AVALANCHE MAPPING IN THE CATALAN PYRENEES, BALANCE AND FUTURE PERSPECTIVES

Oller, P.*; Marturià, J.*; Martí, G.**; González, J.C.*; Martínez, P.*

*Enginyeria Geològica i Risc. Institut Cartogràfic de Catalunya.
**Àrea de Pronòstic. Servei Meteorològic de Catalunya.

Contact e-mail: *pereo@icc.es*
http://www.icc.es/allaus

1 Abstract

Avalanche mapping has been a high priority since the beginning of the project “Study of the Avalanche Risk in the Catalan Pyrenees” in 1986. To this effect, a systematic cartography of the Catalan Pyrenees was started and it was decided that it should be published as “Mapa de Zones d’Allaus” (Avalanche Paths Map), at 1:25.000 scale, in 1995. At present, the whole mountain range has been mapped. The methodology (photointerpretation, field work and population inquiries) has not changed, but the means and techniques to develop the cartography have evolved with the use of new technologies, such as Geographical Information Systems (GIS) and Digital Elevation Models (DEM). Simultaneously, a data base was created in order to store data from each avalanche path (as morphological characteristics and information about avalanche events). This compiled information has provided a great knowledge about the avalanche phenomena in the Pyrenees and it is an important background to attempt new challenges. Future plans include the development of an avalanche information web server and hazard and risk avalanche studies at local scale, running on the top of GIS.

2 Avalanche mapping in Catalonia

The project “Study of the Avalanche Risk in the Catalan Pyrenees”, carried out by the “Servei Geologic de Catalunya” (SGC) and the “Facultat de Geologia” of the Barcelona University, began in 1986. Avalanche mapping was one of the main lines of work in this project and an ambitious systematic cartography of all the mountain range started. The goal was to implement an inventory where avalanche paths and associated information as avalanche characteristics and avalanche events were compiled.

In 1995, the SGC was assigned to the “Institut Cartogràfic de Catalunya” (ICC) and it coincides with the decision of publishing this cartography. This decision entails new approaching that means an important qualitative step (Martí and others, 1996). At the same time, the “Base de Dades d’Allaus de Catalunya” (BDAC), or Avalanche Database of Catalonia, began to develop, the foundation of the future Avalanche Data Server (SDA).

3 The Avalanche Paths Map

The “Mapa de Zones d’Allaus” (MZA) or Avalanche Paths Map is a susceptibility map, a map where the areas with snow avalanche hazard are located. The methodology is based on the French “Carte de Localisation Probable des Avalanches (CLPA)” (Pietri, 1993). It consists in the identification of the sites that have been or can be affected for avalanches from geomorphologic and vegetation criteria, and from the historical register. This map is done on the ICC digital cartographic map at 1:5.000 scale, but it is published at 1:25.000 scale. At present 8 sheets out of a collection of 14 are already edited, and it is bound to be completely published by 2005.

The process to elaborate these maps is based on the identification of the avalanche-prone terrain and avalanche traces using aerial photographs, Digital Elevation Models (DEM) outputs as slope maps and avalanche-prone maps (Marturià and others, 2000), and direct field checking. Eventually the information is completed with population inquiries and winter avalanche observations (Martí and others, 2000). Other information that appears in these maps is related to avalanche defences.

The information is represented cartographically in different colours:

1. Orange colour: avalanche paths mapped from morphological and vegetation criteria.
2. Violet colour: avalanche paths mapped from the avalanche observed activity (historical and present).
3. Garnet colour: avalanche paths where the information from 1 and 2 coincide.

