Recommendations to deal with Snow Avalanches *in Europe*

Edited by Javier Hervás

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Technological and Economic Risk Management Unit
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NEDIES Project

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Abstract

Snow avalanches represent the major natural hazard in Europe's mountain areas during the winter. Harsh, changing conditions regarding mainly snowfall and snowpack in these areas, coupled with the increase in winter sport activities, tourism and therefore urbanisation and lifelines, are responsible for catastrophic avalanches causing significant human losses and structural damages.

This publication mainly addresses recommendations to reduce risk from avalanches in Europe. It includes contributions from experts that participated in the workshop held at the Joint Research Centre in Ispra, Italy, on 11 July 2002, organised by the NEDIES Project (Natural and Environmental Disaster Information Exchange System), as well as from other European experts on avalanche research and disaster management. These contributions focus on recommendations on domains such as avalanche prediction, prevention and mitigation, preparedness and response and dissemination of information to the public. Specific experiences in Austria, France, Iceland, Italy, Spain and Switzerland are discussed, and recommended measures and actions which are also applicable to other European countries are presented.

Acknowledgements

All the participants in the NEDIES workshop held at the Joint Research Centre, Ispra, on 11 July 2002, their co-authors and the other experts that contributed to this publication are kindly acknowledged. Thanks are also due to the organisations, researchers and practitioners that allowed including their photographs and map illustrations in this publication.

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1. Introduction

Snow avalanches are the major natural hazard in Europe's mountain areas during the winter. On average, they cause about 100 deaths in Europe every year as well as severe damage to mountain villages and settlements, infrastructures and forests. Avalanche consequences are particularly serious in Alpine countries such as France, Switzerland, Italy and Austria. Only in Switzerland and Austria, the combined cost of the avalanche prevention and mitigation measures implemented in the last 50 years amounts to over € 1.7 billion.

Awareness of avalanche danger in Europe has substantially increased as a result of recent disasters, especially those which occurred across the Alps in February 1999. Heavy snowfalls and weakness in the snowpack coupled with increasing winter sport activities, tourist development and infrastructure networks for people mobility are the basis of the very harmful consequences of avalanches. These disasters have prompted for further measures, including also legislation, to reduce risk in the most avalanche-prone countries and communities.

Avalanches cannot be considered as a problem limited mainly to local inhabitants of mountainous areas or to their property and infrastructures. They often affect tourists/sportsmen coming from other regions and European countries, including also cross-border transport line users in these areas. Establishing and applying measures to most effectively dealing with avalanches thus requires the involvement of a wide range of stakeholders across Europe.

In order to discuss and draw recommendations to deal with avalanches that can be applied in a European-wide context, an expert workshop was held at the European Commission's Joint Research Centre (JRC) in Ispra, Italy, on 11 July 2002. The workshop was organised in the context of the NEDIES Project (Natural and Environmental Disaster Information Exchange System), which is carried out at the Institute for the Protection and Security of the Citizen (IPSC) of the JRC.

This publication includes the contributions from the workshop participants and other experts in the domains of avalanche prediction, prevention and mitigation, preparedness and response and information to the public. Each chapter focuses primarily on applied and suggested actions and measures in a specific domain. They are based mainly, but not only, on the experience gained in the management of avalanche risk and disasters in a particular European country, including Austria, France, Iceland, Italy, Spain and Switzerland. Special emphasis is given to avalanche prevention, as well as to recommended measures and actions in the above-mentioned domains that can be applicable in any European country. Recommendations are summarised in the last chapter. Finally, the European avalanche hazard scale is included for reference as well as a list of selected websites.

This publication is mainly addressed to European Commission Services, national, regional and local authorities and organisations involved in avalanche risk and disaster management. It can also be of interest to practitioners and researchers.

This publication is also available in digital form to any interested reader through the NEDIES Project website (http://nedies.jrc.it).

2. Recommendations for the prediction of avalanches

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Abstract

This paper aims at putting forward recommendations needed to improve the prediction of avalanches. It does so by addressing what is needed for the various tools and methodologies used by avalanche warning agencies. First we emphasise the distinction between the nature of the forecast into a "Nowcast" and a "Forecast" and why we need to maintain that distinction. We then discuss the estimation of runout. We discuss what information is needed to improve the prediction and how evacuation procedures should be well established and in place prior to an avalanche situation arising. The paper also discusses the importance of being able to evaluate the conditions in the starting zones of avalanches. We also discuss the various modelling efforts intended to improve avalanche prediction and the need for verifications of those models. The importance of data sharing among avalanche organisations was emphasised and suggestions made how that could be encouraged. Finally the importance of the local snow observer is stressed and the opinion stated that, in spite of modern day technology, the long and extensive experience of the local avalanche expert is almost impossible to replace.

2.1 Introduction

It is the wish of every individual connected with avalanche warnings to be able to predict the occurrence of avalanches with a reasonable accuracy, both in time and space (LaChapelle, 1980; Williams, 1998). To be able to do this we need to have at our disposal the latest information regarding past, present and future weather, the accumulation and transport of snow, the layering of the snowpack and its strength and weaknesses and also the past history of avalanches for the area in consideration. We need tools to accomplish this, both to measure the relevant parameters required for the prediction and to disseminate the information and model the various scenarios (Föhn, 1998). Also we need to evaluate the performance of the predictions in order to improve them. In this chapter general recommendations will be put forward in relation to the various aspects mentioned above, but we will not go into detail about individual methods and models but refer to more specialised papers to that effect.

2.2 The prediction: nowcast and forecast

In a forecast issued by an avalanche service, it is necessary to give ample notice to the relevant authorities so as to give them time to act upon the information and take the necessary steps to ensure the safety of the public. These steps could be the evacuation of habitations, closure of roads and railways and possibly recreational areas. The forecasts must also inform the recreational public as to the possible danger of avalanches in areas into which the general public is not likely to venture, i.e. backcountry skiing, mountaineering, etc. (McClung, 2002a,b).

There is a basic difference in the above forecasts, in that one is essentially a "nowcast" and the other a "forecast". The nowcast is necessary in order to warn the general public of imminent danger and the need to take preventive actions immediately. The forecast needs to stipulate what

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could possibly happen in the near future so as to enable the public to plan in accordance with the forecast. This could mean different route or time plan for mountaineers, skiers and commuters. A forecast is also necessary to prepare the authorities for a possible action and enable them to set the necessary wheels in action in case the danger of avalanches becomes imminent.

The "nowcast" needs to stipulate the estimated time of occurrence and the possible extent of the predicted event whereas the "forecast" needs to specify the general area, aspect and the range of elevations of possible events. A class two avalanche can be just as deadly to a skier as is a class five event, whereas a class two avalanche is unlikely to destroy a building but a class five avalanche can wipe out a whole village.

The nowcast has to specify individual avalanche paths and possible runout distances or class of avalanche; the forecast needs to specify the general aspect of slopes and the elevation ranges that are unstable and thus likely to avalanche (Table 2.1). In both instances the prediction needs to be verifiable after the period specified has elapsed. The information thus obtained is used to construct almost all numerical avalanche forecast models including neural network approaches, nearest neighbour, discriminant analysis and expert system approaches (Buser *et al*., 1985; Bolognesi, 1993).

Table 2.1 Format of avalanche predictions

	Nowcast	Forecast
Duration	< 1 day	> 1 day
Extent	Individual paths	Aspect of slopes and elevation ranges
General stability	Important	Very important
Runout distances	Very important	Not so important

2.3 Estimation of runout

As stated above it is of utmost importance that predictions of avalanches in or near inhabited areas contain information as to the possible runout distances within individual avalanche paths. Such estimations are usually done using dynamic avalanche models or statistical methods. In both instances it is necessary to evaluate the amount of snow likely to be released and the conditions of the running surface.

2.3.1 Snow accumulation in the starting zone and conditions of avalanche track

To estimate the amount of snow in the starting zones of avalanches it is possible to employ various sensors to measure snow depth, but to evaluate the areal extent of the initial slab it is necessary to have good records of meteorological conditions during the previous days so as to evaluate the wind loading of the starting zone and also the thermal conditions of the snowpack in order to be able to predict the stability in sufficient detail to predict the size of the release zone (Brun *et al*., 1989, 1992). In addition it is important to have a record of previous slides and the associated fracture areas.

To estimate the runout of avalanches, it is also important to know the conditions of the avalanche path, i.e. is it a good running surface and is entrainment likely, and what effect can this entrainment have upon the runout and to what extent.

3.3.2 Evaluation of area that will be overrun by avalanche

Based upon this information it should be possible to estimate what areas are likely to be overrun by a possible avalanche and thus take appropriate action. In Iceland we have found that it is convenient to divide the areas at risk into predetermined areas of evacuations depending upon the magnitude of the predicted event (Magnússon, 1996). At present we base this evaluation on meteorological conditions, snow accumulation, historical records and expert assessments and model calculations. We have divided evacuations into three different stages depending on the severity of conditions. By doing this it is possible to set down fixed plans for each individual stage and, since each evacuation stage encompasses a predetermined area and thus a set number of houses, it is possible to lay down detailed plans that can be rehearsed and practised. It is well known within crisis management that it is very important to have such a plan in place beforehand, so that during a crisis, time is not wasted on deciding what to do. For example, which individual houses are to be evacuated. This has been decided beforehand and once the level of evacuation is decided, and this is done in the initial stages of the avalanche prediction, it is precisely laid out what buildings are to be evacuated and by what means and by what route. Also where the inhabitants of the individual houses are evacuated to.

The conditions behind the three individual evacuation stages in use in Iceland are listed in Table 2.2.

Table 2.2 The conditions determining the three evacuation stages, as used in Iceland

Evacuation stage 1. An area which relates to known avalanches and moderate snow accumulation. The extension of the evacuation area may be smaller than indicated by the avalanche history i.e. excluding extreme conditions.

Evacuation stage 2: An area which is predominately determined by known avalanches and other paths with similar topological conditions. A possible hazard situation might arise during heavy snow accumulation. The area will be evacuated during impending weather conditions which are known to impose a serious threat of avalanches.

