

# Evaluation Study of Kedunglarangan River To Protect Flood In Pasuruan and Sidoarjo

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## Abstract

Construction of the Kedunglarangan river flood control system designed to prevent flooding every rainy season in the Bangil sub-district. Kedunglarangan River is a river that flows in two regencies Sidoarjo and Pasuruan which has an area of 282.67 km<sup>2</sup> watershed with a river length of 23.7 km. Kedunglarangan river has 4 (four) watershed sub-systems. The scope of this flood prevention work study is the normalization of the Kedunglarangan River starting from the meeting with the Wрати River downstream up to 7 km. Normalization work is carried out with excavation and river widening to meet flood discharge in accordance with the conditions of the study area. If the river excavation work is done in accordance with the design master will form a basin that causes the creation of a dike. In this condition it will be a temporary water reservoir where the water velocity is very low. So the work carried out the impact is only temporary. From the results of analysts, it is more efficient to do river widening and embankment raising rather than increasing river depth. River excavation work like that is very risky to create very fast sedimentation. Normalization method with river widening is one way to maintain the river flow downstream and flood water levels.

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*Keywords:* Widening, deepening, HEC-RAS, Flood Discharge.

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## 1. Introduction

Kedunglarangan River is a primary river. Upstream of Kedunglarangan, it is a meeting of the secondary river, the Wрати river. Whereas downstream of the Kedunglarangan river, it is a meeting between the Golondoro river and the Avour Bawean river. At the downstream of this river directly into the Madura Strait, so one of the factors that influence the speed of river flow at the downstream of the Kedunglarangan river is the tides of sea water. If during rain with high intensity, the water flow in the Kedunglarangan river will be halted and this causes the water level of the Kedunglarangan river to rise. Therefore, the normalization of the Kedunglarangan river is necessary. Normalization of the river is intended to increase the capacity of the river.

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Based on this background, the problems to be examined are:

- 1) What is the flood discharge of the Kedunglarangan River with a return period of 25 years in accordance with the conditions of the study area?
- 2) How is the capacity of the existing cross section for flooding in accordance with the conditions of the study area that occurred with the Hec-Ras program approach?
- 3) What is the alternative cross-sectional design that suits the planned flood discharge capacity?*Structure*

## 2. Literature Review and Hypothesis Development

### 2.1 Hydrological Analysis

In a water building plan, hydrological analysis is needed. From the available data will be used to plan flood discharge plans with a certain return period. Determination of the planned flood discharge must be proportional, not too small or not too large so that it can be used to calculate the size of the building to accommodate the amount of the existing flood discharge plan so that the building fits economic considerations.

### 2.2 Flood Discharge Plan

There are three ways to estimate flood discharge based on rain data, namely using empirical formulas, statistical methods, and using hydrograph units. Of the three methods, the hydrograph method derived from observations is the most reliable way and the results can be in the form of hydrograph charts [7].

The method based on the unit hydrograph theory is the way the flood estimate is based on the unit hydrograph theory. Furthermore, the unit hydrograph used is the Nakayasu synthetic unit hydrograph.

The flood discharge hydrograph can be calculated for various return periods as needed. Classification to determine flood discharge criteria for a certain return period in relation to building construction planning can be seen in Table 1.

Table 1. Re-Classification Based on Type of Construction (in Indonesia)

Jenis Konstruksi	Periode Ulang (tahun)
Bendungan tipe urugan ( <i>earth/rockfill dam</i> )	1000
Bendungan konstruksi beton ( <i>masonry and concrete dam</i> )	500 - 1000
Bendung ( <i>weir</i> )	50 - 100
Saluran pengelak banjir	20 - 50
Tanggul	10 - 20
Saluran drainase	5- 10

### 2.3 Hydrograph Method of the Nakayasu Synthetic Unit

The parameters needed in the analysis using the Nakayasu Synthetic Hydrograph include:

1. The grace period from the beginning of the rain to the top of the hydrograph (Time to Peak Magitude)
2. The grace period from the point of heavy rain to the center of weight hydrograph (Time Lag)
3. Hydrograph time interval (Time Base of Hydrograph)
4. Catchment Area
5. The length of the longest main river channel (Length of the Longest Channel)
6. Run off coefficient

$$Q_p = \frac{C \times A R_o}{3.6 (0.3 T_p + T_{0.3})}$$

with:

$Q_p$  =  $Q_{maks}$ , is the peak flood discharge ( $m^3/s$ )

$C$  = Run off coefficient

$A$  = Area ( $km^2$ )

$R_o$  = Rain unit (mm)

$T_p$  = The grace period from the beginning of the rain to the peak of the flood (jam)

$T_{0.3}$  = The time taken for a decrease in discharge, from peak discharge to 30% of the debit (hour).

## 2.4 Hydraulic Analysis

Hydraulic analysis is needed to estimate the dimensions of the river and water level in the drainage channel or river and to estimate the magnitude of normalization of the cross section of the drainage channel or river according to the magnitude of the flood discharge.

## 2.5 Hydraulic Modeling Using Hec-Ras

Hec-Ras (Hydrologic Engineering System River Analysis System) is used to determine the phenomenon of hydraulic behavior of flow in the channel / river and long-storage object of study by means of simulation / numerical analysis that is able to describe the condition of existing rivers and plans. The scope of Hec-Ras is to calculate water level profiles by modeling steady and unsteady flow, and calculation of sediment transport. The most important element in Hec-Ras is the availability of transverse or longitudinal river geometry.

This software makes it easy for users with a graphical display. In general, Hec-Ras provides the following functions:

- File management
- Data input and editing
- Hydraulic analysis
- Outputs (tables, graphs, figures)

In this study the analysis was carried out using steady flow. Analysis was carried out to determine the profile of the water level and the ability of the river to flow through the discharge. The modeling steps are as follows:

1. Make a schematic of a river network that will be modeled based on the results of field measurements.
2. Entering river geometry data.
3. Define boundary conditions that will be used in the analysis.
4. Enter the flood discharge plan
5. Running a modeling program.
6. Print the results / output.

## 3. Research Method

### 3.1 Types of River Normalization

Referring to the purpose of river normalization, the following are types of river normalization based on the work performed:

#### 1. Widen the River Cross Section

This step can be done if the area around the river still has enough land. This means that it does not interfere with existing land use, for example settlements.

#### 2. Adding River Depth

The step is intended to increase the capacity of the river by deepening the river from its initial depth.

## 4. Results and Discussion

### 4.1 Flood Discharge Plan

In the planning of water structures such as dams, spillways, flood control drainage and so on, it is necessary to estimate the largest debit from a river flow or channel that might occur in a certain period called a flood discharge plan, this is done considering the relationship between rain and river flow where the amount of flow in the river is determined by several factors, namely:

The amount of rain, the length of time of rain, the intensity of the rain, the area of the rain, the width of the river basin and the characteristics of the watershed.

The method used to calculate the flood plan is a hydrograph unit nakayasu synthetic unit.

$L > 15\text{km}$ , then  $T_g = 0,4 + 0,058L$ , then  $T_g = 1,775$  hours

$$\begin{aligned} T_r &= 0,75 T_g = 1,331 \text{ hours} \\ T_p &= T_g + 0,8 T_r = 2,839 \text{ hours} \\ T_{0.3} &= \alpha \times T_g = 5,324 \text{ hours} \\ Q_p &= \frac{A \times R_0}{3,6 \times (0,3 T_p + T_{0.3})} = 3,932 \text{ mm}^3/\text{hour} \\ T_p + T_{0.3} &= 8,163 \text{ hours} \\ T_p + T_{0.3} + 1,5T_{0.3} &= 16,149 \text{ hours} \end{aligned}$$

1. Arching Rise

$$\begin{aligned} 0 \leq t \leq T_p \\ 0 \leq t \leq 2,8 \end{aligned}$$

t	$(t/T_p)^{2,4}$	Qd
0.0	0.000	0.000
1.0	0.082	0.321
2.0	0.431	1.696
2.8	0.967	3.802

