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DAMOCLES

DEBRISFALL ASSESSMENT IN MOUNTAIN CATCHMENTS FOR LOCAL END-USERS

Contract No EVG1 - CT-1999-00007

DETAILED REPORT OF
CONTRACTOR FOR
SECOND ANNUAL REPORT
(1 March 2001 – 28 February 2002)

University of Newcastle upon Tyne
UK

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DETAILED REPORT OF THE CONTRACTOR

Contractor: University of Newcastle upon Tyne

Responsible Scientist: Dr J C Bathurst

Address: Water Resource Systems Research Laboratory
Department of Civil Engineering
University of Newcastle upon Tyne
Newcastle upon Tyne
NE1 7RU
UK

Telephone: +44 191 222 6333/6319

Fax: +44 191 222 6669

Email: j.c.bathurst@newcastle.ac.uk

3.1 OBJECTIVES OF THE REPORTING PERIOD (1/3/2001 – 28/2/2002)

(i) Assembly of Valsassina and Ijuez catchment time series and property data, including field measurements and laboratory analysis of soil samples.

(ii) Creation of SHETRAN model files for the two focus areas.

(iii) Initial SHETRAN simulations for the two focus areas to meet the Newcastle team's obligations to deliver preliminary simulation data to Workpackage 2 (WP2) in Month 18 (August 2001).

(iv) Replacement of project research associate following his departure and corresponding revision of work programme, including the simulation data originally planned for delivery in Month 24 (February 2002).

3.2 METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WORK PACKAGES

3.2.1 Project Staff

The project research associate, Dr Ahmed El-Hames, left the University of Newcastle in November 2001 for a permanent position at the King Abdulazziz University in Saudi Arabia. His departure (an unforeseen event) has inevitably caused a delay in the Newcastle project. However, his replacement, Dr Greta Moretti, has been appointed from 18 March 2002 and a revised work programme has been prepared to enable the project deliverables to be completed on time.

Dr Moretti is already familiar with the project, having contributed 4½ months of work in the summer of 2001 while visiting the University of Newcastle as an Occasional Student in the final year of her PhD studies at the University of Bologna. This work (apart from fieldwork expenses) was not charged to the project. Because of her previous involvement with the project, Dr Moretti will require only a short period of familiarisation.

Mr Aidan Burton (Research Associate) was funded for one month to complete the Llobregat validation.

Mr Rob Hiley (Senior Research Associate) was funded for half a month for computer systems and SHETRAN software support.

3.2.2 Workpackage 4: SHETRAN Landslide Model

3.2.2.1 Summary

This section summarises the work that has been carried out since the beginning of May 2001 regarding data assembly and preliminary SHETRAN simulations for the Valsassina and Ijuez focus catchments. Data assembly included climate data such as precipitation and evapotranspiration, soil and vegetation maps, and discharge records for stations in the catchments and in the surrounding areas. Disaggregation and gap-filling has been done for temporally varied data by applying simple statistical techniques, mainly correlation between stations and/or between values at the same station but at different times. Soil and vegetation properties for both catchments were derived by means of field work and laboratory analysis. Spatial distribution was defined by correlating the derived parameters with available geological and vegetation maps.

Three-day field visits were made to Valsassina in May 2001 and to the Ijuez catchment in June 2001. The Newcastle team was joined by the Milan-Bicocca team for the Valsassina visit and by the Pyreneen Institute of Ecology team for the Ijuez visit.

The Valsassina focus area contains two catchments: the main Pioverna catchment and the small neighbouring Esino catchment.

3.2.2.2 Data acquisition and analysis

(a) Valsassina Catchment, Lombardy, Italy

a.1 Precipitation records

The purpose of the precipitation analysis is to disaggregate the available daily precipitation data into hourly precipitation as required for the landslide model. Precipitation records at daily recording stations have to be disaggregated both temporally as well as spatially using hourly precipitation records wherever available. The statistically based model “Raindist”, developed by Mr Chris Kilsby at WRSRL, was selected for this purpose. Two main relationships have to be defined as input for the Raindist model. These are daily total versus hourly duration for hourly recording stations, and annual total versus elevation for all stations in the surrounding areas.

