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Erosion and Flood Discharge Plans Analysis on The Capacity of The Dead River Lake

Andi Renata Ade Yudono, Muammar Gomareuzzaman

Universitas Pembangunan Nasional Veteran Yogyakarta
[1] E-mail address ade.yudono@upnyk.ac.id; [2] E-mail address muammar.g@upnyk.ac.id

Abstract

Sometimes development is not in accordance with the carrying capacity of the land or area designation because it is not in accordance with the characteristics of an existing area. The dead river lake in Pondok and Parangjoro villages has various benefits for the surrounding community, resulting in land conversion that is not in accordance with its purpose and has a negative impact (erosion) on the surrounding environment. Therefore, it is necessary to know how much erosion has occurred in the area around the Dead River Lake, the magnitude of the planned flood discharge, and the potential for lake water overflow to the surrounding area. The study used several methods, including the use method to determine the amount of erosion, the planned flood discharge to determine the estimated maximum discharge in several return periods, and spatial to determine the capacity of the dead river lake. Based on the results per parameter, it was found that the total erosion in the study area was 30.358,432 tonnes/ha/year or 235,52 m^3 / ha/day with an area of 63,971,488 m^2. The existence of continuous erosion can cause the capacity of the dead river lake to be reduced, and indirectly it can cause flooding due to lake overflow on the 79 day for the 25 and 10 year return period and 80 days for the 5 and 2 year return period.

Keywords: Flood, Erosion, Dead River Lake

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I. INTRODUCTION

The number of recent area developments not according to land carrying capacity or area designation because it carried out is inadequate with the existing conditions or characteristics of an area, which causes a decreasing number of environmental qualities. Decreasing environmental quality, either directly or indirectly, causes environmental problems that can become a disaster.

Landuse change is one of the things that often occurs in land development. The consequences of these changes can result in natural events or can even exacerbate these events, for example, erosion. Erosion that occurs can indirectly affect areas that are on the riverbed, such as silting rivers or lakes where erosion often occurs in the surrounding area. Despite the problems, land-use change is unavoidable due to the need to meet the needs of a growing population number and associated with increasing demands for a better quality of life.

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Lake is basically a hollow in the surface of the earth flooded by fresh water or salt; the whole basin is surrounded by land. The complexity of the lake is basically caused by the relationship between various environmental components such as abiotic, biotic, and cultural. The complexity of lakes can have both positive and negative impacts. The occurrence of an issue that may result be a disaster is one of the negative impacts of the linkages between the various components of the environment.

Flooding can also be called an increase in water flow that exceeds the storage capacity; it can be caused by several kinds of things, including the addition of high water volume and reduction of existing storage capacity. Additions debit of water that is generally caused by two factors: climate and land-use change are resulting in an increase in surface runoff. While the reduction in storage capacity, caused by the silting up of particles of soil or rock around it due to erosion.

Dead River Lake, located in Pondok and Parangjoro Village, Sukoharjo District, Sukoharjo Regency, is one of the lakes formed due to the straightening of the Bengawan Solo river. The lake has various benefits for the surrounding community, so that it results in the conversion of land into buildings. The following is some evidence of land-use change in the area around the lake from the ex-river (Figure 1.)

Figure 1. Landuse change: (a) Comparison Additional buildings seen from the SPOT imagery (2018) and Aerial Photography (2020); and (b) The construction is carried out around

The occurrence of land-use change that is not in accordance with its designation can basically lead to erosion and increased surface runoff. This event can lead to silting, which has an impact on water overflow due to reduced lake capacity. Floods in the study area in 2007 and 2016 will recur if proper management is not carried out. So, it is necessary to know how much erosion occurs in the area around the dead river lake, the amount of planned flood discharge, and the potential for lake water overflow to the surrounding area.

Figure 2. Flood Height Level in 2016

II. LITERATURE REVIEW

A disaster is an event that threatens and disrupts human life due to natural factors, non-natural factors, and human factors. This incident caused casualties, human, environmental damage, property loss, and psychological impacts (UU 24 Tahun 2007 tentang Penanggulangan Bencana). There are various kinds of disasters in Indonesia, most of which are caused by changes in land use and can indirectly trigger secondary impacts such as lakes that experience erosion in the surrounding areas, which can result in silting and flooding.

