Study on sustainable sand mining management in Merapi Volcanic region

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1. INTRODUCTION

Mt. Merapi is one of the most active and feared volcanoes in the world (Voight, et al., 2000) and located approximately 30 km north-northeast from Yogyakarta Indonesia. In addition to threaten people and asset in the downstream, the sediment is important resources for people. The sand mining activities have given some advantages for rural/local people, local government and regulation of sediment movement. Sand and gravel material in Mt. Merapi offer many benefits such as employment opportunity, increase in economical benefit to farmers. However, uncontrolled sand mining has caused serious problems in the watershed such as unstableness of sediment control facility, bridge and irrigation intake by digging nearby, channel and riverbank instability due to riverbed degradation in the downstream, destruction of aquatic and riparian habitat due to artificial armoring. As long as the sand mining is controlled, it can be one of measures for sediment control plan and contribute to the rural economy. From this point, a sustainable sand mining management is urgently necessary to mitigate the above issue and sustain the sand mining beneficial to stakeholders, region and watershed. In this paper, the basic concept of the sustainable sand mining management is discussed.

2. SEDIMENT BALANCE

The current situation of sediment balance in Merapi area is influenced by sediment production, sediment mining and sediment discharge to sea (Figure 1). The lava production data from 1890 to 1992 have been compiled by Siswowidjoyo et al., (1995).The production rates of individual eruptive events are varied widely, from less than 10^6 m^3 to more than $20x10^6$ m^3, but the cumulative volume is proportionally increased and the annual average lava production rate is approximately estimated at around $1.2x10^6$ m^3/year (Figure 2). In Merapi volcanic area, other sediment comes from the non-volcanic basin. The ratio of the sediment production from non-volcanic basin is estimated at 20% of the sediment production from volcanic active basin (DGWR, 2001b), therefore, the sediment production is equal to 0.24 $x10^6$ m^3/year. Thus, the annual average sediment production rate from Merapi Volcano (volcanic active basin) and non-volcanic basin, Q_{spm} , is 1.44 x 10^6 m^3/year. The sand mining volume in the foothills of Mt. Merapi in 2000 was estimated at 5-6 x 10^6 m^3/year (DGWR, 2001a). The sand mining persists not only in the foothills of Mt. Merapi but also in the lower reach of river channel, especially in Progo River. In Progo River, the sand mining activities are concentrated in the lower reach area. The mining rate in the Lower Progo is estimated at about 2,933 m^3/day or 1.07 x 10^6 m^3/year (Indra Karya, 1999). Based on the following data in 2001, the amount of sediment discharge to the sea in year 2001 was calculated. The annual average discharge in 2001 is 83.1 m^3/s, the mean diameter of bed material is 1 mm, the river width is 200 m, and the bed slope is 0.0015. The total sediment discharge, Q_s, calculated by using Ashida and Michiue's bed load transport formula and Ashida and Michiues's suspended load formula, sediment discharge in this area is 1.46 x 10^6 m^3/year.

For no sediment mining case, sediment input and output are relative similar. Under this condition, no erosion and no deposition take place in the channel. Under the present sediment mining condition, it indicates that the riverbed degradation rate in whole Progo River is about 1.10 m/year. On average for the lower Progo River, under the same condition, the riverbed degradation rate is 0.316 m/year. If sand mining in the upper area is still active, it means no sediment supply into the lower area. Under this condition, the slope is decreased from 0.0015 until the equilibrium state of sediment transport is reached. Finally, the slope is estimated to be 0.000156.

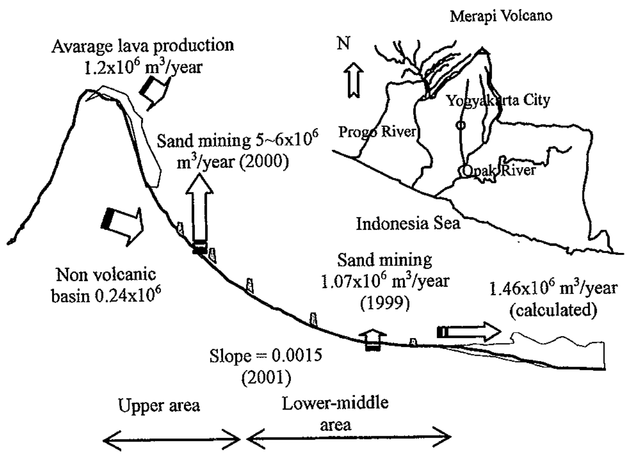

Figure 1 Sediment balance in Merapi area

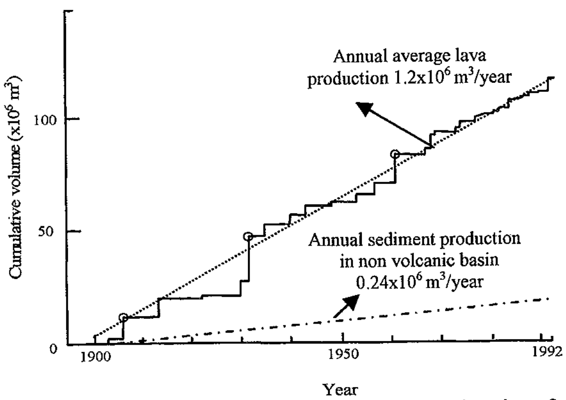

Figure 2 Cumulative volume sediment production from lava production and non volcanic basin