Daily precipitation records were obtained for raingauges in and around Valsassina. The Barzio hourly precipitation data were used to construct a daily total versus hourly duration relationship. A simple Thiessen Polygon method was used for spatial distribution of precipitation data. (No clear correlation between rainfall and altitude was identified.) Raindist was set up for Valsassina and used to disaggregate the daily rainfall in four other stations in the catchment. The resulting hourly precipitation values were prepared as an input data file for SHETRAN covering the period between 1993 and 1999 inclusive. This defines the initial Valsassina simulation period.

a.2 Evapotranspiration data

Evapotranspiration data were derived from the available daily average temperature data at Lierna. This station has a continuous record for 1993 to 1995 which was used with the Blaney-Criddle formula to calculate the daily average evapotranspiration. This value was set to be constant through each day. The values produced for this period were repeated for the following four years as there are no reliable temperature data available for the period of 1996 to 1999.

a.3 Vegetation cover

A vegetation map for Valsassina was prepared using a 1:10000 scale topography map, a landuse map produced by the CARINA project in Italy and, most important of all, a vegetation distribution map prepared by Carta Geoambientale (Regione Lombardia, 1987). In addition, notes taken during the field visit to the area and personal observations were useful for this analysis. By combining these sources four main vegetation types were identified in Valsassina. These are pasture and grass at the valley bottom, pine forest at elevations up to about 1000 m, grass and meadows at elevations up to about 1500 m, and bare rock at higher elevations. Pasture and grass were lumped together and a vegetation map of three vegetation types was prepared for SHETRAN.

a.4 Soil cover

Eighteen soil samples were collected in different locations in the catchment through field work conducted by the Newcastle and Milan-Bicocca teams. These samples were analysed in the laboratory for studying the physical and mechanical characteristics of the soil. Three major soil types were found by analysing the soil samples according to percentage of sand content. Using a geology map provided by Carta Geologica, Regione Lombardia (2001), it was noticed that soil distribution (three classes) is in agreement with the major geological features in the catchment. Figure 1 shows the locations of the soil samples overlaid on geology. Thus, soil coverage was distributed according to this pattern and a map in SHETRAN format was produced and transferred as an input file. A report on the soil analysis was produced by Dr Moretti.

a.5 Discharge record

Only 1½ years of unreliable stage data at the Bellano outlet station are available. For this reason a regionalisation analysis in the study area and a channel bankfull discharge investigation were done instead. The analysis indicates that for a catchment similar to Valsassina, a 1-year flood may reach a maximum of 200 $m^3 s^{-1}$ (Brath and

Franchini, 1998). This value should be used here as a guide limit for the simulation results.

(b) Ijuez Catchment, Northern Spain

b.1 Precipitation records

Daily precipitation records are available for stations in and around the catchment. Hourly precipitation data are available only at Jaca, 10 km away from the catchment. Daily records for Bescos (in the catchment) have therefore been used and disaggregated into hourly values by using the hourly precipitation data from Jaca. However, because of gaps in the Bescos record it was first necessary to generate the Bescos daily record for 1995-97 by correlation with the Jaca record for other years. Following the procedure mentioned above, a daily total precipitation versus duration relationship was constructed for Jaca. The Raindist model was then set up to incorporate the Ijuez catchment and used to disaggregate the Bescos daily rainfall. The resulting hourly precipitation values were prepared as input data files for SHETRAN for the period between 1995 and 1998 inclusive. This defines the initial Ijuez simulation period.

Data for the region show an altitude dependency in annual rainfall. The Ijuez catchment was therefore divided into three rainfall areas according to altitude (800-1200 m, 1200-1600 m, and over 1600 m). Each area has different hourly rainfall values calculated from the Bescos disaggregated precipitation data and based on the annual total precipitation versus elevation linear relationship.

b.2 Evapotranspiration

Pan evaporation data are available for certain years and for the summer months only. Potential evapotranspiration values were therefore derived from the mean daily temperature record (average of maximum and minimum) at Bescos, which is available for 1971 to 1994, excluding 1990, and from 1998 to 1999. The conversion (with the Blaney-Criddle equation) was first carried out for 1991 and 1998, as those years had pan data available. The derived daily evapotranspiration values could therefore be compared with the recorded values and the conversion equation could be calibrated. The calibrated equation was then applied to generate daily evapotranspiration (assumed constant in each day) for 1995-1998.

b.3 Vegetation cover

A vegetation map that contains seven main vegetation types was available. These vegetation types are meadows, beeches, farmed areas, oaks, pines, shrubs, and reforested pines. Tree-like vegetations (including beeches, oaks and pines) were lumped together in one type. Both beeches and oaks cover a small area and including them with pines was therefore considered reasonable. Grass-like vegetations (including meadows and shrubs) were also lumped together to form the second vegetation type. Finally, reforested areas were left as an individual vegetation type. The resulting map of three major vegetation covers was transferred into SHETRAN format.

b.4 Soil cover

Twelve soil samples were collected during the field visit and brought back to Newcastle for further laboratory analysis. From field observations and laboratory analysis it was concluded that the soil does not vary significantly in the Ijuez catchment. However, two main soil types (silty clay and silty clay loam) can be derived with slight differences in the physical and mechanical characteristics. These were best correlated with vegetation cover. It was noticed that soil type 1 is located mainly in areas covered with natural forest while soil type 2 is located in the re-forested areas. Figure 2 shows the original vegetation cover map overlain by the soil sample locations.

b.5 Discharge record

Discharge records for the Aragón River at Jaca were used as a means to generate the discharge at the Ijuez outlet. To do that discharge records were collected from a number of stations in the area. Annual total discharge versus catchment area as well as monthly mean discharge versus area relationships were established using 34 catchments ranging in size from 40 km^2 to more than 2000 km^2. These have been used to scale the mean daily discharge records for the Aragón to the level appropriate for the Ijuez catchment.