2. Curved Down Stage 1

$$\begin{aligned} T_p \leq t \leq (T_p + T_{0.3}) \\ 2,8 \leq t \leq 8,2 \end{aligned}$$

t	$(t-T_p)/T_{0,3}$	Qd
3.0	0.030	3.791
4.0	0.218	3.024
5.0	0.406	2.412
6.0	0.594	1.924
7.0	0.782	1.534
8.0	0.969	1.224
8.2	1.007	1.170

3. Curved Down Stage 2

$$\begin{aligned} (T_p + T_{0.3}) \leq t \leq (T_p + T_{0.3} + 1,5 \times T_{0.3}) \\ 8,2 \leq t \leq 16,1 \end{aligned}$$

t	$(t-T_p+0,5T_{0,3})/1,5T_{0,3}$	Qd
9.0	1.105	1.040
10.0	1.230	0.894
11.0	1.355	0.769
12.0	1.480	0.661
13.0	1.606	0.569
14.0	1.731	0.489
15.0	1.856	0.421
16.0	1.981	0.362
16.1	1.994	0.356

4. Curved Down Stage 3

$$\begin{aligned} t \geq (T_p + T_{0.3} + 1,5 \times T_{0.3}) \\ t \geq 16,1 \end{aligned}$$

t	$(t-T_p+1,5T_{0,3})/2T_{0,3}$	Qd
17.0	2.080	0.321
18.0	2.174	0.287
19.0	2.268	0.256
20.0	2.362	0.229
21.0	2.456	0.204

t	$(t-T_p+1,5T_0,3)/2T_0,3$	Qd
22.0	2.550	0.183
23.0	2.643	0.163
24.0	2.737	0.146

Table 2. Nakayasu Flood Hydrograph for the 25 years Period of the Kedunglarangan Hulu River

t (Hour)	Qd (m <sup>3</sup> /sec)	R1	R2	R3	R4	R5	Q (m <sup>3</sup> /sec)
		51.731	13.446	9.432	7.509	6.341	
0.0	0.000	0.000					0.000
1.0	0.321	16.619	0.000				16.619
2.0	1.696	87.714	22.799	0.000			110.513
3.0	3.791	196.132	50.979	35.761	0.000		282.872
4.0	3.024	156.435	40.661	28.523	22.707	0.000	248.325
5.0	2.412	124.772	32.431	22.750	18.111	15.294	213.358
6.0	1.924	99.518	25.867	18.145	14.445	12.198	170.174
7.0	1.534	79.376	20.631	14.472	11.522	9.729	135.731
8.0	1.224	63.310	16.456	11.543	9.190	7.760	108.259
9.0	1.040	53.784	13.980	9.806	7.807	6.593	91.970
10.0	0.894	46.257	12.023	8.434	6.714	5.670	79.098
11.0	0.769	39.783	10.341	7.254	5.775	4.876	68.028
12.0	0.661	34.216	8.893	6.238	4.966	4.194	58.508
13.0	0.569	29.427	7.649	5.365	4.271	3.607	50.320
14.0	0.489	25.309	6.578	4.614	3.674	3.102	43.277
15.0	0.421	21.767	5.658	3.969	3.159	2.668	37.221
16.0	0.362	18.720	4.866	3.413	2.717	2.295	32.012
17.0	0.321	16.625	4.321	3.031	2.413	2.038	28.429
18.0	0.287	14.848	3.859	2.707	2.155	1.820	25.389
19.0	0.256	13.260	3.447	2.418	1.925	1.625	22.675
20.0	0.229	11.843	3.078	2.159	1.719	1.452	20.251
21.0	0.204	10.576	2.749	1.928	1.535	1.296	18.086
22.0	0.183	9.446	2.455	1.722	1.371	1.158	16.152
23.0	0.163	8.436	2.193	1.538	1.224	1.034	14.425
24.0	0.146	7.534	1.958	1.374	1.094	0.923	12.883
Qmax							282.872