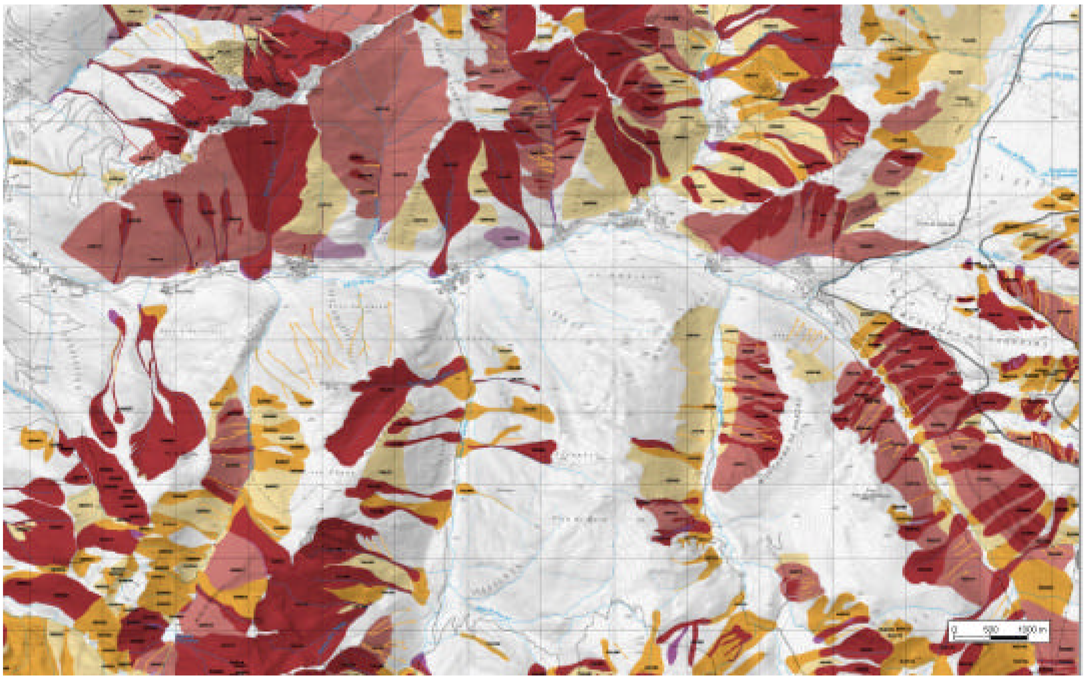

Figure 1: Example of MZA. Sector of the sheet one, "Val d'Aran nord", 1:25.000, published in 1996.

The MZA is a basic document for the location of the process. It is a useful tool for land planning and potential risk areas identification, but it has some limitations. On the one hand the information sources can sometimes be imprecise for different reasons: absence of past avalanche traces (there is no forest beside the avalanche path or the avalanche traces are hidden or have disappeared with time), lack of witnesses or low accuracy in witness descriptions, etc. As a result, usually avalanche limits do not represent extreme avalanches. On the other hand, the scale of the maps, 1:25.000, is not adequate for detailed analysis. Furthermore, another important detail is that these maps do not represent the frequency nor the intensity of the avalanches, that is, they are not hazard maps.

At present, these maps don't have any legal implications in building regulations in Spain, but although sometimes they are used by the administration agents as a base for land planning.

Concluding, the elaboration of the APM has been a good exercise for better knowing and understanding the avalanche phenomena in the Catalan Pyrenees.

4 The Avalanche Data Base of Catalonia

The "Base de Dades d'Allaus de Catalunya" (BDAC) or Avalanche Database of Catalonia is composed of the graphic (maps) and the descriptive (attributes) information gathered during the MZA elaboration process. It contains the available information of the avalanche activity in the Catalan Pyrenees.

The graphic information is mapped at 1:5.000 scale. It consists in three different mapping concepts: avalanche paths, areas defined by the cartographer from geomorphologic and vegetation status analysis; avalanche inquiries, areas mapped with the information obtained from inquiries, they can be sometimes imprecise; avalanche events, observed present avalanches (since 1986).

The attribute information is filed in a digital form. As in the graphic information it is based on the same concepts: avalanche paths, data containing geomorphologic and vegetation status descriptions with summer photographs; avalanche inquiries, data containing information from witnesses descriptions and historical archives; and data from observed present avalanches, containing avalanche characteristics, damage descriptions, event photographs and nivo-meteorological data.

Graphic and attribute information belonging to the same avalanche path have a reference identifier. The graphic information is linked to its corresponding attribute information through this identifier (Figure 2).