Evacuation stage 3: An area which is considered threatened by catastrophic avalanches that need not be included in the known avalanche history; meteorological conditions with extreme snow accumulation and extreme storm conditions. Also included are areas which are threatened during extremely rare meteorological conditions.

These conditions determine what we refer to as the “horizontal” division between the evacuation zones. Subsequently, horizontal lines were drawn to show how far downhill each level extended. The lateral influence zone of each avalanche path was also determined and vertical lines were drawn to show that extent. Each area thus defined was then given a letter that is used when an order for evacuation is issued (cf. Figure 2.1).

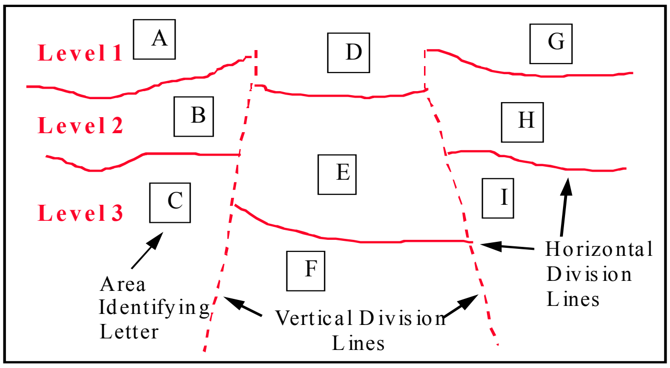

Figure 2.1 The figure shows how the individual evacuation zones are determined. The vertical division lines show the lateral influence zone of the avalanche path or paths and the horizontal division lines show the possible runout of the avalanches as determined by the three evacuation levels**.**

When issuing an order for evacuation, whether it is done by a local avalanche committee, the local authority or a federal agency, it is necessary to have those orders precise and preferably recorded and documented. Those orders should be confirmed by the person or committee that is responsible for carrying out the evacuation. This is necessary in view of possible litigation following an avalanche disaster.

This procedure allows for set procedures for evacuations and clear lines of command.

2.4 Evaluation of conditions in starting zones

In order to facilitate accurate predictions of conditions for avalanche release it is necessary to obtain information about the conditions at starting zones. This is usually accomplished with automatic stations, located at or near the starting zones (Figure 2.2). These stations are connected with telemetry to an avalanche prediction centre so as to make the data available, in real time, to the avalanche forecaster. Instrumentation is usually set up to measure meteorological conditions on the one hand and snow conditions on the other (Lehning *et al.*, 1999).

Figure 2.2 Automatic weather station near the starting zone of avalanches

Figure 2.3 Detailed view of the weather station in figure 2.2. It consists of two temperature sensors, a snow depth sensor, an anemometer and a solar panel to supply power.

2.4.1 Meteorological measurements

Most automatic weather stations are equipped with instruments capable of measuring wind speed and wind direction, temperature and humidity and barometric pressure (Figure 2.3). In addition some stations are capable of measuring precipitation. The common denominator for most of this instrumentation is that it is not designed for the harsh conditions encountered in the starting zones of avalanches (Figure 2.4). It is thus too often the case that when observations are most needed there is some malfunction in either the sensors or the communication.

2.4.2 Snow measurements

Figure 2.4 Harsh conditions at the mountain measurement stations.

The most common snow measurement is the snow depth. This can be accomplished by various means. The most common is an acoustic sensor located up in a mast. It measures the distance from the sensor down to the surface of the snow. That distance is then subtracted from the total distance from the sensor to the ground to get the snow depth. Another method is to use what is often referred to as a "Thermal Staff". It is a stake with a row of temperature sensors every 5 to 10 centimetres. They use the principle that snow is a reasonably good insulator and air temperature fluctuations do not penetrate very far into the snowpack. The height of the sensor where the fluctuations decrease rapidly is an indication of the snow depth. There are other kinds but they all have in common that they give a point measurement. It is thus necessary to extrapolate these point measurements to a larger area in order to get an estimate of the size of a possible slab. It is impossible to install a sufficient number of sensors to accurately measure the overall thickness of such a slab in addition to the fact that most sensors would have to be renewed after each event. In the rare event of such a measurement being obtained it provides valuable information (cf. Figure 2.5).

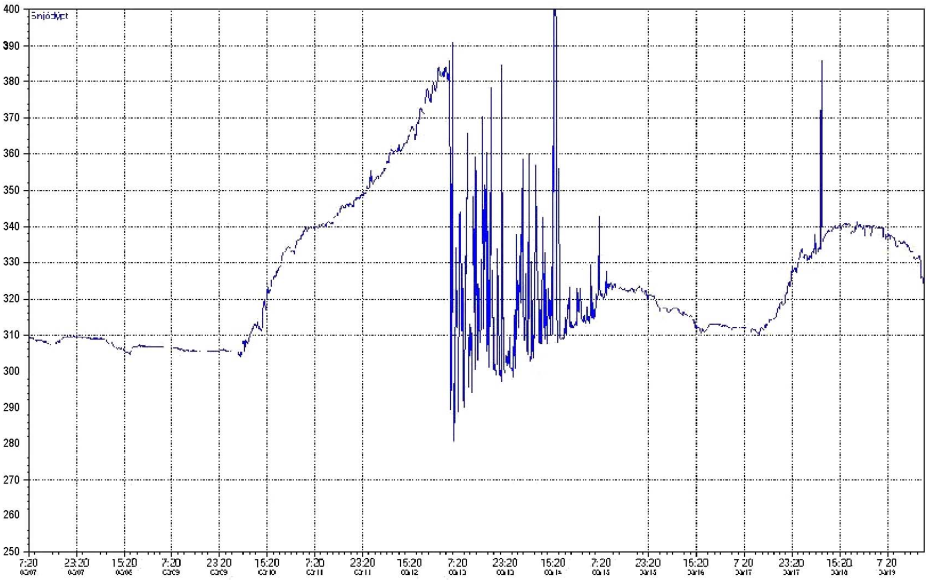

Figure 2.5 Snow depth measurement in the starting zone of an avalanche. Fracture depth of 0.95 metres. The measuring tower survived.

It is thus important to develop methods and models to accurately predict the thickness of such a slab, based on point measurements from carefully selected and safe locations. Such modelling requires accurate topological data of the starting zones and the associated fetch area, with sufficient resolution to enable the simulation models to give an accurate estimate of possible slab thicknesses.

In addition there are measuring devices available that can measure drifting snow (Chritin *et al*., 1998). Usually they are based upon the principle of catching the snow in a bag or a box that will have to measure after the storm has passed, so do not provide information helpful to evaluate the conditions during the storm. Unfortunately those devices are still unreliable and suffer from the drawback that they have to be emptied as they fill up. This inevitably happens during a storm when it is impossible to visit the site to perform the necessary tasks. There are optical sensors, usually referred to as ORG's (Optical Rain Gauges). See for example http://www2.crl.go.jp/dk/c218/EN/COBRA/4.html or http://www.rap.ucar.edu/projects/marshall/Instruments/ETI_ORG.html. They measure particles or droplets as they cross a light beam, but as yet these are extremely expensive.

Similar arguments apply to the snow drift sensors as the snow depth sensors in that they only measure at point locations. Thus it is necessary to model the flow of snow into the starting zone using data from locations situated at carefully selected points (Gauer, 1998, 1999). Again, accurate topological information is a prerequisite for such a modelling.

In addition, some attempts have been made to design and build instruments capable of measuring the layering of the snowpack and the metamorphism taking place. Also there have been some attempts made to construct devices capable of measuring the tensile strength of the snowpack.

The common denominator for any kind of measuring devices used in the harsh conditions encountered at and near the starting zones of avalanches is that they need to be extremely rugged and reliable. They have to be able to withstand gale force winds and severe icing conditions. There are some instruments available that are able to de-ice themselves but as of yet they require enormous amounts of power to be able to cope with the worst conditions. Those that claim to be “energy efficient” have to our knowledge been unable to function under extreme conditions but it is precisely under those conditions that they are most needed.

2.5 Modelling of avalanche release

2.5.1 Types of models

There has been an effort made within the avalanche community to model the various aspects of avalanches dating back several decades. The models range from runout distances to the probability of the release of an avalanche. The methods used are varied including neural network approaches (Stephens *et al*., 1994; Schweizer *et al*., 1994), nearest neighbour (Buser *et al*., 1987; Buser, 1989), discriminate analysis (Obled and Good, 1980), expert systems (Schweizer and Föhn, 1994, 1996) and various statistical methods (McClung, 1994; McClung *et al*. 1992). It is not possible to say which modelling effort is most important; they are all necessary to improve the prediction of avalanches. Figure 2.6 shows an example of a dynamic 2-3 D model we have used in Iceland to estimate runout of avalanches.

Figure 2.7 shows the result of a statistical model run and a simple 1D model that we use in Iceland the predict the possible runout of avalanches and was used to determine the evacuation levels mentioned above.

