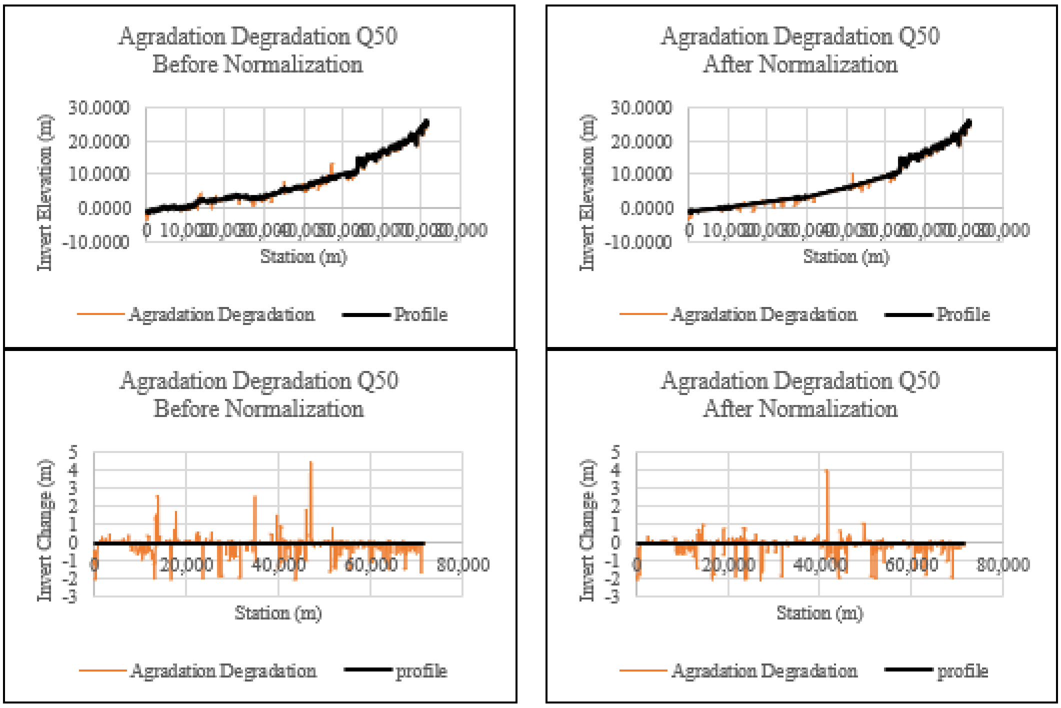

Table 8. At The River Morphology Parameter Design Flood Q50

No	Description	River Morphology Design Flood Q50 Bed Change Before Normalization (m)	River Morphology Design Flood Q50 Bed Change After Normalization (m)
A	Maximum Aggregation	4.37	3.95
B	Maximum Degradation	-2.00	-2.00

No	Description	River Morphology Design Flood Q50 River Hydraulics Before Normalization (Average)	River Morphology Design Flood Q50 River Hydraulics After Normalization (Average)
A	Flow Q (m^3/s)	786.18	786.18
B	Velocity V (m/s)	1.28	1.17
C	Slope S (m/m)	0.000436	0.000491
D	Shear Stress τ (pa)	3.25	4.33

4. Conclusion

Conclusion of the analysis after normalizing the changes in morphology of the Tuntang River due to the Q2 and Q50 Design Floods are as follows:

- In the hydraulic parameters of the river due to Q2 there is a decrease in the average flow velocity (V) of 11.57%, an increase in the average slope of the channel bed (S) by 10.91%, and an increase in the average shear stress of the channel bed (τ) by 16.65%.
- In the parameters of the channel bed change due to Q2 there is a maximum decrease in the height of the aggradation of 66.78% with a maximum depth of degradation of 2.00 m.
- In the hydraulic parameters of the river due to Q50 there is a decrease in the average flow velocity (V) of 8.46%, an increase in the average slope of the channel bed (S) by 12.48%, and an increase in the average shear stress of the channel bed (τ) by 33.27%.
- In the parameters of the channel bed change due to Q50, there is a maximum decrease in the aggradation height of 9.50% with a maximum depth of degradation of 2.00 m.
- Watershed conservation can maintain sustainable land use so that it can keep excess sediment carried into the river channel.
- It is necessary to raise the embankment to keep the overtopping from the flood water level.
- Operation and maintenance activities in the form of river normalization must be carried out periodically.

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