**ANNEX 1**

**"DESCRIPTION OF WORK"**

# DEBRISFALL ASSESSMENT IN MOUNTAIN CATCHMENTS FOR LOCAL END-USERS

# DAMOCLES

**PROPOSAL N°:** **EVG1-1999-00027**

**CONTRACT N°:**

**PROJECT COORDINATOR:** **UNIVERSITY OF NEWCASTLE UPON TYNE**

**CONTRACTORS:**

| | |
|---|---|
| **UNIVERSITY OF NEWCASTLE UPON TYNE (CO)** | **UK** |
| **UNIVERSITA' DEGLI STUDI DI MILANO-BICOCCA (CR)** | **I** |
| **CONSIGLIO NAZIONALE DELLE RICERCHE (AC)** | **I** |
| **UNIVERSITA' DEGLI STUDI DI PADOVA (CR)** | **I** |
| **CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CR)** | **E** |
| **INSTITUTO TECNOLOGICO GEOMINERO DE ESPAÑA (AC)** | **E** |

**DURATION:** **36 MONTHS**

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# 1 EXECUTIVE SUMMARY

Debris flows and rockfalls are a familiar hazard in European mountain areas and regularly cause loss of life, livelihood and property. Hazard assessment is therefore increasingly required in land use planning. However, there are no standard techniques and existing operational techniques are qualitative. DAMOCLES will therefore develop quantitative technologies for assessing the distribution of rapid slope failures and their hazard, for determining the physical impact of debris flows and, hence, for assessing the mitigating effects of torrent control works and land management. It will also disseminate these technologies to end-users for application in land use planning. In order to achieve its goals the project integrates research-based model development with the involvement of local planning and civil protection authorities as data suppliers, advisors and recipients of the project results. Its objectives are:

1) Develop and apply three advanced models for hazard assessment, impact prediction and mitigation studies relevant at local to regional scales : a) a Geographical Information System (GIS) debris flow and rockfall hazard assessment model; b) a small basin (<10 $km^2$) debris flow impact model; and c) a basin scale (<500 $km^2$) landslide erosion and sediment yield model (SHETRAN). Models (b) and (c) will be integrated with (a).

2) Conduct field surveys and assemble databases in support of model development for one region in the Spanish Pyrenees and two in the Italian Alps. Identify debris flow process relationships for insertion in the models.

3) Transfer the technologies to end-users and make outcomes accessible through the public domain. Involve end-users in model applications, including assessment of possible future land use and climate change impacts.

The objectives will be addressed via a set of workpackages over a 3-year period. Progress in these packages will be monitored according to specified milestones and success in achieving in the objectives will be measured in terms of the deliverables for each package. The workpackages are:

WP1) Development of functional relationships for debris flow behaviour derived from field data and existing databases. The results will be improved means of predicting debris flow occurrence as a function of land use change and rainfall return period and improved techniques for mapping debris flow characteristics.

WP2) Development of a GIS hazard and risk assessment methodology using field data, available databases and model developments. This is the core of the project: it will involve statistical and physically based modelling and will benefit from the data and model developments of the other workpackages. The result will be a quantitative hazard and risk modelling technology for rockfalls and debris flows.

WP3) Development of a small basin (< 10 $km^2$) debris flow impact model using field data and a physically based modelling approach. An innovative user-friendly debris flow impact model will be developed, integrating a propagation model and a debris fan digital terrain model and incorporating channel control

structures and land management. The result will be a model for use by end-users in assessing debris flow impacts and the effect of mitigation measures.

WP4) Application of the existing SHETRAN basin scale (<500 $km^2$) landslide erosion and sediment yield model to land use and climate scenario analysis. Spatially distributed simulations of debris flow occurrence and the impact on basin sediment yield will be carried out for current and possible future conditions. The results will be demonstrations of debris flow impact assessment and new guidelines on basin management for end-users.

WP5) Dissemination of the project deliverables. This will be achieved by training courses, workshops, the direct involvement of six-end users in model applications and the placement of relevant deliverables on a web site. The results will be transfer of project technology to end-users and the public domain and a proposal for a standard approach to hazard and risk zonation.

WP3 and WP4 provide important inputs to WP2 which will enhance the capabilities and reliability of the hazard assessment methodology. Between them the three packages will provide a means of examining debris flow problems at a range of spatial scales. Similarly the relationships from WP1 will be used to refine the models in WP3 and WP4. Packages 1 to 4 will all contribute to WP5.

The Consortium consists of six principal (CR) and assistant (AC) contractors. They include one end-user (EU) and are supported by a further five, some of whom are subcontractors.

CO1 University of Newcastle upon Tyne, UK. Project coordinator and leader of WP4 and WP5.

CR2 University of Milan-Bicocca, Italy. Leader of WP2.

AC3 CNR-IRPI (Institute for Hydrogeological Protection in Central Italy), Perugia, Italy. Provision of GIS and web expertise in WP2 and WP5.

CR4 University of Padova, Italy. Leader of WP3.

CR5 CSIC (Pyreneen Institute of Ecology), Zaragoza, Spain. Leader of WP1.

AC/EU6 Geomining Technical Institute, Zaragoza, Spain. End-user and provision of support for CR5.

The remaining end-users are: the Lombardy Region Geological Survey; the Veneto Regional Agency for Environmental Protection; the Autonomous Province of Trento; the Land and Urban Planning Directorate, Aragón; and the Interior and Local Administration Directorate, Aragón. The first three of these are project subcontractors.

The project is aimed at improving the efficiency and reliability of decision-making in the development of European mountain areas, with implications for the quality of life of both mountain dwellers and lowland inhabitants. Its innovative aspects include: a quantitative approach; an emphasis on user-friendliness; the direct involvement of

end-users; consideration of debris flow impacts at a range of scales; provision of new databases; and a proposal for a standard approach to hazard assessment and zonation.

# 2 SCIENTIFIC/TECHNICAL OBJECTIVES AND INNOVATION

## 2.1 Objectives

DAMOCLES will develop and apply advanced modelling technologies to assess hazards posed by rapid slope failures in mountain areas and will disseminate these technologies to local end-users for application in land use planning. In order to accomplish these goals, the proposed work integrates research-based model development with the direct involvement of local planning and civil protection authorities as data suppliers, advisors, and recipients of the project results.

### 2.1.1 *The Problem*

Hazard resulting from rapid slope failure (defined here as debris flows and rockfalls) is a continual threat. In the Province of Lecco in the Lombardy Region of Italy, debris flows and rockfalls account for 80-90% of recorded landslides. Both phenomena are a familiar hazard in European mountain environments and regularly cause considerable loss of life, livelihood, and property (e.g. Simons, 1988; Cancelli and Crosta, 1993; Aulitzky, 1994a; White et al., 1997; Versace et al., 1998). Direct costs such as deaths, personal injuries and financial loss, destruction of infrastructure and agricultural assets can be high even for moderate events. Severe events result in deaths of over 100 men, women, and children. Monetary damage is in the tens of millions of euros. Indirect impacts such as temporary closure of roads and siltation of river courses and reservoirs with debris are less easily defined monetarily but are still clearly significant. For example, just one provincial authority in northeast Italy reports an annual budget of 20 million euros for debris flow management alone.

Hazard posed by rapid slope failures is dynamic. As European mountain areas are increasingly developed, the potential costs of rapid slope failures also increase. Insurance claims as a result of this threat are steadily rising in mountain areas. In addition, the result of development increases the incidence of debris flows by changing their topographic, soil, and vegetation controls. Consequently, there is increasing concern that the spread of roads along with development of leisure and recreational areas, together with changes in agricultural practices and forest management, is having an adverse effect (e.g. Simons, 1988; Garcia-Ruiz and Valero, 1998; Wasowski, 1998). Additionally, changes in climate (including more extreme rainfall events or an altered balance between rainfall and snowfall) and loss of tree cover (due to atmospheric pollution or fire) can similarly change the incidence of slope failure.