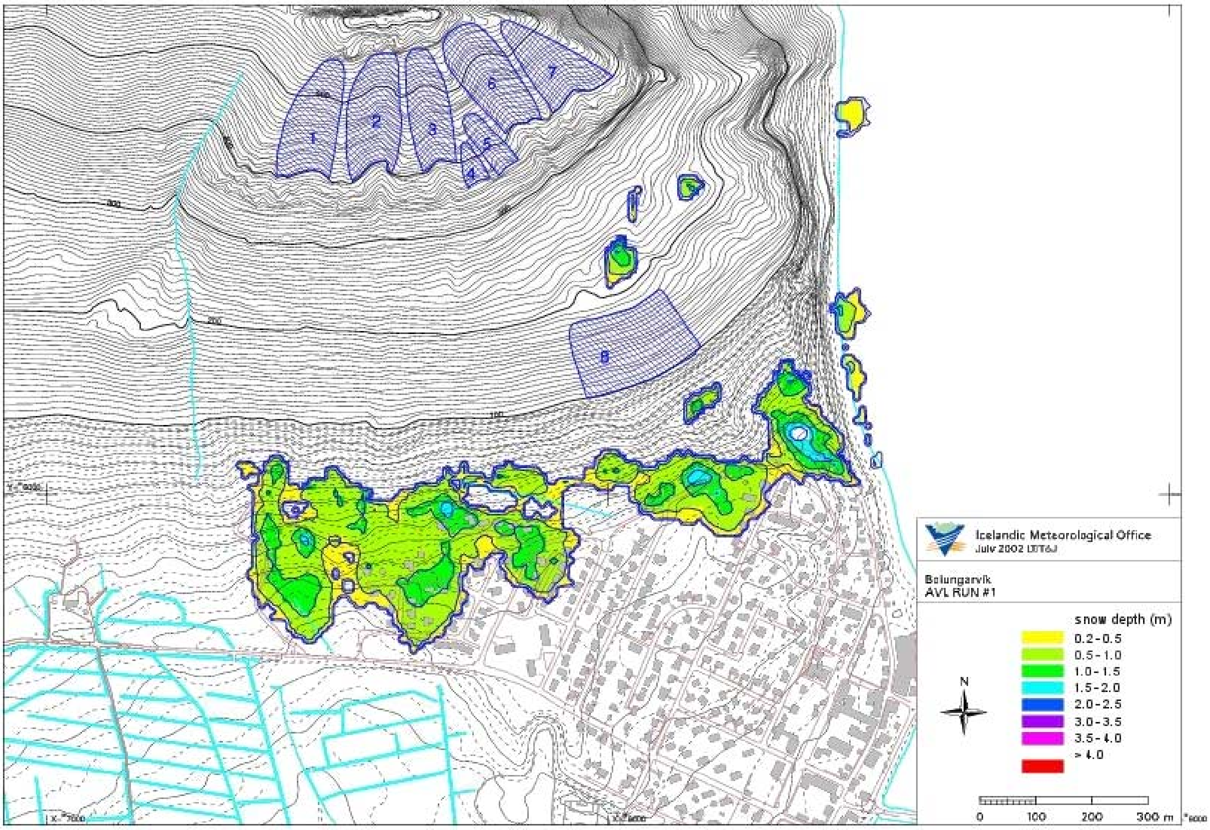

Figure 2.6 Results of a 2D dynamic modelling run for the city of Bolungarvík in NW Iceland. The figure shows the depth of avalanche deposit in the village (original scale 1:7500).

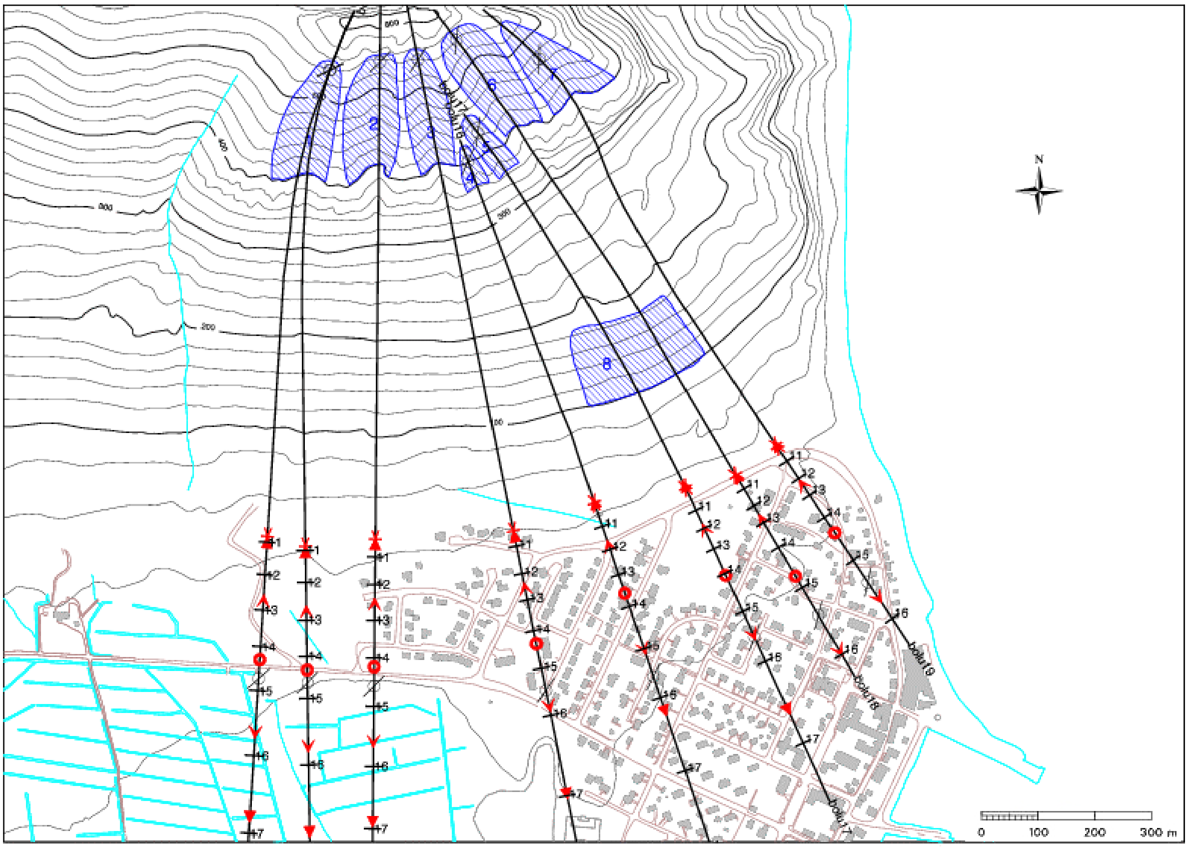

Figure 2.7 Results of a model run based on statistical methods and a simple 1D dynamic model.

Mesoscale weather forecasts are necessary to predict the weather conditions in the starting zone in a detail sufficient to accurately model snow accumulation in this zone, be it by direct snowfall or the transport of snow by wind. It is also necessary to model the redistribution of snow due to wind and erosion (Guyomarc'h *et al.*, 1998). The settlement of the snowpack needs to be modelled, as does the metamorphism taking place within the snow. This is necessary to be able to determine whether the snow is stabilising or there are weak layers forming such as depth hoar. The results of these models can be used in avalanche forecast models of various kinds (Giraud *et al.*, 1994).

Prediction of runout distances is a very important field, both from the point of view of the immediate danger, i.e. how far will an avalanche run in any given conditions and what is the maximum runout of a particular path given the most extreme conditions. The latter of these scenarios is necessary to accurately map out the various hazard zones and determine the criteria behind the individual hazard lines.

2.5.2 Verification of models

In order to improve upon existing models and develop new ones it is necessary to verify the performance of all models. This is done by collecting data on individual events. It is important to know if an avalanche occurred when an avalanche was predicted. It is necessary to know what the conditions were actually like in the starting zone when one has predicted a scenario that has given rise to a further prediction of an avalanche (Föhn and Schweizer, 1995).

Were there weak layers where weak layers were predicted and was the modelled thickness of a potential slab in agreement with the actual thickness of the slab that was released? Was the areal extent of the slab released as predicted by the models? Was the avalanche off the type predicted and did it run as far as was modelled?

All these data are very important for scientists and researchers to improve upon the work being done and devise new methods of approaching the avalanche problem.

The design of defence structures is largely based on modelling results. Thus it is also important to collect data on the effectiveness of avalanche protection measures that have been constructed. There is a lot we do not know about how an avalanche interacts with an obstacle and thus we must collect data to that effect. We need to know if the size of the retaining structures erected in the starting zones of avalanches were sufficient to prevent a release and if similar slopes that did not have such retaining structures release avalanches.

Synoptic data giving rise to avalanche cycles have to be collected as do the local weather conditions prior to and during the event (Roeger *et al.*, 2001a, 2001b).

Thus it is very important to collect data relevant to the various aspects of avalanche modelling for individual events. These data can provide researchers with the tools necessary to test new models and methods and simulate past events.

In order to make the most effective use of the data and coordinate the collection, and since all these data have a spatial component it is recommended that they be collected using modern geographical information systems (GIS). At present most avalanche research institutes are using GIS to map out the areal extent of avalanche runouts and starting zones. But it can also be used to correlate weather data and the aspect of starting zones, coordinate the collection of snow stability data with avalanche release and slab thickness with the runout of an avalanche. There are several aspects of avalanche research that can be made easier by the use of GIS as has already been attested to in the work of the various research facilities (Bolognesi *et al.*, 1996; Leuthold *et al.*, 1996).

2.5.3 Sharing of data

Once data have been collected, they should be made available to other researchers within a reasonable amount of time. This will ensure that the most possible use is made of all data and the likelihood of success of subsequent research projects in related fields is greatly increased. It is a fact that research sponsored by the National Science Foundation (NSF) in the United States requires every recipient to submit the data to a central data centre within a set number of years. It is thus not unreasonable to recommend that the European Union adopts a similar policy. In light of the extensive support that the EU gives to the research community the Union would be maximising the return on its investment if such a stipulation was in place. Not only in the field of avalanches but in every aspect of research sponsored by the various frameworks.

In order to facilitate the exchange of data it would be necessary to standardise the collection of data. Just as it is possible to standardise meteorological observations all over the world it should be possible to do something similar within the field of avalanches. Already an effort has been made to this effect within a project sponsored by the European Union. It is a data bank set up to collect data on the interactions of avalanches with avalanche defence structures. What will happen at the completion of the project is uncertain. It is recommended that the European Union establish a central data centre in which the results of such projects could be stored.

Instead of stipulating various criteria required for projects to be funded, such as “third party participation” and “end users” the EU should try and encourage such standardisation of observations and subsequent sharing of information and data. Most often the end users are the relevant institutions themselves.

