Changes in sediment discharg he collapse of Mt. Bawakaraeng in South Sulawesi, Indonesia

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1. Introduction

It has been more than three years since the collapse of the caldera walls of Mt. Bawakaraeng in Indonesia. Nevertheless, the huge amount of deposited sediments is still generating various environmental and social issues.

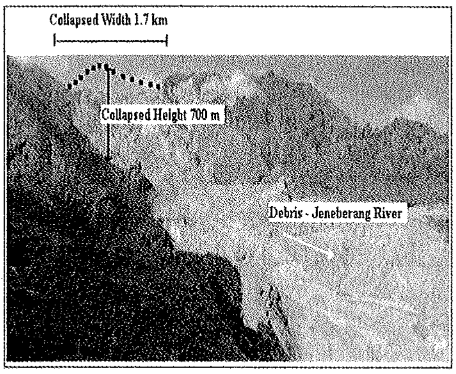

Figure 1 The collapse area of Mt. Bawakaraeng

On 26 March 2004, the caldera walls of Mt. Bawakaraeng (elevation 2830 m) collapsed. The collapsed mass flowed from the caldera outlet for 15–30 min before settling and the deposit volume (calculated at approximately 232 million m^3) covers 7 km of the upstream portion of Jeneberang river [1]. In the rainy season, deposited sediments are washed downstream, resulting in occasional debris flows, turbid water, and sedimentation onto the riverbed and Bili-bili Dam, a multipurpose dam located 31 km downstream from Mt. Bawakaraeng.

2. Research Purpose

Main purposes of the analyses are to evaluate the magnitude of the impact of the change of the basin and how the impact decrease with years. We used rainfall and discharge data from the years 2001 to 2007 to define the changes in water balance and turbidity rates before and after the collapse. Changes in water discharge is analysed to study the channel's stability whereas changes in turbidity is analysed to identify the sediment's exhaustion rate.

3. Change in Water Discharge

One way to identify watershed change is to analyze water discharge because changes made to the landscape alter the timing and amount of waterflow, which over time also affect channel shape and stability [2]. The changes in the relationship between rainfall and discharge before and after the collapse were analyzed by calculating the daily, monthly, and annual rainfall-discharge coefficient:

$$Q = \alpha_{QR} \cdot R \quad \text{.........................} \quad (1)$$

where α_{QR} is the rainfall discharge coefficient, Q is the amount of discharge (mm), and R is the amount of rainfall (mm).

Figure 3 illustrates that RD coefficients substantially decreased after the collapse when analyzed from a daily perspective (i.e., the daily amount of rainfall generates less daily water discharge). Before the collapse, 1 mm of rainfall commonly generated 0.67 mm of water discharge; after the collapse, in 2004, 2005, and 2006, 1 mm of rainfall

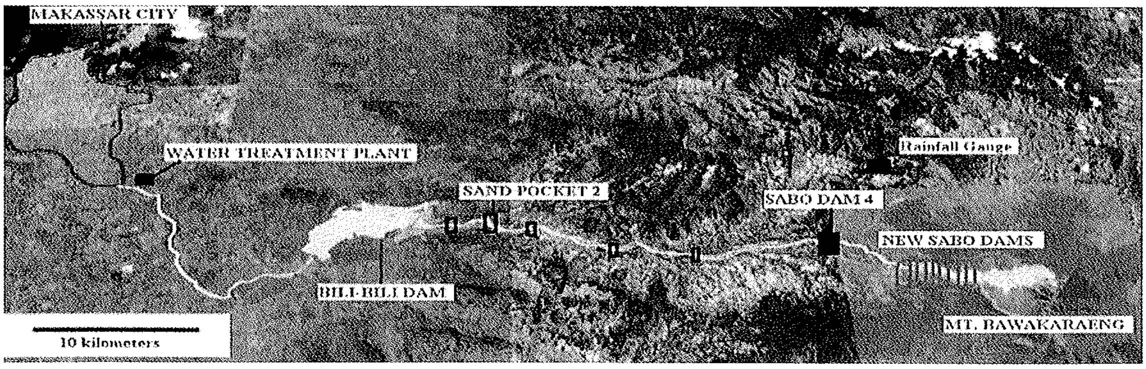

Figure 2 Map of Mt. Bawakaraeng, showing the location of Bili-bili Dam, Jeneberang River, Makassar City, and the sabo dams (*modified map from Google Earth, taken on February 2008*)

generated only 0.45 mm of water discharge.

