Internationales Symposion
INTERPRAEVENT 2000 – VILLACH / ÖSTERREICH
Tagungspublikation, Band 3, Seite 321 – 333

PREDICTABILITY OF THE MASS TRANSPORT OF SEDIMENTS IN ALPINE CATCHMENTS. THE CASE STUDY OF T. THURAS (NW ITALY)

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ABSTRACT

A predictive model is described, whence the magnitude or total debris/sediment volume mobilised by a paroxysmal event in given catchments can be evaluated, combining together 1) the effective (true) catchment area, 2) the average slope of the catchment, 3) the ratio of "active" debris supply areas to the effective catchment area, 4) the estimated depth of in- channel deposits and the extent of the "potential" debris supply areas (landslide masses, old in-channel deposits partly stabilised, erosional gullies, glacial deposits), 5) a frequency factor which is related to the average number of years between paroxysmal events in a given catchment in the time span of one hundred years. In the Thuras catchment (Province of Turin, Piedmont), a retrospective analysis of previous processes was made over the last 45 years, making use of aerial photographs taken about every ten years. An empirical relationship closely linking the effective sub-catchment areas and the sediment delivery fan areas has been found in the form of a linear correlation.

INTRODUCTION

Almost every year, several debris flows take place in the ring of the Italian Alps, provoking damages to houses, interruption of roads and sometimes endangering (and even killing) human lives. Out of the some 20 main valleys in which the mountain range can be subdivided, the Adda Valley (Valtelline) can be deemed emblematic for study the damaging effects of the torrential floods; in the last two centuries (1807-1999), at least 140 tributaries in such valley experienced 170 flood events with destructive effects. Flood damages brought by single catchments are recorded 1 to 5 times a century; most of the events (84%) affected one to four catchments, the others (16%) involved larger portions of territory, contemporarily affecting 5 to 10 sub- valleys, and even more. In 65% of cases, flooding occur in Summer, thus possible dangers regard not only residents but also travellers, holiday makers and so on.

The data kept by the CNR-IRPI Institute in Turin mostly refer to unpublished (archival) reports, historical books, technical magazines, hydrologic records, selected articles from local newspapers, aerial and terrestrial photographs, historical and current cartography. All such materials concern slope instability processes and stream floods recorded in Northern Italy (Alps, Apennine and Po River plain) during a time span which mostly ranges from 50 to 200 years, in some cases extending back to the XVIIth Century. Such heritage allows to establish for not less than 2000 mountain watersheds in Northern Italy morphological characteristics, dynamic behaviour of torrents and paroxysmal flood events throughout time. In addition, almost the whole flood events occurred in NW Italy since 30 years have been systematically surveyed by staff members of IRPI, at the aim to collect the largest quantity of technical informations about the phenomena and their effects. At the same time, several laboratory tests have been carried out in order to characterise geotechnically parent materials as well debris and sediments set in motion by floodwaters. The on- site and laboratory experience acquired in several occasions, allowed to adjust and validate the observations drawn by reading of archival and literature reports and photo-aerial interpretation.

PRELIMINARY FINDINGS

Taking advantage by the knowledge so acquired about the occurrence in space and time and characteristics of the debris mass transport by Alpine torrents, at first a given number of catchments (most of which in the Western Alps) has been selected, according to the different geological and morphological environments, frequency and magnitude of the events. All the catchments more than once, in a global time span of 388 years (1610-1998), undergone to severe floods, often accompanied by transport of heavy detrital masses. Most of the paroxysmal events (67% of cases) occurred 3 to 30 times per century, while in 10% of cases they are reported as happened only once a century; for this reason, a particular dangerousness of next occurring events should be expected. The torrents under consideration are incised in different kinds of bedrock (granite, gneiss, ophiolite, dolomite, calcschist) in very different conditions of Quaternary cover (moraine, debris talus, colluvium), soil and land use. The topographical characteristics also strongly vary (catchment areas between 0.1 and 15 km^2, average slope gradients from 20% to 140%). The elevation range is comprised between 300 and 3500 m a.s.l.