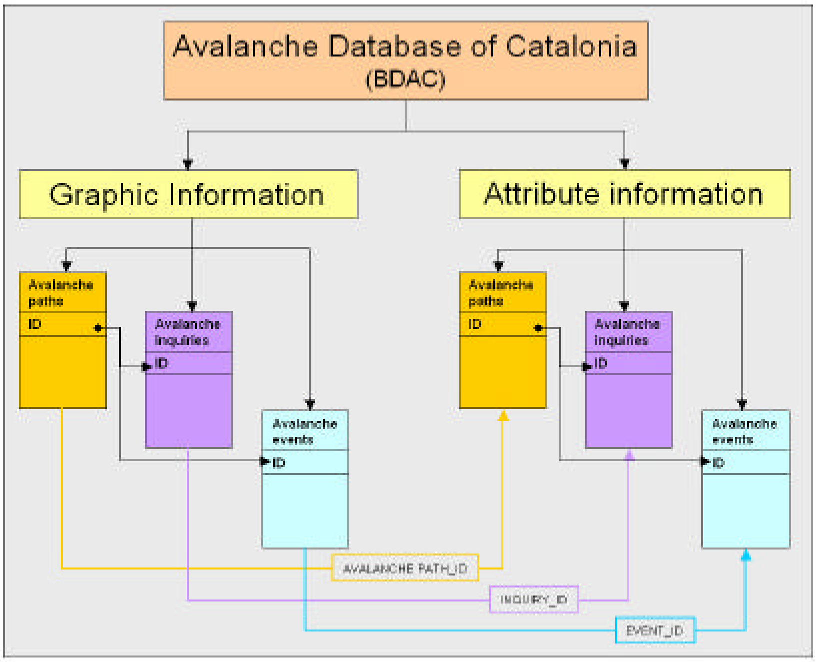

Figure 2: Schematic structure of the BDAC

At present the database is already implemented, but it is in data compiling process. A total number of 15.737 avalanche paths are mapped, 3.797 avalanche areas from the inquiries and 1.144 avalanche events. The attribute database has been implemented with 2.563 avalanche paths descriptions (the most relevant avalanche paths), 1.253 avalanche inquiries and 972 avalanche events.

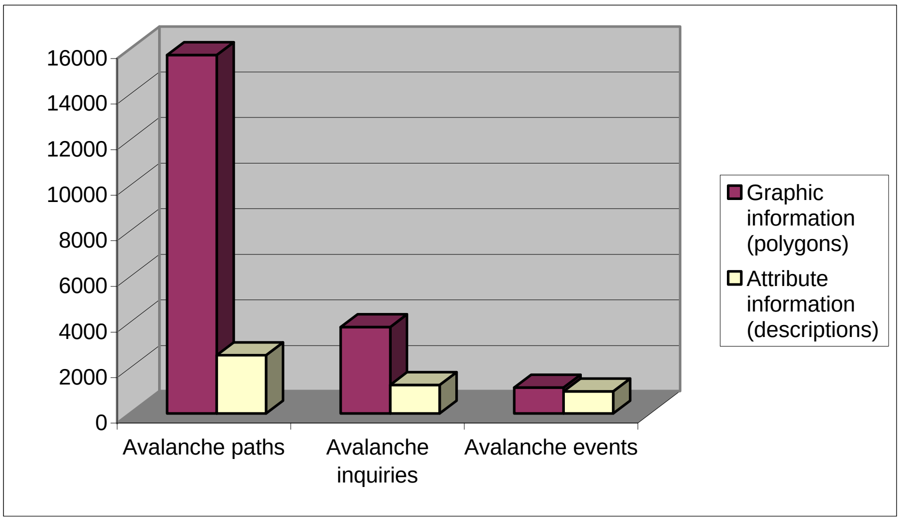

Figure 3: BDAC implementation status

The aim of the avalanche database is to store avalanche data, basic information to understand the avalanche phenomena the Pyrenees and for the development of future applications. For instance, the use of avalanche dynamics models for avalanche hazard and avalanche risk analysis will improve with the BDAC information.

