DEBRIS FLOW CHARACTERISTIC ALONG THE MAIN CHANNEL WITH STRUCTURES IN THE ARENAL DE MEJICANOS, SAN SALVADOR, EL SALVADOR

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1. INTRODUCTION

El Salvador is a country prone to sediment-related disaster, especially debris flow, due to heavy rainfall and volcanic geology. Actually, Arenal de Mejicanos, one of the basin and the river involving the San Salvador Volcano shown in Fig.1, has been vulnerable with debris flow. On the other hand, the Mejicanos city inside of the basin has urbanized disorderly, including the structures like bridges and underpass along the channel of the basin without any design concerning about hydraulic capacity. For example, Fig.2 shows one of the stereotypes bridge which is located at the debris flow path. Actually, when the debris flow occurred, those bridges cause the clogging of the debris flow as shown in Fig.3. Thereafter, inundation by the flood water takes place around upstream side of the bridges. As Fig.3 indicates, excavation works have to be conducted whenever clogging takes place. This research aims to analyze the debris flow phenomena, and analyze the volume of water and sediment discharge to design the channel opening for letting the water/sediment path thorough. For this purposes, authors conducted 1-D numerical simulation of the debris flow.

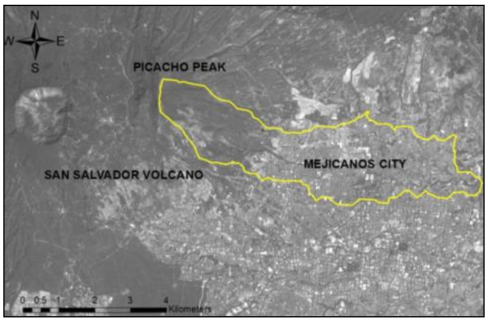

Fig.1 Sub-basin Arenal de Mejicanos and San Salvador Volcano


Fig.2 Narrowing of Channel limiting Hydraulic capacity.


Fig.3 one of the example of excavation works after debris flow.

2. BASIN

The Arenal de Mejicanos basin and river, has the catchment size of 14.79 km^2 and averaged bed slope of 17.81% (MARN 2012). As Fig. 4 indicates, the river channel starts from Picacho with steeper slope (greater than 20 degree). With decreasing the slope angle, the urbanized area appears where the slope angle is still more than 10 degree, which is usually active erosion and deposition of debris flow takes places. On the other hand, averaged monthly precipitation during rainy season is about 340mm, where the precipitation threshold for debris flow is 230 mm/15days; 90 mm/3days and 60 mm/day (SNET, 2004).

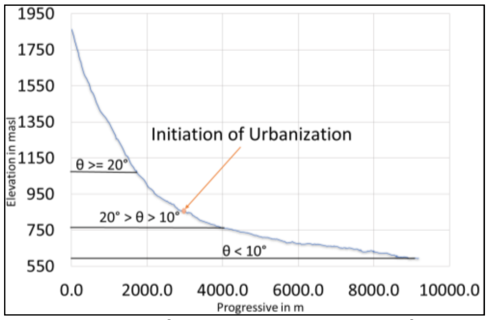

Fig.4 Riverbed Profile using Topographic Information.

3. METHODOLOGY

3.1 Governing Equation

For this study, the governing equations are constructed as following, the mass conservation equation is

$$\frac{\partial h}{\partial t}+\frac{1}{B}\frac{\partial \bar{u}hB}{\partial x}=\frac{E}{c_*} \qquad (1)$$

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, where h is flow depth, $\bar{u}$ is averaged velocity, B is the channel width, E is erosion rate or erosion velocity, C_* is the sediment concentration of the stationary sediment layer. On the other hand, the mass conservation equation of sediment is:

$$\frac{\partial \bar{c}h}{\partial t}+\frac{1}{B}\frac{\partial \gamma \bar{c}\bar{u}hB}{\partial x}=E \quad (2)$$

, where $\bar{c}$ is the spatial average sediment concentration, and γ correction parameter for the sediment transport rate. The momentum equation with diffusion approximation is

$$gh\sin\theta\text{-}gh\cos\theta\frac{\partial h}{\partial x}=\frac{\tau_b}{\rho_m} \quad (3)$$

