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Applications of Simulation Technique on Debris-flow Hazard Zone Delineation: A Case Study in Hualien County, Eastern Taiwan

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Occasional rainfall, steep relief, and sufficient debris flow materials are three major components to trigger a debris flow event in a potential debris flow torrent. Since the topographic, geological and hydrologic characteristics of Taiwan are corresponding to the components of occurrence of debris flows, Taiwan is frequently beset by debris flow problems during typhoon and heavy rainfall. These fast-moving flows accompanied by muds and rocks are capable of destroying houses and lives, washing out roads and bridges, or obstructing streams and roadways. To mitigate and manage hazards induced by debris flows, it is necessary to simulate the debris flow route and deposition process. The outcome is very important for determining a possible affected area for each potential debris flow torrent, which is an essential element for producing hazard maps.

Prediction of affected areas may be divided into empirical-statistical and dynamic methods. Although the empirical-statistical methods are easy to utilize, they should only be applied to certain conditions. Dynamic approaches are physical based and take into account the momentum and energy conservation of the flow. The dynamic methods usually have better simulation performance than the empirical-statistical method. Nevertheless, a major difficulty in developing dynamic models for potential hazard area prediction is the choice of appropriate model parameters.

An empirical method initiated by Hiroshi Iketani to identify the debris-flow hazard zones was adopted by the Soil and Water Conservation Bureau of Taiwan currently. This empirical method is consisted of some certain rules as well as an empirical equation which is a function of the debris flow volume and the slope angle below the apex of a debris flow fan. However, the delineating zone for each potential debris flow torrent is often underestimated or overestimated due to complex topography in compared to aerial photo data from historical debris flow disaster events. In order to improve the accuracy of the empirical model for predicting debris flow hazard zones, it is necessary to establish a model which can simulate hazard zones under different rainfall intensity to maintain a reliable level.

In this study, a two-dimensional (2-D) finite difference numerical model FLO-2D developed by O'Brien et al. was chosen to predict areas potentially endangered by debris flows for downstream guarded areas for potential debris flow torrents in Hualien County. The model is based on the governing equation of 2-D Saint Venant equations for non-Newtonian fluids and can simulate flows over complex topographies and roughness on urbanized alluvial fans and river floodplains. Although the model cannot to take into account the erosion of channel bank, which is typically happened along flow channel and in the upstream areas, the model is suited for simulation of flow routing and debris flow deposition by attaining the purpose of this study.

Firstly, the input values of various numerical parameters and their influence on numerical calculations were carried out by sensitivity analyses. Results indicated that the volumetric sediment concentration and yield stress are two parameters to dominate the behaviour of debris flow. The volumetric sediment concentration for simulating a potential debris flow torrent was calculated using Takahashi's debris flow triggering model, in which the sediment concentration is a function of channel slope. The yield stress used in the Flo-2D model was calibrated by means of back analyses to fit field evidence from historical debris-flow disaster data. Results showed that the yield stress varies with the channel slope. The steeper the slope channel, the higher the yield stress. Other parameters used in the model were retrieved from literatures and field investigation. In addition to the model calibration, accuracy of the Flo-2D model for simulating debris flow hazard zones has been performed to prove reliability of the model. Results indicate that the FLO-2D model can accurately replicate one recent debris flow disaster event triggered by Typhoon Feng-Hung starting from July 28 to 29, 2008 caused significant deposition on alluvial fans and channels in two potential debris flow torrents which are Hualien A124 and Hualien 072, respectively.

With this verified model, the model appeared to be capable of predicting and delineating potentially hazardous zones approximately associated with debris flows in a range of varied environments for a selected frequency design flood event. Thus, this study provides the public agent or private sector the necessary information for executing the relevant policies and resource allocation on debris flow prevention.