International Journal of Civil Engineering and Infrastructure
Vol. 4, No. 2, October 2024

FLOOD INUNDATION ANALYSIS WITH 2-D HEC-RAS MODELLING (CASE STUDY: WAY UMBAN RIVER)

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Received April 08, 2024 | Accepted June 19, 2024

ABSTRACT

The "Way Umban River" is a river that has the potential to cause flooding during the rainy season. Floods are natural disasters that often occur and can cause losses to humans, the environment, and the economy. Flood mitigation helps overcome this problem. Flood modeling analysis is the first step in flood control to identify areas that are vulnerable to flooding. This research analyzes flood modeling using the software HEC-RAS 2-D by unsteady flow type. Three return periods are used, namely 10 years, 25 years, and 50 years. The designed flood discharge is obtained using the HSS Nakayasu method and then used as input in the HEC-RAS model. From the calculation results, the maximum designed flood discharge value for the 10-year return period is 85,03 m3/s, the 25-year return period is 98,30 m3/s, and the 50 years is 108,14 m3/s. Based on 2-D modeling, it is known that the designed discharge value for a return period of 50 years has a wider flood distribution compared to return periods of 10 and 25 years. The ten-year return period flood discharge produces an inundation area of 93,76 ha, the 25-year return period flood discharge produces an area of 98,33 ha, and the 50-year return period flood discharge produces an inundation area of 101,09 ha. Based on the analysis of areas that have the potential to flood, it was found that the locations with the potential to experience inundation are in Tanjungaman Village.

Keywords: *: flood inundation, HEC-RAS, Nakayasu, flood modelling*

1. PRELIMINARY

Flooding is a natural event that can cause property losses and loss of life. Factors causing flooding in rivers can be caused by high rainfall intensity, which can cause an increase in water volume that exceeds the capacity of the channel cross section.

Flood modeling analysis is a basic step in flood control, by conducting flood modeling analysis, it can identify areas that are vulnerable to flooding. One of the flood modeling can be done using HEC-RAS 2-D software. The 2-D model can be used to visualize flood inundation that occurs accurately.

This research was conducted on the Way Umban River, which often floods during the rainy season. Based on these problems, it is important to be able to know the prediction

of flood inundation area with different return times. Different return times are modeled to describe the changing rainfall phenomenon due to climate change. This particular return period discharge is also to determine how much influence the discharge has on the area and height of the inundation. The results of this identification can be used as a basis for consideration in choosing the right alternative flood management solution. This research refers to several previous studies, including:

Mandagi and Suhartono (2019) on flood mapping in Sekampung Udik, East Lampung using ArcGIS and HEC-RAS modeling. Mapping of river sections using ArcGIS software, the data used for this mapping is in the form of DEM data. In this study, flood distribution mapping was carried out on the banana plantation of PT Agro Prima Sejahtera with a land area of 500 ha. Hydrograph discharge was obtained from the SWAT (Soil And Water Assessment Tool) simulation with a peak discharge of 97.90 m3/s on October 6, 2007, a minimum discharge value of 19.25 m3/s on November 14, 2007 and an average discharge value of 41.14 m3/s. The channel has a trapezoidal shape with a Manning coefficient value with a winding and grassy soil channel type of 0.025. The inundation area in this study was 0.001 m2.

Mashuri et al. (2022) on 1-D and 2-D flood modeling studies, in this study flood mitigation was carried out using 1-D and 2-D HEC-RAS modeling on the Way Sulan River. The recurrence period used was 25 years with a design flood discharge of HSS SCS of 124.416 m3/s. From modeling using 2-D HEC-RAS, it was obtained that the maximum water surface velocity and elevation values were higher than 1-D with a difference of 4.19%, in addition, 2-D modeling is a more effective mapping for flood inundation because the distribution of flood inundation produced is more detailed. Areas that are potentially flooded are rice fields of 79.53 Ha, dry fields of 6.83 Ha and plantations of 4.59 Ha.

Lidya et al. (2022) regarding flood control using 2-D modeling, this study was conducted in the Welang River, Pasuruan City, the cause of flooding in the Welang River is sedimentation at the river mouth which causes obstruction of the flow to the sea. The data required in this study are in the form of rainfall data from 2006-2020, data on the distribution of rainfall stations consisting of 6 stations, namely Lawang, Purwosari, Selongko, Sengon Pager, Tutur and Wonorejo stations, in addition because the river mouth leads to the sea, tidal data is needed. The areas that are flooded are agricultural land, settlements, industrial areas and sections of the National Road Bridge. Modeling on the Welang River uses a return period of 25 years with the results of the HSS Nakayasu design flood discharge method of 620.27 m3/s. The type of flow in this modeling uses unsteady flow. Flood control efforts planned on the Welang River include the construction of embankments and river normalization.

