DAMOCLES

DEBRISFALL ASSESSMENT IN MOUNTAIN CATCHMENTS FOR LOCAL END-USERS

Contract No EVG1 - CT-1999-00007

FINAL DETAILED REPORT

MARCH 2001-FEBRUARY 2003

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CONTRACTOR: UNIVERSITY OF PADOVA, DEPARTMENT OF LAND AND AGRO-FOREST ENVIRONMENT – WATER RESOURCES DIVISION

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Section 5.

Debris flows are one of the most hazardous natural phenomena in European mountain areas. Even if these events regularly cause loss of life, livelihood and property and disruption of communications, in Europe there are no standard techniques, uniform approach and available quantitative techniques for hazard mapping. University of Padova DAMOCLES team had the purpose to develop and apply new technologies for determining the impact of debris flows and, hence, for assessing the mitigating effects of torrent control works and land management, with these technologies being transferred to relevant End-users.

A small basin DEbris FLow Impact MOdel (DEFLIMO) has therefore been developed. It's applicable at the scale of a small catchment, typically up to 10 Km^2 in area, containing a mountain torrent channel linked to a fan, and represents the channel and fan in two components. With a user-supplied debris flow hydrograph as its input at the upstream end of the channel, the model routes the debris flow down the channel to the fan using a one dimensional scheme called MODDS (Model One Dimensional Debris flow Surges). This combines semplicity and user-frendly interface design with an innovative ability to account for the effect of structures such as check dams and bridges, constrictions in channel cross section and overbank flow. Tests comparison with other model has been successfully carried out, and implementation in several basins has permitted the validation of the model.

A two dimensional model component represents debris flow propagation and sedimentation on the fan area (DDPM; Debris flow Distribution Propagation Model). The fan is represented by a grid of square cells; transfer of debris flow material from one cell to another occurs under conditions of either uniform flow as a function of gradient or flow over a broad-crested weir. A successful test of DDPM has been completed for the debris flow deposit of 4 November 1966 on the fan of the Rio Lazer (Trento Province).Integration of MODDS and DDPM forms the overall DEbris FLow Impact Model (DEFLIMO). The integration is carried out using the ArcView GIS framework, which enables on the 1-D channel model (based on vector elements) to be linked with the 2-D fan model (based on raster cells). The component models can be run independently or integrated together. After his test at site in the Italian Alps and in Spanish Pyrenees, DEFLIMO model was presented to the End-users at the Padova training course, in September 2002; a continuous assistances of the Padova team to own End-users have guaranteed a real and efficient transfer of the DAMOCLES technology.

Section 6.

6.1 Background

Debris flows are one of the most hazardous natural phenomena in European mountain areas, and regularly cause loss of life, livelihood and property and disruption of communications. The potential for such losses is increasing as the mountains areas are increasingly developed and insurance claims as a result of this threat are steadily rising. Hazard assessment is therefore increasingly required in land use planning in mountain environments. However, in Europe there are no standard techniques, uniform approach and available quantitative techniques for hazard mapping.
In order to clarify with an actual example the socio-economic relevance of the problem, consider that the annual budget of the Autonomous Province of Trento for torrent control works and debris flow management is around 20 millions euros, whereas damages caused by debris flow events can reach tens of millions euros, with hundreds of deaths, since many towns are present on the alluvial fans.
At the beginning of the DAMOCLES Project End-users (Protection Agencies, Geological Services, etc.) used the Aulitzky methodology both to evaluate whether debris flows can occur along a stream and to produce maps with three different levels of hazards on the alluvial fan. This qualitative approach does not allow to assess how critical structures along the channel (i.e. bridges, check-dams, ripraps) affect the debris flow route along the channel, particularly where flooding is likely to occur and the volume of the overflowed material.
In the light of the above, University of Padova team works was focused as a project to develop and apply new technologies for determining the impact of debris flows and, hence, for assessing the mitigating effects of torrent control works and land management, with these technologies being transferred to relevant End-users.