3.2.2.3 Simulations

At this stage only hydrological outputs will be presented here. It is premature to show the results of the sediment yield and landslide simulations although preliminary simulations were carried out before submitting this report. The presented results should not be taken as final as considerable refining will be undertaken during the remainder of the project.

Figure 3 shows the simulated hydrographs at the Valsassina Pioverna and Esino outlets, compared with the input rainfall record. From the regionalisation studies, the results are encouraging in terms of peak magnitudes. Similarly Figure 4 shows the simulated hydrograph at the Ijuez outlet compared with the input rainfall values and the “observed” hydrograph which was scaled from the Aragón catchment. The timing of the peak flows is encouraging but the magnitudes remain to be checked for plausibility.

3.2.2.4 Llobregat validation

Validation of the SHETRAN landslide model has been completed for the November 1982 landsliding event in the 500-km^2 Llobregat catchment in the eastern Spanish Pyrenees. Details of the validation approach have been given in previous progress reports but are summarized here with details of the results.

Because of uncertainty in evaluating the model parameters and other inputs, the aim is not to reproduce the observed occurrence of debris flows as exactly as possible with one simulation but to bracket the observed pattern with several simulations. Between them, these simulations should represent the uncertainty in the key input conditions, considering not only the landslide component of the model but the hydrological and sediment transport components also.

In stage 1, the event hydrological response was simulated, so as to obtain the soil saturation and water flow data which form the input to the landslide simulation. The observed outlet hydrograph was successfully contained in a simulation uncertainty envelope, derived as a function of uncertainty in the overland flow resistance coefficient and the timing of the measured rainfall.

In stage 2, uncertainty in the soil erosion and sediment transport calculations was determined as a function of uncertainty in the soil erodibility coefficients. However, no measurements of sediment yield were available for comparison.

In stage 3, uncertainty in the debris flow simulations was determined as a function of vegetation root cohesion. The cohesion was decreased by 50% and increased by 25% relative to a baseline value (based on literature data), so yielding an overestimate and an underestimate respectively of the observed debris flow occurrence. In each case a preceding simulation was carried out for a rainfall event scaled at 30% of the November 1982 event, so as to eliminate from the main simulation those debris flows which could have occurred as a result of storm events in previous decades. The resulting patterns are shown in Figures 5 and 6. The upper bound (Figure 5) is a considerable overestimate of the observed pattern (around 17,000 debris flows compared with an observation of around 700). However, it reproduces several of the principal clusters in the observed pattern, notably the half-ring of debris flows along an escarpment just to the west of the main north-south valley and clusters in the north-western and north-eastern sectors of the catchment. It is important that such clusters should be reproduced in the overestimate as this provides confidence in the model's ability to represent at least the general features of physical reality. The lower bound (Figure 6) contains rather fewer debris flows than were observed (around 500).

The results demonstrate the desired ability to bracket the observed occurrence of debris flows, based on realistic uncertainty bounds in the model parameters. By indicating those parameters to which the debris flow simulations are most sensitive (and which therefore provide the basis of the uncertainty estimates) the validation also provides important experience which will benefit the Valsassina and Ijuez simulations.

The final stage in the Llobregat simulation is calculation of the uncertainty bounds on the event sediment yield. Simulations were carried out for each combination of the hydrological, sediment transport and debris flow uncertainty runs. In addition the yields were determined without the debris flow contribution. As examples:

(i) For the combination of the maximum flow and maximum soil erodibility estimates, sediment yield is 2.54 x 10^6 t without the debris flow contribution and 7.52 x 10^6 t with the yield from the upper bound on debris flow occurrence (respectively 5080 and 15,040 t km^{-2}).

(ii) For the combination of the minimum flow and minimum soil erodibility estimates, sediment yield is 1.97 x 10^6 t without the debris flow contribution and 2.47 x 10^6 t with the yield from the lower bound on debris flow occurrence (respectively 3940 and 4940 t km^{-2}).

Between them, these two sets of simulations effectively provide maximum and minimum estimates of the event sediment yield. There are no measured data from the Llobregat catchment with which to test the estimates. However, data for a reservoir in the central

Pyrenees (catchment area 1250 km^2) indicate that intense floods can increase the annual sediment yield from a long term average of 350 t km^{-2} yr^{-1} to around 2000 – 3000 t km^{-2} yr^{-1} (Valero-Garcés et al., 1998). A yield of around 6800 t km^{-2} is estimated for the 1996 Biescas event in the central Pyrenees (although this is for a rather smaller catchment of 18.8 km^2) (White et al., 1997). The lower estimates for the Llobregat event sediment yield are therefore not unreasonable. However, the upper estimates seem high, perhaps not surprising given the overestimate of debris flow occurrence in Figure 5.