Alvine et al. (2022) regarding the design flood discharge analysis using the HSS Nakayasu, HSS ITB-1 and HSS Limantara methods. The purpose of this study was to find a design rainfall method that resembles the conditions of the Manikin Watershed in East Nusa Tenggara. The results of the calculation of the design discharge method for the HSS Nakayasu were 1587 m3/s, HSS ITB-1 was 965.4 m3/s and HSS Limantara was 401.32 m3/s. The average rainfall in East Nusa Tenggara Province is 1200-1400 mm/year, thus the results of the design discharge method that are close to the average rainfall are the HSS Nakayasu. The design discharge is obtained by finding the design rainfall value using several methods, namely Normal, Log Normal, Gumbel and Log Pearson III and retested using the Chi square and Smirnov-Kolmogorov frequency distribution suitability tests. The results that

meet will be used for calculating the design flood discharge.

2. METHODOLOGY

Nakayasu Method Design Discharge

Synthetic unit hydrographs are used to estimate the flow discharge in a river due to a given rainfall, as well as to estimate the impact of land use or land use changes on river flow. Synthetic unit hydrographs have an important role because they can estimate the impact of changing hydrological conditions on river flow and plan appropriate actions to manage water more effectively and efficiently. Unit hydrographs are often used to estimate the peak discharge of design floods in watersheds that do not have recorded discharge data.

The equation used in Nakayasu discharge is as follows:

$$Q_p = \frac{A \times R_0}{3{,}6 \times (0{,}3 \times T_p \times T_{0,3})} \quad (1)$$

$$T_p = T_g + 0{,}8\ T_r \quad (2)$$

$$T_r = 0{,}5 \times\ T_g \quad (3)$$

$$T_g = 0{,}21 \times L^{0,7} \quad (4)$$

$$T_{0,3} = \alpha \times T_g \quad (5)$$

Software ArcGIS

ArcGIS software is useful for watershed delineation. Watershed delineation is very important because the delineation function can determine the hydrograph of peak discharge, flood analysis, and water resources management planning and hydrological modeling. The delineation process can be done automatically through Digital Elevation Model (DEM) data to describe the geometry of the earth's surface shape. The principle of using this DEM system is to be able to determine the topographic conditions of an area to be reviewed, so as to determine the hydrological characteristics of the area.

