



Calibration of numerical models for small debris flows in Yosemite Valley, California, USA

P. Bertolo (1) and G.F. Wieczorek (2)

(1) Politecnico di Torino, DITAG, Italy, (2) U.S. Geological Survey, Menlo Park, CA, USA
(paola.bertolo@polito.it, gwieczor@usgs.gov)

Introduction

This study compares documented debris flow runout distances with numerical simulations in the Yosemite Valley of California, USA, where about 15% of historical events of slope instability can be classified as debris flows and debris slides (Wieczorek and Snyder, 2004). Although no people have been killed by debris flows and debris slides in this area, several roads and trails have been damaged since 1851, and some debris flows have carried rocky debris far into the valley even on moderately gentle slopes onto the banks of the Merced River.

Yosemite Valley was glaciated during the Pleistocene and its steep walls consist basically of granitic rocks: the most prominent geologic units within the debris flow study area are the El Captain Granite and the Sentinel Granodiorite (Calkins, 1985).

Debris-Flow Modeling

To model debris flows in the Yosemite Valley, we selected six streams with evidence of historical debris flows including boulder levees and snouts; three of the debris flow deposits have single channels, and the other three split their pattern in the fan area into two or more channels. From field observations all of the debris flows involved coarse material, with only very small clay content. The catchment areas above the debris-flow fans range from 0.3 to 5 km².

We applied the one dimensional DAN (Dynamic ANALysis) model (Hung, 1995) and the two-dimensional FLO-2D model (O'Brien et al., 1993) to predict and compare the runout distance and the velocity of the debris flows observed in the study area. To implement these models, the parameters required for different rheologies (like the

friction angle and the pore pressure coefficient for the Frictional Model, the yield strength and the Bingham viscosity for the Bingham Model, the friction coefficient and the turbulence coefficient for the Voellmy Two Parameter Model) need to be evaluated. As a first step, we calibrated the parameters through the back analysis of three debris-flows channels using a trial-and-error procedure starting with values suggested in the literature. In the second step we applied the selected values to the other channels, in order to evaluate their predictive capabilities.

In the computer program DAN, based on an explicit Lagrangian solution of unsteady non-uniform flow in a shallow open channel, different rheological models for material involved in rapid landslides are available. The DAN model reduces the problem into a one-dimensional formulation which is simple to calibrate. After several back analysis we selected the Frictional Model for the source material, with a bulk friction angle between 24° and 26° , and the Voellmy Two Parameter Model for the variation of material properties along the flow path, with a friction angle ranging between 5.7° and 11.5° (friction coefficient $0.1 - 0.2$) and a turbulence coefficient of 500 m/s^2 . The DAN model can take account also of the amount of material entrained by the flow along the path thereby increasing the final volume deposited. We tested this option, but it didn't influence the runout distance of the study cases, probably because all the events were relatively small debris flows, with a volume of involved solid material less than 1000 m^3 .

FLO-2D is a volume conservation model that distributes a flood hydrograph over a system of square grid elements (FLO-2D Manual): we used the 30 m DTM from the National Elevation Dataset, produced by the USGS, to represent the topography. The program routes hyperconcentrated sediment flows using a quadratic rheologic model for predicting viscous and yield stresses as a function of sediment concentration. For the viscosity, we used a coefficient $a = 2.72$ and an exponent $b = 11$, and for the yield stress relation we used coefficient $a = 0.054$ and exponent $b = 14.5$, selected as the best values from the back analysis. In the input hydrograph the maximum sediment concentration by volume during the simulation was up to 75%. The Manning's coefficient n -values, based on field observations, were 0.05 to 0.2 for the floodplains and 0.04 to 0.75 for the channels.

Conclusions

After parameter calibration using three debris flows we obtained accurate runout distance from both models. The FLO-2D model created a representation of the material spreading on the fan and depicted where the channels split. Both of these results were similar to field observations.

We also obtained a good agreement between the two models for velocities, with max-

imum values of 20 m/s in the upper portion of the channels where the slope is about 30°. Values ranging from 3 to 7 m/s were simulated near the top of the fan.

Both models are strongly influenced by topography: DAN uses a 1-D stream profile, we obtained from the DTM, and FLO-2D uses a 2-D DTM. We used the 30 m cell size DTM available for the study area, that is probably not accurate enough for a highly detailed analysis, but it can be sufficient for a first screening.

Field investigation is the first and most important step to assess potential debris flows because all model input parameters, including the terrain model, can be enhanced using information collected during direct field observations of the site. Although the calibrated values of the rheological parameters used in the models differ from one case to another, the simulated order of magnitude effects of these events can be useful to predict future events in this area in order to produce hazard and risk mapping. These estimated parameters can also give a good range to predict debris flow behavior in other places with geology, morphology and climate similar to the investigated area.

References

- Calkins, F.C., 1985. Bedrock geologic map of Yosemite Valley. Yosemite National Park, California, *with accompanying pamphlet by* Huber, N.K. and Roller, J.A., Bedrock geology of the Yosemite Valley area Yosemite National Park, California, U.S. Geological Survey Miscellaneous Investigations Series Map I-1639, scale 1:24,000
- Hung, O., 1995. A model for the runout analysis of rapid flow slide, debris flow, and avalanches. *Canadian Geotechnical Journal*, 32: 610-623.
- Johnson, A.M., 1970. Physical processes in geology. San Francisco, Freeman, Cooper & Company: 577.
- O'Brien, J.S., Julien, P.Y. and Fullerton, W.T., 1993. Two-dimensional water flood and mudflow simulation. *Journal of Hydraulic Engineering*, 119 (2): 244-259.
- Varnes, D.J., 1978. Slope movement types and processes, *in* Schuster, R.L., & Krizek, R.J., Landslides analysis and control: Washington, D.C., Transportation Research Board, National
- Academy of Science, Special Report 176: 12-33.
- Wieczorek, G.F., and Snyder, J.B., 2004. Historical Rock Falls in Yosemite National Park, California. U.S. Geological Survey Open File Report 03-491.