Combined together, various parameters have been found which allow to evaluate on statistical basis the maximum debris and sediment amounts liable to be discharged during extreme rainfall events. A predictory formula (Tropeano and Turconi 1999) was then expressed as:

$$V = [AE*tgs*r*h*(n+1)*e^{f}]/1000$$

where: V (m^3) is the total displaced volume estimated (magnitude), AE (m^2) is the effective catchment area, h (m) is the estimated mean depth (by field assessment) of the removable layer of sediment involved in motion, tgs is the average catchment slope, r is the per cent of areal extent of materials easily liable to move, related to AE; n $(0\div10)$ is a coefficient expressing a proportion between the debris available in a longer time and AE, and f (exponent of the Napierian number 2.81=e) is a frequency factor defined as above. The determination coefficient (R^2) so resulting (number of variates is 35) is rather significant being equal to 0.696.

We believe that the soundness of the model proposed can be demonstrated not so much by the numerical value above, as by the concreteness of the data offered by the natural environment. At this purpose, a test has been made in a restricted areal range, where the physical conditions (topography, geology, geomorphology) were quite the same for a significant number of catchments. The chosen area (T. Thuras basin) is located in the High Dora Riparia Valley (Piemonte). Here, a short-lasting rain affected on 12 August 1998 almost the entire upper half of the valley between 1900 and 3200 m a.s.l. An analysis of the serious effects the storm left behind it on the slopes, gave rise to the present research.

THE CASE STUDY: SITE DESCRIPTION

The Thuras catchment accounts for an area of 29.4 km², a lenght of the main stream of 8.76 km and a max-min elevation of 3302 m and 1750 m respectively (Fig. 1). Both valley sides are dissected by about thirty sub-catchments of between 0.05 and 4.3 km² in area; the mean slope gradients range from 70% to 130%; the mean slope of the fans is between 20% and 60%. The catchment is incised in Jurassic Calcschist directed SSE-NNW dipping southwestward; the middle part of the right slope is composed by Triassic dolomite rising on steep walls. The valley asymmetry is reflected by several couloirs issuing from the left side into the steepest and large, mixed fans originated by rockfalls, debris flows and snow avalanches (Figs. 2, 3). Avalanche occurrences in the reach of valley under study are recorded since 1895. Between 1934 and 1970 at least thirty events were recorded, during which dirty snow masses accumulated over a front width of up to 100 m and a volume of up to 300,000 m³. Minor detrital masses are occasionally conveyed by avalanches still today (Fig. 4). A minor part of some fans (2%) is also built by large blocks fallen by the rocky slopes upwards (Fig. 5). The opposite slope of the valley is gentler and slightly incised, thus showing a mature stage of evolution, with large, deep-seated slope deformations. Generally, no debris or sediment amounts are in the present geomorphologic conditions supplied to the main stream from the right slope. An exception is made by the carbonatic rocky complex that can yield to the main stream even large (thousands of m³) volumes of coarse debris, which sometimes results in stream damming.

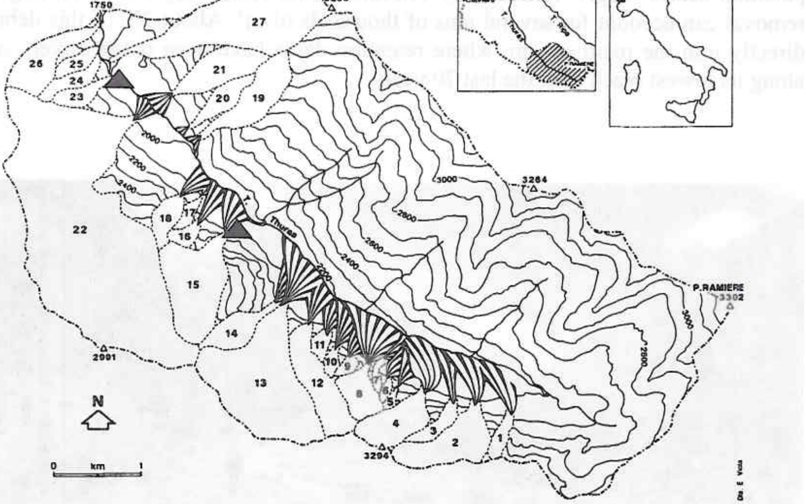

Fig. 1 – Sketchmap of T. Thuras basin, with location of sub-catchments, relating mixed debris fans and and survey sites (triangles) for travel distances of painted sediments in the main stream.