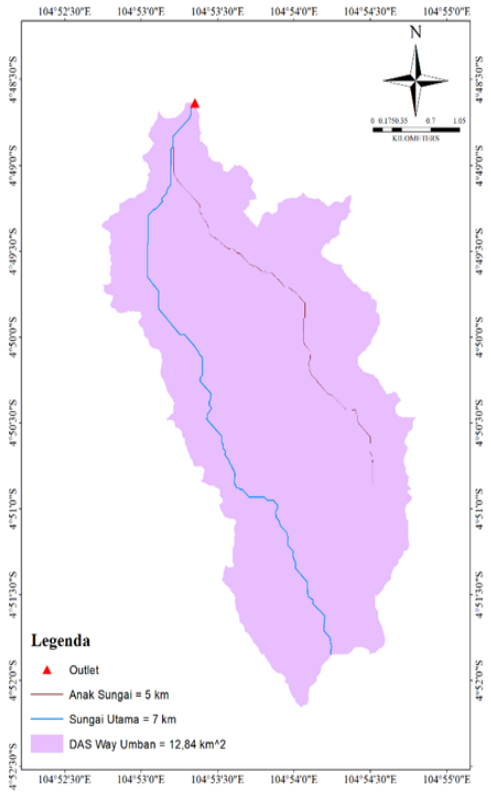

Figure 1. Way Umban Watershed

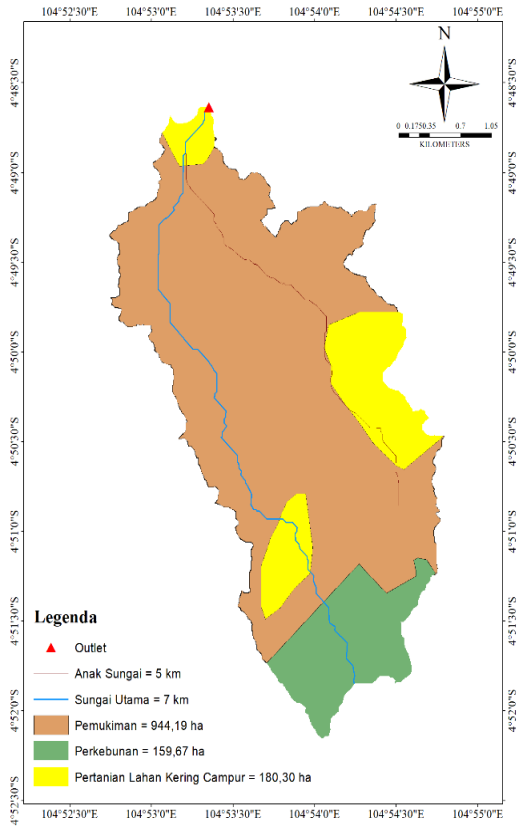

Figure 2. Land Use of Way Umban River

Software HEC-RAS

The modeling carried out in this study uses HEC-RAS 2-D modeling. This modeling can assume the flow of moving water in addition to estimating floods and the environmental impact of human activities that can affect water flow in the river system and flooding in addition to HEC-RAS 2-D, In addition, this software can visualize floods that occur around the river.

Tabel 1. Maximum Annual Rainfall

No.	Year	Kelapa Tujuh Rain Post
		Maximum Value (mm)
1	2012	119
2	2013	101
3	2014	128
4	2015	114
5	2016	98
6	2017	172
7	2018	76
8	2019	87
9	2020	143
10	2021	82
11	2022	110

3. RESULT AND DISCUSSION

Research Location

This research was conducted on the Way Umban River, North Lampung Regency, Lampung Provincie which often floods during the rainy season.

Hydrological Analysis

The hydrological analysis calculation will produce a design flood discharge using the Nakayasu synthetic unit hydrograph method using a return period of 10 years, 25 years and 50 years.

Figure 3. Way Umban River Flood Overflow

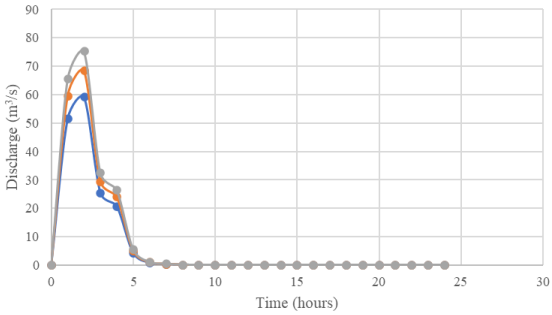

Figure 4. Nakayasu HSS Graphs for 10, 25 and 50 Year Return Periods

Based on Figure 4, it can be seen that the flood discharge value of the 50 year return period is greater than the 25 and 10 year return periods. The 10 year return period flood discharge produces a maximum design discharge of 85,0376 m3/s, the 25 year return period flood discharge produces a maximum design discharge of 98,3057 m3/s while the 50 year return period flood discharge produces a maximum design discharge of 108,1488 m3/s.

Hydraulic Analysis

Hydraulic analysis aims to determine the distribution of floods that occur, such as the area of flood distribution, areas of potential flooding and the height of the flood. Hydraulic analysis is carried out by

modeling floods in the Way Umban River in two dimensions using HEC-RAS.

The following are the results of a flood modeling simulation that occurred in the Way Umban watershed using two-dimensional HEC-RAS (figure,5,6,7 and 8).

