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Analysis of Flash Floods Behaviors in Sentani, Jayapura Regency, Papua

Mujiati[1], David[2], Harmonis Rante[3]

[1]Cenderawasih University, Civil Engineering Department, Waena-Jayapura, Papua, Indonesia
muji_js[at]yahoo.com

[2]Cenderawasih University, Civil Engineering Department, Waena-Jayapura, Papua, Indonesia
david63[at]yahoo.com

[3]Cenderawasih University, Civil Engineering Department, Waena-Jayapura, Papua, Indonesia
harmonisrante72[at]yahoo.co.id

Abstract: ***Flash floods are flows in very large numbers and occur suddenly, flowing from the upstream to the downstream at a very high speed. This study aims to analyze the parameters that influence the occurrence of flash floods in Sentani and to analyze flood behavior Kemiri river and Flafouw river. Hydrological analysis based on maximum daily rainfall data for the last 10 years (2009-2019), and hydraulic analysis on secondary and primary tertiary channels (S. Kemiri) on river geometry then simulated by modeling using HEC-RAS software to calculate one-dimensional water level profiles , in each section of the Kemiri river. The planned flood discharge using the Nakayasu method obtained Q10th = 51.798 m^3/s kemiri river with t = 1.615 hours while the Flafouw Q10th river = 94.804 m^3/s and t = 1.669 hours. The flood inundation when the disaster occurred was 1.00 - 4.00 meters with inundation time <24 hours, but the sediment (sand, stone, and logs) rose until it reached the roof of the house. The results of field observations of the classification of flood hazard levels in several points in Sentani are classified as moderate hazard class (0.75 - 1.50 m), as well as according to the Directorate General of Water Resources (2010) including the medium class (0.50 - 2.00 m) . However, it was not only the impact of the inundation that occurred, what was even more devastating was the very fast speed of water flow from the upstream of the river, which destroyed several settlements, and several other infrastructure. The worst condition was that it (3.00 - 4.00 m), namely in the BTN Gajah Mada Housing, Dobonsolo Village, classification of high hazard areas.***

Keywords: Flash flood, hydrologic/hydraulic, Kemiri River, Papua

1. Introduction

The flash flood disaster that occurred on March 16-17 2019 in several locations in the Sentani area was due to heavy rain at 17.00 WIT. At that time, extreme rainfall (248.5 mm) did fall before flash floods [6]. The rain had fluctuated, until finally between 22.00-00.00 WIT, heavy rain that occurred around the upper reaches of the Cycloops mountain river caused landslides to hold the river channels so that the impact of this flood was getting worse, there were logs and large rocks that were flown downstream. The worst affected areas were the Donbosolo, Doyobaru and Hime Kombe urban villages. The Sentani flash flood disaster has claimed many victims, which killed approximately 58 people, around 4,000 people were displaced and around 350 buildings were damaged [4]. The National Disaster Management Agency (BNPB) also noted that at least three things were the causes of the flash flood disaster in Sentani District, Jayapura Regency, Papua. First is the topography factor, the slope of the Cycloops mountains slope which is the upstream area of several rivers, is more than 40 degrees, so the element of gravity will carry the material very quickly downstream to the lower area. Second is the weather factor, with very heavy rain intensity lasting more than 5 hours causing the Cycloops area to be unable to accommodate the falling water discharge. The Madden-Julian Oscillation (OMJ) phenomenon, namely the confluence of air flow and cloud growth due to the low pressure pattern system in northern Papua, is considered to be the cause of high rainfall at that time. The third is the human factor, namely the land use change in the Cycloops Nature Reserve area so that the water absorption capacity continues to decline, with the opening of community gardens.

Based on the identification of disaster-prone areas, this can be used as a trigger for the occurrence of flash floods in Sentani. Earthquake disasters will geologically change due to the influence of vibrations in the Cycloops mountain area. The existence of landslides that occur in hilly areas with a slope of > 40% has the potential to also occur erosion caused by rainwater, and also affected by earthquakes. Chronology of the Sentani flash floods [6]. Based on this, the researcher wants to make a technical study after the flash flood disaster. Regarding the behavior of flash floods that occurred on 16- 17 March 2019. This study aims to analyze hydrologically and hydraulically so that the trail of flash floods behavior can be traced, with HEC-RAS models.