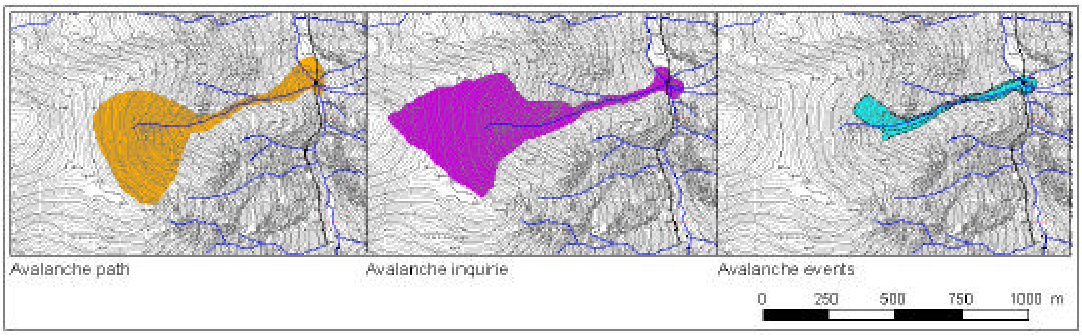

Figure 4: Example of the graphic information: avalanche path NUR127 (Pla de Sallent or Torrent del Roc Roig avalanche path). In orange the avalanche path mapped from geomorphic and vegetation interpretation is represented. In violet the area mapped from the inquiries. In blue the events observed in this area that can be mapped at 1:5.000 scale.

The first result of the BDAC has been a continuous MZA that covers all the Catalan Pyrenees. This map has allowed us to get a global vision of the phenomena and have a first evaluation of the avalanche impact on this region. In rough numbers, in Catalonia the avalanche phenomena affects approximately the 4 % (1.320 km^2) of the territory, but it represents the 36% of the Pyrenean territory.

The avalanche graphic information and the ICC 1:50.000 cartographic databases have been crossed in order to locate the potential risk sites. This estimation allows us to identify and quantify elements at risk by avalanche phenomena. It is an approach to the main risk focuses in the Catalan Pyrenees and therefore the main places where further work should be done (Figures 5 and 6).