One third of the catchment is bare, being mostly vegetated by herbs and shrubs, and conifers on the lower part of the slopes. The slope profile of the talweg is slightly concave to rectilinear in most parts, and abruptly inflects due to two chutes (cascades) connecting the upper sector to the lowest at about 1900 m a.s.l., thus dropping 200 m on a reach 1 km long (Fig. 6). In this reach the contribution of some tributaries directly discharging debris masses into narrow gorges plays a dramatic role in stream sediment behaviour when debris is suddenly released due to channel damming during the floods. Lithological analysis of random samples of the clasts in the main channel shows that in the upper part they are fully composed of calcschist, whereas at the catchment closing the proportion of calcschist to dolomite is nearly equal.

The weather of the area is more humid than the general climatic conditions of the High Dora Riparia valley. The daily rain and/or snow data from 1921 to 1982 (61 years) supplied by the Italian Servizio Idrografico (Thures raingauge, 1703 m a.s.l. near the mouth of the Thuras valley), shows that the annual rainfall/snow depth averaging 938 mm is much higher than the whole Dora Riparia basin (usually 750÷800 mm). The distribution is typically double-peaked (April-May 198 mm; October-November 190 mm, total 41%). Although the average rainfall in July and August accounts for only 5% and 6.8%, respectively, of the annual total, mid-summer storms constitute a triggering factor for rockfalls and especially debris flows in the small watersheds. The higher precipitation in May and June (19.2%) has historically been responsible for catastrophic events (rainfall plus snowmelt) on a larger basin scale.

Local climatic conditions, the high relief energy and geolithology all contribute to a potential debris supply. Released by extreme events once every ten years, large debris removal can account for several tens of thousands of m^3. About 2% of this debris may directly join the main stream, where retention dams have been progressively (re)built along its lowest reach over the last 70 years.

Fig. 2 - Overall view of the Thuras valley, above 1900 m elevation. One may notice the steep rocky walls in the foreground, contrasting with the gentler shape of the valley bottom (Photo 1999, 1st June).

Fig. 3 – Partial view of the left slope of the T. Thuras valley; several minor catchments and ravines, incised in Jurassic Calcschist, with different- sized mixed fans ending into a U- shaped valley bottom (Photo 1998, 29 September).

Fig. 4 – A snow avalanche deposit, still lying in late Springtime on the left slope of T. Thuras valley around 1900 m elevation. Season's rockfalls from steep Calcschist walls upward are witnessed by detritus left on the close-up road (Photo 1999, 1st June).

Fig. 5 – A steep fan (No. 16 in Fig. 1), both built by rockfalls and debris flows, issuing from a couloir accounting for only 12 hectares area. At his foot, one can see traces of debris flow passage, already present after the 1998 event, lately reactivated after storm occurred on half-August 1999. That's a good example of debris flow deposits not yet able to feed the main channel. Overall view of the site is near the centre of Fig. 3.

Fig. 6 – Deeply incised in bedrock, the lower reach of the Thuras torrent sharply contrasts with the upper reach (see Figs. 2 and 3).

SEARCH OF DATA

The Summer 1998 was characterised by an abnormally long-lasting warm period in the Western Italian Alps. The CNR-IRPI meteorological station located 3150 m a.s.l. on the southern slope of Mount Rocciamelone, some 35 km northeastward from the study area, recorded from early June until late August maximum daily temperatures well above zero for 90 consecutive days with peaks close to 10-12 °C. In all the alpine range, these are typical conditions for the development of local, strong convective storms, as in fact happened on the early afternoon of 12 August 1998.

Unfortunately, recording raingauges no longer operate near the study area. We can, however, refer to the data recorded nearby at the Sestriere and Colle Bercia stations the Servizio Meteoidrografico of Regione Piemonte operates. Both are located 10 km north and northwestward from the site of the event at the elevations of 2020 m and 2220 m, respectively. The lower one recorded 14.6 mm of rainfall between 13:00 and 14:30 GMT, and the higher one 6.4 mm during the 20 minutes after 13:30. Despite this low amount of rain, its intensity may be deemed noticeable for the area, almost totally bare of vegetation above 2300 m; rain intensity might also have been heavier near the damaged sites. This can help to explain how, even with no heavy rain, its intensity may still be able to develop intense runoff on steep, unvegetated slopes.