II. 1. LANDUSE CHANGE

According to Kodoatie and Sugiyanto (2002), there are two factors that cause flooding, namely natural and human factors. These two factors are generally related to one another. Humans, as one of the triggers for flooding, are because all human activities are basically carried out to meet their daily needs, but sometimes this is not in accordance with the characteristics of the area, such as the occurrence of land use that is carried out without its designation. According to Wahyunto et al. (2001), land-use change is an increase in land use from one side of use to another followed by a reduction in other types of land use from one time to the next, or changes in the function of land at different periods of time. Landuse change, which is the application of development, can have an impact if it is not carried out properly. This is evidenced by the dead river in the Cisangkuy River, where land use is dominated by settlements, rice fields, industries, and most of the area is empty land, which is generally overgrown with wild vegetation or landfills. As a result of this, the rainy season, some of the surrounding areas are always inundated due to the silting of the dead water (Rohmat, 2009).

II.2. Erosion

According to Hardjowigeno (1995), erosion is a process in which soil is released and then moved to another place by the forces of water, wind, and gravity. It is further explained that erosion is the result of the interaction of climate, soil, topography, vegetation, and human activities on natural resources (Arsyad, 2000). The existence of human activities as a trigger and implementer of development is something that must be considered because the size of erosion can occur due to inappropriate human activity. This is reinforced by Hardjowigeno, 1995, that there are several factors that influence the amount of erosion, including rainfall, soil, slopes, vegetation, and humans. To determine the amount of erosion that exists, Wischmeier and Smith (1978) use all these factors to calculate the rate of erosion; the method is better known as the Universal Soil Loss Equation (USLE) method. The impact of erosion can be seen by relating it to the capacity and the estimated discharge that occurs.

III. RESEARCH METHODOLOGY

III.1. Location and Object of Research

This research area is located between 2 villages, namely Pondok and Parangjoro Villages, Grogol District, Sukoharjo Regency, Central Java Province. The object of his research is the area of the Mati River and its surroundings to calculate the amount of erosion that has occurred and could have an impact on reducing the capacity of the Mati River in the future. The research area is a lake border area which, according to the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia NUMBER 28 / PRT / M / 2015 concerning the Determination of River Boundaries and Lake Boundaries, Article 18 paragraph 4, states that the lake boundaries are at least spaced apart. 50 meters from the edge of the lake. The following is a map of the research area (Figure 3.)

Figure 3.Map of the research area

III.2. Data Analysis Techniques

III.2.1. Erosion Analysis

The data analysis technique used in calculating the amount of erosion, the parametric prediction method using the USLE (Universal Soil Loss Equation) method. This method allows planning to estimate the average rate of erosion in a given plot of land on a slope steepness with a certain rainfall pattern for each type of planting and soil conservation action that may be carried out or that is being used. The USLE equation is as follows:

$$A = R \times K \times LS \times C \times P \quad (1)$$

Explanation:

A = The amount of eroded soil (t / ha / year).
R = Rain Erosivity factor.
K = Soil Erodibility factor.
LS = Slope factor.
C = Plant management factor.
P = Soil conservation Measures.

III.2.1.2. Flood discharge analysis

The hydrological analysis used is flood discharge. The amount of rain plan is determined based on the frequency analysis carried out with the Annual Maximum Series, with the minimum data used in 10 years of time series. In the analysis of the frequency of rain data, a continuous probability distribution is used, namely Gumbel.

i. Gumbel Probability distribution
If the rain data used in the calculation is in the form of a sample (limited population), then the calculation of the rain plan is carried out using a formula:

$$XT = \bar{x} + S \times K$$

Explanation:
XT = Plan rain or discharge with a return period T.
$\bar{x}$ = Average value of rainfall data (X)
S = Standard deviation of rainfall data (X)
K = Gumbel Frequency Factor

ii. Main Intensity
Rainfall intensity is calculated using the Mononobe Method; this is because short-term rainfall data is not available and what is available is daily rainfall data (Kamiana, 2011). By using the Mononobe Method, rainfall intensity for various concentration-time values can be determined from the amount of daily rainfall data (24 hours). The Mononobe formula is as follows:

$$I = \frac{X_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}}$$

Information :
I = Rain intensity plan (mm / hour)
X24 = Maximum rainfall height (mm)
t = Rain duration or concentration time (hour)

iii. Rational Method
The Rational Method is a method used to calculate the peak discharge of a river or channel but with a limited drainage area (Kamiana, 2011). According to Suripin (2004) in Kamiana (2011), the use of the Rational Method can be done by approaching the combined C value or C average and rain intensity calculated based on the longest concentration time.

