The Influence of Movable Dam Type Pneumatic Crets Gate to Reduce Peak Flood Discharge in Mati River

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Abstract. Mati River is one of the rivers in Bali that has experienced very rapid changes related to land use in its watershed area. This change was triggered by the very rapid development of Denpasar City. This change has triggered a decrease in water catchment areas, increasing surface runoff and potentially causing flooding and waterlogging in several areas. Other conditions that support the occurrence of inundation and flooding are the narrow and winding condition of the Mati River body and the relatively flat conditions around the river, making it difficult to drain water to the estuary area. Several flood management efforts have been attempted, starting from normalizing the channel by making the river cross-section wider and with precast concrete, changing the fixed dam into a movable dam and making a pneumatic crest gate type Mati movable dam at the estuary. The construction of a pneumatic crest gate type movable dam is one of the innovations because in addition to its function to increase the river's capacity to accommodate raw water in the future. The pneumatic crest gate was built in 2020 and until now there has been no study conducted regarding its effect on reducing flood discharge. The research method uses a quantitative method and the research results are in the form of a percentage value of the effect of reducing the flood water level in the Mati River during floods.

Keywords: Flood, Mati River Watershed, Pneumatic Crest Gate

1 Introduction

The Mati River basin is one of the rivers that has experienced very rapid changes, especially land conversion that occurs in its watershed area. This change has changed rice fields/dry fields from the upstream in the Padangsambian Kaja area to the downstream in the Tuban area into built-up land for various purposes such as shops, markets, government buildings, schools, and other uses. This condition has the consequence that water absorption during the rainy season becomes smaller and increases the occurrence of surface runoff which has the potential to cause flooding and waterlogging in several areas such as the Monang-Maning area and its surroundings, Padangsambian and its surroundings, Dewi Sartika street in Legian area and its

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surroundings, the Seminyak area and its surroundings and the eastern part of Kuta and the Pura Demak street area and its surroundings. This condition is further exacerbated by the narrow and winding condition of the Mati River body and the flat topography of the area in almost the entire watershed area. The government has made efforts to reduce the potential for flooding and waterlogging through several activities, namely normalizing the river along the south of the Umadwi dam to the Padangsambian area, normalizing the estuary by constructing a pneumatic crest gate movable dam, replacing fixed dams with movable dams (Lange, Dadas and Umadwi dams) and constructing flood pumps in the Padangsambian area. The construction of the Mati River movable dam with a pneumatic crest gate type in 2020 was carried out in an integrated manner between the concept of utilizing water downstream as a raw water reserve and flood control efforts. With this dual-function concept, the pneumatic crest gate was chosen to be able to raise and lower the water level elevation more quickly so that the danger of flooding during rain can be reduced to the maximum. Currently, the pneumatic crest gate movable dam at the estuary of the Mati River has had a positive effect where the water level elevation of the Mati River during floods can be lowered and its discharge can be reduced more quickly. Until now, there has never been a comprehensive study on the effect of the pneumatic crest gate movable dam on the flood management system in Mati River. Therefore, it is very necessary to conduct a more in-depth analysis related to the influence of the operation of the pneumatic crest gate type movable dam on reducing the peak flood discharge, and based on this influence, a guideline is prepared in the Mati River Watershed flood management system.

