Apply HEC-RAS to Simulate the Debris Flow Disaster in Nantou County, Taiwan

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1. INTRODUCTION

On 4 Aug 2023, a debris flow disaster occurred at 3:00 PM and rushed into the downstream village causing a gas station and convenience store to be buried by sediment, and 10 houses were inundated by debris flood. The in-situ survey showed that the amount of deposited sediment was estimated at 30,000 m^3 and the average deposition depth is 2 m. A two-dimensional debris flow model was applied to analyze the sediment movement, bridge blockage, and channel widening affect the debris flow impact zone. This study uses the digital elevation model (DEM, Fig. 1) before the event was set as initial topographic data and field investigation data, and the posterior DSM (Fig. 1) was produced by UAV aerial photos to verify the simulation result. The numerical model can estimate the characteristics of debris flow hazard zone, flow velocity, and deposition depth. The simulated result can provide public agencies with the necessary information for disaster prevention and mitigation plan

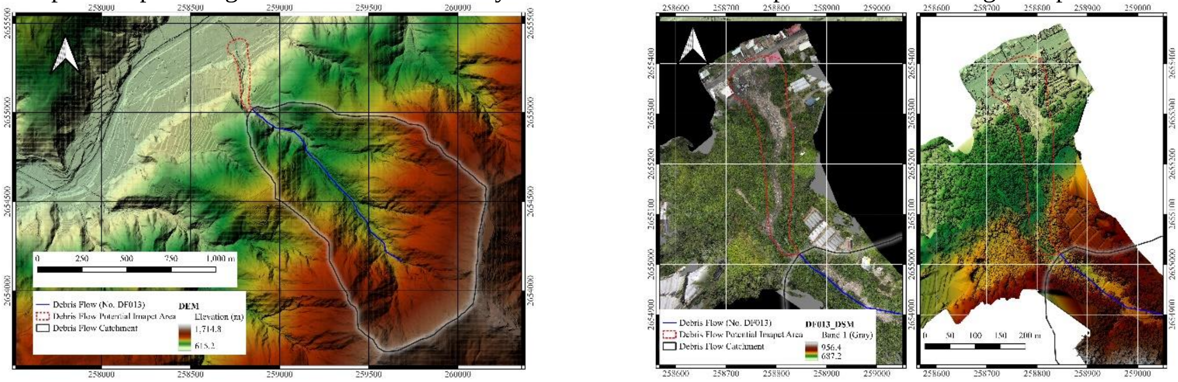

Fig. 1 Location of the study area: Digital Elevation Model (left); Aerial-photo and Digital Surface Model (right).

2. MATERIALS AND METHOD

(1) Site condition

The debris flow occurred at 3:00 PM (August 4, 2023) and the precipitation accumulated up to 648 mm (NanFung Rain Gauge, 88H890) and rainfall intensity was 49 mm/hr. The upstream area didn't appear slump area and the sediment source was mainly from the previous deposition on the river. The amount of sediment volume rushed into the downstream village was estimated at 30,000 m^3. The debris flow formed a deposition zone of 170 m long, 450 m wide, and averaged deposition depth of 2 m. To analyze the debris flow impact zone, this study uses the digital elevation model (DEM, resolution 1 m x 1 m) and high-resolution digital surface model (resolution 0.1 m x 0.1 m) data from UAV-photo.

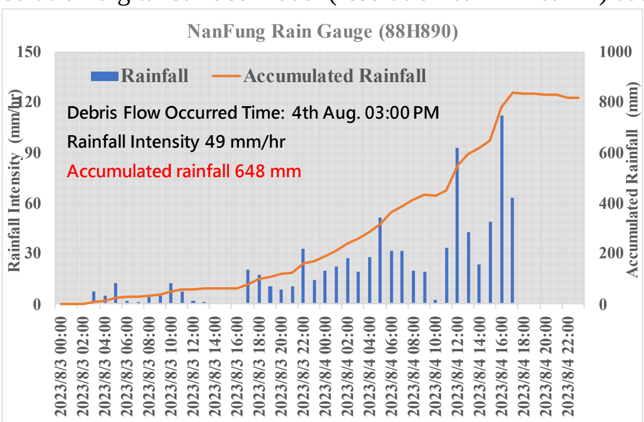

Fig. 2 Rainfall hydrograph of Nanfung Rain Gauge

Fig. 3 In-situ survey of disaster area (date: 2023/08/07)

(2) Scenario of debris flow simulation

This study applied the HEC-RAS 2D debris flow model to simulate debris flow disasters considering channel contraction and widened effect conditions. The HEC-RAS 2D model can be divided into three steps to set up debris flow numerical simulations. The geometry data was obtained from a digital elevation model and converted into a gridded mesh format while considering the retaining wall, bridge block effect, and channel widen condition. The boundary condition is supplied hydrograph and sediment concentration upstream. Once the simulation was complete, the model hydraulics results including flow depth, velocity, discharge, and shear stress. The results can be further exported as SHP format for GIS software to map debris flow impacted areas and plan the mitigation work.