The morphological effects the rainfall triggered were investigated during field recognitions and interpretation of aerial photographs taken just after the event. On the whole, debris flow deposits were left by 27 sub-catchments or ravines, 23 of them on the left valley side (calcschist range) with channel inflows to the main stream between 2350 and 1850 m elevation. Intermediate four catchments inflow from the right side, i.e. out of the dolomitic belt, between 1990 and 1950 m. Two catchments (numbered 8 and 9 in Fig. 1) delivered, in the upper part of their fans, true "rocky mud flow" (Ohmori & Hirano 1988), fed by a freshly occurring rockfall. Catchments in dolomite (No. 19-21, 27) delivered mixed debris flow-hyperconcentrated flow deposits mainly due to scouring of previous sediments and terracing of recent ones. The maximum lenght of the entrenched tracks over single fans stretched 1.3 to 15 km, with single debris flow magnitudes of some cubic meters to thousands of m³. The shape of the calcschist deposits was tipically double-ridged with protrusions along both the mid-course and the final reach, often pushed over tens of meters into the main stream; the length of the single channels averaged several hundreds meters, some reaching up to 1 km; the height of the paired levees above the channel bottom was generally 0.5÷1 m, with some above 2 m; the width in between was 4÷6 m. The area had supplied debris flows several times in the past, as demonstrated by the presence of an extensive series of debris flow deposits that appeared to be of different age; a similar feature has also been found in the French Alps (Van Stein et al. 1988). Usually, the debris flow patches followed the same reaches already occupied in the past events. Often, the lateral ridges left nearby the previous ridges were almost identical in shape and dimensions, making it quite impossible to correctly detect the new patches by the use of aerial photographs alone. A distinctive field criterion was followed to assess: 1) *very old debris flow deposits*; appearance of lateral ridge/s and/or terminal lobe of debris flow waves forming a relief in the field but not evidencing the nature of clasts, being totally covered by soil and finer particles and entirely vegetated by brushes (rhododendron) and herbs; 2) *historical deposits*; most of them recognisable by larger lichen-covered clasts; 3) *very recent deposits* (probably due to the 1988 event) still greyish in surface colour, partly vegetated; and 4) *present fresh deposits* (left by the 1998 event).

In some cases, the flows followed new directions parallel to the old ones as they travelled over the prairies without leaving bottom deposits but only lateral ridges instead. They left the grass paving undisturbed, with an irregular dispersal of debris masses from some dm³ to some m³ in volume, scattered around. A good landmark of the past and present debris flow activity is the military road built 60-70 years ago along the stream on the left slope; the road follows the path of the old footpath for pack-animals reported on the historical map *Gran Carta degli Stati Sardi in Terraferma* (CORPO REALE DI STATO MAGGIORE 1857-1860). On aerial photographs one can recognise that the road obstructions the debris flows created were initially 5 in 1954, then eleven in 1964 and then twelve in 1991; fresh occurrences along the same paths in 1975-1979 and 1991-1998 totalled 5 and 12 cases every couple of years, respectively. Several rocky blocks were already present; some of them are totally lichen-covered with a yellowish patina; the others (ten) are freshly fractured, with a greyish surface and cutting edges. Two of these debris flows contain giant rocky blocks likely fallen from the cliff above in various epochs and still travelling over distances of a few meters to tens of meters; some descend over the stream, generally without leaving their impacts traces, except those blocks fractured by the shock and terrain pushed downward. The largest one, its size estimated to be over 100 m³, had rolled a distance of 800 m, before reaching the opposite bank of the main channel. Despite of the relatively many large blocks, only 4 impact holes, 1÷2 m^2 wide, have been recognized at the foot of the slope. Spaced 5 to 10 m apart, they appeared almost completely filled by finer sediments. This leads to the supposition that rockfalls could have occurred immediately before the debris flow passage/s or during its passage; the flowing mass most likely acted as a shock-absorber. A part of the rocky masses did not fall directly from the cliff, but was probably already present in the upper part of the debris slopes, as can be recognized by past aerial photographs and morphology; several dozens of blocks in fact are still residents inside some couloirs.