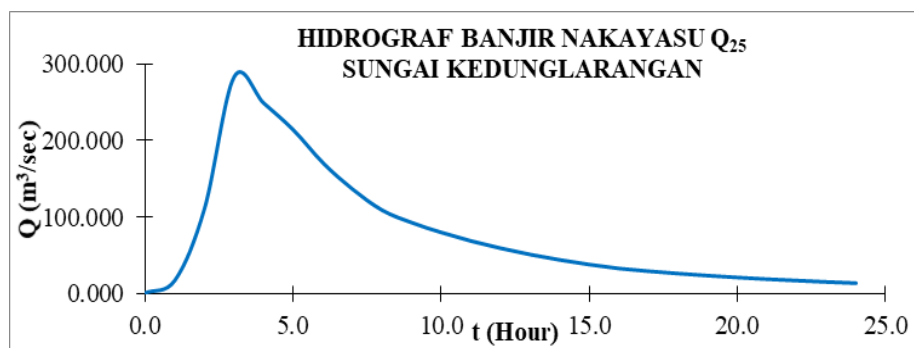


Fig 2. The Nakayasu Flood Hydrograph in the Kedunglarangan Hulu River Chart

#### 4.2 Hydraulic Analysis

Hydraulic aspects were analyzed using the HEC-RAS assist program. By using this assistance program, the flood discharge obtained from the calculation results is simulated against the cross section data of the Kedunglarangan River entered. So we get the results of hydraulic analysis that contains the ability of the Kedunglarangan River to

accommodate the planned flood discharge. In this study, the HEC-RAS analysis uses steady flow simulation, in the sense that the river flow does not change with the simulated time.

Based on the analysis of the Kedunglarangan River profile using the Hec-Ras 4.1.0 application, with a flood discharge plan when the 25-year return period made the Kedunglarangan River run into overflow. Overflow occurs in all cross sections of the river.