For the upper sediment yield estimate, 66% of the total yield is attributed to debris flow supply. For the lower estimate, 20% of the total yield is supplied by debris flows.

3.2.3 Workpackage 5 : Dissemination

The Valsassina simulations were reported at a conference on hydrogeological risks organized by the Land and Urban Office of the Lombardy Region government during 26 – 27 September 2001.

The Llobregat validation formed part of a presentation at the EC High-level Scientific Conference "Link Geo and Water Research" held at Genova, Italy, during 7-9 February 2002 and organized by the Geographical Information Systems International Group. The validation will also be presented as a poster at the 27th General Assembly of the European Geophysical Society in April 2002.

3.3 SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

As noted in the Year 1 Newcastle report, the interests of the project end-users include:

- scenarios for altered hazard as a function of land use and climate change, for a 25-year planning horizon;
- catchment sediment yield (eg for public works);
- event-based responses (eg for different frequency rainfall events);
- rainfall thresholds for landslides;
- peak water discharge and total discharged volume for storm events;
- peak sediment discharge and total discharged volume for storm events.

Example evaluations of these characteristics will be produced for the Valsassina and Ijuez focus catchments as follows:

- development of future land use scenarios (with advice from the end-users) and climate scenarios (using output from the EC projects WRINCLE "Water Resources: the Influence of Climate Change" and SWURVE "Sustainable Water: Uncertainty, Risk and Vulnerability in Europe");

- application of the SHETRAN landslide model to the scenario conditions, giving debris flow occurrence, event-based responses including water and sediment discharges, and catchment sediment yield;
- production of illustrative matrices showing debris flow occurrence as a function of land use (eg forest cover, abandoned land, etc) and rainfall event (extreme, moderate, etc) and the annual sediment yield as a function of land use and climate.

3.4 DISCUSSION AND CONCLUSION

(i) The bulk of the work of obtaining data for the Valsassina and Ijuez focus catchments and creating the SHETRAN files has been completed. The basis has thus been provided for the SHETRAN applications. However, the simulations reported above are only preliminary. Considerable refining of the data files and simulations is required before the final simulations are undertaken.

(ii) Validation of the SHETRAN landslide model for the Llobregat catchment has been completed. The results demonstrate an ability to bracket the observed occurrence of debris flows with simulated distributions and to determine catchment sediment yield within the range of regional observations. The experience gained in model parameter evaluation and validation technique is greatly benefitting the Valsassina and Ijuez applications.

3.5 PLAN AND OBJECTIVES FOR THE NEXT PERIOD

The following activities in WP4 are required to meet the Newcastle team's obligations regarding project deliverables by the end of the project (February 2003). A timetable is attached.

(i) Familiarisation of Dr Moretti with the SHETRAN model.

(ii) Refining of SHETRAN data files.

(iii) Enhancement of SHETRAN landslide model with relationships from WP1.

(iv) Validation of SHETRAN for the focus catchments.

(v) Development of scenarios for future land use and climate.

(vi) Scenario applications with SHETRAN for Valsassina to provide a basis for a revised regional hazard assessment model, as input to WP2.

(vii) Scenario applications with SHETRAN to assess dependency of debris flow occurrence and sediment yield on land use, future climate and rainfall return period for the Valsassina and Ijuez catchments.

(viii) Use of scenario simulation data to develop illustrative guidelines for land management to mitigate debris flow occurrence and impact, for the Valsassina and Ijuez catchments.

To overcome the delays caused by Dr El-Hames's departure, other research associate staff will be taken on by the project for short periods to assist Dr Moretti.

3.6 REFERNCES

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Valero-Garcés, B.L., Navas, A., Machín, J. and Walling, D. 1999. Sediment sources and siltation in mountain reservoirs : a case study from the Central Spanish Pyrenees. Geomorphology, 28, 23-41.

White, S., Garcia-Ruiz, J.M., Martí, C., Valero, B., Paz Errea, M. and Gómez-Villar, A. 1997. The 1996 Biescas campsite disaster in the central Spanish Pyrenees, and its temporal and spatial context. Hydrological Processes, 11, 1797 – 1812.