Several researchers have conducted research related to peak flood analysis on a river or research conducted in the Mati River but none have raised the effect of pneumatic crest gate operations on reducing peak flood discharge. Several studies have been conducted are: Romadhan (2023), conducted a flood analysis but focused more on the border area through the construction of embankments (Romadhan et al., 2023), while researchers conducted a study on the reduction of peak floods due to the operation of pneumatic crest gates (PCG). Mardah, (2017) conducted research related to the effectiveness of flood control that combines conventional systems with eco-drainage and the results showed the need for adaptation of community values in eco-drainage-based flood management (Mardiah, 2017), the difference with the research that will be conducted focuses on reducing peak flood discharge due to PCG operations. Suryadinata et al., (2013) have conducted research related to flood management in the Mati River with the approach of making a retarding basin as a temporary flood reservoir (Norken, and Dharma 2013), the difference with the research conducted by researchers is the PCG operation on reducing peak flood discharge in the Mati River Watershed. Lanang Parwita, (2016) has conducted a study on the performance of the automatic water level recorder (AWLR) of the Mati River to determine the increase in the water level of the Mati River associated with flooding that occurred in the middle of the Mati River (Parwita, 2011), the difference with the research conducted by the researcher is the analysis of the PCT at the river mouth. Mudhina et al., (2023) has conducted an analysis of pollution that occurs in the Mati River which can also contribute to the Mati River flooding, the difference with the current research is the performance of the PCG at the river estuary (Mudhina et al., 2023). Nugroho et al., (2017) have conducted a study on the effect of reducing flood discharge using the retarding basin construction method in the Jepara area (Nugroho, et.al, 2019), the difference with the research conducted by the researcher is the reduction in flooding due to the presence of PCG.

2.1 Data Collection Methods

The data collection method is carried out by collecting secondary and primary data in the following manner: from the Bali Pendia River Basin Office and the Public Works and Spatial Planning Office of Badung Regency in the form of morphological data of the Mati River (River length, watershed area, vegetation, etc.), data on river development policies, from the Meteorology, Climatology, and Geophysics Agency Region III Bali in the form of annual maximum daily rainfall data, data on the operating system and maintenance of the Mati River Pneumatic crest gate.

2.2 Survey, Field Observation, Preliminary Research

The survey was conducted on the Mati River watershed in the estuary, especially at the Mati River movable dam to obtain data on the physical structure of the movable dam and existing PCG. Field observations were conducted along the Mati River watershed starting from the upstream around Padangsambian Kaja to the estuary area in the mangrove forest. Preliminary research as a reference source was conducted on research related to the Mati River from several studies that have been conducted related to retarding basins, downstream pollution, performance of flood control structures, and others.

2.3 Analysis Methods

The analysis used in this study includes hydrological analysis for determining rainfall using the Gumbel and Log Pearson type III methods, the Nakayasu method for design flood analysis, and Manning analysis for hydraulic analysis and river capacity. Peak flood discharge analysis is carried out quantitatively between the discharge that occurs and the discharge that can be passed.

Design rain analysis is an analysis to determine the amount of rain that occurs in an area based on the maximum annual daily rainfall data that occurs in an area. From the available rainfall statistics data, an analysis is carried out to determine the most appropriate frequency analysis method to determine the design rain with a predetermined return period (Sánchez et al., 2018; Hassing, 2006; Merla et al., 2005).

Design flood analysis is needed to determine the amount of discharge in a river section. This design flood discharge analysis is related to the length of the river, the area of the watershed, and the amount of design rainfall (Beura, 2018; Mendez, 2014; Saidu and Lal, 2015). Figure 2.2 shows an illustration of the design flood hydrograph analysis.

Capacity analysis is an analysis to determine the capacity of a river body compared to the discharge that occurs (Sari et al. 2021):

$Q = A\ V$

$V = (1/n)\ R^{2/3} S^{1/2}$

Where

Q : discharge (m3/sec)

A : wet cross-sectional area (m2)
V : water velocity (m/sec)
R : hydraulic radius (m)
S : river bed slope

Pneumatic Crest Gate is a rubber dam protected by steel that is made across a river which has the advantage of being able to lower and raise the water level quickly with a pneumatic system. Visualization of the pneumatic short gate can be seen in Figure 1 and Figure 2:

Figure 1. Penumatic crest gate front and rear view

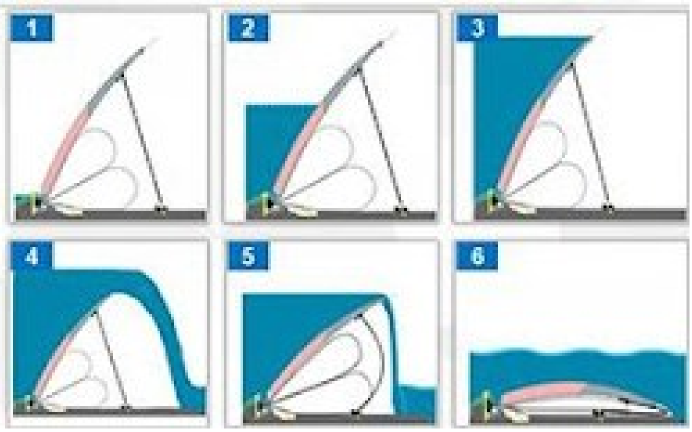

Figure 2. Flow system on pneumatic crest gate

3 Results and Discussion

3.1 River Conditions

The Mati River is a river where the river basin system occupies two administrative areas of Regency/City, namely Badung Regency in the downstream and upstream parts, while the middle part crosses the Denpasar City area. The land use of this river catchment area as a whole is in the form of cultivated land, settlements and urban areas.

This area is a very rapidly developing area so that there is a significant land conversion from agricultural land/dry land to residential land, commerce, industry and other uses. In general, the topography of the Mati River catcment area starts from a rather steep area in the north and flows into the southern sea, where the downstream is influenced by the tidal currents. In general, with a rather flat area in the downstream, it can be said that there are river bends (meanders) at several points, especially the flow after Gatot Subroto street reaches the estuary. This can be seen in the flow along Mahendradata street with a winding river flow as evidenced by the many bridges along the Mati River flow. The cross-section of the Mati River from upstream to downstream has a very varied width and depth. The middle part of the Dead River from the upstream to Gunung Agung street has a fairly wide and deep cross-section profile. While from Gunung Agung street to the downstream has a varied and shallow cross-section and a winding river channel.

3.2 Condition of Mati River Estuary

The estuary of the Mati River was originally a mangrove forest area in the Suwung People's Forest Park, Denpasar. With the flat estuary conditions, the flow in the estuary section becomes winding and spreads to several areas. This condition has an impact on the flow pattern when the flood becomes spread and sometimes carries rice fields that disrupt the flow to the sea. In 2019, the Government through the Bali Penida River Basin Center built the Mati River movable dam which aims to increase the downstream reservoir of the Mati River and facilitate the water operation pattern during floods. The movable dam was built with a pneumatic crest gate system with a span width of 45 m and a dam height of 4 m. This dam is equipped with a right-hand drainage gate with two doors. The current condition of the Mati River dam can be seen in Figure 3.

Figure 3. Mati river movable dam with pneumatic crest gate system

3.3 Hydrological Analysis

Mati River is located in the western part of Denpasar City with a length of 22.43 km and a watershed area of 44.67 km^2. The influential rainfall stations in the study area are the Sading, Kapal rainfall stations in the north, Sanglah and Sumerta stations in the middle, and Ngurah Rai stations in the downstream. Rain data from each station can be seen in Table 1 as follows:

Table 1. Rainfall stations in the Mati River watershed area

No.	Year	Ngurah Rai station	Sanglah station	Kapal station	Average rainfall region (mm)
1	2003	110	98	103	104.3
2	2004	199	102	95	138.7
3	2005	184	110	75	129.1
4	2006	82	120	124	106
5	2007	92	177	81	114.2
6	2008	192	160	80	148.8
7	2009	147	155	100	135.3
8	2010	126	77	120	109.5
9	2011	231	148	102	167.4
10	2012	139	228	97	153.1
11	2013	99	136	163	129.3
12	2014	78	80	112	88.8
13	2015	120	143	166	140.7
14	2016	142	110	100	119.8
15	2017	117	102	130	116.4
16	2018	116	95	154	121.1
17	2019	96	190	109	128.1
18	2020	115	74	218	133.6
19	2021	109	75	239	137.8
20	2022	145	112	124	128.8

Design rainfall is the amount of rainfall that is estimated to occur in a certain area in a certain return period. In this case, the design rainfall will be calculated for a return period of 2 years, 5 years, 10 years, 25 years, 50 years and 100 years. The data used is rainfall data for the area in the Sungai Mati watershed area. The method used in this design rainfall analysis is the Log Pearson Type III method as presented in Table 2.