, where θ is the bed slope, $\overline{\rho_m}$ is the specially averaged mass density of debris flow,

$$\tau_b=\tau_y+\rho f_b\bar{u}^2 \quad (4)$$

, where τ_y is the yield stress at bed surface, and f_b is the friction factor. fb includes the static granular pressure resulting particle-particle contacts, and the shear stress resulting from inelastic particle-particle collisions, which is function of the sediment concentration resulting from the erosion and deposition of the debris flow (by Egashira 2011). Erosion can be calculated as

$$\frac{E}{\bar{u}}=c_*\tan(\theta\text{-}\theta_e) \quad (5)$$

Where $\theta_{e=}$ is the equilibrium bed slope corresponding to spatial average sediment concentration of the debris flow body.

3.2. Initial and Boundary condition

Boundary condition is determined by geometry starting from following steps: First, an area which is more than 20 degree are estimated assuming there are no sediment at the bottom of the channel, since slope is too steep to remain sediment on the channel. Starting from the point where the slope of 20 degree, calculation domain can be determined till the pint of the interest. In this study, downstream end of the calculation domain was assigned at where the urbanization begins as shown in Fig. 4. In between the two points, one single slope channel with 16 degree as averaged bed slope is employed for the initial condition. Concerning about the water discharge from upper boundary, based on rainfall-runoff coefficient, the catchment area, monthly average rainfall during rainy season, 8.45 m^3/s is estimated. Additionally, the 0.1m is used for sediment size, 15m for the channel width, and 10m for the potential erosion depth. Concerning about calculation, dx 10m and dt=0.01, and the total duration of calculation is 2000s, which is as same as the duration of time for the water supply.

4. RESULTS

Fig.5 shows the time series of depth and discharge of debris flow, and river bed elevation at the point of 2400m in the Fig.3. In this figure, water supply started at the time of zero. As this figure indicates, the debris flow reached at this point within 88 seconds. Since the point is 900m downstream from the upper boundary, celerity of the debris flow is about 10m/s. After it reached to the point, water depth reached to 0.8m and debris flow discharge of 90 m^3/s, which is about 10 times larger than supplying water volume. Thereafter, water depth

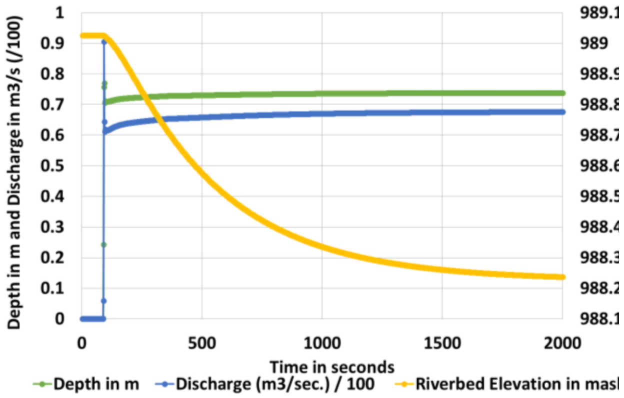

Fig.5 Time series of debris flow depth, discharge, and river bed elevation at the point of 2400m in the Fig.3

decreased to 0.7m and gradually increases till 0.74m. The debris flow discharge also has similar trend. Concerning about the river bed elevation, initially it is 989.3m, and starts to decrease because of riverbed erosion by the debris flow. The river bed elevation keeps decreasing till 988.2m, which is mostly reached to equilibrium level. Therefore, about 1.1m of erosion takes place at this point by the debris flow.

5. CONSLUSIONS

Based on the discussion above, following points can be re-stated again as conclusion.

1) The situation of debris flow in Arenal de Mejicanos in El Salvador was well documented.
2) Most importantly, design of the river structures along the river, especially bridge and underpass does not concern about volume of debris flow.
3) 1-D numerical simulation was conducted in this reach for estimating the debris flow discharge.
4) Boundary condition was estimated by the area and local rainfall.
5) On this numerical simulation, shear stress with changing of sediment concentration were implemented.
6) Based on the numerical simulation, the celerity of debris flow was calculated as about 10m/s, and debris flow discharge is about 10 times larger than the volume of only water.

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