2.6 Snow observer network

Until we have attained the distant goal of having perfect instrumentation everywhere and accurate models to tell us exactly the conditions as they are in the starting zone of avalanches we must rely on a network of people who are experienced and dedicated enough to be willing to go into the field and obtain the necessary data.

2.6.1 Monitoring staffing

For every area where there is the possibility of avalanches it is necessary to employ a person or persons who are responsible for monitoring the conditions and stability of the snowpack. These persons must be able to travel in difficult and dangerous terrain since as of today it is the only way to obtain reliable data about the snowpack. Such persons must be provided with good working conditions and supplied with the necessary tools to be able to accomplish, in safety, what is required to produce as accurate predictions as possible (Magnússon, 1996).

2.6.2 Tools and resources

In addition, this network of snow observers is vital in the effort to gather the data on avalanche events that are needed for the verification of the accuracy of the predictions and to improve upon the models used. Modern technology must be made available to these observers in data gathering efforts. Such devices include GPS mapping devices, communicating devices to transmit the data obtained and other tools that make the difficult task of collecting data as easy and enjoyable as possible. It is our experience in Iceland, that following the disasters in 1995 when funding was made available for us to “properly” employ snow observers and to provide them with good tools and working conditions, the quality and amount of data collected increased dramatically.

Further, when a person is happy and content in his or her job and made to feel important in greater scope of things, he or she is more likely to make the additional effort sometimes needed. The scientists and researchers must give these people the recognition they so rightly deserve. Also they stay longer in the job and thus provide what is the most valuable asset of any snow observer, experience, and a continuity of observations.

2.7 Conclusions

In the above, the various aspects involved in the prediction of avalanches were mentioned and suggestions given as to what is needed to improve upon the present status.

The difference in predicting avalanches that threaten residential areas versus what is needed for avalanche forecasts for recreational users and what needs to be included in the two different types of prediction was discussed.

The importance of the estimation of runout was discussed and an example given as to the use of such an estimate in predicting the possible extent of avalanches. Within that scope a suggestion was made as to the response in light of such a prediction.

A rundown of the necessary instrumentation in aid of avalanche prediction was discussed and the observation made as to the inadequacy of present sensors. The modelling effort was reviewed and a suggestion for further and closer collaboration between the various avalanche institutes was made. A recommendation was put forward to the European Union as to put an emphasis on projects that can provide solutions to the problems at hand. It must provide support to the institutes that have been focusing on these problems, some of them for a long time. The scope of the projects must take into account what is feasible to accomplish and concentrate on taking small but secure steps towards a better understanding of the problem of predicting avalanches. It is not possible within one project to supply all the solutions to all the problems. It is better to take smaller steps and let each project rest on the shoulders of the previous one and to ensure that concurrent projects do not overlap excessively but at the same time advocate consultation among the various projects.

Finally the importance of an effective snow observer network is discussed and that everything must be done to ensure the well being of such a network.

2.8 List of recommendations

- Differentiate between backcountry forecasts and forecasts for residential areas.
- Encourage modelling of the various aspects of avalanche predictions through funding from the EU Research Framework Programmes.
- Take small steps which produce results, not unrealistic ones which promise total solutions.
- Encourage cooperation between the various avalanche agencies and institutes.
- Prevent duplication of work through qualified reviewing.
- Spatial data should be collected using modern GIS.
- Initiate an effort to develop instruments of sufficient robustness to withstand the extreme conditions encountered in the starting zones of avalanches.

- Encourage the sharing of data and experimental results. Stipulate that projects funded by the EU shall release the data acquired after a set period.
- Encourage that a strong system of snow observations be maintained in all the relevant areas.
- Establish a central European Data Centre for Avalanches.

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3. Recommendations for the prevention of avalanches: The French experience

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Abstract

As a natural risk, avalanches cause around 100 fatalities in Europe every year. Most of these victims are practising some kind of touristic winter sport, especially off-piste skiing. They are supposed to be "risk takers" or to behave in a context of "accepted risk". They are killed by the avalanches they have released, which can be quite small. On the other hand, every 20 to 30 years or so, extreme snowfalls bring about major avalanches that flow down to the bottom of the valley. People are caught in their houses and in their vehicles. Although the resulting fatalities are quite small on an average basis, they are not acceptable, since these people are in a situation of "risk adversity", definitely not in a situation of risk acceptance. There are also "intermediate situations" where some parts of Europe are hit, with a return period averaging 10 years, but during years of exceptional snowfalls the whole Alps are more or less involved. This happened in 1999, and as a result, avalanche risk management was reassessed in the Alpine countries. France was no exception, as we further propose to explain and comment.

3.1 Introduction

Four major avalanche disasters took place in Europe in February 1999 (Brugnot, 1999a). These disasters seemed to be the result of very rare situations, which does not mean excessive intensity of a given parameter like solid precipitation but a never reported combination of different factors. In this respect, precipitation and wind velocity/direction appeared as a more relevant criterion; however the influence of temperature and, more generally of the "history" of snow cover also seemed to be part of the problem.

Another striking fact is that the situation was one of widespread danger and large scale crisis management, i.e. each disaster site was not considered as the most dangerous one but that other sites around were under closer scrutiny and many evacuations had been performed.

After these catastrophes administrative and judiciary inquiries took place, especially in France where both kinds of procedures are started as soon as accidents related to natural or technological hazards occur, whenever these accidents claim human lives.

After the Montroc disaster of 1999, the French Minister of Environment summoned an administrative panel. In France, such a panel has investigating power but only delivers recommendations, whose purpose is to improve a risk management system, not to determine liabilities. This panel brought out a report that analyses the French avalanche risk management system and proposes a set of measures aimed at improving this system. These measures are listed in Table 3.1.

The French avalanche risk management system is generally considered as having been drawn up in the early 1970s, after an avalanche had devastated a youth hostel in Val d'Isère in February 1970, claiming 39 lives. This disaster had also been followed by an administrative inquiry that had produced many results: it has led to the creation of new organisations, new technologies and new administrative procedures, within a time frame of five years (1971-1975).

With no direct connection to the "post-Montroc" investigation, a decision had been made to conduct an assessment of the activities of ANENA (*Association Nationale pour l'Etude de la Neige et des Avalanches,* French Association for Snow and Avalanche Studies), The results of this investigation were presented at the 30 year anniversary of this entity, created in 1971 as a non-profit organisation whose raison d'être was to coordinate all endeavours aimed at avalanche mitigation (Mettoux and Cartier, 2002).

So we have three milestones to show the evolution of French policy as far as avalanche risk management is concerned:

- 1970: As a basis, the report issued by the interministerial panel chaired by *préfet* Jacques Saunier and all directly ensuing reports and measures (Mission Interministérielle d'étude sur la sécurité des stations de montagne, 1970).
- 1999: The report ordered by the Ministry of Environment after the Montroc avalanche (Inspection Générale de l'Environnement, 2000).
- 2000: The documents produced as an outcome of an "assessment procedure" whose purpose was to look 30 years back and to consider what had been achieved and which advances were needed (Mettoux and Cartier, 2002).

The second and third actions were partly overlapping but the second one was more focused on prevention, since buildings had been hit in the Montroc accident, whereas the third was more global, considering all aspects of avalanche policy.

As a matter of fact, prevention and prediction cannot been dissociated, as it clearly appears from the above-mentioned post-Montroc report. What makes sense is the choice to deal with protection of permanent objectives, like buildings or roads, which will be the case in the continuation of this chapter.

3.2 The Val d'Isère disaster and the subsequent measures

After this disaster that took as many as 39 lives early in February 1970 (cf. Mission Interministérielle d'étude sur la sécurité des stations de montagne, 1970), the public was really disheartened in France, all the more because all these victims were young people on holidays. The government appointed a panel, named after Jacques Saunier, whose members were mostly members of the High Public Administration.

This panel insisted both on space-related and time-related measures. In this section we will mainly deal with the former set of proposals, after having mentioned that regarding time-related measures the proposals of the Saunier panel were the basis for the creation of the French avalanche forecasting network that is still in operation.

The Saunier panel stated that spatial data were almost equivalent to nil, that no coherent system of maps and event databases existed, but only local data collection efforts that could not be considered as producing actual databases. Its recommendations insisted that such a comprehensive system should be created and, in addition to hazard maps, risk zoning maps should be drawn up. Programmes were thus started whose acronyms below are now familiar to French mountain town and transportation planners and researchers:

- EPA: *Enquête Permanente sur les Avalanches* (avalanche events survey); EPA also refers to the file produced by this survey.

- CLPA: *Carte de Localisation Probable des Avalanches* (map of extreme avalanche limits). This name is being revised, since it does not describe very well what these maps are about.
- PZEA: *Plan de Zone Exposées aux Avalanches* (avalanche zoning maps). This acronym is now quite ancient, because avalanche zoning is now performed according to a procedure common to all natural hazards (the *Plan de Prévention des Risques,* PPR), which was created in 1982, revised in 1995, but definitely tailored along the PZEA procedure.

This system worked smoothly until recently. About 3,000 avalanche paths are monitored in France by 300 observers through the EPA, whereas around 700,000 ha of French territory are included in avalanche maps. Most French communities seriously exposed to avalanche danger have a plan for risk prevention (the PPR, the offspring of the PZEA). Most EPA and CLPA data are now digitised and CLPA is now available through Internet.

The French government is officially responsible of the EPA and CLPA, which are maintained by Cemagref jointly with the Forest Service (*Office National des Forêts*, ONF). The PZEA/PPR are more complex techno-political tools, since they are decided by, and drawn up under the authority of the local representative of the central government (the *préfet*). Communities, however, are all the more closely associated to the process because it is their task to "transfer" PPR information into the general zoning process (the *Plan Local d'Urbanisme* or PLU, the Local Land Use Plan), which is their responsibility.

This depiction is sufficient for our purpose; we only have to add a very central element to the architecture of the French prevention system, i.e. whenever all the above measures are completed on the territory of a commune indemnification by insurances is quite automatic for any private property affected, should avalanches or other natural hazards bring on damages. More details on the French system are available on an Internet site (Jurisques, 2000).