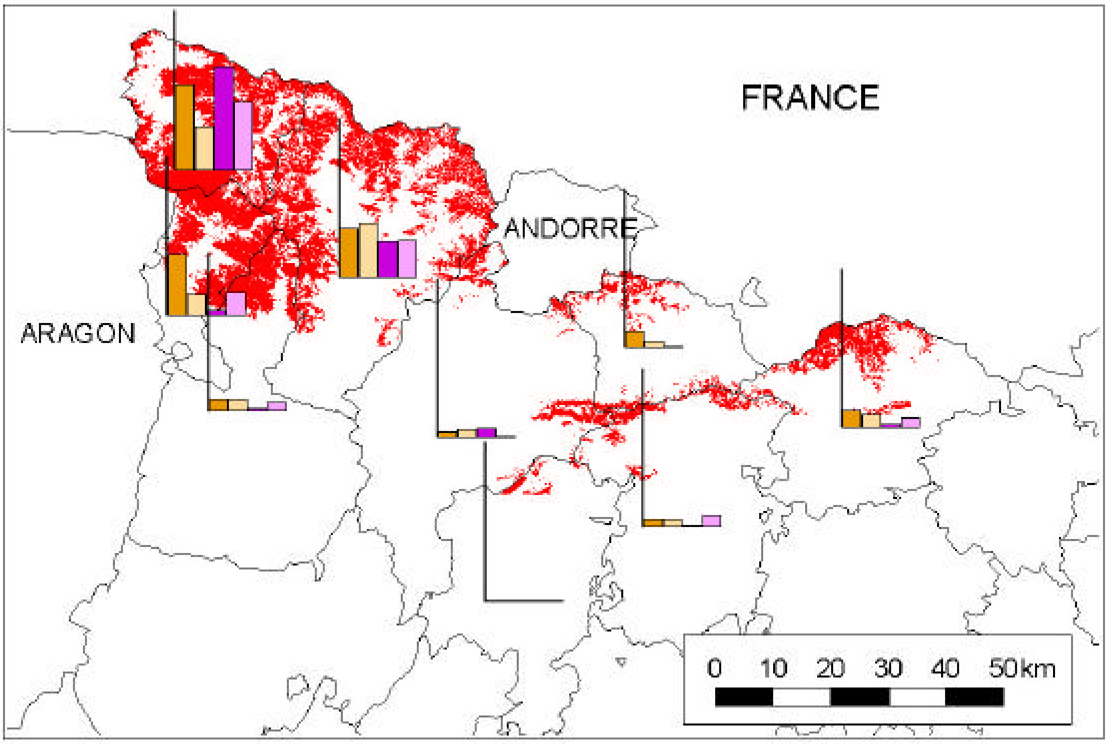

Figure 5: Extension of the avalanche phenomena in the Catalan Pyrenees (in red). The bar charts show the relative area and infrastructures potentially affected by avalanches per each administrative region. The black line (x axis) indicates the 100%. Orange colour: portion of region territory susceptible of being affected by avalanches. Light orange colour: territory susceptible of being affected by avalanches with respect to the total territory affected in the Catalan Pyrenees. Violet colour: buildings susceptible of being affected by avalanches with respect to the total. Pink colour: roads susceptible of being affected by avalanches with respect to the total.

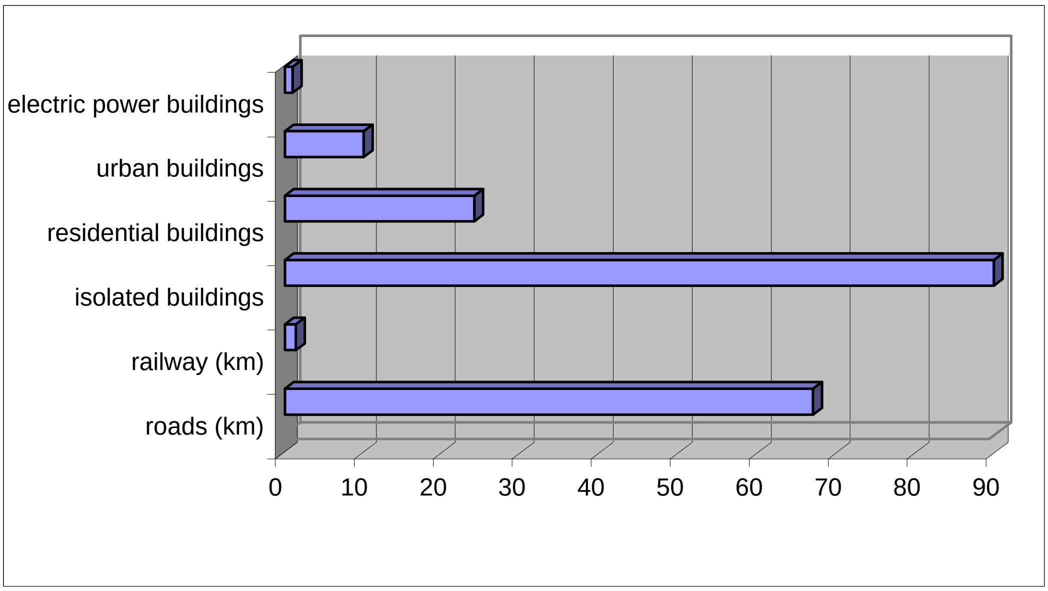

Figure 6: Buildings and roads potentially affected by avalanches in absolute numbers.

At the same time, the attribute database will be useful for characterizing the avalanche phenomena in the Pyrenees, at the present time not well known. An example of querying the attribute database is shown in Figure 7. It shows the monthly distribution of different kind of avalanches observed from 1986 to present.