$$Q = 0.278 \times C \times I \times A$$

Information :
Q = Peak runoff discharge (m3 / sec)
C = Flow rate
A = Area of drainage area (Km^2)
I = Rainfall intensity (mm / hour)

III.2.1.2. Dead River Capacity Analysis
Analysis of the Dead River Lake capacity using spatial analysis using GIS. The data used is the topography of the Dead River Lake by processing the shape of the basin (lake).

IV. FINDING AND DISCUSSION

IV.1. GREAT EROSION ON THE AREA AROUND THE DEAD RIVER LAKE

The amount of erosion in the study area can be determined using the USLE method. The parameters in the USLE method consist of 5 parameters, including Rain Erosion (R), Soil Erodibility (K), Slope (LS), Plant Management (C), and Soil Conservation Measures (P). The following is a per-parameter explanation of the study area:

a. Rain Erosivity Factor (R)
The rainfall data used to calculate the erosivity factor were obtained from rainfall data at BBWS Palur, Mojolaban District, Sukoharjo Regency, which is the rain station close to the research area. Basically, the high and low rainfall will have an impact on the amount of surface runoff, which can also affect the amount of erosion that occurs. Based on the rainfall data, the erosivity value is obtained, which can be seen in Table 1.

Table 1. Rain Erosion (R) Value of Dead River Lakes from 2010 to 2019

Year	R
2010	2059,231
2011	1589,626
2012	1724,867
2013	1754,951
2014	1228,826
2015	1171,178
2016	2736,547
2017	2422.01
2018	1832.19
2019	2254,346

Source: Calculation Results, 2020.

b. Soil Erodibility Factor (K)
Based on direct observation and determination in the field, according to Soepraptohardjo's (1961) classification, it can be seen that the type of soil in the research area is an alluvial soil type. Based on soil testing in the field (research area), there are two textures on alluvial soil types, including dust clay texture at a depth of 0-35 cm and sandy clay at a depth of 35-81 cm. Furthermore, after knowing the characteristics of the soil contained in the study area, it was found that the K value contained in the study area was for texture. For dust clay, an Erodibility value is obtained of 0.377, while for sandy clay, and Erodibility value is obtained of 0.733, which can be seen in Table 2.For the Erodibility value for soil texture (M) is obtained from Hardjowigeno (2010), and for organic percentage, it is obtained from BH Prasetyo and D. Setyorini (2008)

Table 2. K Value per Soil Texture

No.	Type of soil	Soil Texture	Soil Texture Value (M)	Organic Matter (%)	Erodibility (K)	Average Soil Thickness (cm)
1.	Alluvial	Clay dust	3245	0.33	0.377	35
2.	Soil	Sandy clay	6330		0.733	46

Source: - Soil Type and Texture: Primary Data
- Soil Texture Value: Hammer (1979) in Hardjowigeno (2010).
- Organic Ingredients: BH Prasetyo and D. Setyorini (2008).

c. Slope Factor (LS)

The research area is an area with a landform origin of the fluvial process, which is dominated by the shape of a flat field. Based on measurements in the field and analysis of topographic maps made by combining the RBI maps with the elevations obtained from the use of a drone. Based on these results, it is found that there are three types of slopes found in the study area. The following is an illustration of the shape of the terrain (Figure 4.) and the slope of the slopes in the study area (Table 3.).

