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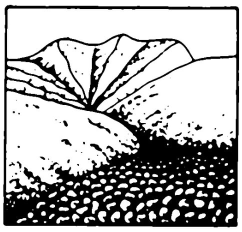
DEBRIS FLOWS: Disasters, Risk, Forecast, Protection

Pyatigorsk, Russia, 22-29 September 2008



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Conference logo is based on a figure from S.M. Fleishman’s book on Debris Flows (Moscow: Geografgiz, 1951, p. 51).

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Debris flow hazard assessment in Dolomites: a simulation model approach

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Оценка селевой опасности в Доломитовых Альпах: подход через моделирование

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This article presents a procedure for evaluating the debris flow hazard on a local scale; this approach was applied to three basins near Cortina d’Ampezzo, Eastern Dolomites, Italy. The procedure consisted of a geomorphologic and geological study to determine the potential initiation zones and design volumes of future debris flows for each basin. The bi-dimensional numerical code FLO-2D was applied to analyse the sample basins with 5 different rheologies. The hazard areas have been delineated as a combination of runout, flow depth and velocity. A final hazard map, at a scale of 1:10000, provides an essential tool for local land use planning.

1 Introduction

Debris flow-prone areas can be easily identified through field experience and evidence of previous events. However, it is the accurate prediction of runout distances, velocities and the knowledge of flow rheology that can reduce damages, providing means to produce hazard maps and to provide parameters for the design of protective measures.

During the last decade, the bi-dimensional model FLO-2D (O’Brien et al., 1993) is being used increasingly for debris-flow simulation as a useful tool for predictive purposes and hazard map delineation, in many studies on hazard and risk assessment (Tecca et al., 2006).

The aim of this paper is to present a procedure to assess the debris flow hazard at local scale using FLO-2D to model both propagation and expansion of debris flows. The methodology has been applied to three small basins of the western slope of the Mount Pomagagnon (Cortina d’Ampezzo, Italian Eastern Alps). The results focus on the assumed approach and on its possible application to other mountainous areas.

2 Study area

The debris flows basins are located on the left side of the Boite R. Valley, in the Eastern Dolomites, Italy (Fig. 1). 325 debris flow watersheds have been detected in the whole area, characterised by the presence of high Triassic dolomites and limestones cliffs. The bedrock is covered by very thick quaternary deposits, mainly screes and landslides deposits formed by coarse (sands to blocks) granular soils with slope angles ranging from 35°–40°, at the base of the cliff, to 10°-15° at the valley bottom.

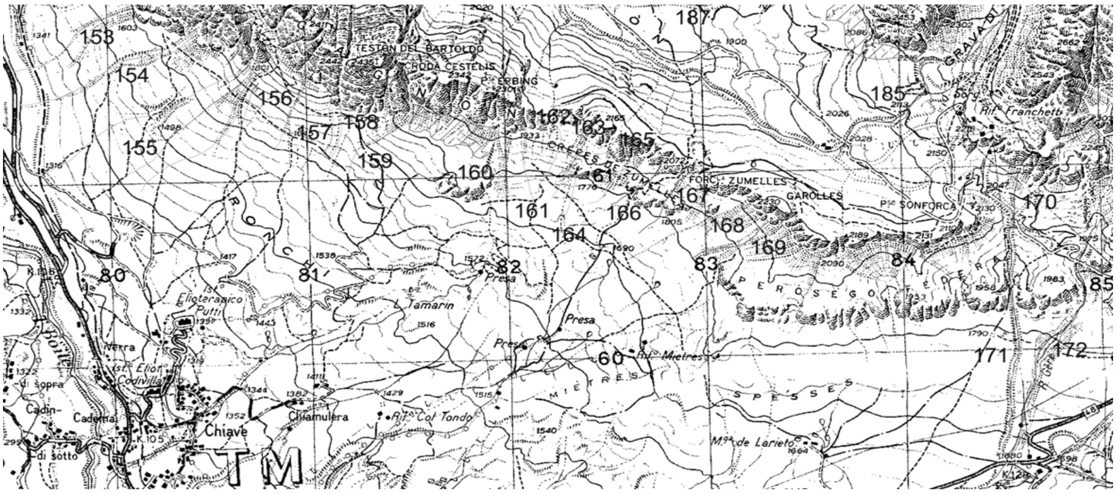


Figure 1. Location of the three debris flow channels: no. 154, 155, 172.