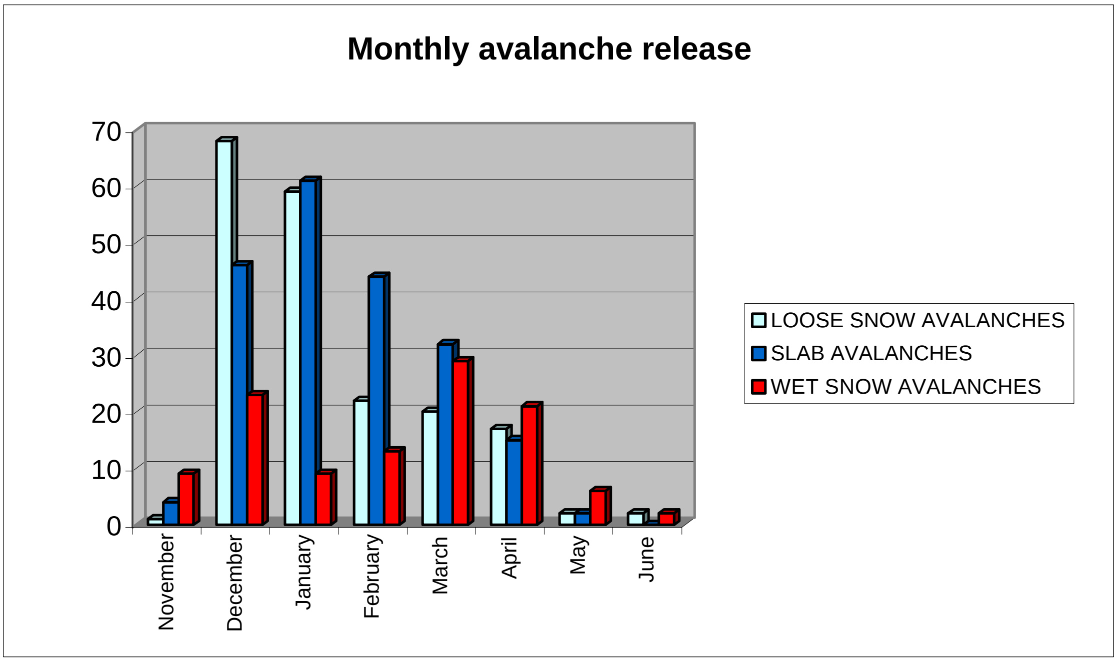

Figure 7: Number of avalanches observed since 1986 and documented in the BDAC. The graphic shows the monthly distribution of different types of avalanches. It has been elaborated with the information from 507 avalanches.

5 Other avalanche maps

Other kinds of avalanche maps have been made for specific needs. The BDAC is the information source from which are made all these detailed cartographies.

5.1 Detailed avalanche susceptibility maps

These maps are conceived for municipality scale plans and intend to show a first hazard classification but they are not useful for building purposes. They are made at 1:10.000 scale in nonbuildable land and they were conceived as a classification to specify the kind of study previous to an eventual action. In these maps avalanche areas mapped in the MZA are distinguished in a unique colour (defined as high avalanche hazard) and areas of probable extreme run-out are added according to statistical calculations (Furdada, 1996), and defined as medium avalanche hazard. This new concept aims to avoid the lack of information of the MZA. The avalanche-prone terrain is mapped attending DEM analysis too, independently from vegetation cover to avoid actions favourable to avalanche release (Marturià and others, 2000). This third item is defined as low hazard.

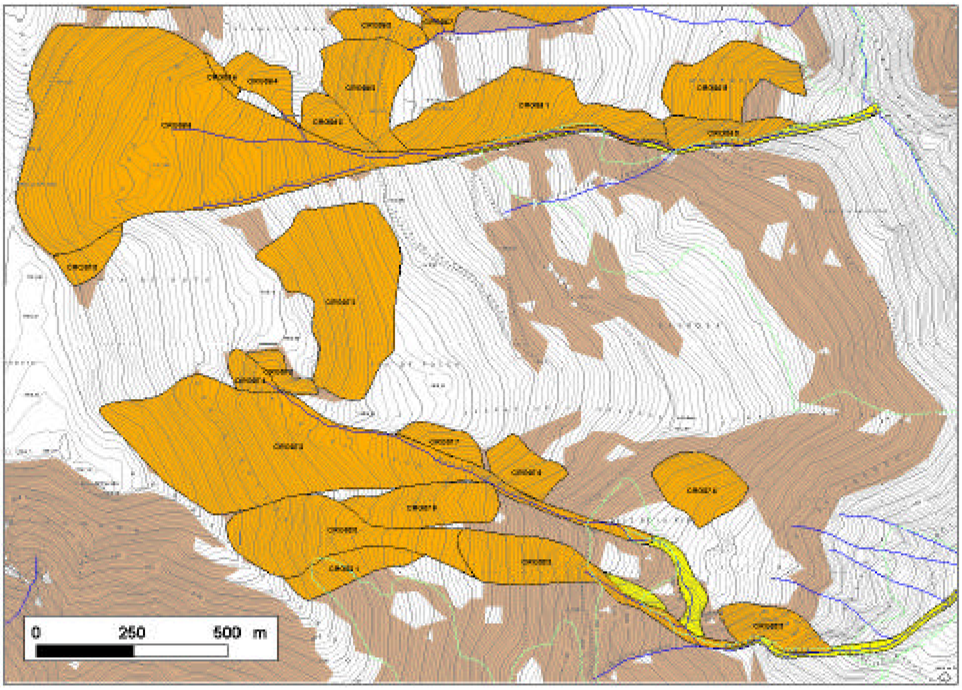

Figure 8: Example of detailed avalanche susceptibility maps. Orange colour: high avalanche hazard; yellow colour: medium avalanche hazard; brown colour: low avalanche hazard at present conditions. White colour: no avalanche evidence.