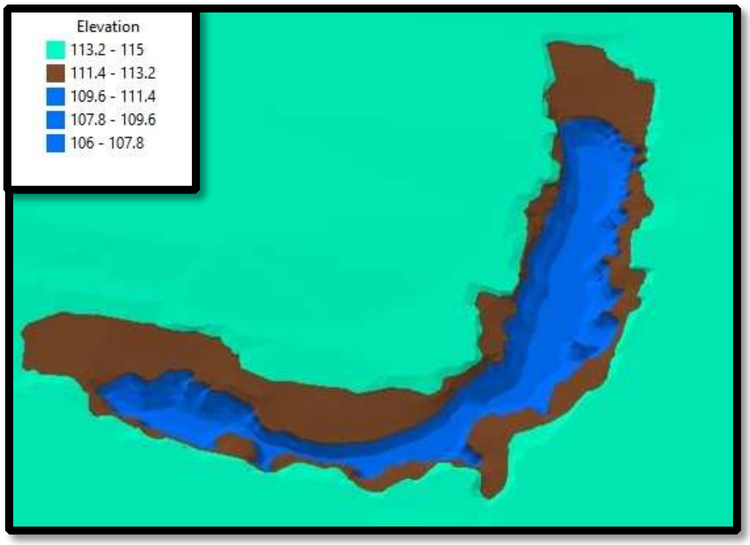

Figure 4. Dead River Lake in the Study Area (3D)

Table 3. Slope Value at the Research location

No.	Slope (%)	LS value
1	3.49	0.25
2	21.26	1,2
3	53.17	9.5

Source: Primary Data, 2020.

d. Plant Management Factor (C)
Plant management factors can be identified from the type of land use known by using aerial photography interpretation and direct observation in the field. In the study area, there are three types of land use, Settlement, Moor, and mixed gardens. The following are the types of land use along with the value of crop management factors (Table 4.)

Table 4. Landuse in the study area

No.	Type of Use	Factor Value
1	Settlement	0.2
2	Moor	0.7
3	Mixed Garden	0.2

Source: Primary Data, 2020.

e. Soil Conservation Measures (P)
Soil conservation measures can be seen from the interpretation of aerial photographs and direct observations in the field, so that there are two kinds of soil conservation actions that have been carried out, including soil conservation using traditional terraces and soil cultivation by planting along contour lines.

Based on the results obtained per parameter such as Rain Erosion (R), Soil Erodibility (K), Slope (LS), Plant Management (C), and Soil Conservation Measures (P), then the values of all these parameters are entered into the method formula. USLE and the results show that there are 63 locations with different sizes of erosion in the study area, while the total erosion in the study area is equal to 30,358.432 Ton / Ha/year or 83.174 Ton / Ha/day or 235.52 m^3 / Ha/day with an area 63,897.60 m^2. The following is a map of erosion land units (Figure 5.) in the study area.