6.2 Scientific\technological and socio-economic objectives

The whole understanding of development and depositional processes of debris flow is still problematic from the scientific point of view. The gap gives continuously new motivation to improve the theoretical and experimental studies. In fact, the knowledge of the debris flow risk and impact represent the necessary condition to manage and protect mountain lands and its population. For these reasons, a data collection on past debris flow characteristic in Veneto Region and in the Autonomous Provinces of Trento and Bolzano was conducted in order to development a methodology for the assessment of debris flow volumes and magnitude-frequency relations of debris flow volumes. This debris flow database it was necessary to the development of a user-friendly small basin debris flow impact model (DEFLIMO). This model permit to simulate the debris flow propagation and, thus, to product detailed hazard map of the fan area, with valuable information about deposition patterns, which can lead to an efficient land-use planning. Transfer of the technologies and results to the End-users has been considered essential in all the phases of the modelling development, both for matching one of the most important objective of Damocles project and for its positive feedback to model development.

6.3 Applied methodology, scientific achievements and main deliverables

WP1 *"Development of functional relationships for debris flow behavior"*

In order to make up a simple and user-friendly archive of all the debris flow-prone streams, a data collection from several sources ("Ufficio Bacini Montani, Prov. Autonoma di Bolzano", "CARFRA project, Ufficio Geologia e Prove Materiali, Prov. Autonoma di Bolzano", CORINE database, First Intervention Squad reports (FI), newspapers and others publications) was carried out for the Veneto Region and the Autonomous Provinces of Trento and Bolzano. A standard form used in the setting up of the database was developed, featuring administrative characteristics, morphometry, geology and geomorphology, land use, water discharges and recorded debris flow events.
Based on this database, empirical analysis was conducted in order to estimate the debris flow magnitude (i.e. the volume of debris material discharged during a single event) and the magnitude-frequency relations of debris flow volumes. The debris flow database permitted also the support of model development and to improve mapping and data analysis techniques.

WP3 "*Development of a small basin debris flow impact model*"

The use of mathematical models in the simulation of diverse hydraulic phenomena has become essential, as a predictive tool, in the evaluation procedure of engineering designs and in the mapping the safety degree of areas conditioned by fluvial systems. The researchers were forced to revert to physical modeling in order to simulate the effects of floods events on hydraulic works and their environmental context. Dealing with the triggering, routing and spreading of debris flows the necessity for modeling is even higher, because only a large number of scenarios may be helpful for the mud/debris flow hazard assessment (Laigle & Marchi, 2000), i.e. considering the simultaneous occurrence of certain rheological parameters and peak discharge values for a given total sediment volume. The first step for developing a mathematical model for mapping hazard areas which can be affected by debris flow flood deals with the simulation of its routing along a channel reach. This channel could be an undisturbed alluvial stream, a torrent reach or entire longitudinal or cross-stream works for controlling the phenomenon, an artificial fixed-bottom channel designed to convey the debris flow, or a combination of the previous considered situations. The length of the channel taken into consideration can originate upstream of the fan. In fact, the debris flow routing upstream of the fan apex could be decisive for the flooding evolution and for evaluating and mapping hazard areas.
The second step consists of the estimation of the channel cross-sections where debris flow surges overflow and start to propagate on the fan sub-areas close to the embankment.
In the Italian Alps, the fans slopes generated by debris flows are rarely less steep than 3% (D'Agostino, 1996). Lower fan gradient are clearly possible but the fan edification is dominated by fluvial transport processes or, in some cases, by a mixed transport where bedload events alternate with debris flows (Marchi *et al.*, 1993, 2002). Taking into consideration such field evidence, the main hypotheses considered for developed a tools for mapping hazard zones were:

- assuming the validity of the convective-diffusive simplification to the complete 1-D dynamic Sant-Venant equation;
- decoupling the 1-D from the 2-D simulation, in the sense that, after a side overflowing has occurred in the 1-D model, the later flow "hydrograph" moves on the fan without affecting the channel by way of back-water effects.

These hypotheses are too severe for modeling flood in lowland areas, but may be more acceptable in case of fluxes moving on steep slopes. They offer simultaneously the capability to develop an user-friendly numerical simulation not affected by regime transition problems (Fread, 1988) and by the coupled solving of the 1-D and 2-D governing equations.