In its upper reach, the usual channel width was widened up to 70 m by the impulsive water and sediment inflow from left tributaries; locally, lateral erosion occurred on the right side. About 3 km downstream, at around 2000 m elevation, a fan-like deposit totally dammed the channel. The lower reach, where the channel is mostly incised in bedrock, was locally debris-choked by materials brought by lateral inflows and torrential processes were strengthened. Little damage was brought to a check dam downstream at 1750 m elevation, where conventionally the catchment under study has been closed.

Grain-size analyses revealed no substantial differences between the debris flow deposits in the upper sector of the valley and the torrent deposits found at the lowest end of the channel, showing in both cases 55÷60% of gravel and a mean diameter of around 4 mm. However, single cases constituted the exception, *e.g.* for a coarse stony deposit belonging to a dolomitic belt, which reveal 84% of clasts >84 mm and a mean diameter of 130 mm. A sharp affinity was shown between the sizes of a lateral new-built cone from dolomite and the deposits in the main stream 300 m below.

The event mobilised an estimated total of 100,660 m³ of debris, 11,700 m³ of which (assuming an average thickness of 0.30 m) directly inflowed in the main stream over reaches 50 to 200 meters long. Most of the debris was supplied by the Calcschist (75%), the rest by dolomite (25%); the contribution in surface units was 7500 m³/km² and 6300 m³/km², respectively.

ELABORATION OF DATA

A representative group of catchments and ravines (N= 18), all incised in Calcschist alone and in very close topographical, structural and geomorphological conditions was selected for a series of measurements. These aimed to assess 1) the area (effective) and slope gradient for both catchment and associated fan, 2) the whole length of debris flow tracks recognised for the various periods, 3) the volume of mobilised material, assuming a mean value of 1 m^3 for 1 m length, and 4) the sediment delivery area. In addition, a long-term estimate of accretion of each fan (if present) was attempted, assuming a starting condition =0 since the last glacial retreat in the valley (10,000 yrs.) and evaluating a present-day mean depth of each fan=5 m.

The best method of measurement was to compute the length of debris flow tracks, assuming track length as a surrogate to represent the magnitude of the events (Van Stein 1993). Using a mean cross value it was possible to evaluate the percent fluctuations of the mobilised material referred to a reference datum fixed in 1963 for best picture definition.

The statistical approach rests on the fact that in very small catchments, like those under consideration, the probabilities for sediments being carried in motion are quite equal for slopes, channel incisions and active fan areas. The key factor taken into consideration was the "sediment delivery area", meaning with such term not only the fan but the entire sediment-delivery system. This involves 1) rockfall products, 2) debris amounts stored in the ravines plus 3) the debris mantle covering the catchment slopes, 4) the entrenched channel deposits, 5) the active fan debris potential (so defined by interpolation between the debris flow tracks network).

Finally, an empirical relationship linking the effective catchment area (A_E) and the sediment delivery area (SDA) for every catchment has been found in the form of a linear correlation that demonstrates a good coefficient of determination (R^2= 0.81). Thus a formula for predicting the magnitude (total volume involved in motion) of an extreme debris flow event in a given sub-catchment can be stated so:

$$M= (aA_E + b)\, mh\ \mathrm{tg}\#\#\#$$

where M (m^3) is the total displaced volume (magnitude) estimated, A_E (m^2) the effective catchment area, h (m) the estimated mean depth (by field assessment) of the removable layer of sediment involved in motion, and tg### the average catchment slope. The parameters a and b have been obtained by the correlation ($y= ax+by+c$) between A_E and SDA, where a= 0.542 and b= 0.0151; m (= 0.019) is a coefficient expressing the average sediment contribution due to the 1998 debris flow event; it is drawn as % of the sum of all sediment delivery areas.

RESULTS AND DISCUSSION

Data processed as above result in a fairly satisfactory correlation (R^2= 0.67) between observed and computed magnitude values for the basin under study (Fig. 7). Of course, the predictory model can be reliably applied only in the ambitus of calcareous schist and/or comparable kinds of rocks, and for catchment areas of 0.1÷1.5 km^2 provided by active alluvial fans. For good results it is critical that the accuracy of photo interpretation be tested in the field to carefully assess the depth of deposits the floods can remove. That is, a fairly good estimation can be ensured only after a good field experience.