It is now increasingly recognized that hazard assessment forms an important part of land use planning in mountain environments. Those authorities with the responsibility for protecting populations, settlements, and infrastructure from the threat of rapid slope failures are particularly concerned with three critical aspects: **1**) The spatial distribution of the phenomenon; **2**) Predicting their occurrence and impact; and **3**) Minimising the impact.

2.1.2 *Objectives*

This project will develop technologies for assessing the distribution of rapid slope failures and their hazard, for determining the physical 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. To achieve these aims, the specific project objectives are to:

1) Develop and apply advanced models for hazard assessment, impact prediction and mitigation studies, relevant at a range of scales including: **1**) A Geographical Information System (GIS) model for assessing the debris flow and rockfall hazard; **2**) A debris flow model for predicting the local on-site impact in basins up to 10 $km^2$; and **3**) A landslide sediment yield model for predicting debris flow occurrence and sediment yield impact in basins up to 500 $km^2$. Models (2) and (3) will be integrated with (1).

2) Conduct field surveys and assemble databases in support of model development and refinement. The surveys will include the spatial distribution and characteristics of rapid slope failures and information on meteorological and geomorphological controls. Field data collection and data analysis will identify process relationships for insertion into the models.

3) Transfer the technologies to end-users and make outcomes accessible through the public domain. Model applications will include assessment of possible future land use and climate change impacts.

## 2.2 Innovation

Debris flow and rockfall *hazard* is the potential for adverse impacts caused by existing and future debris flows and rockfalls. It refers to the probability of occurrence of a particular magnitude of event within a specified area over a given period of time. The term *risk* is introduced to account for the combination of likelihood and significance of event, involving the expected degree of loss due to a particular magnitude of rapid slope failure. *Hazard assessment* refers to the procedures and techniques used to identify and delimit the potential for loss-inducing rapid slope failures in terms of magnitude, frequency and type. However, hazard assessments can only effectively be undertaken where some appreciation of, and concern about, the possible adverse effects of impact (ie risk) has been acquired by the relevant land managers and decision makers, together with an understanding that slope failures are scientifically explicable events, not random occurrences. *Education* is therefore a pre-requisite for assessment (Jones, 1995).

Hazard assessment involves both *prediction* and *forecasting* (Jones, 1995). Prediction concerns the establishment of the general likelihood and character of slope failure within specified areas; it is a spatially extensive exercise concerned with establishing zones of different levels of threat. Forecasting concerns the identification of the location, timing, magnitude and character of individual future events and is more closely linked with simulation models. An example of forecasting is the identification of conditions likely to result in the generation of debris flows within an area over a limited period of time.

A number of techniques have been developed and applied to identify and map natural hazards, e.g. combining information on past events with geomorphological surveys (Aulitzky, 1994b). However, there is *no uniformity* of approach in Europe and available techniques are *approximate* (because of *lack of data*) and give only *qualitative* or *relative* estimates of hazard. They do not allow, for example, the contribution of critical channel features (bends, obstacles, etc) to debris flow impact to be assessed or conversely appropriate control structures to be designed. In addition these approaches may not always provide a sound basis for determining the *effects of change* in the local environment (e.g. removal of forest cover), especially if the area has not previously been considered hazardous.

The search for quantitative techniques has made use of recent developments in computer power and *Geographical Information System (GIS) techniques* (e.g. Kienholz et al., 1984; Kienholz & Mani, 1994; Carrara et al., 1991, 1995). Incorporation of geotechnical stability models and data layers in a GIS framework (Van Westen, 1994) provides *a promising approach* and offers the potential for both prediction and forecasting. However, the combination of factors which triggers debris flows and rockfalls is not always fully understood and there remains uncertainty in the application of the technique.

There is a considerable literature on *debris flows* (e.g. Johnson, 1984; Takahashi, 1991; Iverson, 1997), including modelling developments (e.g. Chen, 1987; O'Brien, 1993; Hungr, 1995). A number of recent EC projects (e.g. EC, 1998) have investigated debris flow behaviour (e.g. EROSLOPE I, DEBRIS-FLOW-RISK and RUNOUT), producing models for debris flow transport and deposition in the fan area. However, the research nature of available models and the difficulties of applying their constitutive rheological laws reduce their *user-friendliness*. *Poor data availability* has also hindered their validation.

Despite considerable research on *debris flow trigger mechanisms* (e.g. Sidle et al., 1985; Crozier et al., 1986; Guzzetti, 1998), *improvements in process modelling* are needed to meet the needs of end-users (EC, 1998). This requires both improved databases and model developments. To be of use for forecasting, the databases must be able to indicate the effects of land use change and rainfall return period on debris flow occurrence. Similarly, physically based models are required for simulating the impacts of possible future conditions. Following improvements in computer power and the development of GIS and Digital Terrain Models, factor of safety geotechnical models have been combined with hydrological models as a basis for simulating spatial and temporal occurrence of landslides in river basins. Mostly these are limited to scales of a few square kilometres (e.g. Montgomery and Dietrich, 1994; Wu and Sidle, 1995). However, through the use of an innovative technique for modelling hydrological and debris flow responses at dual resolutions, the SHETRAN model is able to simulate both *debris flow occurrence* and the resulting *sediment yield* at scales up to about 500 $km^2$ (Burton & Bathurst, 1998).

There has been considerable research into rockfall processes (e.g. Cancelli & Crosta) but there has been no incorporation of this into DTM methodologies and very little work on statistical modelling through GIS, mainly because of difficulties in identifying source and runout areas.

DAMOCLES will advance end-use capability in debris flow and rockfall hazard assessment, while at the same time advancing scientific understanding of the problem, as follows:

1) Provision of *new databases* at scales from individual debris flows to river basins, according to the project's *model requirements*.
2) Development of *quantitative relationships* on debris flow occurrence (including land use and rainfall return period effects) and characteristics (e.g. volumes of material mobilized, runout distance.)
3) Development of a *quantitative GIS model* for debris flow and rockfall hazard assessment, incorporating both statistical and physically based approaches.
4) Development of a *user-friendly debris flow impact model* for basins up to $10km^2$ , capable of representing the effects of *stream control works* and *land use change* in the fan area.
5) Application of the advanced SHETRAN model to simulate *debris flow occurrence* and the resulting basin *sediment yield* as a function of possible future land use and climate *scenarios*.
6) Application of (4) and (5) to enhance the *prediction* and *forecasting* capabilities of (3).
7) *Education* of end-users through their direct involvement in the project.

8) Development of a proposal for a *standard approach* to hazard assessment and zonation based on the project deliverables.

# 3 PROJECT WORKPLAN

## 3.1 Workplan Structure

Achievement of the DAMOCLES project's objectives requires the carrying out of individual research tasks and the integration of the outputs of those tasks into an overall product larger than the sum of its components. To meet this requirement, the work has been divided into five workpackages closely related to the objectives specified in Section 2. These are:

WP1 Development of functional relationships for debris flow behaviour derived from field data and existing databases.

WP2 Development of a GIS hazard assessment methodology using field data, available databases and model developments.

WP3 Development of a small basin debris flow impact model using field data and a physically based modelling approach.

WP4 Application of a physically based, basin scale, landslide erosion and sediment yield model to land use and climate scenario analysis for selected sites.

WP5 Dissemination of the project deliverables via training courses, workshops, implementation by end-users and placement of demonstration material on a web site.