Starting from such assumptions, the One Dimensional Debris flow Surge simulation (MODDS) and the Distribution Propagation Model (DDPM) are briefly presented. Their successive integration (DEFLIMO) was carried out using the ArcView GIS framework, which enables MODDS, based on vector elements, to be linked with DDPM, based on raster cells.

With a user-supplied debris flow hydrograph as its input at the upstream end of the channel, the model routes the debris flow down the channel to the fan using a one dimensional scheme called MODDS (Model One Dimensional Debris flow Surges). This model combines simplicity and a user-frendly design with an innovative ability to account for the effect of structures such as check dams and bridges, constrictions in channel cross section, overbank flow and over-elevation depth on the outside bend of a curve. The model can be run choosing between two options: a) routing simulation in a confined channel for which overflow is not allowed; b) routing simulation for the actual channel geometry and capability to estimate the overflow. The presence of bridges is one of the most frequent cause of diversion in the lower part of debris flow torrents. Checking and designing the stream cross-section in correspondence to road crossings is a pressing demand from local authorities (torrent control and public safety). For any cross-section used for describing the channel geometry the superimposition of a bridge is possible.

For the MODDS model, several sensitivity analysis were carried out, and show a lower limit of bed slope (4%), outside which sediment volume loss is not acceptable (> 15%). MODDS model was also compared with the DAMBRK subroutine for non-Newtonian fluid simulations (Fread, 1988); tests comparison has shown super-imposable results.

A two-dimensional model component represents debris flow propagation and sedimentation on the fan area (DDPM, Debris flow Distribution Propagation Model)

The debris flow distributed propagation model DDPM is a DEM-based model. Its philosophy is a strong simplification of the two phase mixture governing equations. Finite element or volume numerical schemes require a user with a good knowledge of the phenomena and of numerical tools. The flow modelisation over an abrupt change of slope or in presence of surrounding buildings needs a dense elements mesh and a very short computational time step (*Dt*). The essential construction of a refined mesh and the very short *Dt* require considerable time for computation. The goal of approaching the 2-D propagation by looking for a robust and not time expensive computational scheme is still justified, mainly to test a scenario of debris flow events. The fan is represented by square cells and each cell is identified by its altitude above sea level. The cells of the fan are distinguished as either the source cells and the conductance cells. The source cells are input areas. They receive the input hydrograph and are, normally, located along to the embankments of the channel where debris flow overflow occurs. The conductance cells are the remaining ones flooded by debris flow coming from the surrounding cells. The mass transfer exchange between cells is governed by two different mechanisms: the first one is gravity, and the second one is the broad-crested weir. The model supports input hydrographs in different areas. Each source cell can have an own input debris flow hydrograph. The input parameters are then the digital elevation model of the fan area, the coordinates of the source cells and its corresponding input hydrograph.

The integration of MODDS and DDPM models, named DEFLIMO (Debris Flow Impact Model), was carried out on the Arc-View GIS framework, which enables the 1-D model (based on vector elements) to be linked with the 2-D fan model (based on raster cells). DEFLIMO can be run as an integrated model linking 1-D and 2-D sub-models with a raster representation of the alluvial fan. Nevertheless, it can also be used with only the one-dimensional sub-model to compute flow propagation along the channel or the unique two-dimensional model to compute the spreading on the alluvial fan starting from selected source cells. In the first situation the unsteady flow routing in the channel is computed: overflowing heights and discharges are assessed for each critical cross section at each time. In the second case DEFLIMO can run only the 2-D submodel. The 2-D submodel requires input boundary condition such as the discharge resulting for overflow, and the assignation of the coordinates of the grid cells where the overflow occurs. A delineation of the maximum extent of the flow area is produced at the end of the computation. Dynamic evolution of accumulation process in sedimentation cone is visualized through snapshot series with predefined times intervals (*Dt*). Both the MODDS (1-D) and DDPM (2-D) models conserve mass individually. In the combine DEFLIMO model the flow volume remains in the channel for the 1-D part and in the 2-D step the "overbank" flow spreads out over the alluvial fan where flows maintain constant masses as they move downslope. Such condition highlight the importance of flow path topography, then an appropriate DTM representation through a precise field topographic survey is necessary.