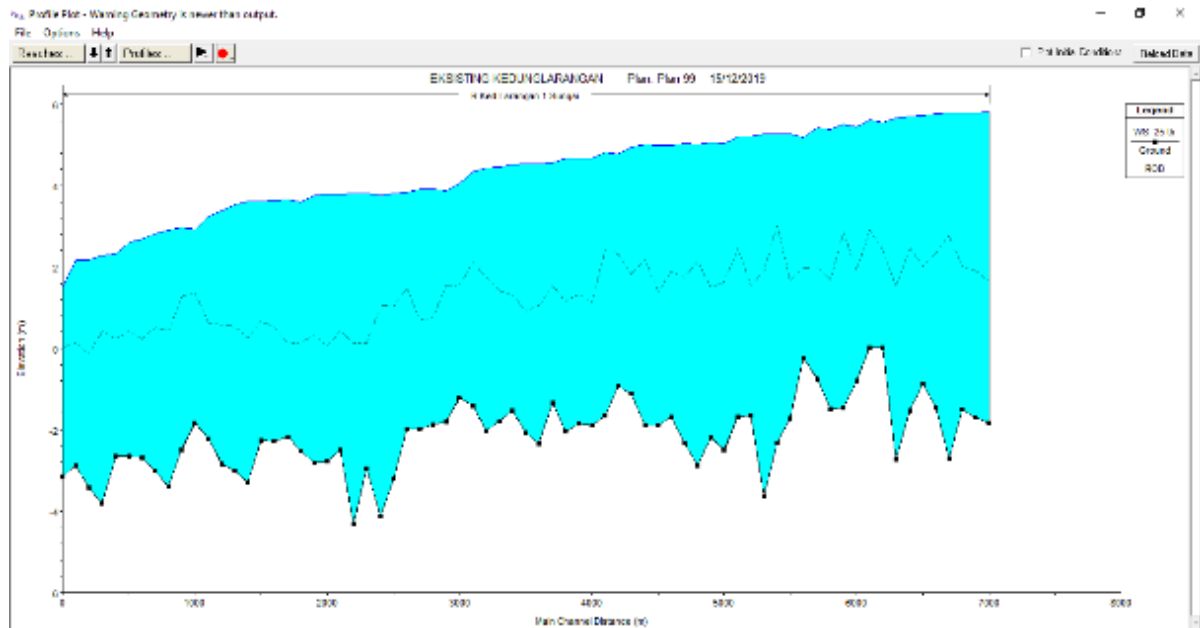


Fig 3. Existing Long-sectional Simulation Results

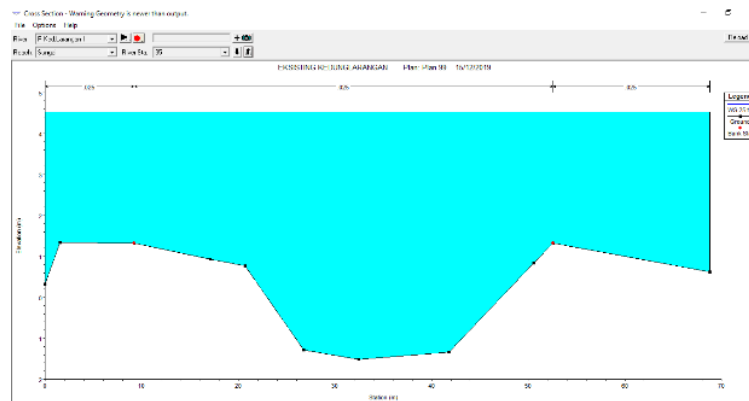


Fig 4. Existing Cross-sectional Simulation Results

### 4.3 Analysis of the New Dimensions

Re-planning of the dimensions of the Kedunglarangan River profile is done by planning the height of the new channel (H) and the width of the cross section (B).