To understand the methodology for carrying out and integrating these packages
it will be helpful to know the roles and responsibilities of the DAMOCLES partners. These are identified by participant number, name and role (CO = coordinator, CR = principal contractor, AC = assistant contractor, SC = subcontractor, EU = end-user):

CO1 University of Newcastle upon Tyne, UK.
Major roles in WP4 and WP5; minor roles in WP1, WP2 and WP3.

CR2 University of Milan - Bicocca, Italy.
Major roles in WP2 and WP5; minor roles in WP1, WP3 and WP4.

AC3 National Research Council - Institute for Hydrogeological Protection in Central Italy (CNR-IRPI), Perugia, Italy.
Major roles in WP2 and WP5.

CR4 University of Padova, Italy.
Major roles in WP3 and WP5; minor roles inWP1, WP2 and WP4.

CR5 Higher Council for Scientific Studies, Pyreneen Institute of Ecology, Zaragoza, Spain.
Major roles in WP1 and WP5; minor roles in WP2, WP3 and WP4.

AC/EU6 Geomining Technical Institute, Zaragoza, Spain.
Major roles in WP1 and WP5.

SC7 University of Bologna, Italy.
Participation in WP2 and WP5.

SC/EU8 Lombardy Region Geological Survey (GSLR), Italy.
Participation in WP2 and WP5.

SC/EU9 Veneto Regional Agency for Environment Protection (ARPAV), Italy.
Participation in WP3 and WP5.

SC/EU10 Autonomous Province of Trento (ASSM), Italy.
Participation in WP3 and WP5.

EU11 Land and Urban Planning Directorate, Aragón, Spain.
Participation in WP5 (Not funded by project).

EU12 Interior and Local Administration Directorate, Aragón, Spain.
Participation in WP5 (Not funded by project).

In addition, all six end-users are providers of data that may be used in any of the workpackages. The participant links are as follows:

### 3.2 Workplan Methodology

This section provides a brief description of the workpackages to indicate the basic approach, the complementarity of the packages and their linkages. The Pert diagram in Section 3.3 summarizes the links between the packages. It should be noted, though, that the links do not necessarily imply dependence. For example, WP2 will be enhanced by the outputs of WP3 and WP4 but is not completely dependent on those outputs for success. Also, while the principal flow of information is from top left to bottom right, feedback can also occur in the opposite direction. The workpackages are listed in Table 1 and described in Table 3. The deliverables are listed in Table 2.

Although aiming at a general hazard assessment methodology, the work will be based on three focus areas, both for demonstration purposes and to make the best use of participant experience and provision of data by the end-users. Focus area A is in the Pyrenees. Focus areas B and C are in the Alps.

WP2 is at the core of the project since this will produce the overall hazard assessment methodology. Its principal demonstration focus area will be B. Data will be assembled from this area by CR2 (Milan-Bicocca) and SC/EU8 (Lombardy Region Geological Survey). Data may also be used from focus areas A and C. A rockfall model will be developed by CR2 and along with the database and results from WP3 and WP4 will be combined into a GIS modelling methodology by CR2, AC3 (CNR-IRPI) and SC7 (Bologna). This methodology will be applicable at a range of scales.

WP3 will provide a debris flow impact model, applicable at the small river basin scale ($<10km^2$). Its principal development and test focus area will be C but data from focus areas A and B will also be used. Field data will be assembled by CR4 (Padova), SC/EU9 (ARPAV) and SC/EU10 (ASSM). The model itself will be developed by CR4 with emphasis placed on user-friendliness, physical realism and relevance to practical problems. The model will be available as a stand-alone code but will also be linked into the hazard assessment methodology of WP2.

WP4 will make use of an existing but unique physically based, spatially distributed landslide erosion and sediment yield model, applicable at basin scales up to $500km^2$ (SHETRAN). This will be applied by CO1 (Newcastle) to one site in focus area A and one site in focus area B or C (the final choice depending on data availability). Data will be provided by CR5 (Pyreneen Institute of Ecology), AC/EU6 (Geomining Technical Institute), EU11 (Land and Urban Planning Directorate), EU12 (Interior and Local Adminstration Directorate) and the relevant contractor and end-users for focus area B or C. The model will be applied to give spatial distributions of landslides and debris flows for a range of land use and climate change scenarios, both as a comparison with and for input to the hazard assessment methodology of WP2. In addition it will be used to explore the impact of debris flows on river basin sediment yield and to develop illustrative guidelines on land management for minimising debris flow occurrence and sediment yield impact.

WP3 and WP4 provide important inputs to WP2 which will enhance the capabilities and reliability of the hazard assessment methodology. In particular they, along with model developments in WP2, will provide a capability for both prediction and forecasting of rapid slope failures. The specific type of forecast which could be considered in the project is the

identification of conditions likely to result in the generation of debris flows within an area over a limited period of time. The workpackages also complement each other by enabling debris flow problems to be examined at a range of spatial scales.

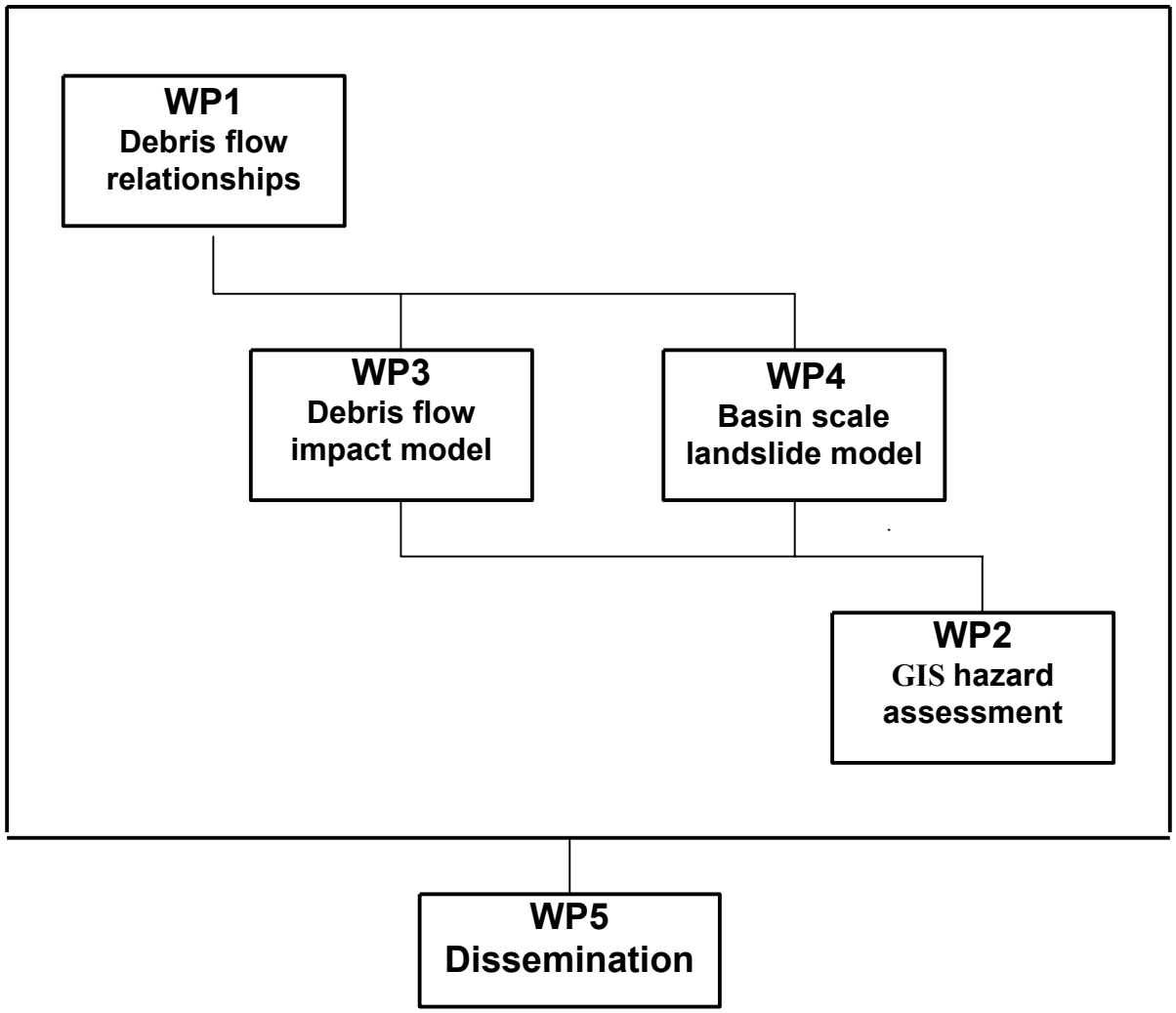
A major challenge in the DAMOCLES project will be to ensure integration of the WP3 and WP4 outputs with the requirements of WP2. This will require close collaboration between CO1 (Newcastle), CR2 (Milan-Bicocca) and CR4 (Padova) and agreement at the start of the project on data exchanges, data formats and exact areas of responsibility. The project quality assurance procedure provides a rigorous standard for the required management.