Exemplificative study cases of DEFLIMO for three debris fan (Rio Lenzi and Rio Rudan, Trento Province, Italy, and Sahùn River, Benasque Valley, Spain) were useful in order to developed, calibrated and validated the model. The final hazard maps obtained from the application of the model in these basins, are report and brief commented.

The Lenzi torrent is a tributary of the Fersina River in the Adige valley (near Trento city). Its basin drain an area of 2.43 km^2 and ranges in elevation from 1407 m (fan apex) to 2409 m. The basin is prone to generate granular debris flows. In the 1882 an extraordinary precipitation event occurred all around the Province of Trento, triggering a massive debris flows along the Rio Lenzi stream. Several deep channels (still active) were incised in the upper part, delivering huge amounts of sediment to the main channel which built many lateral deposits downstream. In 1917 and 1951 other smaller debris flow events affected the catchment fan. In 1966 extraordinary rainfalls produced a debris flow which flooded the lower part of the fan. The field evidence of such events allow the application of the Aulitzky (1994) method for mapping debris flow hazard areas on the fan. DEFLIMO model was applied for assessing a more current hazard map scenario and for comparing it with the Aulitzky approach. The simulated debris-flow surge entering at the upstream channel cross-section has a total volume of 30000 m^3 (D'Agostino & Marchi, 2001) and a peak value equal to 120 m^3/s. The exhaustive simulation with the DEFLIMO application, have furnished a hazard map of the Rio Lenzi fan area, with the sediment distribution in terms of the flow levels at a selected time of computation (Fig. 1).

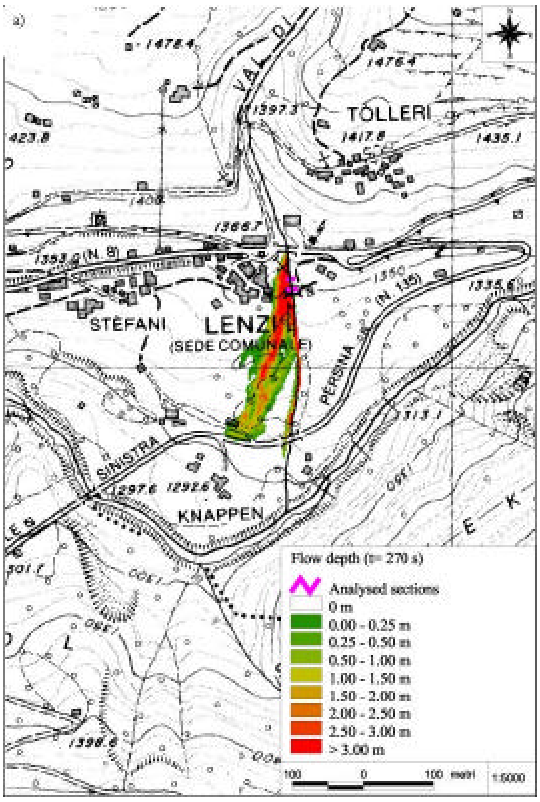

Figure 1. DEFLIMO application on Rio Lenzi fan: debris flow depths (m) on the fan area represented at the time 270 s.

The second basin in witch there was implemented the DEFLIMO model is the Rio Rudan watershed, a small catchment located in the Province of Belluno (Veneto Region). The upper part of this basin is characterized by the steep cliffs of the Antelao peak (3264 m.) and by a large scree slope. At this important accumulation of talus material triggering of debris flow usually occurs; debris-flow deposits located downstream of this zone indicate that debris flows are a recurring geomorphic process in this area. The upper watershed portion also shows the presence of vast sediment sources areas, and the supply of mobilizable sediment is rarely a limiting condition for debris flow occurrence. The average slope of the Rio Rudan between the waterfall and the National Road is 24%. The torrent is channelized 50 m upstream of the National Road n. 51; the banks here are concrete walls (2 m) and the cross section is rectangular. The channelized reach of the torrent passes through the hamlet of Peaio (860 m.s.l.) before flowing into the Boite River at 800 m.s.l.m. The Melton index analysis shows that Rio Rudan can be considered a debris flow-generated fan. The routing of a debris flow down the channelized reach was simulated using the 1-D MODDS model; its peak solid discharge was evaluated from the peak liquid discharge (Hashimoto et al., 1978). Considering the activity and the location of sediment sources, the peak discharge of the debris flow for the considered return time turns out to be around 112.5 m^3/s. The simulation carried out with the 1-D MODDS model (fig. 2) shows that the channelized final reach have three critical sections: a) near the second bridge – section 30 – and b) on the left side of two sections, section 41 and 42. The total overflow volume is about 300 m^3.