Figure 1: Flash floods in Sentani area

2. Material and Methods

Study area

This research was conducted in the areas most severely affected by the Sentani flash floods on March 16-17 2019. The Yahim sub-watershed covering the Kemiri and Flafouw rivers is an area affected by flash floods, namely damage to river ecosystems, changes in river hydrometry, changes in cross-sections, and damage to several water structures (embankments, bridges, cliff/gabion reinforcement, and house buildings). The research was conducted in July-September 2020, by conducting field observations on the two rivers, and obtaining information from the public about flash floods that occurred. The Kemiri River as a tributary of the Yahim River has an upstream river at the foot of the Cycloops Mountains, with a river length of 9.1 km and catchment area of the Yahim Sub-watershed of 13.49 km^2. The Kemiri River was one of the rivers that was most severely affected during the flash floods in March 2019, which saw a large amount of landslide material in the form of soil, stone and logs. The Kemiri River administratively crosses the Sentani District, Jayapura Regency. The slope of the Kemiri river bed is in the range (10–12)%, while the upstream part is 40%, while the downstream part is 0.2%. The Kemiri River meets the Yahim River and empties into Lake Sentani.

Hidrograph

Hydrograph is a graphical representation of one of the flow elements with time. The flow element consists of water level (H), discharge (Q) and sediment discharge (Qs). The hydrograph itself is a response to rain that occurs in an area. each region or watershed has a different hydrograph shape depending on the watershed conditions and characteristics. The hydrograph has three important parts, namely: the rising part, the top part, and the lower part. The Nakayasu hydrograph was developed in Japan and is very popular in Indonesia. The calculation of design flood discharge for a water structure in Indonesia generally uses the Nakayasu method coupled with other methods as a comparison. The general equation for the Nakayasu Synthetic Unit Hydrograph is as follows:

$$Qp = \frac{12*A*Ro}{3.68*(0.3*Tp+T0.3)} \quad (1)$$

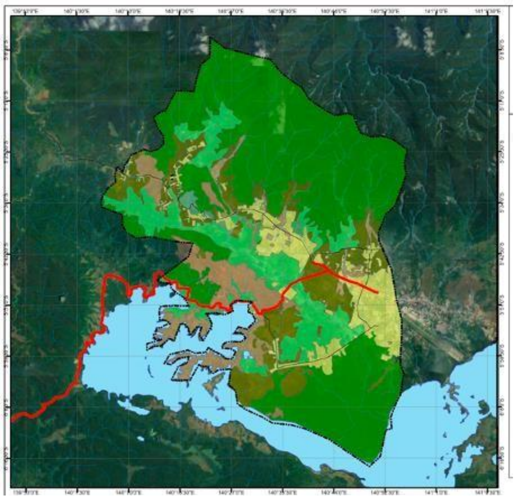


Figure 2: Location of Kemiri catchment and watershed boundary

3. Methodology

The analysis method used in this research is descriptive quantitative, Hydrological Analysis, which is to determine the flood hydrograph and peak discharge based on the maximum (extreme) daily rainfall data in the Sentani watershed, on March 16, 2019, which is 248.5 mm, the rain data was obtained from the Regional BMKG V Jayapura. Hydraulic analysis, along the river based on the interpretation of the river situation and tracking the behavior of flash floods that occurred March 16-17, 2019, based on discharge data from hydrological analysis and field observations. Analysis of flood behavior with HEC-RAS software specifically for the Kemiri river from the middle and lower reaches of the river, it is known that the surface profile of the flow lengthwise and across the river. The height of inundation/flooding at several review points so that the classification of flood hazard classes can be determined.

Table 1: Maximum daily rainfall for different return periods

Gumbel	Return Period					
	2	5	10	25	50	100
Rainfall (mm)	98,35	109,93	117,56	127,16	134,72	141,78

4. Results and Discussion

A unit hydrograph for a catchment area is defined as a discharge hydrograph originating from one rain unit that is evenly distributed with a uniform rate over a certain duration of time [15]. The condition in Yahim Sub-watershed and Sentani Watershed there is no discharge hydrograph data, so a synthetic unit hydrograph (HSS) was formed, in this study using HSS Nakayasu. The results obtained for the two rivers namely the Kemiri river and the Flavouw river are:

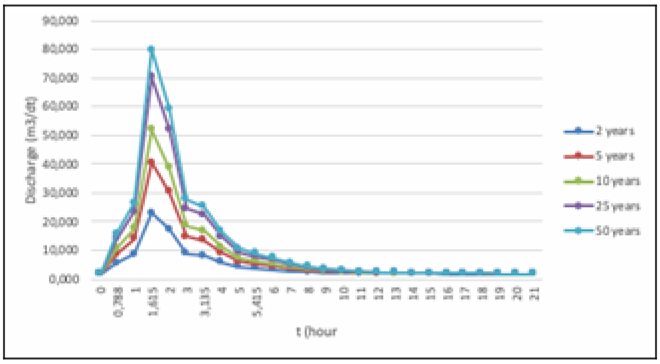


Figure 3: Outflow hydrographs Kemiri River

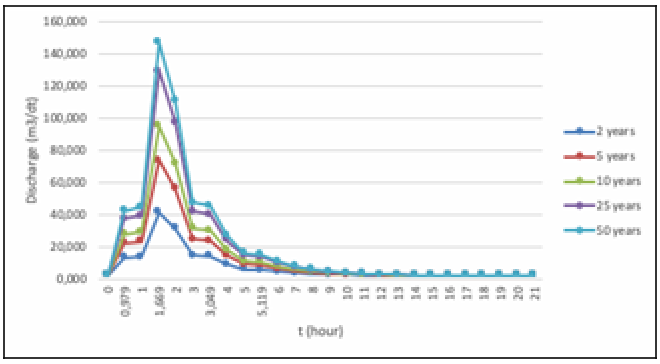


Figure 4: Outflow hydrographs Flafouw river

The parameters used in the hydrological analysis are the area of the watershed (A) = 12,022 km^2, the length of the river (L = 9.1 km), the unit net rain is 1 mm / hour, the river density (D) = 0.757, so that the base flow (Q = 1,814 m^3/s). While the hydrograph parameter for river length L <15 km, the concentration time is 0.985 hours, with a standard rain duration (Tr=0.788 hours). Time from flood to peak hydrograph (Tp=1.615 hours), with watershed characteristics (α = 1.543) and time from flood discharge to 0.3 times flood discharge (T0.3 = 1.519 hours) and flood peak discharge (Qp = 1.666 m^3/s).

Hydraulic analysis was conducted to determine the river's ability to accommodate the planned flood discharge loads. One of the causes of flooding is the overflow of the river that is unable to accept the flood discharge that occurs. The stages of creating a hydraulic model using HEC-RAS software are starting a new project, entering geometry data, entering flow data and boundary conditions, performing hydraulic calculations, and viewing the analysis output. The analysis results obtained are the geometric profile of the Kemiri river, a longitudinal profile of 45 points, starting from point P1 to P45. The upstream part of the river (P45), middle (P29) is the location on the Kemiri-Sentani highway bridge, the downstream part (P1) near the mouth of Lake Sentani.