WP1 provides for improved understanding of the relationships between debris flow behaviour and characteristics and environmental variables, including land use. Data collection, mapping and data analysis will be carried out by CR5 (Pyreneen Institute of Ecology) and AC/EU6 (Geomining Technical Institute) for three basins (up to 5500 $km^2$ in total area) in focus area A. Relevant data may also be used from focus areas B and C. Relationships linking, for example, debris flow occurrence, runout distance and volume of material mobilized as a function of relevant meteorological, geomorphological and land use conditions will be developed and used to refine the models in WP3 and WP4. It will be particularly important to be able to model the control on debris flow occurrence and behaviour exercised by forest cover, in order to represent the impacts of afforestation and deforestation. The package will also provide detailed location maps and occurrence probability maps of rapid slope failures in the focus area, of particular interest to AC/EU6 (Geomining Technical Institute), EU11 (Land and Urban Planning Directorate) and EU12 (Interior and Local Administration Directorate).

WP5 defines the practical aspect of the DAMOCLES project in terms of technology transfer. It is important that the project should not only advance our knowledge of rapid slope failures but also put that understanding at the disposal of end-users. All the participants have important roles in this package and it will therefore be led by CO1 (Newcastle). The principal and assistant contractors will provide and transfer the information, while the project end-users will be the immediate beneficiaries. Other end-users from outside the project may also be able to participate in certain parts of the transfer. The main dissemination procedures are training courses mounted by CR2 (Milan-Bicocca) and CR4 (Padova), workshops to be led by CO1 and attended by all participants, demonstration implementations of the models and methodologies in the relevant focus areas (CO1, CR2, CR4, CR5 and AC/EU6) and the placement of demonstration results on a web site (led by AC3 (CNR-IRPI) and involving all participants). End-user advice and needs will be important in defining these procedures.

Each of WP1, WP2, WP3 and WP4 involves to a greater or lesser degree the collection of field data and the use of existing databases. The actual data required vary between the workpackages and the responsible participants will therefore manage their own data assembly programmes in each package. However, experience and expertise will be shared between participants, partly because the data provision for each package will involve more than one participant and partly because opportunities will be taken through meetings to transfer procedures formally. In addition the project quality assurance procedures will provide standards for recording data exchange and storage.

### 3.3 Graphical Presentation of the Project Components (Pert diagram)



# 1. Workpackage list

| Work-Package No[4] | *Workpackage title* | Lead contractor No[5] | Person-months[6] | Start month[7] | End Month[8] | Deliverable No[9] |
|---|---|---|---|---|---|---|
| WP1 | Development of functional relationships for debris flow behaviour | 5 | 68 | 1 | 30 | D1, D2 |
| WP2 | Development of a GIS hazard assessment technology | 2 | 40 | 1 | 30 | D3, D4, D5 |
| WP3 | Development of a small basin debris flow impact model | 4 | 81 | 1 | 30 | D6, D7 |
| WP4 | Application of basin landslide model to scenario analysis | 1 | 31 | 1 | 30 | D8, D9 |
| WP5 | Dissemination of project deliverables | 1 | 57 | 1 | 36 | D10, D11, D12 |
| | **TOTAL** | | 277 | | | |

[4] Workpackage number: WP1 - WPn
[5] Number of the contractor leading the work in this workpackage.
[6] The total number of person-months allocated to each workpackage.
[7] Relative start date of the work in the specific workpackage, month 0 marking the start of the project, and all other start dates being relative to this start date.
[8] Relative end date, months 0 marking the start of the project, and all end dates being relative to this start date.
[9] Deliverable number: Number for the deliverables(s)/result(s) mentioned in the workpackage: D1-Dn

## 2. Deliverables list

| Deliverable No[10] | *Deliverable title* | Delivery Date[11] | Nature[12] | Dissemination Level[13] |
|---|---|---|---|---|
| D1 | Debris flow relationships and database | 21 | Da | RE[a] |
| D2 | Debris flow maps and mapping procedures | 30 | Da | RE[a] |
| D3 | Debris flow and rockfall database for GIS | 24 | Da | RE[a] |
| D4 | Hazard and risk assessment technology | 30 | Me | RE[a] |
| D5 | Review of rockfall and granular flow models | 18 | Re | RE[a] |
| D6 | Debris flow database for impact model | 15 | Da | RE[a] |
| D7 | Debris flow impact model | 24 | Me | RE[a] |
| D8 | Debris flow impact scenario simulations | 24 | Si | RE[a] |
| D9 | Guidelines for basin land management | 30 | Me | RE[a] |
| D10 | End-users trained in project technologies | 36 | Eu[b] | PU |
| D11 | Project technologies in public domain | 36 | Me | PU |
| D12 | Proposal for standard approach to zonation | 36 | Me | PU |

[a] Restricted level refers to deliverable as input to another component of the project. All deliverables will be made public via deliverable D11.

[b] Trained end-user.

[10] Deliverable numbers in order of delivery dates: D1 - Dn

[11] Month in which the deliverables will be available, month 0 marking the start of the project, and all delivery dates being relative to this start date.

[12] Please indicate the nature of the deliverable using one of the following codes:

**Re** = Report **Da** = Data set **Eq** = Equipment
**Pr** = Prototype **Si** = Simulation **Th** = Theory
**De** = Demonstrator **Me** = Methodology **O** = Other (describe in annex)

[13] Please indicate the dissemination level using one of the following codes:

**PU** = Public
**RE** = Restricted to a group specified by the consortium (including the Commisssion Services).
**CO** = Confidential, only for members of the consortium (including the Commission Services)

# 3. Workpackage description WP1

**Workpackage number:** 1
**Start date or starting event:** Project start date
**Lead contractor number:** 5 - Pyreneen Institute of Ecology
**Person-months per partner:** 1-3; 2-2; 3-0; 4-3; 5-56; 6-4

**Objectives and input to workpackage**

1) Develop quantitative relationships for debris flow characteristics.
2) Assess effect of extreme rainfall characteristics on debris flow magnitudes.
3) Assess the most geomorphologically active areas at hillslope and basin scales in focus area A
4) Assess effect of vegetation cover and land use change on debris flows.
5) Assess importance of debris flow for basin sediment source and sediment yield.