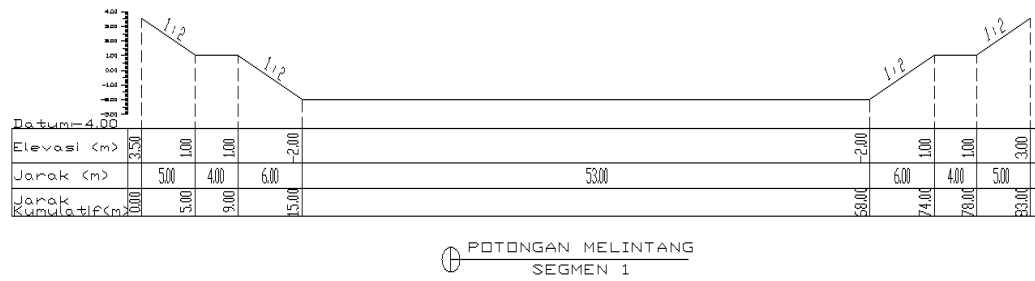


Fig 5. River Segment Section 1 Plan

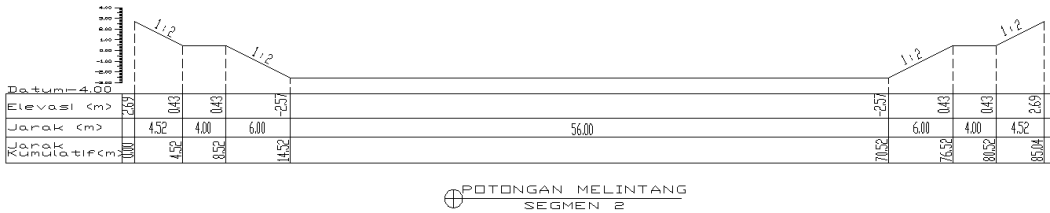


Fig 6. River Segment Section 2 Plan

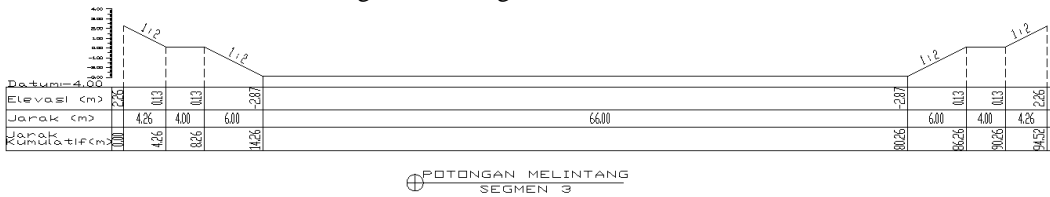


Fig 7. River Segment Section 2 Plan

After the author has planned the dimensions of the channel in 3 different segments and the planning of the channel elevation from upstream to downstream, the following figures 8 to 9 are the results of the HEC-RAS analysis.

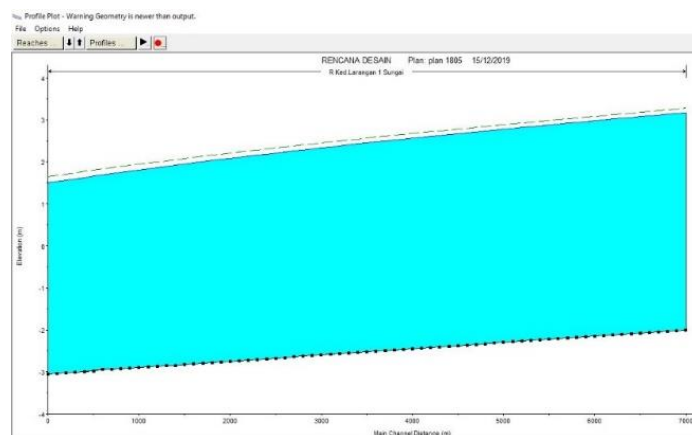


Fig 8. Long Section Simulation Results Redesign

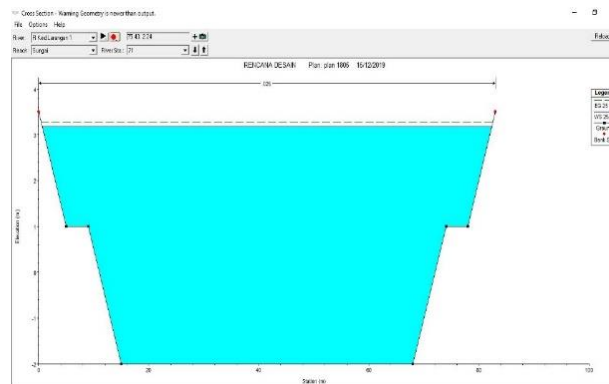


Fig9. Cross Section Simulation Results Redesign

## 5. Conclusion and Recommendations

### 5.1 Conclusion

Based on the analysis and calculation that has been done, it can be concluded as follows:

1. Kedunglarangan River flood discharge with a return period of 25 years with 4 parts of the watershed (Sungai Kedunglarangan Hulu, Wрати River, Golondoro River, and Avour Bawean River) as follows:
  - Segment 1 (STA 0 + 000 to STA 3 + 700) = 487,544 m<sup>3</sup> / sec
  - Segment 2 (STA 3 + 800 to STA 5 + 700) = 521,557 m<sup>3</sup> / sec
  - Segment 3 (STA 5 + 800 to STA 7 + 000) = 605,966 m<sup>3</sup> / sec
2. Based on the results of the calculation analysis, the existing Kedunglarangan River is unable to accommodate flood discharge with a return period of 25 years.
3. To overcome the flooding in the Kedunglarangan River with a return period of 25 years, it is necessary to redesign the cross section of the river by adding a width of 30m to 35m and adding a depth of 2m to 3m.

### 5.2. Recommendations

This Final Project only discusses the handling of the Kedunglarangan River flooding starting from the meeting with the Wрати River in a 7km long direction. For this reason it is necessary to normalize the Kedunglarangan River to the estuary so that flood handling in the Kedunglarangan River can be maximized.

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