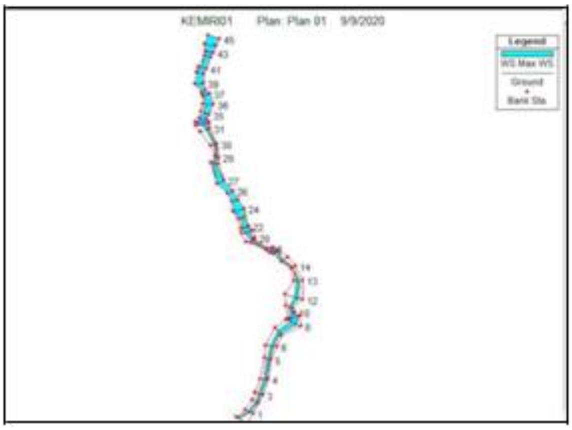


Figure 5: Geometric of Kemiri river

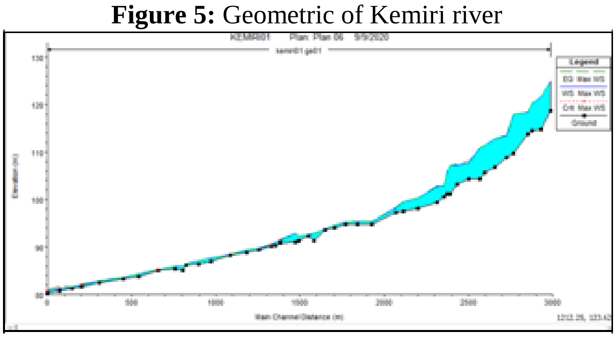
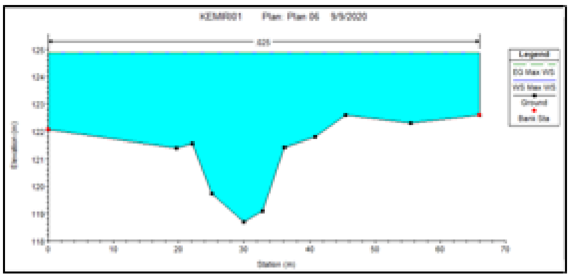
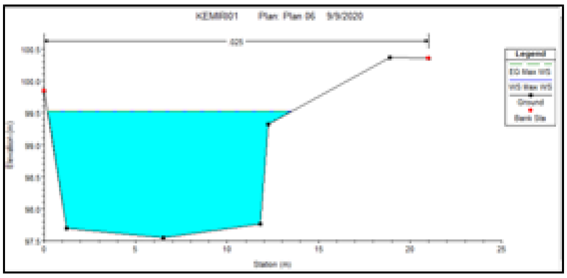


Figure 6: Water surface profile along main channel for Q100



(a)



(b)

Figure 7: Cross section Kemiri rivers (a) P45 (b)P29

In general, the slope affects the flash floods response. The greater the slope, the lower the infiltration rate. The slope in the two sub-watersheds is dominated by > 40%. That is, the slope factor is one indicator to determine the response.

Analysis of the Sentani flash flood behavior 2019, apart from the flow conditions in the Kemiri river, the impact of the flash flood that occurred in Sentani also resulted in settlements and other infrastructure being affected. The behavior of the flash floods that swept through residential areas as seen in the image below, indicates how powerful the flow rate in the Kemiri river is. The results of field observations in locations affected by the flood showed very large sand and stones up to the middle area of the settlement.

Figure 7: Location of the Kemiri river (a) before, (b) after

Table 2. Identification of depth at several points

Point	Location	depth (m)
P1	Jembatan Sungai Kemiri	1.10 - 1.50
S1	Kantor Lurah	0.90 - 1.40
R1	Rumah warga	1.02 - 1.30
P2	Doyo Baru	1.20 - 1.40
P3	BTN Gajah Mada	3.00 - 4.00
S2	Perumahan Doyo	1.10 - 1.40
P4	Doyo Baru (Gereja)	0.90 - 1.00
P5	Jembatan Komba	0.50 - 1.00
S3	Kalkotte	1.03 - 1.22

The classification of the flood hazard level is based on the BNPB, 2012, the categories of several points in Sentani are classified as moderate hazard class (0.75 - 1.5m), as well as according to the Dirjen SDA (2010) including medium class (0.5 - 2.0 m). However, it was not only the impact of the inundation that occurred, what was even more devastating was the very fast speed of water flow from the upstream of the river, which destroyed several settlements, and several other infrastructure (bridges, schools, churches, and other public facilities). The worst condition was that it drowned almost as high as a house (3.0 - 4.0m), namely in the BTN Gajah Mada Housing, Dobonsolo Village, which was classified as a high hazard area. According to residents' information, the flow of water quickly crushed their houses, and some did not even have time to save themselves, causing many victims to be swept away and missing.

5. Conclusion

The results of hydrological and hydraulic analysis are measuring the level of flash flood danger in the Sentani watershed, by dividing the catchment area into sub-catchment areas to estimate runoff. The hydrological/hydraulic model simulation calculates the runoff hydrograph according to different climates and helps to delineate the resulting flood inundation areas. Urbanization is one of the factors that influence banjir bandang response. The high intensity of built up areas reduces water infiltration and increases the potential for runoff. The results of this study can be used for urban planning purposes, especially residential areas and design of flood control structures in several rivers in the Cycloops Sentani mountain valley.

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Author Profile

Mujiati has an MT degree in Civil Engineering from the University of Indonesia in 2004-2006, while her Doctoral degree was obtained from Hasanuddin University Makassar during 2013-2017, now as a senior lecturer in the Civil Engineering Department of Cenderawasih University, Papua.