A simple method to estimate the amount of rainfall required for a natural landslide dam to overflow

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INTRODUCTION

Many landslide dams occur in Japan. Most recorded landslide dams breached when the reservoirs overflowed causing floods downstream. Therefore, knowledge of when a landslide dam reservoir will fill is necessary to plan for evacuation and other emergency work.

Since the volume of dam reservoirs increases with run-in flow resulting from rainfall, the relationship between rainfall and the amount of run-off is important for predicting when a dam reservoir will fill. This relationship has been studied in mountainous areas, for which several models have been developed, but in many models parameters must be identified from reliable long-term data. Often, there are insufficient data on the rainfall and flow rates in mountainous areas, such as in the Kii Mountains where landslide dams occurred in 2011.

Therefore, we introduce a simple method of predicting the amount of rainfall needed to fill a landslide dam reservoir for the initial emergency work at the time the landslide dam occurred. We report a case study of application of this simple method to a landslide dam that occurred at Ambon, in the Republic of Indonesia, in July 2012.

METHOD

In mountainous areas, the proposed relationship between total rainfall and total loss of rainfall is:

$$L=a\times(1-\exp(-R\times b)) \qquad (1)$$

where L (mm) is the total loss of rainfall, R (mm) is the total amount of rainfall in a rainfall event, and a and b are coefficients [*Endo*, 1985; *Fujieda*, 2007]. *Uchida et al.* [2013] applied this relationship to 164 basins in mountainous areas of Japan, and found that $b = 1.422\times a^{(-1.073)}$. Therefore, in **Eq. 1**, we replaced b by $1.4\times a^{(-1.1)}$ in this study. *Uchida et al.* [2013] showed that a = 30–300 for 90% of the 164 rivers, and 70–150 for 40%.

The available capacity of a landslide dam required to fill the reservoir in any period is determined by the total rainfall minus the total loss of rainfall for that period. So that:

$$V=(R-L)\times S\times 10^{-3} \qquad (2)$$

where V (m^3) is the available (vacant) capacity of a dam and S (m^2) is the basin area of the river dammed by the landslide. Determining V and S will give the relationship between the amount of rainfall in a period and the unused capacity of the dam using **Eqs. 1** and **2**.

CASE STUDY

On July 12, 2012, a large landslide occurred at Ambon in the Republic of Indonesia and

formed a landslide dam on the Way Ela River. The dam was 166.4 m high and 1550 m long. The area of the dammed river basin was 11,500,000 m^2. At 17:20 on July 24, 2013, the water level of the landslide dam reached the level of the spillway, which was at an elevation of 194 m, and then breached [*Ishizuka*, 2013]. The Public Works Research Institute (PWRI) of Japan, the Directorate General of Water Resources (DWRM), and the Research Center for Water Resources (RCWR) of the Ministry of Public Works of the Republic of Indonesia had measured the water level of the reservoir using buoys. The PWRI collected hourly rainfall data based on satellite data. In this study, we used these data. The total loss is rainfall minus outflows calculated from the water level of the reservoir. In this case, we did not include the effect of water leakage from the dam. Fig. 1 shows the relationship between the total rainfall and the total loss of rainfall. From the relationship, **Eq. 1** becomes:

$$L=601.5(1-\exp(-R\times 0.0012)) \qquad (3)$$

Fig. 2 shows the estimated rainfall amount that causes overflow by **Eq. 2** and **Eq. 3**.

In this case, the reservoir filled after about 51 mm of rainfall, while we had estimated that about 100 mm would be required from **Fig.2**

CONCLUSION

Although only approximate, the method can be used in the early stages of landslide dam measurements, when plans regarding the handling of a possible emergency must be made but there are often insufficient data. In comparison with other models for estimating the rainfall-runoff relationship in mountainous areas, this method estimates only the total amount of rainfall needed to fill the landslide dam reservoir, but it is rapid. The accuracy of the estimates was acceptable for practical use in this case study.

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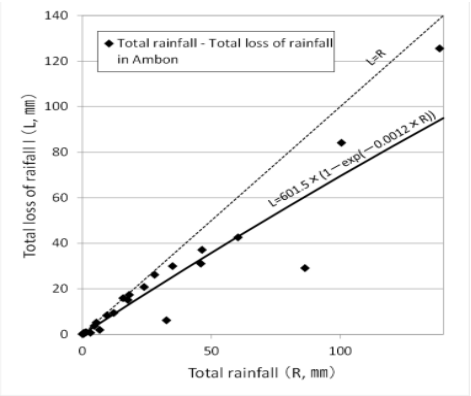

Fig. 1 The relationship between total rainfall and total loss of rainfall at Ambon.

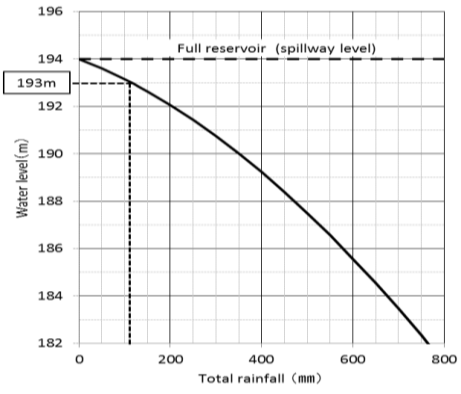

Fig. 2 Estimated rainfall amount causing overflow.

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