Table 2. Results of design rain analysis using the Log Pearson type III method

No	Return period (years)	G	Extrapolation (mm)
1	2	0.0251	125.36
2	5	0.8505	143.46
3	10	1.2737	153.73
4	20	1.5659	161.25
5	25	1.7121	165.15
6	50	1.9813	172.58
7	100	2.226	179.62
8	200	2.4452	186.17
9	1000	2.9016	200.59

Design flood is the maximum discharge in a river or channel with a predetermined return period. If the design flood is used as the basis for planning. the flood that occurs can be channeled without endangering the stability of the building. Based on the design rainfall analysis from the maximum daily rainfall data. the amount of the design flood discharge can be calculated with a return period of 1. 2. 5. 10. 25. 50.

In the process of determining or analyzing the design flood discharge. the initial step is to create a unit hydrograph. Where the unit hydrograph is the transformation of rainfall data into discharge data. This study uses the Nakayasu Unit Hydrograph calculation. The following is the calculation of the Nakayasu (Synthetic Unit Hydrograph):

Watershed and Rainfall Parameters. The following are the watershed and rainfall parameters of the Mati River:

Watershed area (A) = 22.26 km^2

River length (L) = 22.43 km

Unit rainfall height (Ro) = 1 mm

Coefficient (α) = 2.5

Peak time (tp) and time lag (tg) calculation

Time coefficient (Ct) = 0.553

Peak time (Tp) and time lag (Tg):

$Tg = 0.4 + (0.058 * L) = 1.70$ hour

$Tr = 0.75 \times Tg = 1.28$ hour

$Tp = Tg + 0.8\ Tr = 2.72$ hour

$T_{0.3} = \alpha \times Tg = 4.25$ hour

$Tp + T_{0.3} = 6.97$ hour

$Tp + T_{0.3} + 1.5\ T_{0.3} = Tp + 2.5T_{0.3} = 13.35$ hour

Peak Discharge Calculation (Qp)

$$Qp = \frac{A\ x\ Ro}{3.6\ (0.3\ Tp + T_{0.3})}$$

Qp = 2.448

Hydrographic Curve. The following is the calculation of the Nakayasu hydrograph curve:

Rising Curve

$0 < t < Tp$ ➔ $0 < t < 2.72$

Descending Curve Stage I

$Tp < t < (Tp + T_{0.3})$ ➔ $2.72 < t < 6.97$

Descending Curve Stage II

$(Tp + T_{0.3}) < t < (Tp + 2.5T_{0.3})$ ➔ $6.97 < t < 13.35$

Descending Curve Stage III

$t > (Tp + 2.5T_{0.3})$ ➔ $t > 13.35$

Flood hydrographs with various return periods can be seen in Figure 4.