Timetable for Newcastle WP4 activities, March 2002 – February 2003

	2002										2003	
	M	A	M	J	J	A	S	O	N	D	J	F
Familiarisation	━	━										
Refine SHETRAN files			━	━	━							
Enhance SHETRAN			━	━	━							
Validation				━	━	━	━	━				
Scenario development		━	━	━	━							
WP4/WP2 integration		━	━	━	━	━	━					
Scenario applications									━	━	━	━
Land management guidelines											━	━
Reporting											━	━

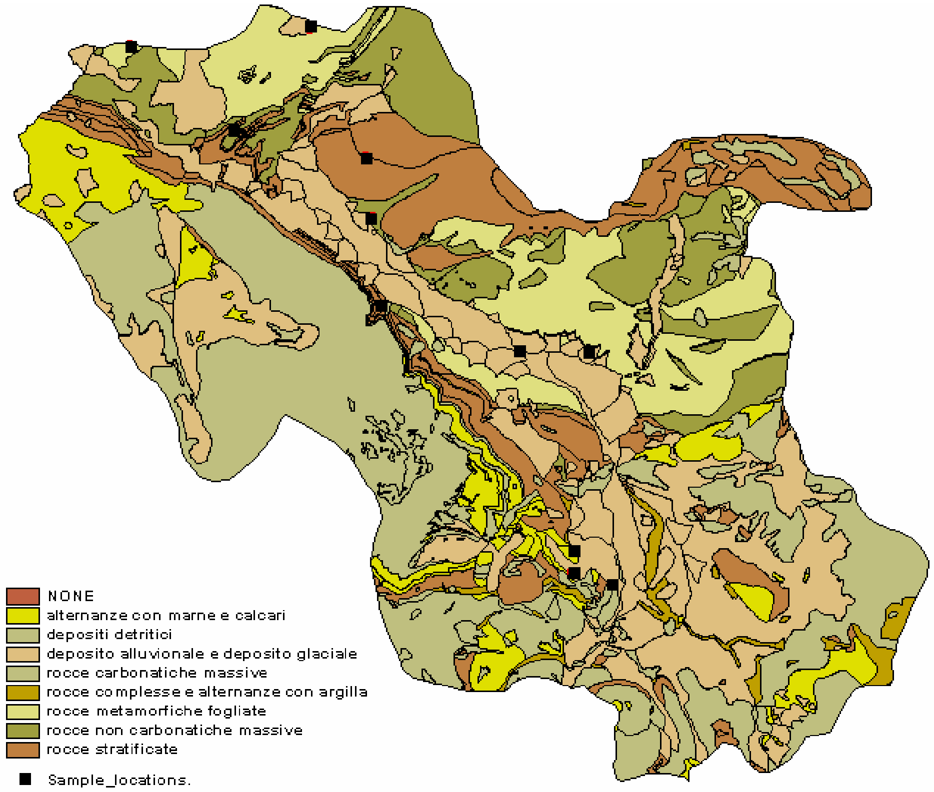


Figure 1 Valsassina geology and soil sample locations

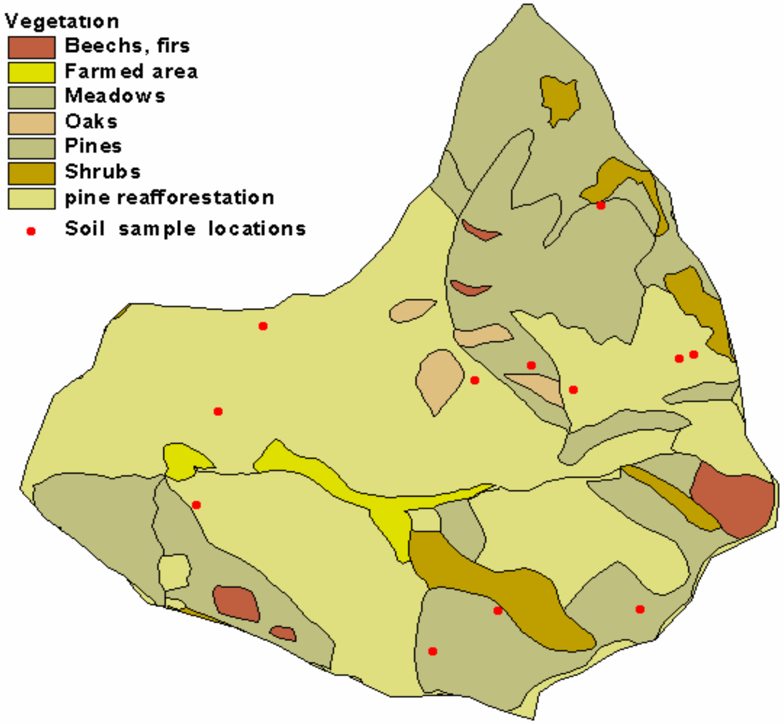
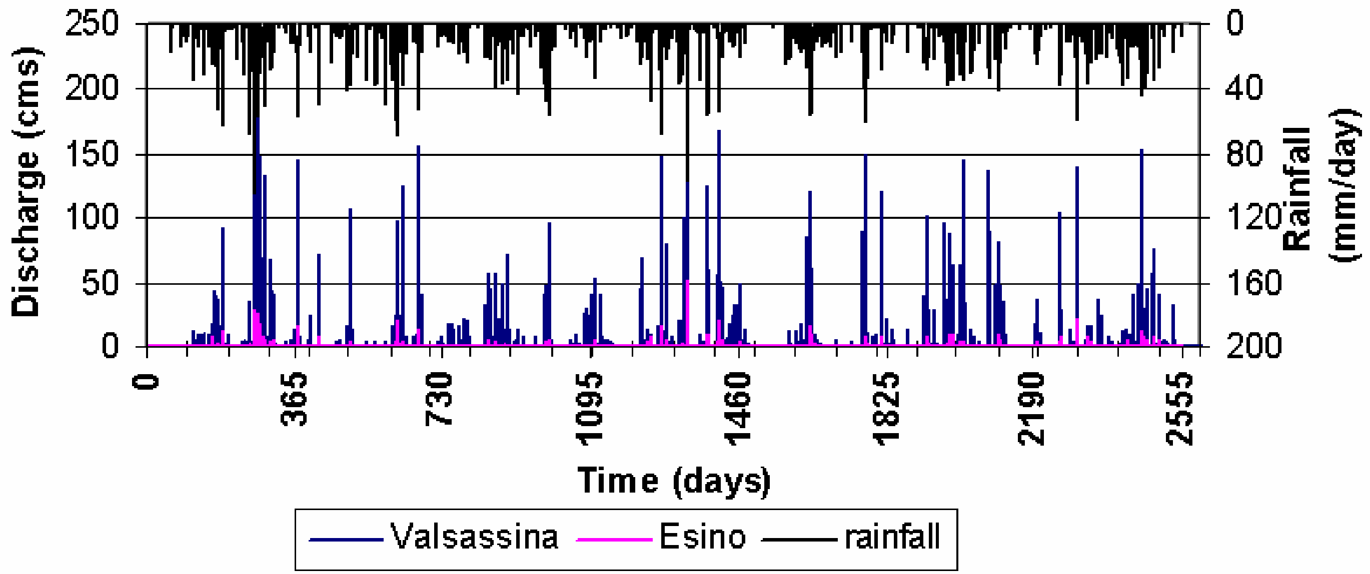