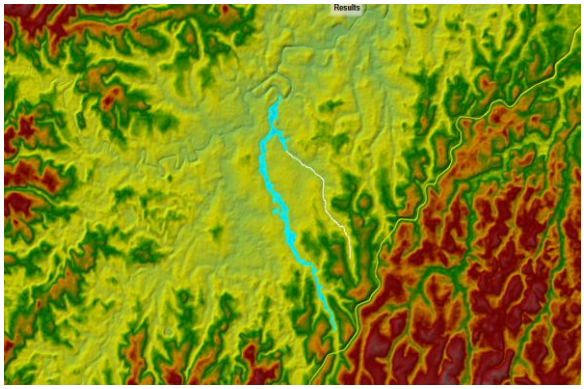

Figure 5. Flood simulation results for a 10 year return periods

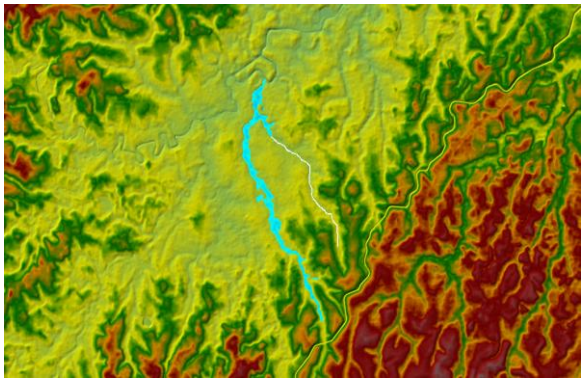

Figure 6. Flood simulation results for a 25 year return periods

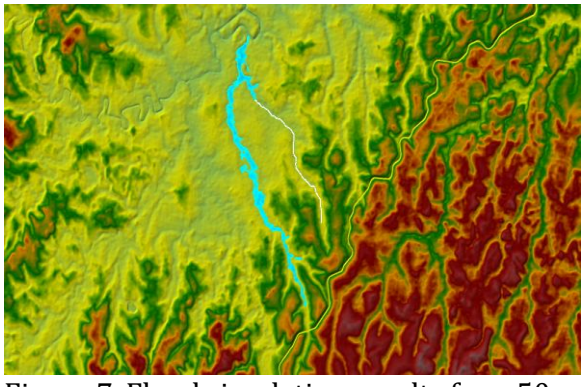

Figure 7. Flood simulation results for a 50 year return periods.

The distribution of floods that occur produces a different distribution for each return period. The larger the return period, the wider the resulting distribution. The following are details of the depth of flooding that occurred in the Way Umban watershed.

Table 2. Flood Depth Results Data Based on HEC-RAS Modeling

Return Period Water Discharge (year)	Flood Depth (m)
10	0,1 – 1,5
25	0,2 – 1,8
50	0,2 – 2,1

Table 3. Details of Flood Distribution Results in Village Administration

Village	Flood Areas (ha)		
	Q 10 years	*Q 25 years*	*Q 50 years*
Cempedak	5,36	5,49	5,58
Kelapa Tujuh	11,09	11,35	11,59
Kotabumi Ilir	5,97	6,54	6,92
Kotabumi Tengah	9,23	9,70	10,04
Sri Basuki	8,18	8,90	9,41
Tanjungaman	17,05	17,99	17,93
Tanjungharapan	23,45	24,56	25,53
Tanjungsenang	13,40	13,76	14,04