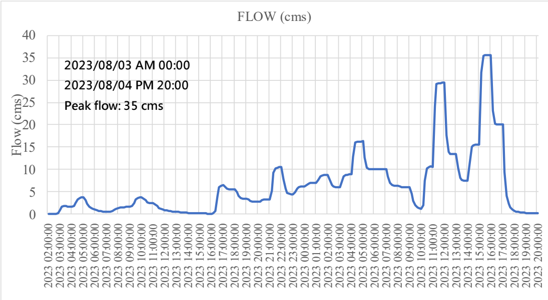

Fig. 4 Flow hydrograph of unsteady flow boundary condition

Table 1 Parameters of the simulation

Case Number	Discharge Q_p (m^3/s)	Model parameter			
		n	Tau	Mu	Cv%
Run 1	35	0.06	1000	250	0.3
Run 2	35	0.06	2000	250	0.3
Run 3	35	0.06	1000	1000	0.3
Note	Q_p: Peak discharge; Cv: Concentration (%); n: Manning's roughness coefficient (s/m$^{1/3}$); Tau: shear stress (Pa); Mu: Viscosity (Pa·s)				

The debris flow initial state considered the different shear stress and viscosity of debris flow to start the simulation. Based on the field survey data, the simulation domain could be identified as **Fig. 1**. The parameters used in the model are listed in **Table 1**, the mesh size is 10 m x 10 m and the number of grid points is 13,432. The flow hydrograph was estimated by the rainfall-runoff model of HEC-RAS and imported as the upstream boundary condition for debris flow impact analysis.

3. RESULTS AND DISCUSSIONS

The simulation result indicates that the gas station in the outlet of the debris flows and has a direct impact on it. The debris flow directly rushed into the gas station and nearby building, and which large amount of sediment buried the building. The effect of bridge blockage resulted in sediment overflow on the road and the maximum deposition depth was 3.4 m. Considering the channel-widening effect, although the debris flow still rushed into the gas station, at which the deposited depth was 0.8 m and the inundation area was reduced from 29,550 m^2 to 3,770 m^2. (Fig. 5 and 6).

4. CONCLUSIONS

HEC-RAS can analyze debris flow with four non-Newtonian methods. The main parameter considers volumetric concentration, yield strength, and dynamic viscosity, which can be easily set up to estimate the impact of a debris flow event. In this preliminary study, the model considering the effects of bridge blockage, retaining wall, and channel-widening, the simulation of deposited area, depth, flow velocity, and inundation area were calculated. The result indicates that the bridge blockage severely affects the debris flow downstream impact zone. Through this case study, the debris flow impact simulation depends on the detailed field investigation and needs to consider the effect of bridge blockage and engineering work. Applied the HEC-RAS for debris flow simulation can provide the necessary information for officials to plan mitigation and engineering plans.

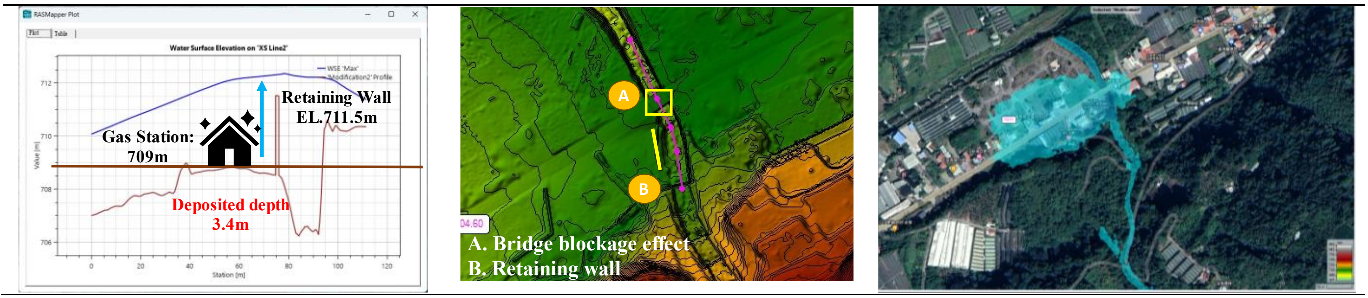

Fig. 5 The debris flow disaster simulation results: (left) Cross section, (mid) location of bridge and retaining wall, (right) inundation area.

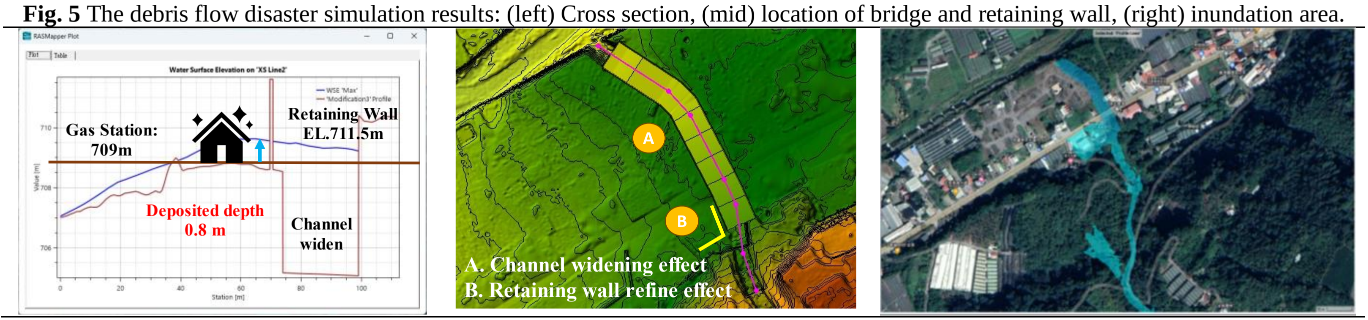

Fig.6 The debris flow disaster simulation results: (left) Cross section, (mid) location of channel-widen, (right) inundation area.

References

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Keywords: Debris flow, In situ survey, Bridge blockage effect, HEC-RAS 2D.