

Development of a Watershed Management System; Rainfall-runoff and Sediment Production-discharge Simulation Model

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Abstract. This study developed a model to predict rainfall-runoff, sediment production and sediment discharge processes under extreme rainfall events. The frequency of heavy rainfall events has increased in recent years in Japan, which may also increase the risk of landslides. However, accurate prediction of shallow landslides is still difficult. Rainfall amounts, soil infiltration rates, changes in the water table, and soil mantle instability have all been used to predict landslides. However, such predictions often overestimate the number of landslides or predict that landslides will occur later than they actually do. Models have also been developed to estimate the amount of soil entrained into rivers below landslide areas, but such predictions are also difficult because not all of the soil from landslides mixed into the water. Here, we present a newly developed model, the Watershed Management System (WMS), which evaluates rainfall-runoff, sediment production, and discharge processes more accurately than former models by introducing debris flows instead of shallow landslides as the driver of sediment production.

Keywords: Watershed Management System, rainfall and runoff, sediment production and discharge, simulation model, erosion and sediment control, sabo

1. INTRODUCTION

To develop erosion and sediment control plans and appropriate sabo dam systems, it is first necessary to predict rainfall-runoff, sediment production, and sediment discharge processes under extreme rainfall events. Such management plan could include both structural and nonstructural countermeasures to prevent sediment related disasters due to the rainfall. However, it remains difficult to predict shallow landslides with any accuracy. We developed a new

model called the Watershed Management System (WMS) to evaluate rainfall-runoff, sediment production, and sediment discharge processes in areas where debris flows, rather than shallow landslides, are the main sediment production process.

2. MODEL DEVELOPMENT

Sediment production includes such processes as shallow landslides, debris flows, torrent/riverbed erosion, bank erosion, and deep-seated landslides. Because the WMS is intended to be applied to ordinary watershed management activities and less than 100-year frequency events, we exclude deep-seated landslides, which are rare. To avoid the ambiguity of the rate of entrainment of shallow landslides, we consider zero-order basins where shallow landslides occur to be torrents. The occurrence of debris flow in the zero-order basins (torrents) is estimated according to the flow condition, calculated by a rainfall and runoff sub-model. Following debris flow estimation, a sedimentation sub-model computes the discharge rate. Here, we consider shallow landslide to be debris flow.

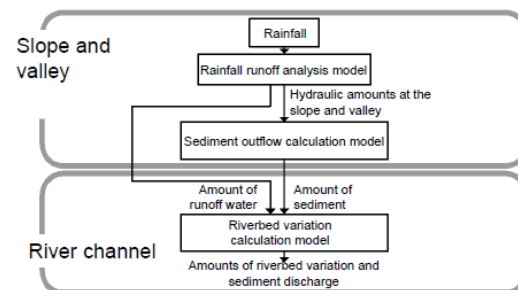


Fig. 1 The structure of the Watershed Management System (WMS)

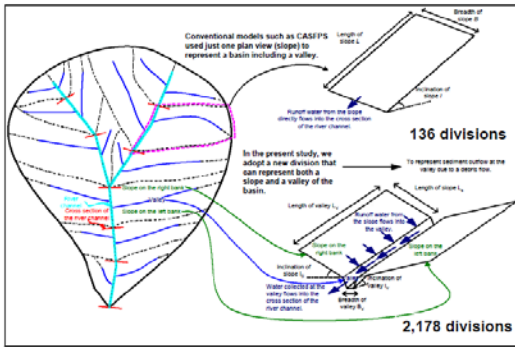


Fig. 2 Partition of a basin

3. MEASUREMENT

The study site was the Sumiyoshi River, located in the Rokko Mountains. Rainfall and runoff were measured at various locations in the basin, and sediment discharge was measured at various scales; including plots, slopes, and basins. Flow discharge data were used to determine the parameters of the two-layer intermediate flow model in the system. Loss of rainfall did not need to be given separately but was instead calculated automatically.

Bedload was measured using pipe hydrophones. The acoustic data were converted to the bedload transport rate using a pit bedload sampler calibration. Turbidity was measured to estimate the suspended load.

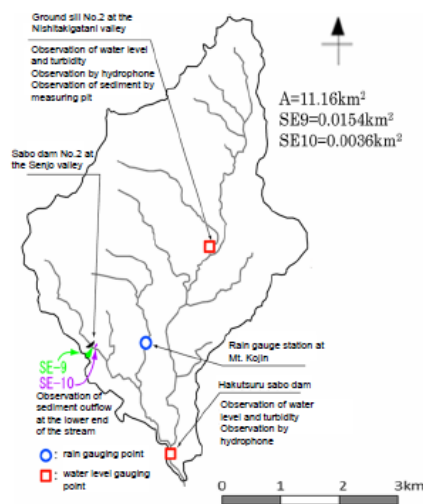


Fig.3 Observation locations for verification

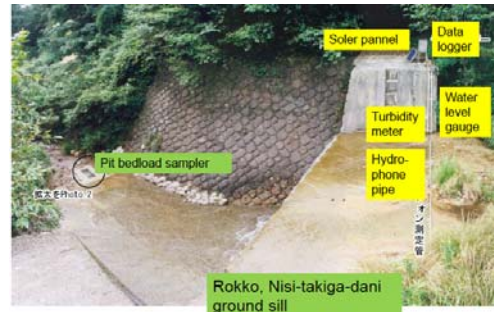


Fig.4 Sediment measurement system

4. APPLICATION OF THE MODEL TO THE SUMIYOSHI RIVER

The WMS was applied to the Sumiyoshi River, and the effectiveness of sabo dams in controlling sediment flow was evaluated for both usual and extreme flood events. The drainage area of the Sumiyoshi River is 11.16 km². In our previous model, the Computer-Aided Sabo Facilities Planning System (CASFPS) the river basin was partitioned into 136 sub-basins, as the sediment supply was assumed to be equal to the sediment transport capacity at upstream ends. For the WMS, the Sumiyoshi River basin was partitioned into 2178 sub-basins to evaluate the surface erosion of slopes and debris flow in torrents.

5. RESULTS AND DISCUSSION

The WMS successfully modeled measured values of runoff and sediment discharge. The system was also applied to extreme events to predict the ability of sabo dams to control sediment discharge. The study area includes 63 sabo dams, and the results indicated that no sediment disasters would occur if the sediment-trap capacities of several downstream dams are maintained by excavation.

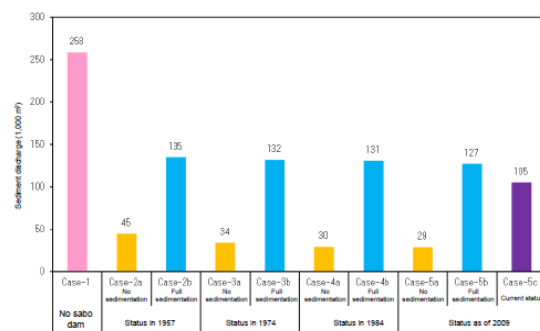


Fig.5 Computed sediment discharge from the mountain area; without sabo dams, no and full sedimentation of sabo dams in 1957, 1974, 1994, 2009 and current status.

REFERENCES:

[1] Mizuyama, T., Y. Tomita, K. Ido, M. Fujita; ComputerAided Sabo Facilities Planning System, Journal of Japan Society of Erosion Control Engineering, 50-6, 1998, pp.40-43 (in Japanese with English abstract)