**Description of work**

1) Geomorphic mapping in 3 mountain river basins of total area 5500km$^2$ in focus area A at 1:50,000 scale to determine spatial distribution of debris flows and sediment sources and to identify the most affected subbasins.
2) Incorporate geomorphic maps into a GIS with the geomorphological, soil hydrological, vegetation cover, and current and past land use characteristics.
3) Field measurement of debris flow characteristics (scar size and gradient, runout distance, vegetation cover, substrate properties) to provide a database for determining debris flow relationships for improved modelling. Data from all focus areas.
4) Statistical analysis of the information in the GIS, a) to rank the factors explaining debris flow occurrence and related phenomena, and b) to assess probability of debris flow occurrence in the study area.
**5)** Statistical analysis of meteorological information to classify the rainfall events and to determine their return periods. Assess relationship between rainfall of different return periods and occurrence of debris flows of different magnitude, using historical and present-day data. Data from all focus areas.

**Deliverables**

D1) Quantitative relationships for debris flow characteristics, including effect of land use and rainfall return period, as input to WP3 and WP4; and debris flow characteristics database, as input to WP5.
D2) Geomorphological map of debris flow characteristics and debris flow occurrence probability map for focus area A, as input to WP5; statistical and cartographic procedures for automatic identification of geomorphologically and hydrologically active basins likely to generate debris flows, as input to WP5.

**Milestones and expected result**

Month 15: Preliminary debris flow relationships for WP3 and WP4.
Month 21: Final debris flow relationships for WP3 and WP4.
Month 30: Final cartographic products and database, for WP5.
Result: Improved means of predicting debris flow occurrence as function of environmental change. Improved techniques for mapping debris flow characteristics.

# 3. Workpackage description WP2

**Workpackage number:** 2
**Start date or starting event:** Project start date
**Lead contractor number:** 2 - University of Milan-Bicocca
**Person-months per partner:** 1-2; 2-30; 3-3; 4-3; 5-2; 6-0

**Objectives and input to workpackage**

1) Data collection on rockfalls and debris flows at basin scales up to 3000 $km^2$ in focus areas.
2) Development of GIS models for debris flow/rockfall hazard and risk assessment applicable at local to regional scale.
**3)** Testing and adoption of different numerical techniques for rockfall and granular flow modelling.

**Description of work**

1) Data collection (field survey, high resolution topographical surveys with ALTM, and aerial photography), including historical event and physical property data, and creation of a database for GIS and numerical modelling. Generation of accurate Digital Terrain Models (DTM) for fans susceptible to debris flow reactivation, using 1:2000 and 1:5000 scale maps.
2) Using the database and fan DTMs, develop GIS hazard and risk models considering source area for rapid slope failure, debris flow tracks and alluvial fans. Approach will be statistically as well as physically based, the latter including development of a rockfall model from DTMs and maps. Approach will also use hydrological models (eg. SHETRAN from WP4) to describe soil saturation as a debris flow trigger and will incorporate debris flow impact modelling (track and fan) (e.g. from WP3). Demonstration application in focus area B.
**3)** Compare available rockfall and granular flow models. Compared with classical approaches, the more sophisticated rockfall codes can simulate the failure of falling blocks. Particulate flow codes model the initiation and spreading of granular flows and enable the effectiveness of passive countermeasures to be tested.

**Deliverables**

D3) Databases, thematic maps and DTMs, as input to WP5.
D4) GIS statistically and physically based technology for hazard and risk assessment, including code for simulation of rockfalls from GIS data. Input to WP5.
D5) Review of rockfall and granular flow models. Input to WP3.

**Milestones and expected result**

Month 18: Recommendations on granular flow model, for WP3.
Month 24: Preliminary hazard and risk assessment technology for WP5; databases for WP5.
Month 30: Final assessment technology, for WP5.
Result: Quantitative hazard and risk modelling technology for rockfalls and debris flows.

# 3. Workpackage description WP3

**Workpackage number:** 3
**Start date or starting event:** Project start date
**Lead contractor number:** 4 - University of Padova
**Person-months per partner:** 1-2; 2-2; 3-0; 4-74; 5-3; 6-0

**Objectives and input to workpackage**

1) Data collection on debris flow characteristics for model development.
2) Development of a 1-D user-friendly model for debris flow propagation and impact (in terms of hazard on the fan).
**3)** Application of model to small basin (<10km$^2$) in focus area C; design of torrent control works and planning of land use in the fan area.

**Description of work**

1) Measurements of debris flow characteristics (volume of material mobilized, runout distances, etc) in experimental and instrumented basins. Acquisition and analysis of a) precipitation and water discharge data, and b) existing thematic maps (land use, geology, etc).
2) Development of the model using a Muskingum-Cunge approach modified to account for the flow rheology, the ratio of flow depth and sediment diameter at the debris flow front and relationships from WP1. Innovative integration of the propagation model and a fan DTM. The fan area will be pre-processed to extract a potential hydrographic net and to estimate the degree of connection with the critical (low conveyance) cross section of the main stem. For each critical section (e.g. at bridges, bends, etc) the hazard is defined by a thematic DTM window. Development of user-friendly graphics and data input-output.
**3)** Creation of debris flow data base for a small basin in focus area C. Detailed survey of channel reaches (critical sections) and fan areas and creation of detailed fan DTM. Integration of data (including thematic maps) into a GIS system. Validation of model.

**Deliverables**

D6) Comprehensive database on debris flow characteristics and impacts in small basins, as input to WP5.
D7) Simple 1-D debris flow impact model integrated with a GIS, for use alone or as part of WP2.

**Milestones and expected result**

Month 18: Preliminary impact model for WP2.
Month 24: Final impact model for WP2.
Month 30: Application to design of impact mitigation measures for WP5.
Result: Innovative user-friendly model for use by end-users in assessing debris flow impact and effect of mitigation measures.

# 3. Workpackage description WP4

**Workpackage number:** 4
**Start date or starting event:** Project start date
**Lead contractor number:** 1 - University of Newcastle upon Tyne
**Person-months per partner:** 1-24; 2-2; 3-0; 4-2; 5-3; 6-0

**Objectives and input to workpackage**

1) Selection of 1 application basin (<500km$^2$) in focus area A and 1 in B/C and assembly of SHETRAN database.
2) Application of SHETRAN to model debris flow spatial and temporal occurrence and impact on basin sediment yield for land use and climate scenarios.
**3)** Development of guidelines for basin management to minimize impacts.

**Description of work**

1) Selection of test river basins according to availability of recorded debris flow events, associated meteorological and basin response data and basin thematic data (topography, soils, vegetation).
2) Assembly of data, including field measurements, and creation of SHETRAN data files. Enhancement of SHETRAN with relationships from WP1. Model validation for past conditions.
**3)** Development of future land use scenarios (with advice from end-users) and climate scenarios (using proven in-house experience in statistical downscaling from GCM data and rainfall return period data from WP1).
**4)** Application of SHETRAN to scenario conditions for the test basins, giving debris flow spatial and temporal occurrence at event scale and basin sediment yield at annual scale. Assess dependency of debris flow occurrence and sediment yield on land use, future climate and rainfall return period.
**5)** Production of illustrative matrices showing debris flow occurrence as a function of land use (e.g. forest cover, abandoned land, etc) and rainfall event (extreme, moderate, etc) and the annual sediment yield as a function of land use and climate (for 2000, 2040, 2090). Indicate extent to which sediment yield impact is attenuated by upstream basin area.