5.2 Avalanche hazard maps

Zonification maps

In urban areas and in urban plans, zonification maps at 1:5.000 scale are made, based on the Swiss Regulations (1984). A zonification is made according to the possibility of building and it is represented by three different colours. Red colour means that new building should not be permitted, in the blue zone building should be permitted with major restrictions, and in yellow (eventual) areas building should have no restrictions but evacuation and emergency plans should be needed; in white areas no hazard evidence has been observed. These maps are obtained crossing avalanche frequency and avalanche intensity data gathered in the BDAC, and are completed with the aid of avalanche dynamic models. The best BDA data, the best accuracy of the results.

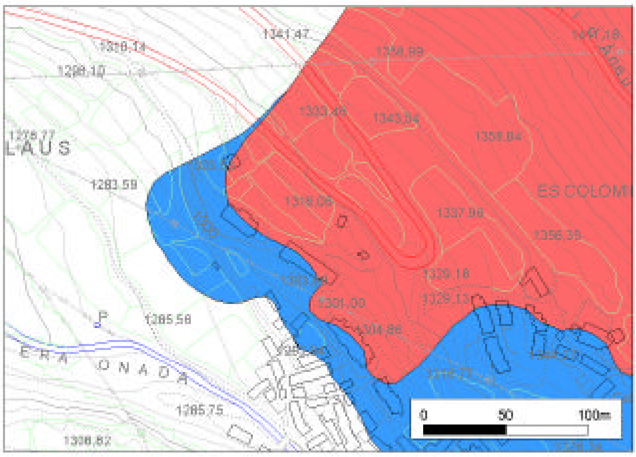

Figure 9: Example of a zonification map

At present these maps don't have any legal implication because of the lack of specific avalanche hazard regulations. They are only used as technical recommendations.

Avalanche frequency maps

These maps have been made mainly for linear vulnerability items like roads or railway lines. In these cases it is more important to know the frequency of the avalanches than the intensity because almost all the avalanches can generate danger for winter transit if they reach the vulnerable item. As the purpose is planning they are made at 1:10.000 scale. The goal of the maps is to focus on the most problematic avalanches for conceiving the corresponding defence or warning works.