The debris flows occur during intense summer rainstorms with a biennial or higher frequency; volume estimation of past events in the three studied basins range between 6000 and 30000 m^3. Discharges of debris often affect existing buildings, and may dam the Boite River. Basic morphometric parameters of the three basins are listed in Table 1.

Table 1. Main morphometric parameters of the three basins coded as in the geomorphological map

	n. 172 (Gere)	n. 155 (Fiames)	n. 154
Rock basin area (km^2)	0.66	0.13	0.03
Basin maximum elevation (m a.s.l.)	3218	2450	2308
Channel length (m)	2097	1417	953
Mean channel slope (°)	18	23	25

3 Methodology

In this study, we established a three-step approach to assess debris flow hazards

The first step consisted of a geomorphologic and geologic air-photo interpretation and of field surveys, in order to identify the potential debris flow initiation zones and the availability of loose material, in order to assess for each basin the maximum potential total volume (V_{tot}) of the process. V_{tot} has been assessed as the sum of the initial volume (V_i) and the scour volume along the flow channel (V_c), based on scour rate of 15-25 m^3/m for the dolomitic area (Marchi and Tecca, 1996). The second step predicts the runout and depth of deposits through numerical simulations using FLO-2D, a two-dimensional finite difference routing model for water and non-Newtonian flows on alluvial fans. The model can predict the area of inundation, flow velocity and depth, and simulates flow cessation, maintaining mass conservation for both the water and sediment volumes. FLO-2D is a rigid bed model; the flood hydrograph is routed solving the momentum equation that includes the viscous and yield stresses (FLO-2D Software Inc., 2006).

The design debris flows (V_{tot}) have been routed for five different rheologies. Because no clearly delineated debris flow was available for back-analysis, the range of variability has been selected based on the rheological properties calculated through the analysis of a similar debris flow (Tecca et al. 2003). The rheological properties values, calculated for a sediment concentration by volume Cv= 0.55, are listed in Table 2.

Table 2. Calculated yield stress and viscosity for Cv=0.55.

Rheology	Viscosity η (Pa s)	Yield stress τ_y (Pa)
R 1	2	3893
R 2	36	928
R 3	88	218
R 4	135	83
R 5	147	184

A roughness n-value of 0.18 was assumed, typical for open ground with debris; the specific weight of the mixture γ_m and the resistance parameter for laminar flow K, were assumed equals to 26.5 kN/m^3 and 2285 respectively, as suggested values for debris flows. The hydrologic model CLEM (Cazorzi, 2002) has been used to predict the design storm rainfall-runoff hydrograph, assuming flow velocities of 2 m/s and 0.03 m/s in the flow net and over the slope respectively. The maximum annual rainfall series (1984-2004) of the nearest station have been analyzed; the design hydrograph has been obtained, considering the upper confidence limits of depth-duration-frequency curve for a return period of 200 years. The sediment concentration by volume assigned to the hydrograph, ranges between not less than 0.3 along the rising and falling limbs of the hydrograph, and a maximum of 0.55 corresponding to a mature debris flow. The peak discharge was assigned a sediment concentration slightly less than the frontal wave to account for water dilution.

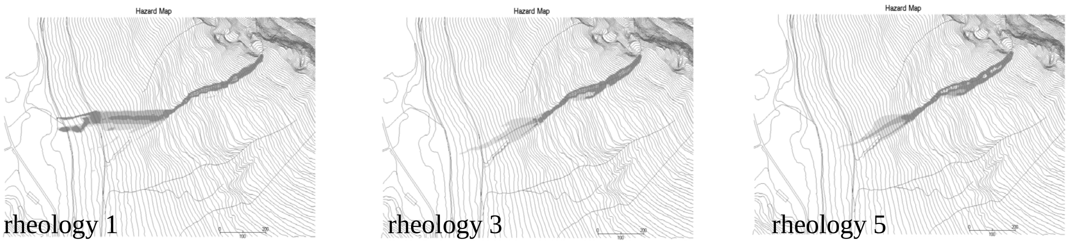
For each rheology, adebris flow hazard map has been obtained: different areas are classified into different hazard levels defined in terms of a combination of flow depth (h) and the product depth times velocity (hv), based on literature data and on our own experience on Dolomites debris flows (Table 2).

Table 3. Hazard degrees range.