Figure 2 Ijuez vegetation distribution and soil sample locations

Figure 3 Simulated Hydrographs at the Pioverna and Esino outlets, compared with rainfall, 93-99



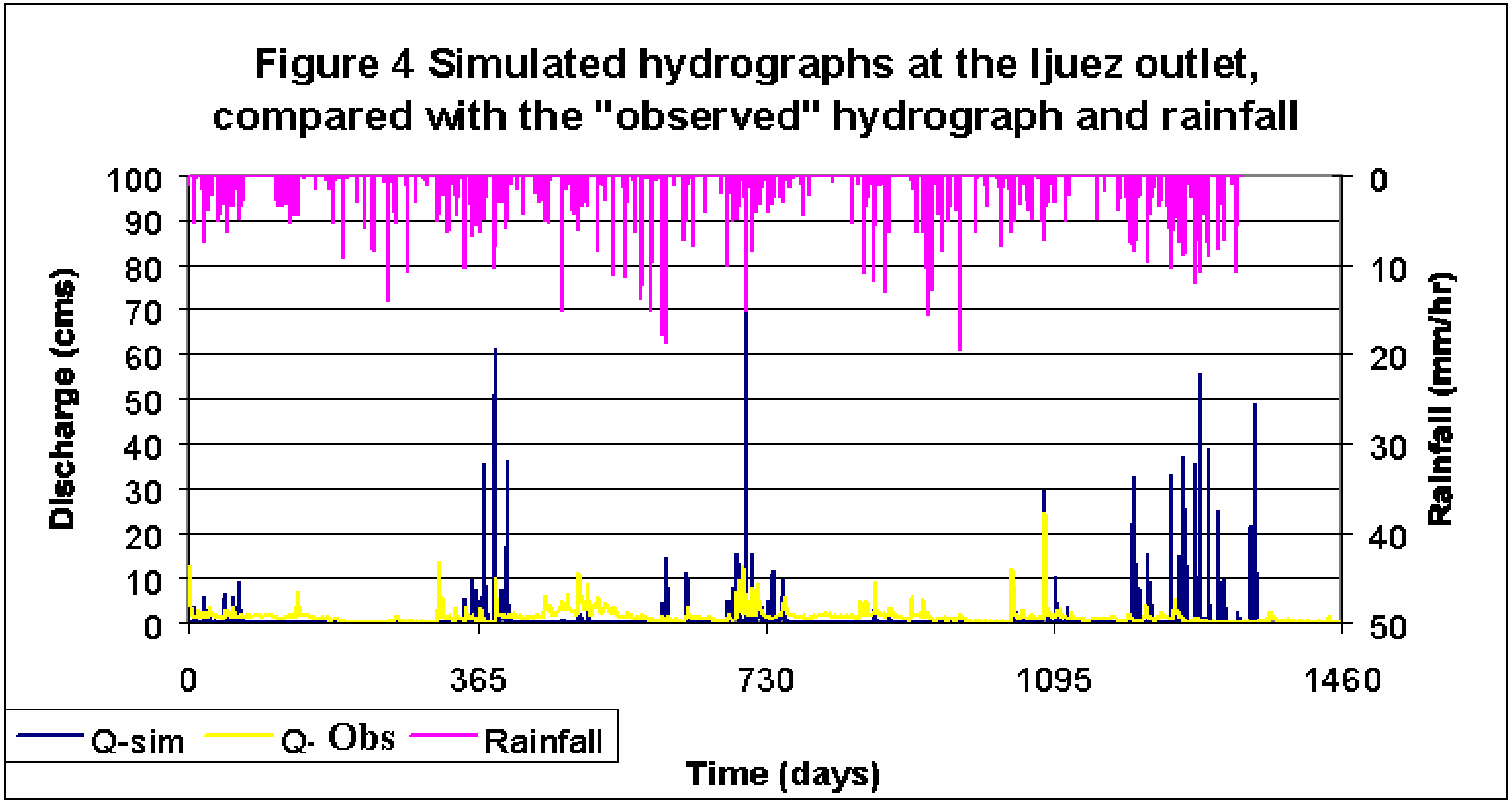


Figure 4 Simulated hydrographs at the Ijuez outlet, compared with the "observed" hydrograph and rainfall