3.3 The Montroc avalanche and the recommendations of the advisory panel

The Péclerey avalanche that hit Montroc (Haute Savoie) in February 1999, causing 12 fatalities and destroying several chalets (cf. Inspection Générale de l'Environnement, 2000), 29 years after the Val d'Isère avalanche, also shocked the public opinion but especially all avalanche specialists and the communities of the Chamonix Valley as a whole. Surely, some "close alerts" or "near collision" had taken place since 1970 but Péclerey was not among the hit list of the most dangerous avalanches in France, not even among the about 100 avalanches of the Chamonix valley. Unlike other places, the hamlet had not been evacuated. As a matter of fact, it was not located in a red zone, only in a "partially blue" one.

This fact was a source of many afterthoughts on the possible danger of having no connection between space-related prevention and time-related hazard prediction. It explains most of the practical recommendations issued by the panel appointed after the accident. This panel had to evaluate the system set up after 1970, to assess what was still relevant after 30 years and what had to be corrected due to the imperfections of the existing system, possibly explained by a new context.

These recommendations are reported in Table 3.1 (cf. Inspection Générale de l'Environnement, 2000). In the following sections we will primarily comment those recommendations that are relevant to the purpose of this chapter.

Table 3.1 Recommendations of the Inspection Générale de l'Environnement (2000)

I. Analysing nivo-meteorological hazard

1. Identification of the most dangerous avalanche paths (MDAP): life and property are exposed whereas these paths have "complex" behaviour.

2. Determining a long-term objective for a local (i.e. enjoying a better spatial accuracy) avalanche forecasting system, then drawing up an action plan to attain this goal taking into account existing know-how.

II. Better taking into account avalanche risks in land planning activities

3. Active and passive avalanche protection structures subjected to heavy duty, as those of Taconnaz, behaved correctly so far; their survey and maintenance should be carried on properly.

4. Cross fertilisation of the Avalanche Permanent Survey (EPA) and the Avalanche Map (CLPA) as they are integrated in an Information System containing data on avalanches and other mountain natural hazards.

5. Clarifying the role of all the public organisations that are involved in gathering and processing avalanche data (DDAF or *Direction Départementale de l'Agriculture de la Forêt*, ONF/RTM, Cemagref). ONF/RTM would collect data on behalf of the State, while Cemagref acts as a control and validation agency. These provisions must be included in documents duly contracted between the State on the one hand, and Cemagref and ONF/RTM on the other hand. This should provide an opportunity to draw up a by-law stipulating that RTM's activity covers interministry domain.

6. Setting up, under the authority of the *préfet* of the *département* an operational task force involving all relevant organisations (RTM, DDE, DDIDPC and Météo-France).

7. Drawing up an avalanche guidebook based on current best practices.

8. Defining a set of rules governing building practices in avalanche exposed areas, which should be clearer and simpler than is currently the case. It is recommended to carry out a legal study to determine the possibility of introducing into the law the obligation of hiring a technical consultant when building in an avalanche exposed zone, whatever the built surface amounts to.

9. Making Chamonix risk zoning document (PPR) over. Making Montroc avalanche zoning over through cross-examination by several experts.

10. Requesting each *préfet* to perform special studies carried out for all MDAPs (see 1)

III. Combination of prevention and crisis management provisions

11. Preventive information should be delivered as requested by existing procedures like DICRIM (*Document d'Information Communale sur les Risques Majeurs*) but adapted to a mostly tourist population. Education and training of local responsible persons should be reactivated (ANENA programmes) and a "security protocol" drawn up for tourist resorts.

12. Drawing up, under the mayor's authority, a communal rescue plan that should make clear evacuation and confinement procedures in a way consistent with the PPR. This plan should take into account the road safety and railway traffic.

13. Limiting, in case of avalanche crisis, the inflow of new tourists from Annecy and Geneva through Bonneville.

14. Updating the law regarding the communal safety advisory panels and avalanche artificial release procedures (PIDA)

15. Carrying out post disaster analysis: in the future these analyses should take into account snow cover properties in the starting zone and damages occurred in the runout zone. The building resilience but also the efficiency of alert and evacuation procedures will have to be assessed.

16. A census of the buildings located in the red zone should be completed; for each building unit a special study should determine the best solution, e.g. evacuation in case of crisis, summer occupancy only or expropriation.

IV. Comparison with other European countries

17. Exchanges with responsible persons and bodies in the neighbouring countries should be intensified with the aim of improving the French and European avalanche mitigation procedures and also to develop a European expertise.

18. Starting on an experimental basis a new generation of avalanche zoning documents. This endeavour will have to be coordinated with neighbouring countries attempts and require better maps and increased funding.

19. Updating the findings of the Saunier panel taking the opportunity of the international seminary "30 years of avalanche prevention in France - results and advances to come".

3.3.1 Determination of the most dangerous avalanche paths (MDAPs)

Recommendation no. 1 is improperly enclosed in the "prediction" section, whereas it is one of the more central as far as prevention is concerned. The underlying intent is to determine what are the more dangerous avalanche paths on the French territory, using the same criteria for all avalanche paths. This is quite different from the current procedures, where avalanches are compared within a small territory. The basis for this study was to come up with a set of criteria selected by experts who not only agree on each criterion but also on its relative weight: this multicriteria analysis involves hazard-relative data, like gradient, starting zone area but also vulnerability-related data, which describe all kinds of exposed human objects. The latter were attributed high values.

One particularity of this attempt is that it was "semi-centralised" (or "semi-decentralised"!). Practically, a national working group was expected to decide on the criteria as specified above. Now, the second step of the process is underway, i.e. local working groups are applying to their sector the "toolbox" delivered to them by the central commission, which will have to harmonise the results. This ultimate step will be open to political pressures but the concept is not to get a perfect classification, only to detect some spots that are really exposed without anybody being aware of it.

An underlying concept, which found its place in the wording of the recommendation, is this concept of avalanche paths that, in special conditions, could display an "abnormal behaviour". This refers not necessarily to exceptionally high physical parameters like velocities, flow depth or runout distances but, for instance, as was the case for Péclerey, to unexpected trajectories.

Recommendation no. 10 provides that these MDAPs will benefit from special studies, but does not specify what these special studies are. This point will be addressed in section 3.3.5.

3.3.2 Avalanche databases

Recommendations 4 and 5 refer to avalanche databases. In some respect they are more political and organisational than purely technical. It is a fact that in France avalanche related data are scattered among at least two different databases, as was seen previously. On the other hand, other sources of information are available, especially those data due to recent historical research that is developing rapidly. All these data have to be included in a "meta database" that will provide access to all data related to a given avalanche path (hazard approach) or to a given part of the territory (risk approach). Recent research results in the field of databases makes it possible, as it enables to include in the databases objects like pictures, videos or newspaper scans.

3.3.3 Avalanche guidebook

In order to practically enforce the 1995 law, i.e. to support those who had to draw up PPRs, the French Ministry of Environment decided to bring out a series of "guidebooks", one for each natural hazard. Most guidebooks are now available, as are those related to floods, forest fires, landslides or earthquakes (Ministère de l'Aménagement du Territoire et de l'Environnement et Ministère de l'Equipement, du Transport et du Logement, 1997).

The fact that the avalanche guidebook was put off is probably explained by the fact that the French central administration, located in the Northern part of the country, was not at ease with a phenomenon that was rather rare, located in small areas but capable of mass killings. For the same reason existing French guidebooks are not very specific for flash floods, especially in mountain conditions, and high velocity landslides.

So the Péclerey avalanche breathed new life into the avalanche guidebook that is now close to completion (Ministère de l'Aménagement du Territoire et de l'Environnement et Ministère de l'Equipement, du Transport et du Logement, 2003).

Among the many important points that were discussed, we would like to underline one that is quite central as far as recommendations for avalanche mitigation are concerned.

The committee set up to draw up this guidebook had to tackle the question of relation between prevention and prediction. This question is definitely central when one is to consider very rare phenomena, generally defined both by very low level of probability but also by very high level of potential destruction. Usually the zoning specialists proposed to paint "blue" a zone exposed to this kind of phenomena, with a provision that "in case of a snowfall exceeding some given parameters such a zone will be evacuated". This solution transferred the responsibility both to avalanche meteorological forecasters and also to rescue planners and managers.

To face these difficulties, the solution being considered is to have on the one hand a zoning for material damages, based on the 100-year return period (annual frequency 0.01), and on the other hand a zoning for human losses, based on a concept called the AMV (*Avalanche Maximale Vraisemblable*), the maximum likely avalanche. The first kind of zoning results in prescriptions for building location and characteristics; it does not rely on weather prediction and evacuation procedures. The second kind of zoning results in prescriptions for evacuation plans; one of the factors to consider is the possibility of evacuating a given zone in realistic conditions, which depends on the number of housing units to evacuate but also on the roads that has to be kept open in safe conditions (cf. section 3.3.6). A legal snag is that such technical measures are under the responsibility of the mayor whereas, as was already mentioned, PPRs are the responsibility of the central government (the *préfet*).

These questions are still being discussed and legal consequences are under scrutiny, but one can regret the fact there is little scientific discussion about the question of the relationship between protection and prediction in the case of very exceptional events. One point of outstanding interest is the spatial accuracy of weather prediction: to take into account the possibility of spatially accurate avalanche prediction to assess the safety level of an inhabited sector is to bet on scientific progress, but this is not realistic right now. This opens the way to a new realm of interdisciplinary research.

3.3.4 Improvement of building practices

This point is very significant; unfortunately the most important provision has "disappeared" with little hope of surfacing any time soon. In France, whenever a new house is planned to exceed 170 m² in terms of net dwelling area, the intervention of an architect is required. The investigating commission being convinced this was a factor of improved safety, for this kind of professional not only have a technical know how but also an involvement in terms of responsibility, proposed this limit to be reduced to zero. This proposal was shelved and the corresponding recommendation was restricted to drawing up an avalanche construction guidebook, which provides general concepts about avalanche effects.