Definition of mud or debris flow intensity			
	Maximum depth h (m)		maximum depth h times maximum velocity v (m^2/s)
High	h>= 1.0 m	OR	v h > =1.0 m^2/s
Medium	h>= 0.4 m	AND	v h >= 0.4 m^2/s
Low	h>= 0.2 m		v h >= 0.2 m^2/s

4 *Results*

The following values of design debris volumes, for Gere, Fiames and no. 154 basins, were estimated for numerical simulations: 30000, 30000 and 15000 m^3. Five runs with the different combinations of rheologies were calculated for each basin. As an example, Figure 2 shows the hazard zonation at n. 154 basin, for the lowest, medium and higher viscosity (rheologies 1, 3 and 5 respectively).



rheology 1 rheology 3 rheology 5

Figure 2. Hazard maps at no. 154 debris flow site for the rheologies 1, 3 and 5.

In case of low viscosity, the velocity and flow depth show high intensity values (v>1 m/s and h>1 m) until the flows reaches the road; medium or low intensity are indicated in the middle slope. Different flow behaviour is displayed with the rheologies 3 and 5 where high hazard is exclusively related to the flow path and to the upper part of the slope, whereas the middle part is located within the moderate hazard zone. The lower part of the slope was considered a low hazard zone because indirect impact by slurry flows or afterflows seem to be here possible. Very low hazard was only defined at the marginal parts of the slope.

The final hazard map (1:5000) for the n. 154 debris flow is obtained by superposition of the hazard maps obtained for each rheology, combining the different hazard classes, and delineating comprehensive low, medium and high hazard areas. This map is not presented here as it cannot be well displayed for space reasons. However, the runs showed the most critical channel section is located just where the slope decreases its gradient and the debris flow, depending on the rheology, would break out of the channel and mainly move downslope on the southern sector of the slope.

5 Discussion and conclusions

The results obtained show the need of a comprehensive debris flow hazard assessment and the usefulness of such studies for adequate urban planning. The fast growth of urbanisation and the limited space in the valley floors have created a need to construct buildings and transportation links on the debris fans.

The study establishes a procedure to evaluate the debris flow hazard at a local scale applied to three debris flow catchments of the Cortina d’Ampezzo area. The final hazard maps showed that all three basins had a moderate or even high hazard degree in the areas already urbanized or selected for future urbanisation. The multi-step approach established for hazard assessment combines the results obtained from a geomorphologic– geologic study and numerical simulations. Taking into account the different steps of the assessment, volume estimates of the design debris flows were a rather problematic and delicate task because of the lack of historic data. This problem can be overcome by the use of a two-dimensional numerical model that simulates the debris flow spreading on the fan. Such two-dimensional modelling, however, strongly depends on the accuracy of the digital elevation model and never replaces the critical examination in the field of the simulation results focusing on morphologic and hydraulic aspects. Because of its simplicity and the very low cost– benefit rate, the present approach can be applied to debris flow catchments in other mountainous areas.

References

Cazorzi F., HyGrid2k2, Guida di riferimento. Università degli Studi di Udine, 2002.

Marchi L., Tecca P.R. Magnitudo delle colate detritiche nelle Alpi Orientali Italiane. – Geoingegneria Ambientale e Mineraria, vol. 33, No. 2–3, 1996, p. 79–86.

Meei-Ling Lin, Kuo-LungWang, Jih-Jen Huang. Debris flow run-off simulation using FLO-2D. An example of Chui-Sue River watershed, Taiwan. – Geophysical Research Abstracts, vol. 6, 05923: 2004.

O’Brien J.S., Julien P.Y., Fullerton W.T. Two-dimensional water flood and mudflow simulation. – Journal of Hydraulic Engineering, vol. 119, No. 2, 1993, p. 244-259.

FLO-2D, 2-Dimensional Flood Routine Model Manual. Version 2004.10. FLO-2D Software Inc., Nutrioso, AZ 85932, 2004.

Tecca P.R., Deganutti A.M., Genevois R., Galgaro A. Velocity distribution in a coarse debris flow. – Rickenmann D. & Chen C.-L. (eds.). Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment. Proceedings of Third International Conference. Davos, Switzerland. Rotterdam: Millpress, 2003, p. 905-916.

Tecca P.R., Armento C., Genevois R. Debris flow hazard and mitigation works in Fiames slope (Dolomites, Italy). – Lorenzini G., Brebbia C.A., Emmanouloudis D. (eds.). Proceedings of the 1st International Conference on Monitoring, Simulation, Prevention and Remediation of Dense and Debris flows. Rhodes, Greece. Southampton: WIT Press, 2006, p. 15-25.