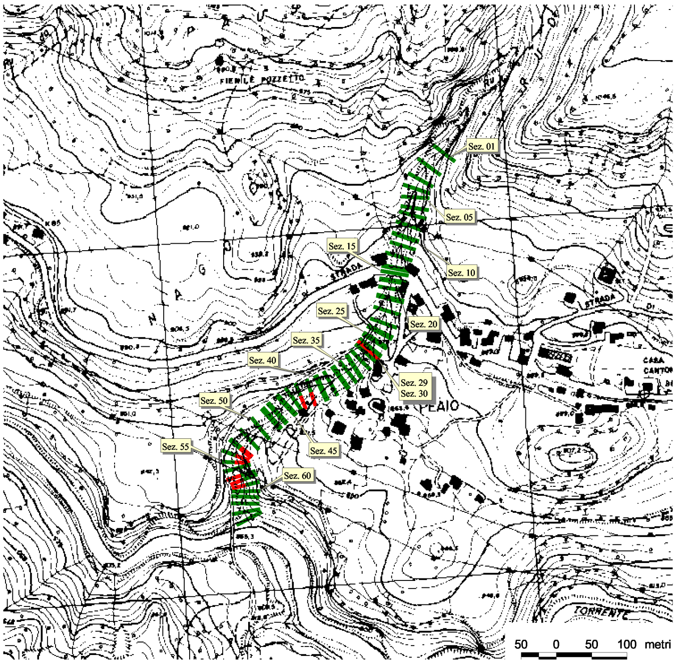

Figure 2. 1-D MODDS output map. Red colour individualize overflow sections.

The thirty model application has been carried out for the Sahùn River. The catchment of the Sahùn stream (3,26 km^2) takes origin from the Oriental south slopes of the Tuca Cambra mountains in the Benasque Valley (Spanish Pyrenees). Sahùn reach length within the alluvial fan is 830 meters, average slope of the fan is 13%. The application of Melton index (0,74) and the analysis of the critical cross sections (bridges and bends) and debris flow magnitude, associated to extraordinary floods, underline the possibility of considering potential overflow and debris flow hazard areas on the fan. The application of the 1-D MODDS model to Sahùn torrent benefits of field activities, detailed topographic survey, thematic maps and hydrological data supplyed by IGME of Zaragoza. The quantification of the potential debris flow volume was evaluated with several equations; the simulated debris flow surge entering at the upstream channel cross-section on the fan apex was estimated in 40000 m^3. Peak solid discharge was evaluated by using volumetric method from liquid discharge data (Hashimoto *et al.*, 1978), and pointed out a value of 197,00 m^3/s. The bridges are the most critical cross sections in the analyzed area, the first located at the top, and the second one in the medium part of the fan. Simulations of two possible scenarios (with and without re-entering solid material leaked out from first bridge at the top of the fan) underlined the insufficiently of the first bridge (section 15), while the second bridge is able to conduce higher discharges (up to 586 m^3/s) without lateral overflow. The simulations conducted with MODDS model emphasized the insufficient conveyance of any intermediate section too, particularly section 16. Figure 3 shows a hazard map elaborated using Ikeya (1981) method for the evaluations of debris flow runoff.