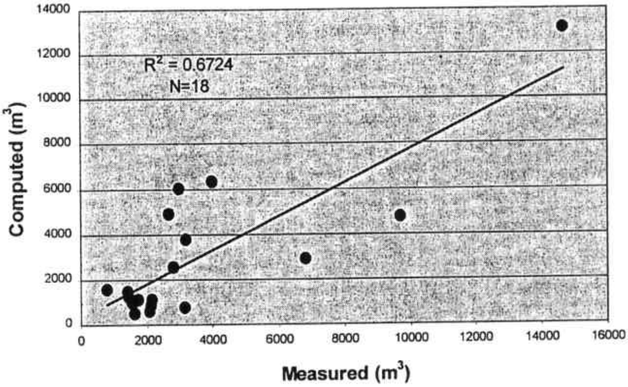

Fig. 7 – Computed-measured magnitude values of debris flows deposits in the small-catchment subsystem in the Thuras Valley..

In the basin under study four other debris flow events of comparable magnitude occurred over the past fifty years: on 13-14 June 1957, 13-14 August 1972, 9 June 1978 and 23 July 1988. This can be confirmed by sequential air photographs taken in 1954, 1963-1964, 1975, 1979, 1991 and elsewhere by archival reports, both deposited at the IRPI Institute. Therefore, with a mean time of occurrence of 10 years only, the event here described should not deemed as exceptional, but as a normal pulsatory evolution of the valley reach under study. The sediment production over the valley bottom could be estimated at 10,000 m³/decade, the sediment input in the main stream at 1000 m³/decade, equalling the debris/sediment volume still to be delivered by the rocky catchments.

According to the findings by Kotarba et al. 1987 who assessed sediment transfer in the Polish Tatra Mountains by regular field measurements for over 5 years, it can be said that in the area studied here the slope subsystem consists of "various sequences of slope units, as rockfalls, debris slopes, debris flow deposits and so on, which develop *quite independently from one another in usual weather conditions;* the linking between the slope and stream channel subsystems is only sporadically possible during extreme (catastrophic) rainfall".

The computations allow the estimation, altough extremely simplified, of amounts and times of debris/sediment production, transfer and release by the whole slope subsystems in the Upper Thuras Valley. The model can be summarized in three steps: 1) Remote debris/sediment production in the catchments and couloirs, 2) Debris/sediment reworking over the fan areas and the floodplain, 3) Sediment input into main stream. Under this regard, although the rockfall delivery volume at a first sight appears huge, it prove to be an unimportant debris supplying agent, accounting only for 2% of the whole debris volume. Originally, the number of the largest boulders visible by aerial view, averaging a few tens of m³ each, was 110. From 1963 to 1979 it rose by 30%, suddenly dropped to less than one half in 1991, then grew again to 101 in 1998. A reason for this change can be inferred from the partial burial of some boulders under the debris flow deposits. The superficial density of large boulders ranges from an average of 4 per hectare to a maximum of seven.

Both steps 1) and 3) roughly account for 1,000 m³/year, and step 2) for 10,000 m³/year. In other words, it can be said that the fans-to-valley bottom areas are ten-fold more active than the source areas, which are almost equivalents to the entries in the main stream. In the catchment under study one can estimate that in 50 years, assuming a layer depth of 0.3 m, the volume delivered by minor catchments should equal the whole sediment available to motion resident in the main channel, so that a recharge time of about 50 years is required. Thus the residence time for a given particle of sediment in the valley bottom (channel excluded) approximates to $1x10^4$ years, whereas the residence time in the main channel is around 50 years.

Although channel-storage plays an important role, it has received relatively little research so far. According to Trimble, 1983 "the floodplain conveys a much smaller proportion of the water discharge than the relative widths might suggest. Likewise, only a small proportion of the sediment entrained onto the floodplain may be transported because of the decrease in tractive force... Thus, the floodplain acts as a filtre or bottleneck for sediment". The author estimated a ≥25 year return frequency for extreme discharge events in the Coon Creek, Wisconsin, U.S.A. For a Spanish catchment, the average residence time of sand and gravel stored in the main channel is approximately 28 years (Batalla et al. 1995). Also Dietrich & Dunne, 1978 emphasize the storage role of the valley floor sediments for a catchment in Oregon, U.S.A., having found that "the debris fans at tributary mouths store the equivalent of 800 years of bedload discharge". After Aulitzky, 1980 in the Austrian Alps "in debris-accumulating torrents debris so stored on larger and low-gradient floodplain reaches can be mobilised again during the extreme events. These torrents tend to self cleaning at mean intervals of 35 years".