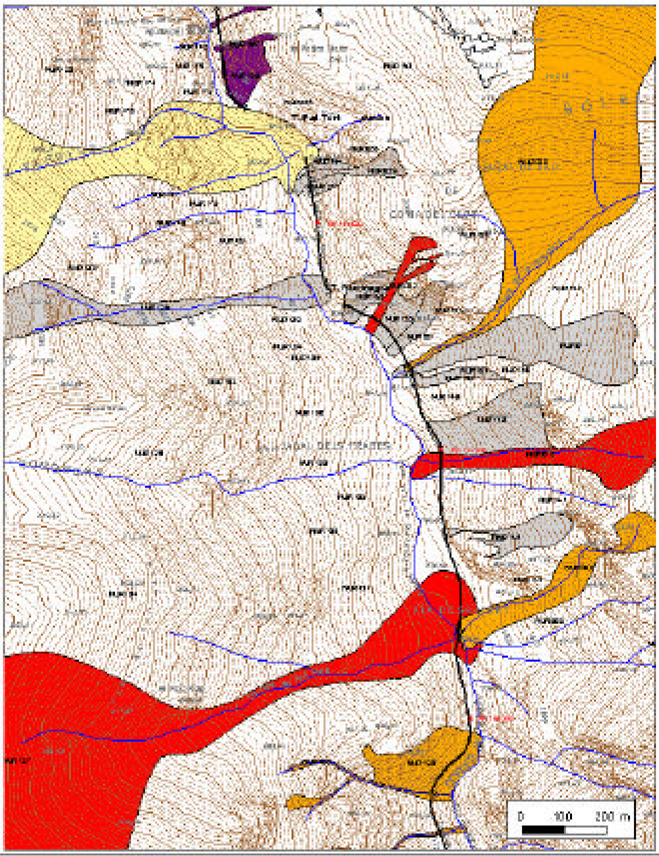

Figure 10: Example of avalanche frequence along the upper part of de rack train of Vall de Núria. Violet colour: the avalanches reach the railway line with high frequency; Red colour: the avalanches reach the railway line with medium frequency; Orange colour: the avalanches reach the railway line with low frequency; Grey color: there is no information about frequency.

In the future other kind of maps can be made from the BDAC as for example mountaineering maps, sky resort managing maps, etc.

6 The Avalanche Data Server

The “Servidor de Dades d’Allaus” (SDA) or Avalanche Data Server, is a system conceived for querying and analysing all the information managed by the ADBC. As the goal is the information to be consultable for users (researchers, enterprises, administration, individuals, etc...) without special skills on Information Technologies (IT) environments, our main objective was to develop an easy interface that costs them the minimum to be operative. So the decision was easy: a Web enabled environment.

In terms of IT architecture, SDA is composed of three different levels (tiers):

a. Data: build on the BDAC (repository) and a middleware that allows geographical queries over vector data stored in the database.

b. Application: integrates the different software that makes possible the access to all the information managed by the ADBC for a wide range of clients.

c. Client tier: in our case all of them are Web browsers but, in general terms, this level could integrate many other clients that want to make use of the information.

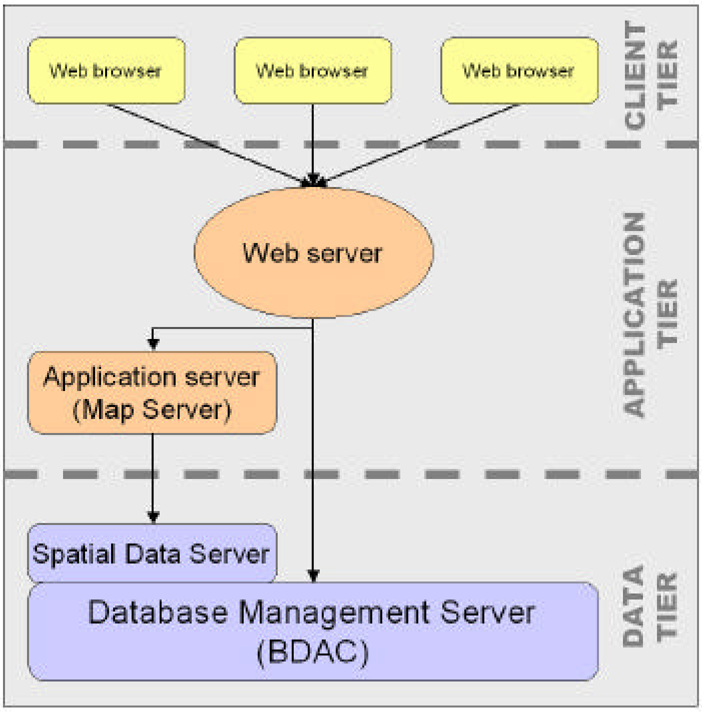

Figure 11: System architecture of the Avalanche Data Server

This architecture is conceived as a strong platform that provides security, availability and scalability issues. The first release will be completely operative in 2005.

7 Conclusions

The “Mapa de Zones d’Allaus” (Avalanche Paths Map) is a basic document for the location of the avalanche process. It is a very useful tool for land planning and identification of the potential risk sites, but it is not adequate for detailed analysis.

An avalanche data base is an essential tool to store the information related to the avalanche paths map and the information gathered every snow season for avalanche control and in research. It is basic for any avalanche work: it allows fast query and analysis and it enables to make more accurate maps. This is the reason why the “Base de Dades d’Allaus de Catalunya” (Avalanche Database of Catalonia) was created and it is consultable at the “Servidor de Dades d’Allaus” (Avalanche Data Server). It has the purpose of being an available site where anyone, avalanche professional, technician, researcher, individual, etc, should be able to do its searches fast and easily.

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