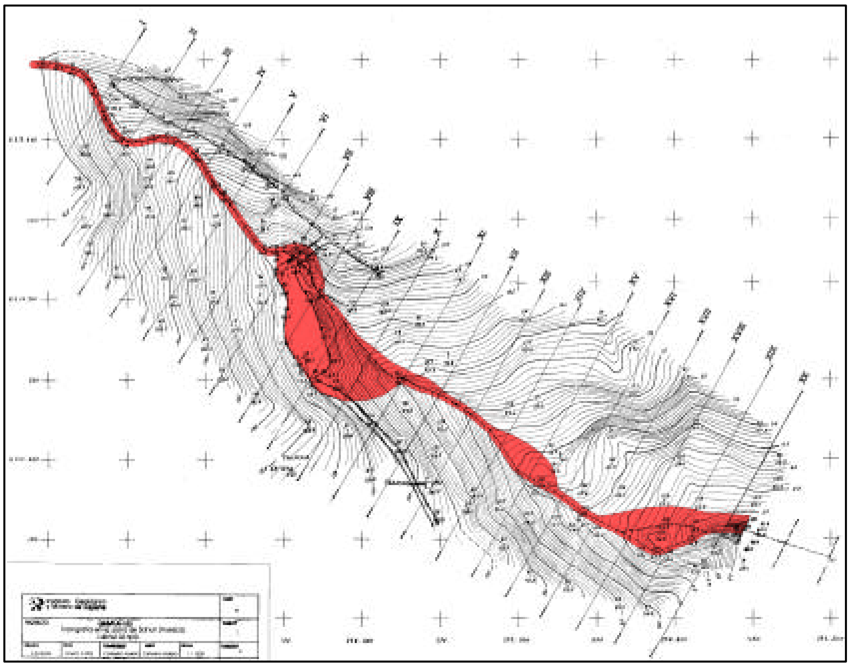

Figure 3. Hazard map of the Sahùn fan area.

WP2-WP3 “*Integration of modelling approaches*"

A demonstration linking of the Workpackage 2 (WP2) and Workpackage 3 (WP3) , as an integrated approach for debris flow hazard assessment on alluvial fan has been carried out in collaboration with the University of Milano Bicocca. Taking into account this framework , the local debris flow impact model DEFLIMO can investigated in detail the hazard at sites of interest, including sites (fan area on small catchment < 10 km2) identified in the regional scale map.

WP5 “*Dissemination of project deliverables*"

Training course related with the application and implementation of the Work Package 3 (*Small Basin Debris Flow Impact Model*) was hold on the campus of the Agricultural Faculty of the University of Padova (Agripolis) at Legnaro (PD). Sessions were organized in two days; Tuesday 10, 2002, was dedicated to the presentation of the 1-D and 2-D Models and also to discuss the different types and characteristics of gully-channelised debris flow, limits of the two models, field of applications and data set inputs requirements. A video showing triggering, propagation and sedimentation of a debris flow was used to facilitate the exchange of ideas between end-users (geologists, practicing engineers, forestry managers, technicians). A typical practical-individual technical session using 10 dedicated-PC was carried out on the GIS laboratory, Wednesday 11, 2002. A report titled *Methodological guide: case studies and applications* was prepared and given to all participants. The PDF file of this document is available on the DAMOCLES Project website (http://damocles.irpi.pg.cnr.it/).

6.4 Conclusion including socio-economic relevance, strategic aspect and policy implication

The debris flow impact model DEFLIMO is applicable at the scale of a small catchment, typically up to 10 km^2 in area, containing a mountain torrent channel linked to a fan, and represents the channel and fan in two components. The proposed model improves upon existing impact assessment techniques such as the Aulitzky (1994) index because it accounts for obstructions to debris flow movement along the channel (including the effect of torrent control works) and provides a quantitative and time-varying simulation of debris flow propagation and deposition on the fan. It also represents an improvement in user-friendliness and can be easily adopted for multiple simulations assessing different characteristics of potential debris flow floods in terms of volumes, channel geometry, land use on the fan and related resistances to motion.

The simplified DEFLIMO model should clearly be considered of an engineering type and needs to be validated in the field by comparison with natural events. However, the advantage of such a methodology has been pointed out in debris-flow hazard mapping and related risk assessment.

We think that the results obtained in the test areas investigated by the DAMOCLES Project (Northern Italy and Spanish Pyrenees) are applicable in other mountain areas worldwide, and the outputs produced by DEFLIMO can prove useful in ascertaining fan debris flow hazard in the mountain areas of Europe.