3. SUSTAINABLE SAND MINING

The view point in sustainable sand mining is how to determine the allowable sand mining volume. Determining the allowable sand mining volume, the following steps are necessary. First, the designed bed slope, i_{bd}, is decided. In consequence of first step, it is necessary to estimate how many groundsills must be installed for degradation measurement. If the designed bed slope is much less than the original bed slopes, the numbers of groundsills are larger. Next step, sediment discharge to sea, Q_{s1}, is calculated for the designed bed slope. Finally, the allowable sand mining volume, Q_{sa}, can be calculated upon the value of design sediment production rate, Q_{spd}, and the sediment discharge to sea as follows.

$$Q_{sa} = Q_{spd} - Q_{s1} \quad (1)$$

If we used Q_{spm} as Q_{spd}, Q_{sa} is equal to $Q_{spm} - Q_{s1}$. For instance, if the designed bed slope is 0.0015, the sediment discharge to sea, Q_{s1}, is 1.46 x 10^6 m^3/year. Thus, under this condition, the allowable sand mining volume is around zero. In the other case, if the designed bed slope is 0.0010 and the sediment out to sea, Q_{s1}, is 7.8 x 10^5 m^3/year. Therefore, the allowable sand mining volume is estimated at 6.6 x 10^5 m^3/year. Relation between i_{bd} and the allowable sand mining volume, Q_{sa}, is shown in Figure 3.

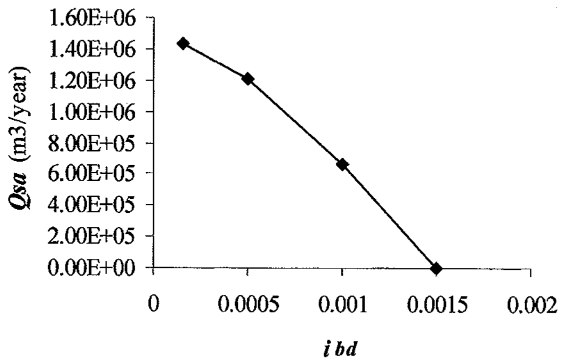

Figure 3 Relation between the allowable sand mining volume, Q_{sa}, and the designed bed slope, i_{bd}.

4. OTHER PROBLEM

The lava production rates of individual eruptive events vary widely, from less than 10^6 m^3 to more than 20x10^6 m^3. Therefore, the sediment supply rate, Q_{supply}, from the Merapi volcano also changes very much. Thus, it is very important to determine the maximum allowable sediment discharge, Q_{s2}, for each of the designed bed slope. Q_{s2} is a sediment discharge that causes the bed slope to return to the original bed slope. Relation between i_{bd} and Q_{s2} is shown in Figure 4. If Q_{supply} is less than or equal to Q_{s2}, this condition will not cause aggradation. But if Q_{supply} is much bigger than Q_{s2}, this condition will cause aggradation. For instance, if a huge eruption occurs with the sediment production rate of 20 x 10^6 m^3/year like 1930, it is predicted that the bed slope changes from the designed bed slope to 0.0086. This condition is quaite danger for stability function of river structures such as irrigation water intake because this sediment production rate is much larger than Q_{s2}. In order to reduce the proposed sediment discharge to be the allowable sediment discharge, especially under huge eruption, it is necessary to be controlled. Therefore, the structural sediment measurement such as sabo works, is one alternative to be implemented to control sediment production.

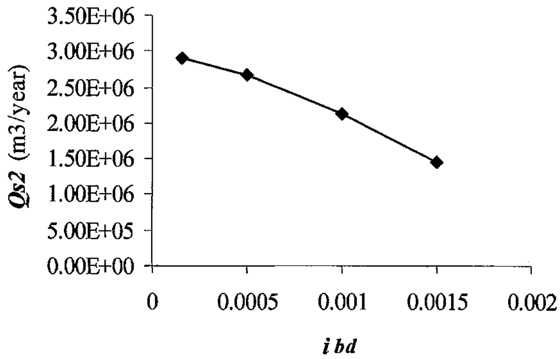

Figure 4 Correlation between the sediment supply, Q_{s2}, and the designed bed slope, i_{bd}.

5. CONCLUSION

Sand mining activity can be used as one alternative to control sediment discharge. Therefore, sustainable sand mining management is an important point as a part of the sediment control plan, the regional development, to reduce and mitigate the sediment disasters. However, under huge eruption, sabo works is necessary used to mitigate the sediment disaster.

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