3.3.5 Dealing with MDAPs, updating PPRs

We will not again comment on MDAP determination, but describe how recommendations 1, 9 and 10 evolved into an unexpected action, which is sometimes the case in this kind of situation. The basic question was that the necessity of improving the zoning practices in highly exposed areas was not contested, but an open question was what technical measures were available to this purpose. Modelling was part of the solution but also part of the problem, because the results were very sensitive to untested hypotheses that are result-oriented. Historical research was also considered, but for exceptional and very ancient events it provides data that can range from reliable to quite fuzzy, at least in spatial terms.

So a proposal stood up, which consisted in organising a "contest" with several experts who would work on the same avalanche paths and whose results will be compared and discussed. Before proposing it as a method to address the MDAP question, a test was made on the Brévent avalanche path, in Chamonix Valley. The results of this test were encouraging. On the one hand, it made it possible to improve avalanche zoning in this very exposed sector; on the other hand, it brought forth many methodological results that will be useful for improving the zoning of MDAPs, which should start in 2002. Five teams of experts took part in the Brévent experiment, among them an Italian and a Swiss one.

3.3.6 Information to the public and rescue plans

As these topics are not central to our chapter we will not dwell on them very long but only mention three facts.

Information on natural hazards, which is a constitutive part of prevention, is developed on a very organised and rational basis in France. One point that has been missed is that it does not provide for these quite temporary inhabitants, as tourists are. This point has been clearly stated but no simple solution has been proposed so far.

As for emergency planning, we will only repeat that this is a point that cannot be dealt with in an absolutely independent way, since it is linked to zoning: evacuation procedures are doomed if the zoning has been too "optimistic".

Another important point that we will only mention is a part of no. 14. Artificial release of avalanches is mostly used to make ski runs safer but it is also employed to secure roads, and so interferences are possible between evacuation of exposed inhabited sectors and securing the roads necessary for this evacuation (Figures 3.1 and 3.2).

Figure 3.1 Artificially released avalanche forming a dust cloud that cuts off the road to col d'Ornon in the French Alps (reproduced by permission of Cemagref / P. Beghin)

Figure 3.2 Artificial powder snow avalanche coming from the blasting of the Dard peak's summit cornice at Vanoise, French Alps, and reaching the forest (reproduced by permission of Cemagref / C. Vion)

3.3.7 Comparison with other European countries

As JRC has already taken these items seriously, we would only provide information on a seminar we have organised in Chamonix in April 2000 for the members of the investigation panel and representatives of Haute Savoie (France), Valle d'Aosta (Italy) and Valais (Switzerland), in charge of avalanche hazard management. A geologist of Bavaria Lander was also invited. This seminar provided useful exchanges and some results were used by the advisory panel in their final report (ANENA, 2000). Other such seminars should have taken place in Sion (Switzerland) and Aosta (Italy) on a yearly basis, but unfortunately this was not possible. A meeting also took place in Brussels to meet the demand of the Commission that had been "questionned" on the avalanche accidents of February 1999 by the Parliament (Brugnot, 1999b). More systematic information can be obtained through the final report of a UE programme on avalanches (SAME, 2000).

3.4 A seminar on thirty years of avalanche policy in France

As it was already stated, it is a coincidence that when the Montroc disaster took place preparations had been started for a seminar whose aim was to have an in-depth look into the French avalanche mitigation system. So it is not a surprise that this seminar became the target of the recommendation no. 19 of the advisory commission.

This seminar took place in November 2001 in Grenoble. From the many recommendations it provided, we will only retain those that are really complementary to what has already been mentioned.

3.4.1 Zoning

It was proposed to make the databases interactive, i.e. to enter information provided by citizens, complementing, and possibly contesting, "official data".

3.4.2 Structural measures

This point was mentioned in the Montroc administrative panel (item 3), but not detailed. The Grenoble seminar insisted on the necessity to carry out a comprehensive operation, including first a census on existing avalanche protection structures and second a strategy for a systematic check-up of all permanent avalanche defences.

3.4.3 Residual risks and economic studies

Wherever avalanche exposed areas are protected by structural measures, inhabitants have a feeling of high confidence and as soon as these structures are built or reinforced, they demand new building rights. To help local authorities resist such claims, it is considered as central to avalanche protection to assess residual risks, which have to be determined according to a political process. An outcome of the process is to make it clear that these structural risks are never reduced to zero.

As a result, economic studies have to be made systematically, in order to compare the efficiency of all kind of vulnerability-reducing structural and non-structural measures. Now frequent in Switzerland (they are mandatory whenever federal funding is requested, cf. Heinimann *et al.*, 1998), these studies are not common in France.

3.4.4 Comprehensive evaluation of avalanche risk management

Avalanche risk is managed by a plurality of partners, which is probably impossible to avoid. This makes it all the more necessary to have periodic check-ups of the "safety chain". These check-ups will have to address all the elements of avalanche risk management, prevention, prediction, emergency management, etc. It is explicitly recommended to use the procedures of quality management.

3.5 Recommendations for the prevention of avalanches

We could have started this chapter with an orderly list of recommendations, extracted from those that are already listed in this section. We could have detailed each of them as if they were the pure product of our imagination. Our choice was to display a process of public policy building, which implies an historical dimension and must be considered as a whole. Holistic approaches are fashionable but useful, since trying to reduce complexity at any cost may be very dangerous. Avalanche risk management is a good example of this.

On the other hand, politics entails judgement and choice and this makes it both sound and inescapable to determine priorities. So, on the basis of what has been discussed and depending on our expert feeling, we propose our "hit list".

3.5.1 "Cleaning" red zones

Based on a process like the MDAPs selection process started in France but also on available information on highly exposed spots (cf. Figure 3.3), we propose to make all these zones clear of any permanent inhabitants. The new procedure must be result-oriented, which implies:

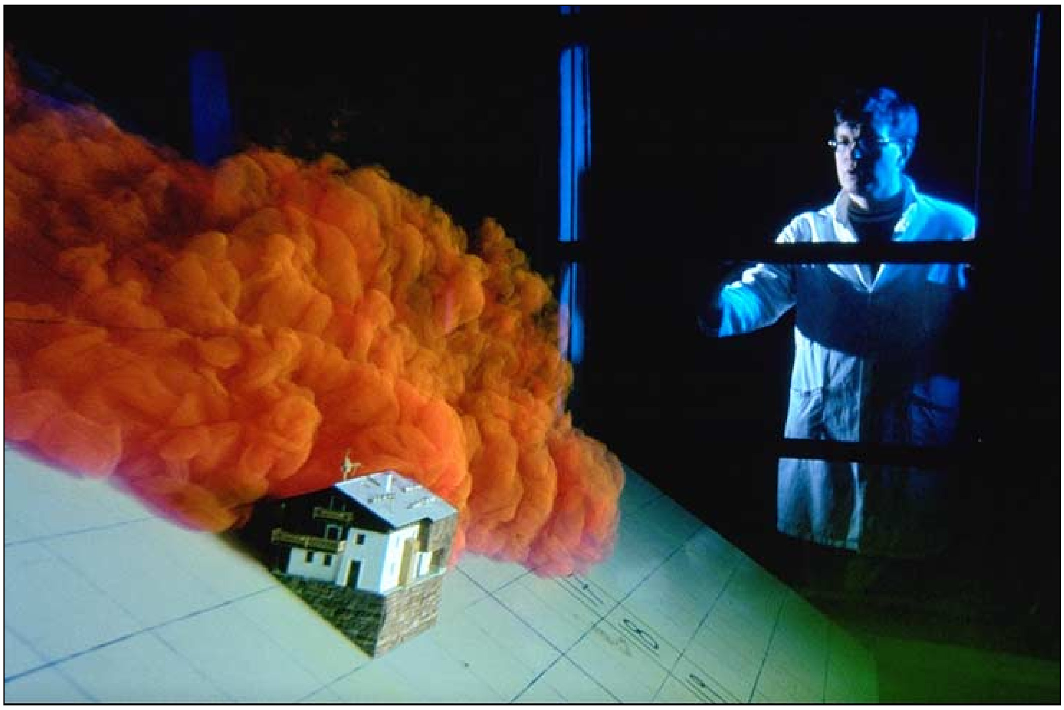

Figure 3.3 Laboratory physical modelling of a powder avalanche in a submerged channel: dense liquid in water (reproduced by permission of Cemagref / P. Poulet)

- It must be planned, i.e. priorities must be set, and a realistic deadline must be fixed for the whole operation (10 years?).
- Indemnification must be provided.
- Seasonal occupation by a private owner should not be accepted as a solution.
- The exposed property should not be sold to a private owner, i.e. it must be removed from the property market.
- The exposed property should be bought by a public authority and transferred to a public or private non-profit entity that could use it on a seasonal basis for environment related purposes.
- The "cleaning" must be made definitive, i.e. the law regulating this process should not be repelled easily. A solution consists of including this provision, as most of the provision of the following items, in a European directive, if politically feasible, considering the attributions of Europe and Member States. Such a directive would make sense for natural hazards as a whole.

To illustrate our purpose we are tempted to put forth the example of the French "Conservatoire du Littoral" or similar systems in Europe actively buying zone of high ecological interest.

3.5.2 "Informing" in blue zones

In blue zones, there is a growing consensus to stop protecting anybody and anything at any cost with any kind of costly permanent defences. One of the cheaper, inherently non-structural measures is to provide for any buyer to be fully informed of the risk the property he/she is willing to buy. So we propose these zones to be left in the property market, but the risk information be transferred, and if necessary updated, in case of any new transaction.

Measures should be taken to reduce vulnerability to the agreed acceptable level, using economic tools to determine those most efficient.

3.5.3 Avalanche zoning

In order to support the measures in 3.5.1 and 3.5.2, the zoning procedures must be harmonised, especially regarding the limit separating the red zone from the blue zone.