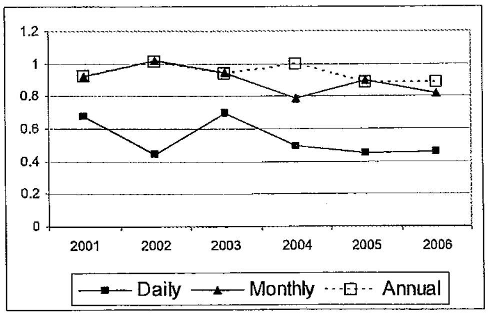

Figure 3 Daily, monthly, and annual rainfall discharge coefficients for 2001–2006.

The decreasing trend in the daily discharge coefficient can be explained by the ability of upstream deposited sediments to store water. The sediment deposited upstream is not flat in most areas and has undulations that allow the formation of water pools. Moreover, the porosity of these sediments is rather high, at 0.40 (CTI, 2006), enhancing their ability to absorb and retain rainfall water. In addition, fresh sediments (from slope or gully erosion) arrive from time to time; these cover the natural and former drainages and convert surface flows into subsurface flows, thus slowing discharge. This accounts for the insignificant decrease in RD coefficients when analyzed from monthly and annual perspectives.

Compared to the daily RD coefficients, the monthly and annual coefficients are similar before and after the collapse. Before the collapse, the monthly and annual RD coefficients were on average 0.96; these decreased to approximately 0.88 in 2005 and 2006. In the year of the collapse (2004), the monthly RD was 0.78, whereas the annual RD was 0.98. It is noteworthy that these figures may represent an underestimation of rainfall intensity because rainfall tends to become greater as elevation increases (the highest installed rainfall gauges at the Jeneberang catchment are only at 1010 m). Therefore, the annual coefficients of close to 1.0 might be overestimations due to the underestimation of rainfall.

4. Turbidity Rate before and after the Collapse

Turbidity is an expression of the light-scattering optical property of water (Dunne, 1978). To evaluate the effect of the change in discharge on the turbidity rate, a turbidity-discharge coefficient was identified (assuming that turbidity is proportional to discharge):

$$T = \alpha_{TQ} \cdot Q \quad \text{.............................} \quad (2)$$

where α_{TQ} is the turbidity-discharge coefficient, T is turbidity (NTU), and Q is the amount of discharge (mm).

Before the collapse, the daily turbidity-discharge coefficient averaged 3.22 (i.e., every 1 mm of discharge generated 3.22 NTU).

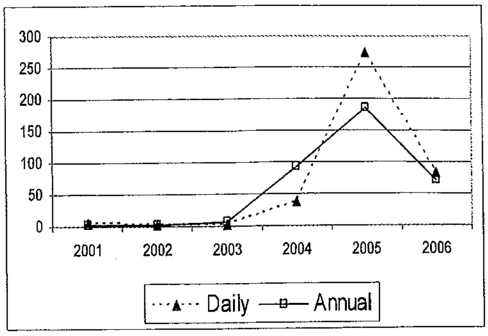

Figure 4. Daily and annual turbidity-discharge coefficients, 2001–2006.

As can be seen in figure 4, the coefficient increased sharply to 37.06 in 2004 and 274.34 in 2005, before decreasing to 83.48 in 2006. In 2004, there was a large range in daily turbidity, which resulted in a higher annual coefficient (92.7) than the daily coefficient. However, in 2005, the annual coefficient (184.79) was lower than the daily coefficient. Both the annual and daily coefficients fell by 30% 2 years after the collapse.

Three months before the collapse, the turbidity rate began an unusual increase. Thus, we suspect that small slope failures might have occurred from early December 2003. Before the collapse and the small slope failures, the maximum turbidity rate was 407 NTU. Within the first rainy season after the collapse, this rate increased by > 300 times to 125,159 NTU. The maximum turbidity rate declined to 33,241 NTU in 2006 and 3933 NTU in 2007. Before the collapse, the minimum turbidity rates in the dry season were normally close to zero. However, after the collapse, the turbidity rate decreased to a minimum of only 22 NTU in October 2007.

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