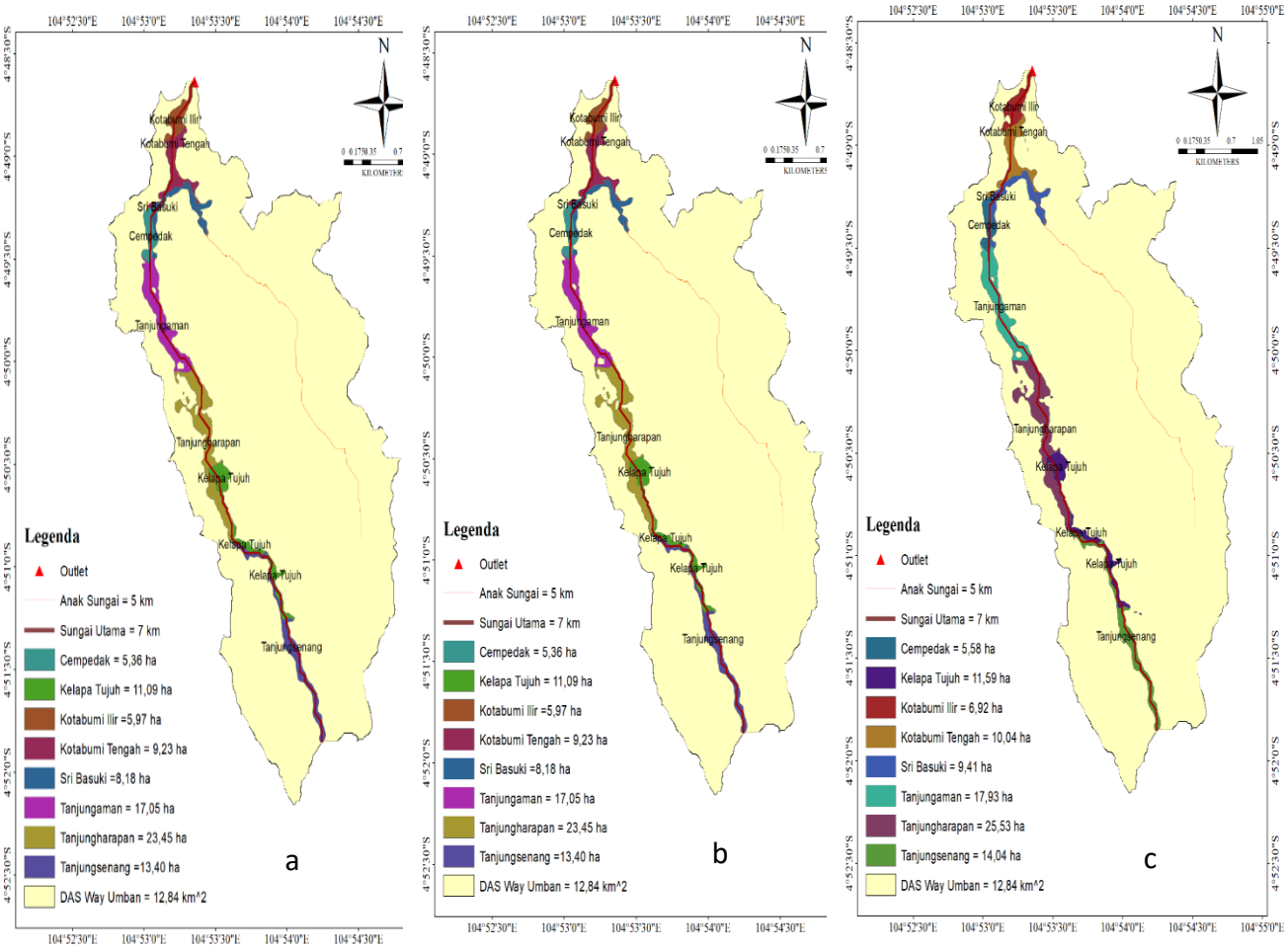

Figure 8. Results of Flood Distribution Based on Village Administration a) in a 10 year Return Period,b) in a 25 year Return Period, c) in a 50 year Return Period

CONCLUSIONS

Based on the results of flood discharge calculations designed by the HSS Nakayasu method, different flood discharge values were obtained at each return period. In the 10 year return period flood discharge, the maximum flood discharge is 85,0376 m3/s, the 25 year return period design flood discharge produces a maximum discharge of 98,3057 m3/s and the 50 year return period design flood discharge produces a flood discharge of 108,1488 m3/s. This shows that the greater the return period used, the greater the resulting flood discharge.

The distribution of inundation obtained based on the simulation results produces a different area at each repeat period. The 10 year return period produces an inundation area of 93,7645 ha, the inundation area at the 25 year return period is 98,3323 ha while the inundation area at the 50 year return period is 101,0912 ha. Based on this, it was found that the increase in inundation area that occurred was influenced by the use of large flood return discharges.Kedalaman banjir pada DAS Way Umban diperoleh berdasarkan hasil simulasi HEC-RAS modeling, the simulation obtained different depths at each repeat period. The results of the flood depth simulation analysis for 3 flood discharges with a return period of 10

years produce a flood depth of 0,1 m to 1,5 m, flood discharge with a return period of 25 years produces a depth of 0,2 m to 1,8 m, flood discharge with a return period of 50 years produces a depth of 0,2 m to 2,1 m

The areas affected by the overflow from the Way Umban River consist of the villages of Cempedak, Kelapa Tujuh, Kotabumi Ilir, Kotabumi Tengah, Sri Basuki, Tanjungaman, Tanjungharapan and Tanjungenang. There is a village with the greatest potential for flooding in the Way Umban watershed, namely Tanjungaman Village. From the results of the simulation that has been carried out, it is obtained that the distribution of inundation that inundates Tanjungaman Village at a 10 year return period flood discharge produces an area of 17,05 ha, at a 25 year return period flood discharge produces an area of 17,99 ha while at a 50 year return period flood discharge year resulted in an inundation area of 17,93 ha.

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