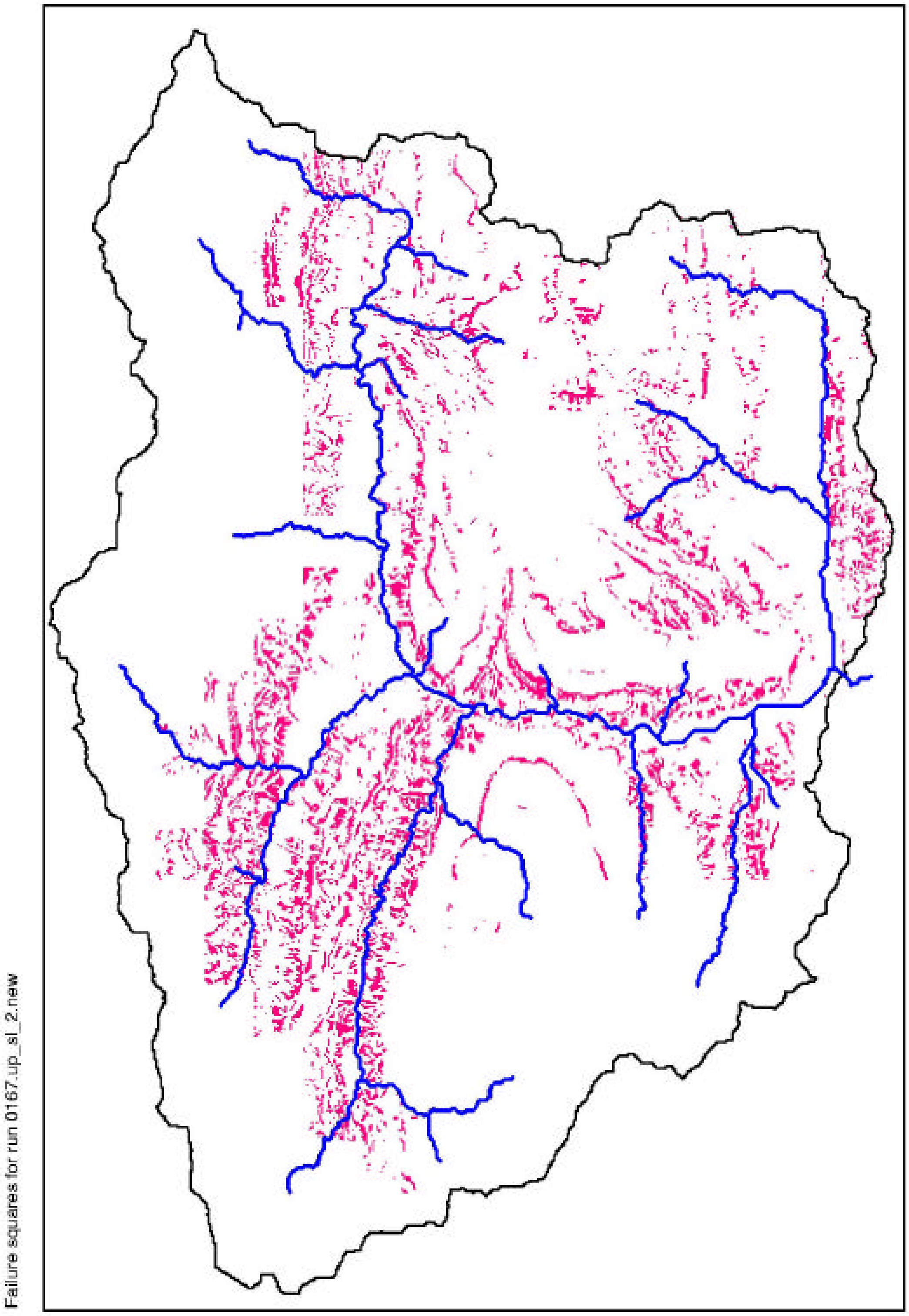


Figure 5 Upper bound for debris flow occurrence in the Llobregat catchment (Each dot represents a debris flow.)