**Deliverables**

D8) Spatially distributed simulations of hydrological and debris flow response for current and possible future conditions, as input to WP2.
D9) Illustrative guidelines for basin land management to mitigate debris flow occurrence and impact, as input to WP5.

**Milestones and expected result**

Month 18: Preliminary simulation data for WP2.
Month 24: Final simulation data for WP2.
Month 30: Illustrative guidelines for WP5.
Result: Demonstration of debris flow impact assessment for current and scenario conditions for 2 basins up to 500km$^2$ and new guidelines on basin management for end-users.

# 3. Workpackage description WP5

**Workpackage number:** 5
**Start date or starting event:** Inception meeting with end-users
**Lead contractor number:** 1 - University of Newcastle upon Tyne
**Person-months per partner:** 1-8; 2-11; 3-4; 4-20; 5-12; 6-2

**Objectives and input to workpackage**

1) Dissemination by training courses for end-users.
2) Dissemination by workshops.
3) Dissemination by end-user involvement in model applications.
4) Creation of a project website and placement of relevant deliverables on the site.

**Description of work**

1) Training courses on the models and procedures developed in WP2 and WP3 will be held for 10-12 staff of the project end-users.
2) Two workshops will be held (one in Spain, one in Italy) to present the project deliverables (including management guidelines) to any interested party.
3) The project end-users will be involved throughout the project as data suppliers, recipients of the project results and advisors on project objectives. They will gain an understanding of the required data provision, the use of the data in model applications, and model capabilities and limitations.
4) A web site will be created which provides basic information on project results as they become available, technical documents, guidelines and prerequisites for model application, the databases, appropriate model codes and demonstrations of model applications, including GIS maps and impact mitigation analysis.
5) A proposal will be prepared for a standard approach to collecting data and carrying out rapid slope failure hazard and risk zonation at the regional and local scale, as a means of introducing uniformity into land use planning.

**Deliverables**

D10) End-users trained in the project technologies.
D11) Project technologies in the public domain.
D12) A proposal for a standard approach to hazard and risk zonation.

**Milestones and expected result**

| | |
|---|---|
| Month 6: | Website on line. To be maintained for 3 years after the project ends. |
| Months 28-34: | Workshops and training courses; proposal for standard methodology. |
| Result: | Transfer of project technology to end-users and the public domain; contribution to formation of International Centre for Hydrogeological Risks at University of Milan-Bicocca. |

## 4 CONTRIBUTION TO OBJECTIVES OF PROGRAMME/CALL

The proposal is submitted to the:

Specific RTD Programme "Energy, Environment and Sustainable Development"
Part A "Environment and Sustainable Development"
RTD Activities of a Generic Nature
(i) The Fight Against Major Natural and Technological Hazards
I.1 Natural Hazards
I.1.2 Floods and hydrological risks.
The proposed work contributes to the relevant objectives as follows:

1) "*…through a better understanding of processes, mechanisms and events generating natural ……. hazards, to develop technologies and methods ……. for environmental impact assessment, risk forecasting, prevention, evaluation and mitigation*." The underlying ethos of the project is to develop technologies for hazard assessment which are firmly based on a physical understanding of the processes controlling rapid slope failures. Thus the field data collection and data analyses will enable the necessary relationships defining debris flow behaviour to be developed for insertion in the two impact prediction models. Similarly, GIS analysis of the assembled databases will highlight the factors for the hazard assessment model. The sound physical basis will be essential to the use of the models for examining future scenarios including mitigation procedures. More empirical approaches would have less basis for extrapolation beyond the conditions for which they were developed.

2) "*Support to improved decision-making systems, including evaluation and validation tools for assessing hazards ……*" It is a principal objective of this project to develop models for assessing the hazard posed by rapid slope failures and to disseminate the resulting technologies to relevant end-users to improve the efficiency and objectivity of their decision-making.

3) "*Mitigation strategies with a view to providing input to EU policies and relevant directives*". The models provide a basis for exploring the mitigating effects of, for example, torrent control structures and land management on debris flow impact. While aimed initially at local end-users, the models could equally well be used in the development of more general strategies. Part of the project is also concerned with preparing a proposal for a code of standards for collecting and analyzing data for land use planning and formulation of associated laws.

As a *research project*, the work will be aimed at obtaining new knowledge on rapid slope failures in European mountain areas and both developing and improving modelling technologies to address an important Community socio-economic problem. End-users will be closely involved to help focus and steer the work.

Within the wider consideration of the *Fifth Framework Programme*, the proposed work has clear implications for improving the quality of life (reduced threat to life and livelihood) and for sustaining the economies of Europe's mountain areas (e.g. by providing a basis for reducing damage to infrastructure).

# 5 COMMUNITY ADDED VALUE AND CONTRIBUTION TO EU POLICIES

## 5.1 The European Dimension of the Problem

The hazard posed by rapid slope failures is common to all Community countries with mountain environments. Further, it is relevant not just to the local inhabitants but to all users of these environments. These include winter and summer tourists who may boost local populations by a factor of ten, owners of equipment, infrastructure and land who live elsewhere, and users of roads and railways. For example, the Biescas campsite tragedy of 7 August 1996 in the Spanish Pyrenees affected holidaymakers from throughout Europe. Devastation of communication and transport links is also well documented. For example, five people were killed by a debris flow on the Italian section of the Trento-Bolzano-Brennero highway on 15 August 1998. The hazard clearly has a European dimension.

A European approach to assessing the hazard carries a number of advantages. While acknowledging that a great deal of expertise is available at the national level amongst scientists, engineers, and civil protection authorities, this expertise is unevenly dispersed between countries. A number of techniques have been developed to identify and map natural hazards and are used as standards by the relevant authorities in some European countries. In Austria, for example, hazard mapping combines information on past events with geomorphological surveys (e.g. Aulitzky, 1994b). However, there is by no means a uniform approach in Europe. For example, the Lombardy Regional Geological Survey has no model or a specific law regarding debris flow hazard evaluation and prevention. In addition, engineering practice may be based empirically on local knowledge and experience, overlooking new techniques developed elsewhere. This applies particularly to recent advances in GIS and river basin modelling techniques. At the same time, those developments may be in the form of research studies published internationally but not easily assimilated and applied locally. A European consortium therefore provides benefits in terms of introducing new technologies and experience from different countries, combining technologies in complementary fashion, disseminating the technologies to end-users at a European scale, and proposing a code of standards.

## 5.2 The European Added Value for the Consortium

The DAMOCLES project will unite four European research teams of proven and complementary expertise. No single European agency is able to provide the width of expertise or assemble the range of datasets to tackle the problem as comprehensively. This applies particularly to the complementarity of field data collection and modelling skills and the complementarity of model scales (regional, small basin, large basin). The direct involvement of six major end-users from Spain and Italy is also a major force for dissemination of the project technologies and the development of standard methodologies at the European level.

## 5.3 EU Policies

This project is relevant to EU policies which require environmental impact assessments. These policies include Cohesion and Agriculture. For example, the Agriculture Policy promotes afforestation as an alternative use of agricultural land and the development of forestry activity on farms. Vegetation cover is an important control on debris flow occurrence and the project methodologies could therefore be applied to assess the impact of afforestation

in mountain areas. Because of the physical basis of the models, the impacts of different options for afforestation could be explored before any one was implemented, enabling the optimum to be selected, ie the one with the least adverse effect.

Similarly, the Cohesion Policy calls for environmental protection and socio-economic development to be reconciled. The project methodologies could therefore be applied to provide environmental impact assessments related to relevant socio-economic developments in mountain regions.