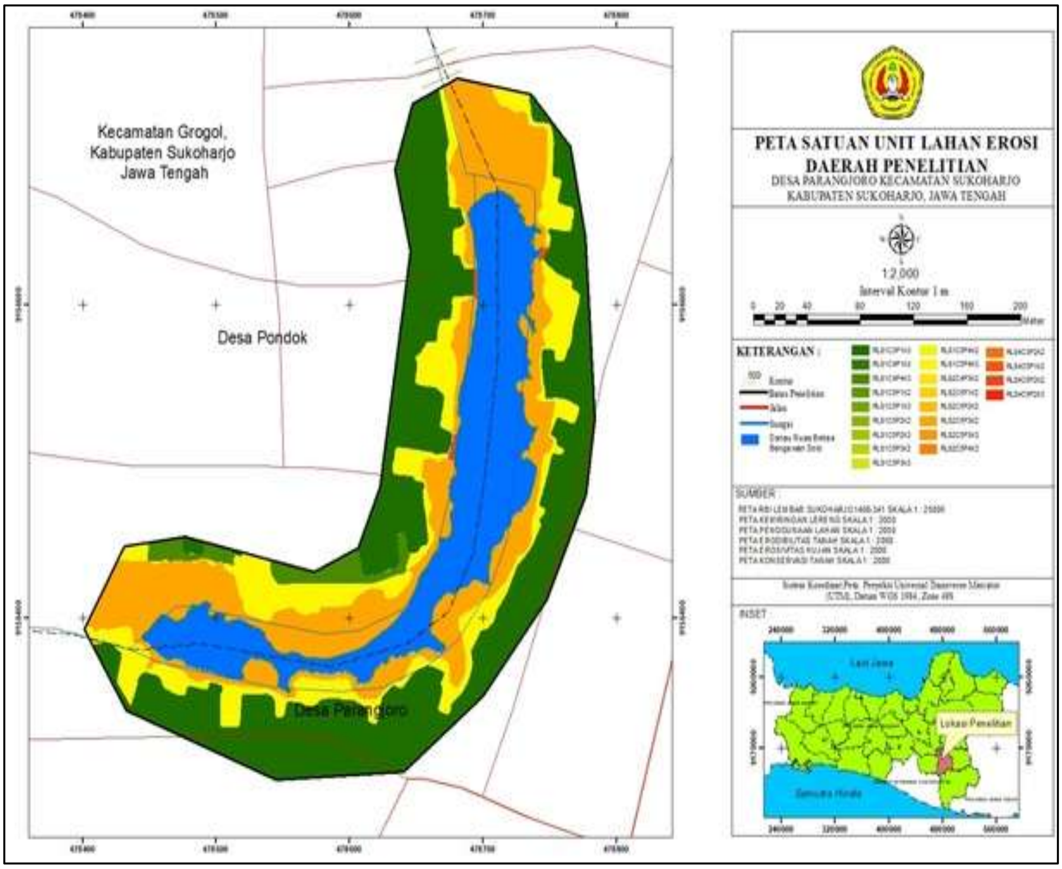

Figure 5. Map of Erosion Land Units.

The occurrence of erosion will be able to reduce the capacity of the existing Mati River Lake so that the capacity of the existing Dead River Lake is equal to 78,901.10 m^3 will be reduced to 78,665.58 m^3 in 1 day.

IV.2. Flood Discharge Plan on the area around the Dead River Lake

Based on the calculation of the planned flood discharge in the return period of 2 years, 5 years, 10 years, and 25 years, it is found that the planned flood discharge value is 83,46 m^3 / second for the 2 year return period, 107,55 m^3 / second for the 5 year return period, 123,24 m^3 / s for a 10 year return period, and 143,4 m^3 / second for a 25 year return period. The planned flood discharge value is strongly influenced by land use, which indirectly represents the characteristics of the area. The results of the planned flood discharge calculation can be seen in table 6.

Table 6. Calculation Results of Planned Flood Discharge

Type of Landuse	C	I (mm / hour)				A	Q Total (m^3 / sec)			
		2	5	10	25	(Ha)	2	5	10	25
Moor	0.2	1.49	1.92	2,2	2.56	1.23	83,46	107,55	123,24	143,4
Mixed Garden	0.1					0.23				
Settlement	0.75					4.86				
Dead River Lake	0.9					2.14				

IV.3. Effect of Planned Flood Discharge on Dead River Lake

The capacity of the dead river lake can accommodate the planned flood volume/discharge for all return periods. However, the erosion that occurs can reduce the capacity of the lake so that at a certain time and capacity, it will result in overflow floods originating from the dead river lake. The following table shows the estimated volume of water that will fill the lake, the lake storage capacity, and the estimated time and capacity of the lake until it is unable to accommodate the planned flood discharge, which can be seen in table 7.

Table 7. Estimated Inability of Sungai Mati Lake to accommodate flood discharge

Basin Capacity (m^3)	The average volume of water in the lake (m^3)	Erosion (m3 / Ha / day)	Birthday Period (year)	Planned Flood Discharge (m3 / hour/day)	Estimated time is unable to accommodate the discharge of the planned flood (Day…)	Estimated volume of runoff (m^3)
78,901.10	60,171.78	235.52	2	83,46	80	60.255,24
			5	107,55		60.279,33
			10	123,24	79	60.295,02
			25	143,4		60.315,18

V. CONCLUSION AND FURTHER RESEARCH

Based on the results per parameter, the results show that there are 21 locations with different sizes of erosion in the study area, while the total erosion in the study area is 30,358.432 Ton / Ha/year or 83.174 Ton / Ha/day or 235.52 m^3 / Ha/day with an area 63,971,488 m^2. The occurrence of erosion will reduce the capacity of the existing Dead River Lakes. If erosion occurs continuously and with stable/constant environmental conditions, according to calculations using the USLE method, the dead river lake will be covered by existing materials.

The existence of water in the dead river lake can overflow around the lake if there are continuous erosion and the addition of high water discharge. Based on the calculation results, the estimated time at which the dead river lake cannot accommodate the amount of water is one of which is due to the erosion that has occurred. Therefore it is necessary to carry out appropriate management so that the erosion that occurs can be minimized or even eliminated so that silting of dead river lakes will not occur.

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