The question of exceptional avalanches, very rare with very high destruction power, must be dealt with according to the following principles:

- If an emergency does not exist nor is planned, the zone should be classified as red.
- If an emergency plan is being prepared, any decision should be put off waiting for this plan to be issued.
- If an emergency plan is available, the decision should depend on the expected characteristics of the avalanche and on the emergency plan, taking into account the numbers of persons to evacuate, road safety (is artificial release necessary to ensure it?), etc.

This last point particularly needs further investigation.

3.5.4 Avalanche databases

Avalanche databases should be improved in such a way that within 5 years every European citizen be able to consult on line all data related to a given avalanche in an interactive way. This means that he/she must be able to provide alternative information, which has to be fed into the system and displayed on request. Common features, including a minimal level of accuracy should be defined for the maps to be displayed.

3.5.5 Making risk studies mandatory

Any time a new measure is considered to decrease avalanche risk, a risk assessment study should be carried out, especially when structural measures are involved. The frame of such a risk study should be flexible, but it must enable the decision maker and all stakeholders to compare the measure proposed with alternative measures. No public funding should be available as long as such a study is not produced. The residual risk must be decided according to a process of political discussion.

3.5.6 Evaluation procedures

This recommendation is essentially common to all aspects of avalanche risk management. We advise a global and periodic safety audit to be carried out in a given territory, in order to evaluate the avalanche risk management system as a whole. The central part of this audit should be an analysis of the whole mitigation system impacted by extreme conditions. To this purpose, scenarios should be agreed on, which would provide references both for spatial mitigation (prevention) and temporal mitigation (meteorological forecasting, emergency planning, avalanche release, and rescue).

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4. Integral risk management in avalanche prevention and mitigation: The Swiss approach

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Abstract

Massive snowfall occurred all over the Swiss Alps during three periods in February 1999, leading to a total amount of fresh fallen snow of several metres across the Swiss Alps. During and shortly after these three periods, major avalanche activity was recorded with a main peak after the third period. More than 1,000 disastrous avalanches occurred, causing damage to people, settlements, property, forest, road and railway infrastructures. Since the last major avalanche winter in 1951, Switzerland has spent more than € 1 billion to protect people and property. The post-event analysis revealed that in most cases the measures taken since 1951 showed an efficient behaviour. Some deficiencies occurred in the context of the organisational measures. The paper discusses the efficiency of the existing measures (see also Ammann and Föhn, 1999) and lists new projects which have been started in Switzerland as a consequence after February 1999. A major effort is put on an in-depth education of the security responsibles in the communities and on an improved crisis management.

4.1 Introduction

In February 1999, Switzerland was struck by disastrous snowfall and subsequent avalanches. Massive snowfall occurred during three periods in February 1999, leading to a total amount of fresh fallen snow of several metres across the Swiss Alps. During and shortly after these three periods, major avalanche activities were recorded with a main peak after the third period. More than one thousand disastrous avalanches occurred (Figure 4.1), causing damage to people, settlements, property, forest, road and railway infrastructures.

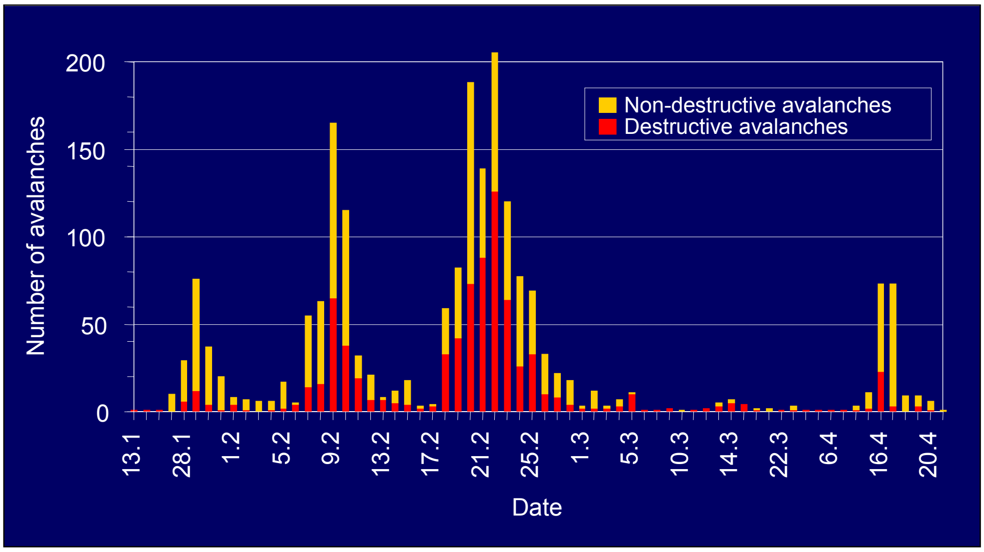

Figure 4.1 Number of destructive and non-destructive avalanches during the catastrophic periods in 1999 all over the Swiss Alps

Post-event analysis (SLF, 2000) revealed a return period for this situation in the order of 50 years, corresponding to the other major avalanche situation during the last century in January 1951 (SLF, 1952; Schneebeli *et al*., 1997). The February 1999 avalanches caused 17 deaths and damages of over 600 million Swiss francs (equivalent to € 410 million). The direct damages induced by avalanches, snow pressure and snow loads amounted to around 440 million Swiss francs. The indirect damages due to financial losses in the tourist sector, loss of income in commerce, industry, power supplies and interruptions of road and rail transport were approximately 180 million Swiss francs (Nöthiger *et al*., 2002). 27,000 people had to be evacuated. Several regional and international high voltage lines were out of service. 1,400 hectares of forests were damaged and problems with flooding were encountered later in May and June, due to heavy rainfalls combined with snowmelt run-off. About 100 million Swiss francs (€ 68 million) were due to exceeding snow loads and snow gliding on roofs and houses.

Intense avalanche activity causing damage to people and objects occurs approximately every 10 years in the Swiss Alps. During the heaviest avalanche winter of the 20th century, in 1951, 98 people were killed, 73 in buildings. The total economic damage was 25 million Swiss francs (effective value of 1951; SLF, 1952). In February 1999, 28 people were caught in inhabited areas or on roads and 17 of these died, of which 11 died in buildings (Figure 4.2). This number is relatively small in comparison with earlier avalanche winters, despite the fact that there were significantly more people in the mountains due to the growing development of leisure and tourist activities. In 1999 lines of transport were mainly affected. As a result of intense development in alpine areas and increase in individual mobility, interruption of transport, power and communication links had graver consequences than 50 years earlier and this should be weighted accordingly. Additionally, in the course of the winter 1998-99, 77 avalanches affected 131 snow sport tourists, of whom 19 were killed. Despite these losses, but seen the limited number of fatalities and property loss, the measures taken in Switzerland during the last decades to protect cities, villages and settlements proved to be very efficient.

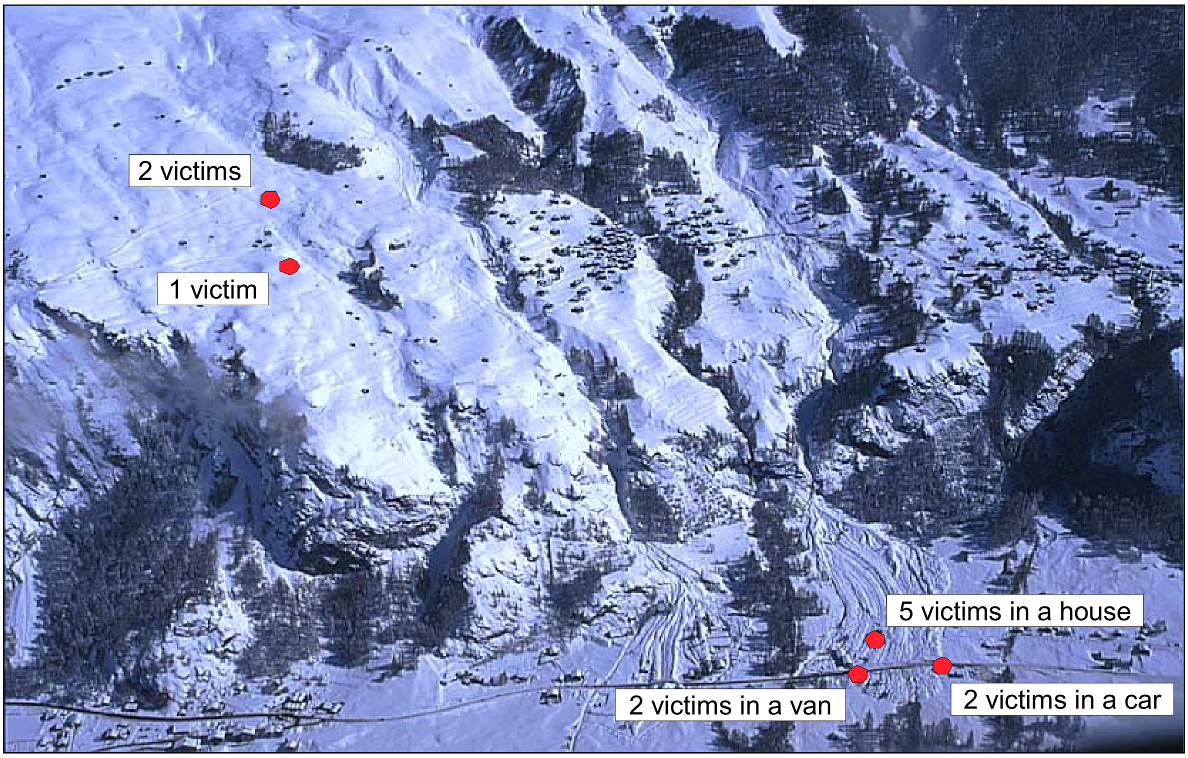

Figure 4.2 On 25 February 1999 several avalanches killed 12 people in Evolène, Canton Valais, Switzerland

Over the last 50 years, the following types of prevention and mitigation measures have been continuously established in Switzerland:

- Organisational measures.
- Avalanche hazard mapping and land-use planning.
- Technical measures.
- Eco-engineering and silvicultural measures.