# 6 CONTRIBUTION TO COMMUNITY SOCIAL OBJECTIVES

## 6.1 Quality of Life and Health and Safety of the Citizens

Developments in the mountain regions of Europe (e.g. ski resorts, campsites and other tourist facilities, forestry operations, altered agricultural practices) tend to benefit inhabitants of lowland regions more than those of the mountains. However, the environmental problems that may arise form such developments (including increased incidence of debris flows) are borne disproportionately by the latter group (often poorer members of society), or their local authority budgets. For example, the cost of remedial work in the wake of debris flow and other environmental problems attributed to development of Les Arcs ski resort in France was estimated in 1981 at about 55 million francs, most of which had to be borne by the local municipality until reimbursement was eventually obtained from the resort. The social aspects of the project are thus most clearly defined by the potential that the project deliverables hold for improving the quality of life through better management of mountain region development. By helping to identify rapid slope failure hazards and potential impacts (including the effects of different development strategies) the project will enable the measures necessary to minimise future losses or costs to be undertaken by those with the funding (i.e. developers) rather than leaving the cost of remedial action to be borne by the local communities and hard-pressed local authority budgets. Even more starkly, by pointing the way to risk mitigation, the project holds out hope for a minimisation of human deaths and injuries, including the psychological stress and trauma suffered by those caught up in rapid slope failures. The project therefore represents an investment aimed at improved hazard mapping and debris flow impact prediction which will improve the quality of life of poorer, as well as other, levels of European society, and mountain dwellers as well as lowland inhabitants.

## 6.2 Environment and Natural Resources

The development of mountain areas is taking place amidst conflicting economic, social and environmental pressures. The economic value of the hazard assessment predictions which contribute to development decisions is therefore increasing rapidly, placing an ever greater premium on their accuracy and overall reliability. It follows that, insofar as the responsible authorities (e.g. in the EU) possess a superior and dynamic capacity to provide hazard and risk assessments, they can better design, implement and manage development strategies suited to current and future needs. It is also increasingly accepted that large investments in environmental protection should be supported by relatively minor investments in predictive modelling. The project should be viewed in this light, as a long-term investment in the latest environmental technology aimed at improving the efficiency and reliability of decision-making in the development of European mountain regions. In environmental terms this can translate into more efficient environmental impact assessments, planning decisions and management of land use to maintain environmental quality.

## 6.3 Employment, Education, Training and Working Conditions

Abandonment of agricultural lands in mountain areas is an indication of loss of traditional activities and employment. Counterbalancing this is the rise in tourist and other service related occupations. However, for tourist related employment to be sustainable, the services provided (from accommodation to communication links) must be considered safe and should be profitable (requiring in part affordable insurance). Planning authorities in the Pyrenees, for example, are concerned at the risk associated with the spread of second residences as tourism

increases in mountain areas. Identification of areas considered most at risk from rapid slope failure is therefore important for locating development in safe areas. Likewise, application of impact prediction models enables protection schemes to be designed for specified levels of threat (e.g. the one in a hundred year event), forming a defined basis for insurance estimates. By these means the project technologies can indirectly benefit local employment. However, the benefits of careful hazard assessment and its incorporation into development zoning can extend more widely. For example, the interruption of road and rail links by debris flows can have economic (and therefore employment) consequences far beyond the mountain area through which the links pass. If the risk of such interruption can be reduced, so is the potential for loss of employment.

# 7 ECONOMIC DEVELOPMENT AND SCIENTIFIC AND TECHNOLOGICAL PROSPECTS

Dissemination of the project results is a key element of DAMOCLES and is therefore allocated its own workpackage. As explained in Section 3 this accounts particularly for transfer of the results to the project end-users and the placement of the results in the public domain via a web site. However, the exploitation of the results after the end of the project also needs to be considered. Both aspects will be addressed in a Technology Implementation Plan to be developed by the DAMOCLES consortium in the early stages of the project and agreed with the EC.

# 8 THE CONSORTIUM

## 8.1 Overview of the Consortium

The six principal and assistant contractors provide a comprehensive and complementary range of expertise and resources, integrating in particular field study, GIS analysis, mathematical modelling and teaching. They include one end user and are supported by a further five.

**CO1** **University of Newcastle upon Tyne**, UK. Project coordinator and leader of WP4 (application of the SHETRAN landslide model) and WP5 (dissemination).

**CR2** **University of Milan-Bicocca**, Italy. Leader of WP2 (GIS hazard assessment methodology).

**AC3** **CNR-IRPI**, Perugia, Italy. Provision of GIS and web expertise in WP2 and WP5.

**CR4** **University of Padova**, Italy. Leader of WP3 (small basin debris flow impact model).

**CR5** **Pyreneen Institute of Ecology**, Zaragoza, Spain. Leader of WP1 (debris flow behaviour relationships).

**AC/EU6** **Geomining Technical Institute**, Zaragoza, Spain. End-user and provision of support for partner CR5.

The partners complement each other as follows:

University of Newcastle upon Tyne: Large basin modelling and related data provision.

University of Milan-Bicocca: GIS hazard assessment modelling and data provision.

University of Perugia: GIS and web expertise.

University of Padova: Debris flow modelling and related data provision.

Pyreneen Institute of Ecology: Debris flow field surveys and mapping.

Geomining Technical Institute: End-user interest and field surveys and mapping.

The remaining end-users are:

**SC/EU8** **The Geological Survey of the Lombardy Region**, (GSLR), Italy.

**SC/EU9** **The Veneto Regional Agency for Environmental Protection** (ARPAV),Italy.

**SC/EU10** **The Autonomous Province of Trento** (ASSM), Italy

**EU11** **The Land and Urban Planning Directorate**, Aragón, Spain.

**EU12 The Interior and Local Administration Directorate**, Aragón, Spain.

Letters of intent from all six end-users are attached at the end of this annex. The means by which the end-users are involved in the project (assistant contractor, subcontractor or unfunded participant) depends on intended contribution and institutional arrangements. Subcontracts are let to GSLR, ARPAV and ASSM for supporting experimental catchments, data provision and participation in project meetings and training courses. The end-users from Aragón are unfunded.

## 8.2 Description of the Participants

### 8.2.1 *Partner 1 : University of Newcastle (UNEW), UK*

*Role*

UNEW will perform the overall project coordination as well as leading WP4 and WP5. Within the University the work will be carried out by the Water Resource Systems Research Laboratory (WRSRL), Department of Civil Engineering.

*Experience*

The Water Resource Systems Research Laboratory (WRSRL) is one of the leading international university research centres in its field and, with 8 academic staff, 10 research staff, 20-25 research students and multi-sponsor research income of over a million pounds a year, it is also one of the largest. Innovative research has been conducted over many years to develop a range of leading-edge technologies: these include hydrological, sediment and contaminant transport modelling systems such as SHETRAN, hydroinformatic tools and decision support/management systems. The aim is to improve the ability of decision-makers to address a spectrum of urgent concerns over management of the water environment and engineering infrastructure. Rigorous procedures are in place to verify the system computer codes and to demonstrate their fitness for purpose. In addition it has become increasingly apparent that modelling developments must be integrated more effectively with field programmes and several integrated programmes have therefore been developed, notably in the UK, Chile, Spain and Switzerland. The WRSRL has coordinated a number of EC projects (eg POPSICLE, GRACE and WRINCLE) and been a partner in others (eg MEDALUS, VAHMPIRE and FRAMEWORK), all of which are concerned with aspects of environmental change impact modelling. The WRSRL is located in the Department of Civil Engineering, which received the highest ratings (5, 5A and 5-star) in the 1989, 1992 and 1996 national research assessment exercises, reflecting international excellence in research. The Newcastle campus is also well known for its cross-faculty Centre for Land Use and Water Resources Research which, since 1985, has been spearheading interdisciplinary research on integrated land and water resource management.