6.5 Dissemination and exploitation of the results

The data base archive of debris flow occurred in Veneto Region and in the Autonomous Provinces of Trento and Bolzano ,created in order to support empirical or semi-empirical developments in debris flow modelling and to tested and improved models, is held on the project website (http://damocles.irpi.pg.cnr.it/).

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DEFLIMO was installed and is being used by the Torrent Control Agency of Trento Province, by the ARPAV-Avalanche Center of Arabba of Veneto Region and by the "Associazione Italiana di Idronomia". Debris flow hazard assessment obtained from the outputs of the simulation software DEFLIMO were presented to other potential end-users, including the Torrent Control Agency of the Valle d'Aosta Region, the Soil Defence Agency of the

Fiuli-Venezia Region and to Soil Defence Agency of the Veneto Region, the Torrent Control Agency of the Tucumán Province of Argentina. All these new potential end-users proved interested in the results obtained. The Torrent Control Agency of the Valle d'Aosta Region is using the MODDS component of DEFLIMO to design new open check dams for mitigating debris flow hazards at the small catchment scale; the Soil Defence Agency of the Fiuli-Venezia Region is considering using DEFLIMO to identify the areas were debris flow risk is high in the Rio Moscardo fan; the Soil Defence Agency of the Veneto Region might consider adopting DEFLIMO to obtain the hazard assessment for several fan areas located on the Piave and Cordevole Valley.
Advanced, application and results of the project were presented in several international and national (Italian) conferences, like the workshop "Métodos para la predicción de riesgos de movimientos de laderas en areas de montaña" (Zaragoza, May 14-15, 2002); the ECO-GEOWATER Workshop *GIS and Natural* Hazards (Milano, 18-22 November 2002); the National Symposium *Gestione Integrata dei Bacini Idrografici* (Bari, 2-3October 2002).
The UNIPD's team will attend the International Conference Debris-Flow Hazards, Mitigation, Davos, Switzerland, September 10-12, 2003; the XXX IAHR Conference at Thessaloniki, Greece, 24-29 August 2003, and the next EGS Assembly at Nice, April 2003.

6.6 Main literature produced

Peer Reviewed Articles:

Authors	Date	Title	Journal	Reference
D'Agostino V. & Marchi L.,	2001	Debris flow magnitude in the Eastern Italian Alps: data collection and analysis.	Physics and Chemestry of Earth, Part C.	Vol. 26/9, 657-663
Lenzi M.A.	2001	Step-pool evolution in the Rio Cordon: Northeastern Italy.	Earth Surface Processes and Landforms.	Vol. 26, 991-1008
Lenzi M.A. & Mao L.	2003	Analisi del contributo del trasporto solido in sospensione alla produzione di sedimento del bacino del Rio Cordon nel periodo 1986-2001.	Quaderni di Idronomia Montana	Vol. N. 21 (in press)
Lenzi M.A.	2002	Stream bed stabilization using boulder check dams that mimic step-pool morphology features in Northern Italy.	Geomorphology	Vol n. 45, 243-260.
Lenzi M.A.	2002	Debris-flow hazard assessment using numerical models and GIS: case studies in central Italian Alps and Spanish Pyrenees.	Environmental Science and Environmental Computing	Submitted
Lenzi M.A., Mao L. & Comiti F.	2003	Inter-annual variation of suspended sediment load and total sediment yield in an instrumented alpine catchment over 16 years.	Hydrological Science Journal des Sciences hydrologiques	Submitted

Non refereed literature:

Authors / Editors	Date	Title	Event	Reference	Type[1]
Lenzi M.A., D'Agostino V. Gregoretti C. & Sonda D.	2003	A simplified numerical model for debris flow hazard assessment: DEFLIMO.	3° International Conference Debris-flow Hazards, Mitigation; Davos, Switzerland, September 11-12, 2003	Accepted for publication; 13 pp.	Proceedings
Bathurst J.C., Crosta G.,García-Ruiz J.M., Guzzetti F., Lenzi M.A. & Ríos Aragués S.	2003	DAMOCLES: Debrisfall Assessment in Mountain Catchments for Local End-Users.	3° International Conference Debris-flow Hazards, Mitigation; Davos, Switzerland, September 11-12, 2003	Accepted for publication; 12 pp	Proceedings
Lenzi M.A., D'Agostino V. Gregoretti C. , Sonda D. , Guarnirei A., Comiti F. & Mao L.	2002	Modellistica della propagazione delle colate detritiche e della sedimentazione nei conoidi alluvionali: guida metodologica, casi di studio ed applicazioni.	DAMOCLES Training Activities, September 10-11, 2002, University of Padova.	University of Padova, 74 pp.	Report
Sonda D.	2002	Valutazione della pericolosità idrogeologica sui conoidi alpini.	University of Padova	University of Padova, PhD "in Idronomia", 256 pp.	PhD. thesis
Lenzi M.A.	2002	Nuevos modelos para la predicción de riesgos geomorfológicos en abanicos aluviales; un ejemplo de los Alpes Dolomíticos.	Workshop "Métodos para la predicción de riesgos de movimientos de ladera en áreas de montaña » ; Zaragoza, May 14-15 2002.		Oral presentation
Lenzi M.A.	2002	Valutazione della pericolosità e del rischio idraulico sui conoidi alpini.	Seminario "Gestione integrata dei bacini idrografici", Bari, October 2, 2002; University of Bari and "AIDI"		Oral presentation
Lenzi M.A.	2002	Debris flow hazard assessment using numerical models and GIS.	ECO-GEOWATER "GI and Natural Hazards" workshop; Novembre 18-22; University of Milano Bicocca		Extended Abstract and Oral presentation
Lenzi M.A.	2002	Bedload and sediment budget in the instrumented catchment of the Rio Cordon (Northeastern Italy).	XXVII EGS General Assembly,Nice, April, 21-26, 2002	Geophysical Research Abstracts, Vol. 4, 2002, ISSN 1029-7006	Abstract and Poster presentation
Lenzi M.A.	2002	Suspended sediment load and sediment yield during floods and snowmelt in the Rio Cordon (Northeastern Italy).	XXVII EGS General Assembly,Nice, April, 21-26, 2002	Geophysical Research Abstracts, Vol. 4, 2002, ISSN 1029-7006	Abstract and Oral presentation

[1] Type: Abstract, Newsletter, Oral Presentation, Paper, Poster, Proceedings, Report, Thesis

Mao L. & Lenzi M. A.,	2002	Impact of limitation in sediment supply on bed load transport in the instrumented catchment of the Rio Cordon, Italy.	AGU Fall Meeting, S. Francisco, USA, December 6-10, 2002	Eos. Trans. AGU, 83(47), Fall Meet. Suppl., Abstract H11C-0851, 2002.	Abstract and Poster presentation
D'Agostino V.	2002	La difesa idrogeologica e le sue implicazioni territoriali.	Convegno La Gestione Forestale nel Veneto; "Le esperienze maturate come supporto per l'ammodernamento legislativo e normativo del settore", Padova, February 23, 2002		Oral presentation
Lenzi M.A.	2002	Valutazione della pericolosità e del rischio idraulico sui conoidi alpini.	Convegno La Gestione Forestale nel Veneto; "Le esperienze maturate come supporto per l'ammodernamento legislativo e normativo del settore", Padova, February 23, 2002		Oral presentation
D'Agostino V.	2001	Elementi per la progettazione delle briglie aperte.	Università Europea d'Estate sui Rischi Naturali, Cemagref. Post-graduated Training Course on "Rischi torrentizi", Serre Chevalier, September 10-15, 2001, France		Proceedings
Lenzi M.A.	2001	Fluvial geomorphology and biological-ecological analysis to planning and designing torrent control and restoration works.	4th Inter-Regional Conference "Environment and Water: Competitive use and conservation strategies for water and natural resources, Fortaleza, Brazil, August 2001.	In Alves Soares A., Mattana Saturnino H(eds.)Competitive use and conservation strategies for water and natural resources, 56-66.	Proceedings
D'Agostino V., Sonda D., Piccoli E.,	2000	Delimitazione su conoide delle aree soggette a pericolo di debris flow medianti indagini di campo.	"Taller sobre degradación ambiental en cuencas torrenciales", University of La Plata, Argentina, La Plata, 9-10 November 2000.	pp.16	Paper