FINAL REMARKS

The predictive formula we propose for assessing the debris flow magnitude connected to paroxysmal events has been, of course, calibrated to the physical conditions of the area where the event may occur; a big advantage has been drawn by the fresh and contemporary occurrence of many debris flow processes concentrated in a narrow area. Thus the suitability of the model to other environments with geolithological and geomorphological characteristics similar to those under study depends upon a systematic knowledge of the sites. The study needs to follow several steps, which should start from a specific geologic experience connected to a correct geomorphologic analysis both in the photo interpretation and the field recognitions. To ameliorate the intrinsic meaning of the computed magnitudes it is necessary to know, through historical data, the extreme events occurred in a given area and the relevant recurrence times. This should allow to estimate the possibility that a given event could occur, thus a dangerousness level to be assigned.

Although the debris flows (and some rockfall) on 12 August 1998 in the 19-km² high-mountain catchment in study mobilised a total of more than 100,000 m³ of materials, they had little effect on sediment transport and water discharge along the main stream, which, however, received some newly-brought 12,000 m³ of coarse sediments. Gravel and pebbles conveyed by the minor torrents to the main stream traveled over a maximum distance of 200 m. A comparison should be made to the Tatra Mts., where maximum distances of bedload transport in local streams generally range from 120 m to 200 m for a water velocity of 5÷6 m/s (Kotarba et al. 1987).

The mean recurrence intervals of debris flow events in the Thuras basin, closely depending upon reloading times of the debris flow couloirs and fan channels, can be roughly assessed as occurring every 10 years or even less in analogy to other scattered cases reported in California (Hupp et al. 1987), Poland (Krzemien 1988), and Taiwan (Kuo-Liang Pan et al. 1998).

Although at a sub-catchment scale the 1998 event should be deemed extreme, at a larger catchment scale it was not so important. In fact, field measurements based on the tracks left by the flood passage revealed a specific Q_{max} (water/debris) of around 70 m^3/s km^2 from the right side tributaries, whereas in the middle reach of the main channel the peak discharge was around 0.5 m^3/s km^2. Morphological evidence suggests that the bankfull discharge alone might probably have been 3 to 4 times greater. The recurrence interval of extreme floods in the main stream could be not less than 40 to 50 years or more, as confirmed by historical documents.

A step forward in this study has been subsequently made, by detecting the further displacements of sediments downstream the main channel of T. Thuras. At this purpose, transects of painted stones have been provided in the early Winter 1998, then surveyed at the beginnings of Summer 1999, after several days of snowmelt waters. Two 1-metre wide stripes of channel deposits were marked on-site all along the ordinary flood section, at (a)2100 m and (b)1840 m respectively (Fig. 1). The sites differ both in parent rocks (calcschist and dolomite respectively) and overall channel slope profile (8% *vs.* 27%). With peak discharges estimated, by the traces left behind, at 10-30 m^3/s, (re)found gravel and cobbles travelled along overall distances of 260 m downstream the site (a). Also the site (b) was partly reworked, but downstream it, probably due to a major stream energy, only one cobble was found by chance, partly buried in the sediment mass trapped just behind the check dam to which the Thuras basin has been closed. In such case the distance traveled was *ca.* 500 m over a drop of 90 m. Regarding the site (a), we have found that the reference strip has been dismembered in the reason of 5%. The displaced individuals (N= 50) have been carried downstream quite independently of their size, *i.e.* any significant analytical correlation was proved to exist between distance and clast's size. On the contrary, groups of clasts expressed as volumes computed at regularly increasing distances downstream, show a fairly good fit with increasing distances according to a power fonction. In other words, one can say that the bulk of the coarse superficial sediments had moved for the first twelve meters in the reason of 72%; a significant quantity (13%) was still found up to100 m and lately (9%) in the stretch 230÷250 m. This means, roughly speaking, that several tons of coarse sediments had travelled, on the whole, several tens meters downstream. Such datum gives food for thought how many a "usual" seasonal discharge can influence the mountain stream transport.

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