*Personnel*

The team will consist of a senior academic (Project Coordinator and team leader) and a Research Associate supported by the WRSRL Computer Manager.

**8.2.2** *Partner 2 : Università degli Studi di Milano-Bicocca (UNIBICO), Italy*

*Role*

UNIBICO will lead Workpackage 2. Within the University the work will be carried out by the recently founded Department of Geological Science and Geotechnology. Subcontracts will be let to the University of Bologna (which with CNR IRPI is a leading centre for the use of GIS in hazard zonation) and the Lombardy Regional Geological Survey (which is charged with landslide management in the region). The Survey will be an important end user of the project results.

*Experience*

The Department of Geological Science and Geotechnology has been recently founded as part of the new University of Milano-Bicocca (transferred from the Department of Geology, University of Milan). Its main research subjects concern the assessment of risks: hydrogeological (landslides, floods, groundwater contamination, etc.), seismic and volcanic, environmental on land and at sea. The staff is composed of about 25 persons (professors and researchers) with experience in different fields of geology and of risk assessment. Through previous positions at the University of Milan the staff developed extensive experience in the field study and modelling of debris flows in the Italian Alps and the Apennines, with a particular interest in the rainfall conditions triggering flow formation. They played a central role in analysing recent catastrophic events, in particular the 1987 Valtellina and the 1994 Piemonte disasters. These analyses have enabled a detailed database on debris flows in northern Italy to be assembled.

*Personnel*

The team will comprise two senior academics and two researchers, plus a senior academic at the University of Bologna.

**8.2.3** *Partner 3 : CNR-IRPI, Perugia, Italy*

*Role*

The Consiglio Nazionale delle Ricerche-Istituto di Ricerca per la Protezione Idrogeologica nell'Italia Centrale (CNR-IRPI) will play a major role in WP2 and WP5. A subcontract will be let to an independent engineer who will provide expertise for the development of a GIS-based web system for disseminating project results.

*Experience*

The CNR-IRPI Institute in Perugia is one of the leading research institutions for regional landslide hazard assessment in Italy. The Perugia group has extensive experience in landslide mapping at different scales and in different physiographic environments, acquisition of relevant thematic information from aerial photograph interpretation and field survey, interpretation of landslide hazard assessment using multivariate statistical techniques, use of historical information on natural catastrophes to assess landslide and flood hazard, use of GIS for thematic data storage and analysis, and production and use of high quality digital elevation models for geomorphological research. Geologists at IRPI are currently working with the Lombardy Region Geological Service and with the Umbria Region Planning Office in preparing landslide inventory and hazard maps at various scales, and devising methodologies

for the proper application of such maps.

*Personnel*

The team will consist of two senior researchers and the subcontracted engineer.

**8.2.4** *Partner 4: University of Padova (UNIPD), Italy*

*Role*

UNIPD will lead Workpackage 3. Within the University the work will be carried out by the Department of Land and Agroforest Environments. Subcontracts will be let to the Veneto Regional Agency for Environmental Protection and the Autonomous Province of Trento.

*Experience*

The Department of Land and Agroforest Environments at the University of Padova, through its Water Resources Division, develops education and research activities in the field of forest hydraulic, watershed management, hydrology and water resources. Forest hydraulic and watershed management research areas include sediment transport and debris flow analysis and modelling, extreme flood analysis, fluvial geomorphology and risk-based decision analysis, stabilization, rehabilitation and restoration of torrents disturbed by debris flow and channel incision. Field work in experimental and instrumented basins (Rio Cordon and Chiesa, Veneto Region; Rio Maso di Calamento, Trento Province), GIS and remote sensing technology, data assimilation, and hydraulic modelling are used for monitoring variability and change of erosion processes and mass movements. The Department carries out fundamental and applied researches into the physical processes governing the dynamics of water and sediment in the alpine environment. The initiation and the behaviour of debris flow propagation at steep slopes, and the debris flow hazard in urban areas are subjects of investigations . The assessment and prediction of volume, run-out , and deposition of mass movements in small basins of the northeastern Italian Alps (< 10 $km^2$ ) are examined. With the support of mountain torrent control agencies (Veneto Region and Trento Province) the design, construction and monitoring of experimental grading control structures are conducted. The Department, through its Water Resources Division, has been involved in several EC funded RTD projects, such as “Instability, erosion and solid transport on steep mountain slopes”, EROSLOPE I project; “Dynamics of water and sediment in alpine catchments: processes and prediction”, EROSLOPE II project, (ENVIRONMENT Programme); “Ricerca integrata sulla degradazione dei versanti in territori montani”, R.I.V.E.T. project (EPOCH program); ‘Weather radar and flood and storm hazard’ (EPOCH programme), ‘Storms, floods and radar hydrology’ (ENVIRONMENT programme), and EUROTAS (Fourth Framework Programme).

*Personnel*

The principal investigators at the University of Padova will be a full professor and two assistant professors.

**8.2.5** *Partner 5 : Insituto Pirenaico de Ecologia (CSIC), Spain*

*Role*

CSIC (Consejo Superior de Investigaciones Científicas) will lead Workpackage 1. Within CSIC the work will be carried out by the Instituto Pirenaico de Ecologia (Pyreneen Institute of Ecology) and specifically the Institute's Department of Soil Erosion and Land Uses.

*Experience*

The work of the Department of Soil Erosion and Land Uses is focused on the hydrological and geomorphological effects of land use changes at different time and space scales. It has a scientific staff of 7. At present its research activities include the effects of land use change from traditional management, sediment budgets at the basin scale, identification of sediment sources using GIS, current and past fluctuations of sediment yield determined from lake and reservoir sedimentation studies, use of GIS for geomorphic and land use mapping, assessment and spatial prediction of geomorphic hazards by GIS and multivariate analysis, and the impact of tourism on soil erosion and on land management organisation. The Department has a lengthy research background in extreme events and large debris flows and played a central role in analyzing the August 1996 Biescas campsite disaster. It specialises in field based studies and operates an experimental station and three experimental catchments in the neighbouring Pyrenees. The Department was a partner in the EC VAHMPIRE project (Validating hydrological models using process studies and internal data from research basins; tools for assessing hydrological impacts of environmental change), supplying information for modellers and studying runoff and sediment transport from small experimental catchments and experimental plots.

*Personnel*

The team will be led by the Head of the Department of Soil Erosion and Land Use and will consist also of four other members of the Department.

**8.2.6** *Partner 6: Instituto Tecnológico y Geominero de España (ITGE), Spain*

*Role*

ITGE will participate as an assistant contractor and end-user principally in Workpackage 1. It will contribute to the project via its Zaragoza Projects Office.

*Experience*

Formerly known as the Instituto Geologico y Minero de España (IGME), ITGE is a public research organization within the Spanish Ministry of the Environment with a total staff of 400. It was founded in 1849 with the aims of carrying out research, technological development and technical assistance in geology, mineral resources, groundwater, natural risks, geoenvironment and related disciplines in Spain. It is the national research and information centre on earth sciences and related technologies and is the equivalent of Geological Surveys in other countries. Included in its work is the geological mapping of Spain at various scales and investigation of the relationship between geology and its resources. Of relevance to DAMOCLES, ITGE studies geological risks, seeks to understand the causes of catastrophic events associated with these risks, and provides risk assessments for client organizations. Its activities additionally encompass the analysis of natural and anthropic risks, statistics of natural disasters, prevention of natural risks, theory and forecasting of risks and climatic change.

*Personnel*

The team will be led by the Chief of the Aragón territorial section of the ITGE and will involve also the Chief of Geological Studies in ITGE.

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