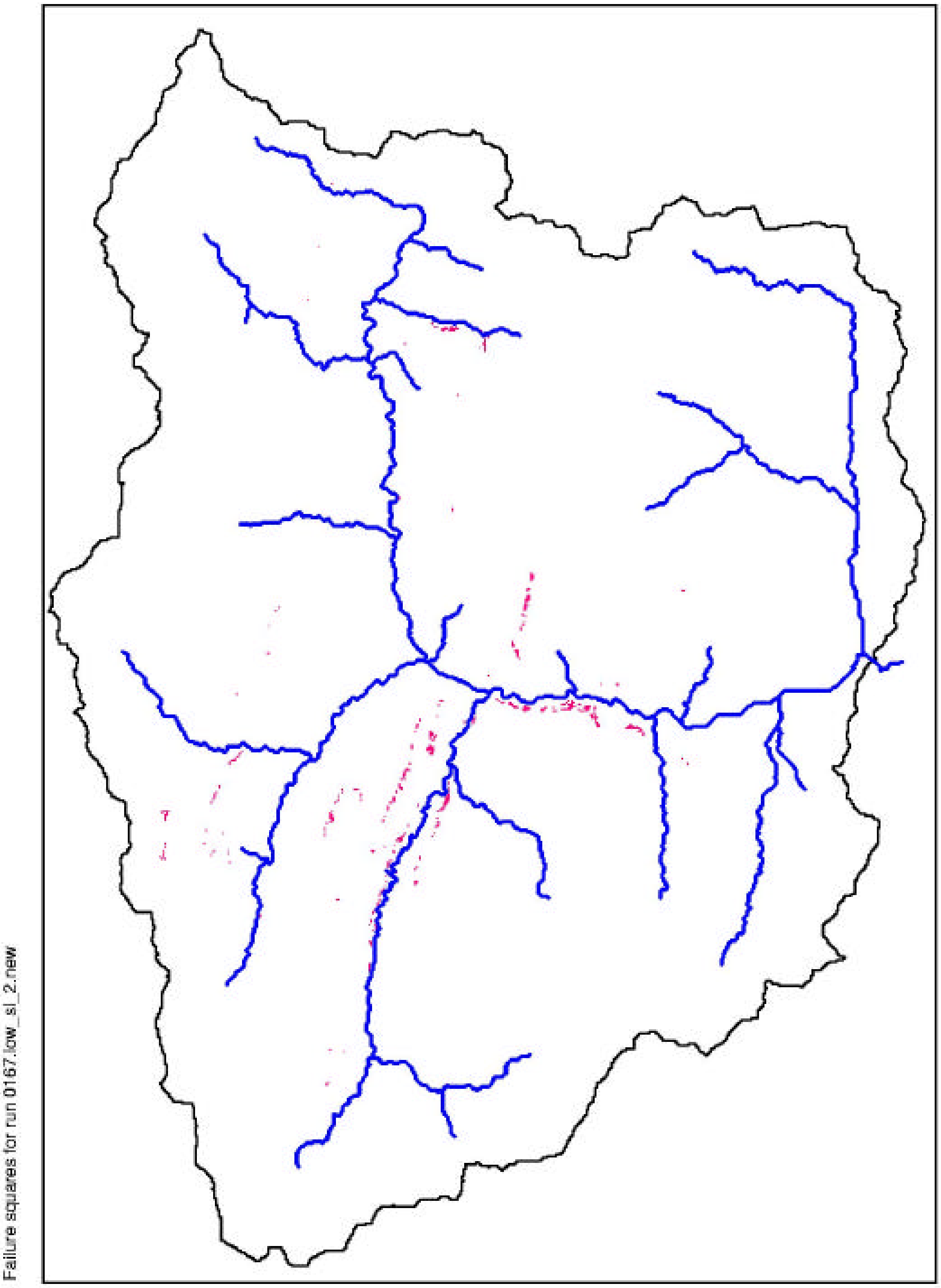


Figure 6 **Lower bound for debris flow occurrence in the Llobregat catchment.** (Each dot represents a debris flow.)