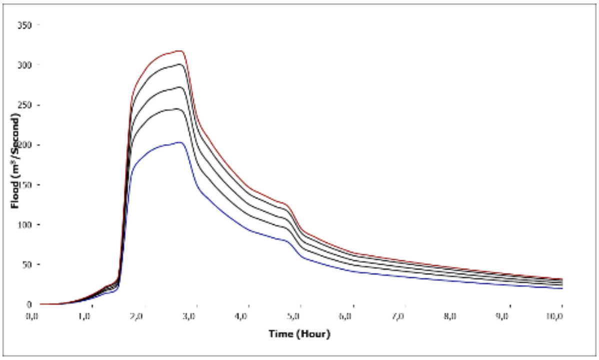

Figure 4. Mati river flood hydrograph

The advantage of pneumatic crest gate dams is their ability to provide precise control of water flow and water level quickly and efficiently. They are also easier to operate compared to some other types of traditional dams. However. they require regular maintenance to ensure the pneumatic system is operating properly. Based on the operating system conditions of the Mati River dam with a pneumatic crest gate system. the following points can be conveyed: a. The main function of the dam is to control the Mati River flood after the Umadwi dam segment/point because the Umadwi dam has a higher elevation. This function can be carried out easily because the gate operation can be carried out easily as desired. This flood control operating system can reduce the potential for flooding in the downstream part of the Mati River in several locations. namely: the potential for waterlogging on Jalan Dewi Sri and its surroundings. the potential for waterlogging around Jalan Blambangan (POLRI Housing and Lavender Hotel). the potential for waterlogging around Jalan Patih Jelantik and its surroundings. the potential for waterlogging around the Kuta area in general; b. In addition to flood control. the Mati River movable dam can also act as a reservoir for raw water at the mouth of the Mati River so that it can add to the potential for raw water storage.

The Movable Dam of the Mati River with the Pneumatic Crest Gate type has an effect on reducing flooding in the Mati River. This is based on the results of the hydrological analysis as in Table 3.

Table 3. Flood discharge conditions of Mati River

No.	Movable gate	Q25 (m3/dt)	River capacity (m3/dt)	Capacity of movable gate (m3/dt)
1	Lange	109.78	99.19	
2	Dadas	128.08	93.21	
3	Umadwi	185.93	165.23	
4	Muara	297.79	159.33	420.31

Based on the results of the analysis above. it shows that the Mati River Movable Dam has the ability to reduce the peak flood discharge of the Mati River from an initial water height of 4.5 m to 2.07 meters or is able to reduce the water level during a flood by 46%.

4 Conclusion

Based on the analysis that has been done. several things can be concluded related to the influence of the bending motion of the Mati River Estuary on the decrease in the discharge of the Mati River Bank as follows: a. The current flood management system of the Mati River is divided into three parts. namely the upstream. middle and downstream parts. Handling the upstream part is relatively easier because the discharge and catchment area are still small and the river capacity is still very large so that it can pass the existing flood. Flood management in the upstream area is more emphasized on maximizing channel capacity by dredging sediment and garbage in the channel body. Handling the middle part is faced with several problems. namely the varying river flow and even some spots that are bottlenecks (Jalan Resimuka Bridge and Jalan Nakula Bridge). The presence of irrigation dam buildings that make the flow somewhat blocked when flooding occurs (Lange movable dam. Dadas movable dam. Umadwi movable dam). Handling in the middle part is more emphasized with the movable dam operating system to pass water faster to the downstream part. In the downstream part. There is a lot of sedimentation in the river body and winding channels. Flood management is carried out by constructing a movable dam at the mouth of the Mati River and constructing a river embankment with a pre-cast structure downstream of the Uma Dwi dam. To reduce flooding, the area in the downstream has also been equipped with a flood control pump and trash rack to prevent garbage from being carried away by the water flow downstream; b. Judging from the analysis of the Mati River flood. it shows that the design flood value in this river is only able to accommodate a maximum flood discharge with a return period of 25 years or Q25. The results of the design flood discharge analysis from various consecutive return periods are $Q_2 = 200.88$ m^3/s. $Q_5 =$ 243.98.88 m^3/s. $Q_{10} = 269.57$ m^3/s. Q25 = 297.79. m^3/s and $Q_{50} = 315.25$ m^3/s; c. The pneumatic crest gate type movable dam has a major influence on reducing the peak flood discharge in the Mati River watershed. This can be proven from the capacity before the movable dam was 159.33 m^3/s and after the movable dam the capacity became 420.31 m^3/s or an increase in capacity of 163.79%. Judging from the height of the flood water level. it can be said that there was a decrease in the water level from the previous height of 4.5 m to 2.43 m.

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