The costs of the damages (over 600 million Swiss francs, € 410 million) of the 1999 avalanche winter are very high. It is noteworthy however that the damages would have been very much higher without the means of protection established in the past decades. Approximately 10 km of snow supporting structures have been built annually since 1951. About 1.5 billion Swiss francs (over € 1 billion) have been invested in avalanche defence structures until present. In the context of integral avalanche protection, road closures, evacuations, artificial avalanche release and improved avalanche warning have been applied increasingly since 1951. The annual financial investments for avalanche protection and forestry projects culminated at around 70 million Swiss francs in 1990 and have levelled out at approximately 40-50 million Swiss francs (€ 27-34 million) on an annual basis since.

4.2 Organisational measures

Organisational measures of protection have an important role both for prevention and in acute situations. As a result of the Swiss federal structure, these means are organised separately at the cantonal and communal levels. The authorities and the general public receive the necessary information from the Swiss Federal Institute for Snow and Avalanche Research (*Eidgenössischen Institut für Schnee- und Lawinenforschung*, SLF) in Davos. The institute's avalanche warning service bases its information on measurements and model calculations from about 100 automatic stations (IMIS network), on observations and measurements made by around 80 observers, on snow profiles, on measurements and data from the Swiss Meteorological Service (MeteoCH) and from the German Weather Service (*Deutscher Wetterdienst*, DWD), as well as on information delivered by local avalanche specialists, mountain guides, security services and ski mountaineers (Russi *et al*., 1998; Ammann *et al*., 2001). Organisational measures on the national level include the daily avalanche hazard bulletin, issued by the SLF at 17.00 hrs as a forecast for the following day. In addition, the SLF provides every day at 07.00 hrs an upgrade of the bulletin, issued as "regional bulletins". A total of 8 regions have been defined for this reason, covering the entire avalanche prone area of Switzerland. It is self-evident that the bulletins are issued in German, French and Italian language. Three days in advance to a severe meteorological situation (considerable probability of heavy snowfalls exceeding 1 m of fresh fallen snow within 3 days), the SLF, in cooperation with the Swiss Meteorological Service (MeteoCH), sends out an early warning message to cantonal, regional and local crisis management teams. This information enables the crisis management teams in the cantons, regions and in the communities to be prepared to foresee and to take the necessary preparedness and emergency measures. In fact, the communities are responsible for the security of their people and they have to decide on adequate measures in a crisis situation thus protecting life and property. Emergency measures include temporary evacuations of houses and settlements or closure of roads and railways. The artificial release of avalanches also belongs to the organisational measures. The cantons have the overall responsibility on their territory and support the communities in their task to provide the necessary security.

4.3 Avalanche hazard mapping

This plays an important role for land-use planning in Switzerland since the 1960's. Four zones according to the avalanche impact intensity are defined: red zone (prohibited area for constructions), blue zone (limited possibilities for constructions if houses are reinforced), yellow zone (for powder snow avalanches), white zone (no limitations). The zones are differentiated according to avalanche return periods (30 and 300 years) and to avalanche impact pressure (30 kN/m^2). Avalanche hazard mapping proved to be very efficient in February 1999.

4.4 Technical measures

These consist in avalanche defence structures (mainly steel bridges and wire nets), avalanche deflecting and catching dams and protection sheds for roads and railways (Figures 4.3 and 4.4; cf. Figure 4.7). These long-term, permanent protection measures proved to be very efficient. Up to 500 damaging avalanches could be prevented in February 1999. A few avalanche defence structures were damaged.

The most valuable measures in regard to sustainability are of course eco-engineering and silvicultural measures. The protection forests play an important role to prevent avalanches from starting. Experiences in February 1999 were very positive. Only very few avalanches had their starting zone within the forested area. Eco-engineering measures are used in areas where afforestation is possible. To protect the growing trees from starting avalanches, snow gliding and creeping, temporary, wooden paravalanche constructions are used in parallel. This technique proved to be very efficient.

Figure 4.3 Snow nets stabilise the snow in a potential avalanche starting zone

Figure 4.4 Avalanche retaining dam in Trun, Canton Grisons, Switzerland

4.5 Lessons learnt in the February 1999 catastrophe

The lessons learnt in Switzerland from the February 1999 avalanche catastrophe have been briefly summarised in (Colombo, 2000) and are extensively discussed in (SLF, 2000). Following is some more detailed information on the different types of measures as listed above and their effectiveness during February 1999 (see also SLF, 2000).

4.5.1 Organisational measures

Analysis of the SLF avalanche warnings and the crisis management in the 5 most affected cantons shows that the system of subsidiarity for organisational means for coping with the extraordinary situation proved to be efficient. Further improvements must nevertheless be made in this field:

- The various avalanche commissions are differently equipped with decision making aids such as InfoBox, NXD2000 or IMIS stations, and these disparities should be reduced (Bründl *et al*., 2002; Lehning *et al*., 2002).
- The level of qualification of the members of the avalanche commissions is also very variable and should be improved. Some of the security responsibles in the communities, the regions and the cantons were not trained and prepared enough to cope with this catastrophic situation. This was especially true for regions which are not regularly affected by avalanche threats. Continuous education of these experts in special courses will help to improve the situation.
- These analyses emphasised two important points: firstly, a complete network of avalanche specialists should be established, and secondly, an early warning and information system is required. The latter should guarantee exchange of information between the numerous decision makers and information sources and also keep the public well informed (crisis management and information exchange tool). During February 1999, some major problems in crisis management occurred due to non-coordinated actions, missing information, interruption of communication, etc. The vulnerability of people with regard to mobility and to their information and communication needs is continuously increasing. It is important to have the necessary tools but also the adequate information. The information to the public has to be improved. An information and communication system has to be established providing the necessary possibilities on a local, cantonal/regional, national and especially also on an international level. Particularly for touristic areas, an efficient information policy is required. This system can also be used to counter other catastrophic situations such as floods and storms.
- Early warning information 3 days in advance of major snowfalls, the national and regional avalanche forecasting bulletins and additional information on actual snow and weather situation were very useful for the security responsibles in their decision making process (Figure 4.5). But also the public was continuously informed about the current snow and avalanche situation via internet (http://www.slf.ch), radio, television and telephone (++41 187).

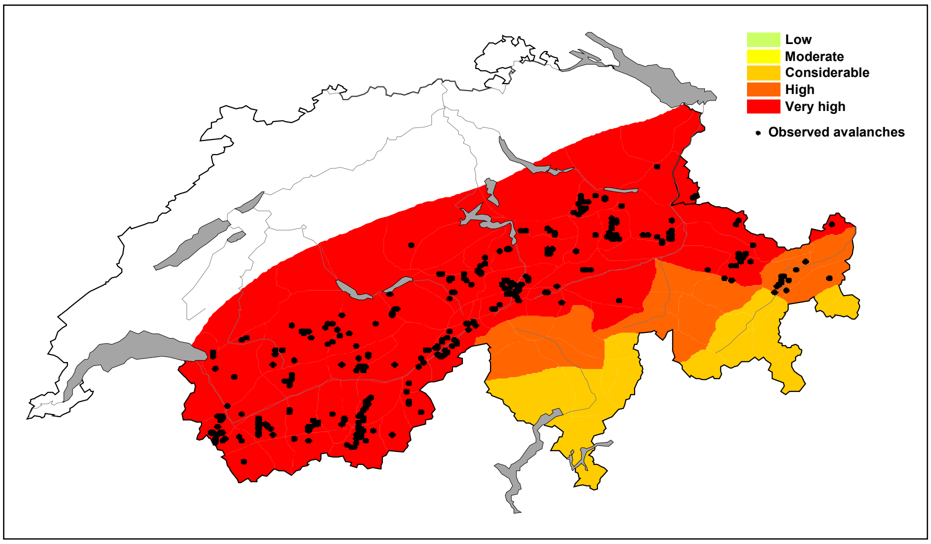

Figure 4.5 Avalanche danger situation in Switzerland and recorded avalanches in February 1999. Avalanche danger forecasting is an efficient tool to support local security responsibles in their decision process

- The existing Swiss network of automatic snow and weather stations showed some regional gaps and some technical limitations in specific weather situations. The network has to be completed and regional gaps have to be closed.
- The precision in time and space of the avalanche bulletins has to be improved. To minimise the periods of time when roads have to be closed or people evacuated, the basic information for the decision process has to be improved. To do this, a comprehensive insight into the avalanche formation process has to be gained.
- Artificial avalanche release caused quite extensive damage (SLF, 2000). Regulations and security procedures have to be re-examined. Regular triggering avoided the formation of large avalanches in many areas. The method was generally useful; however, there were also significant damages to buildings and diverse infrastructures, confirming that there is risk involved. The danger of artificially triggered avalanches being larger than expected or of not being triggered artificially but occurring later cannot be avoided. Estimation of possible extreme runout areas and organisation of large-scale closures proved to be essential for avoiding damages, in particular in cases where avalanches reach valley bottoms. The result of artificial releases must be verified in order to make the method a useful instrument for increasing the safety of roads and infrastructures. If the result is not clear, it is very delicate to interrupt means of protection such as road closures. The security staff, including mine throwers and rocket shooters, must be well qualified and have attended obligatory courses guaranteeing this.

4.5.2 Avalanche hazard mapping

In a small, densely populated country like Switzerland, land-use planning has an important function for risk reduction due to natural hazards. The analysis of the application of avalanche hazard maps show that there are large discrepancies between the different cantons. In some potentially endangered communities there are no avalanche hazard maps. The use of an avalanche cadastral map is not established in all cantons. Analysis of damages in Wallis for example, showed that ten buildings were affected in red hazard zones, and 109 in blue or yellow zones of avalanche hazard maps. In general, the avalanche cadastral and hazard maps were used as an important basis for the planning of road closures and evacuations (Figure 4.6). There is only sparse quantitative information on the size of the avalanche fractures.

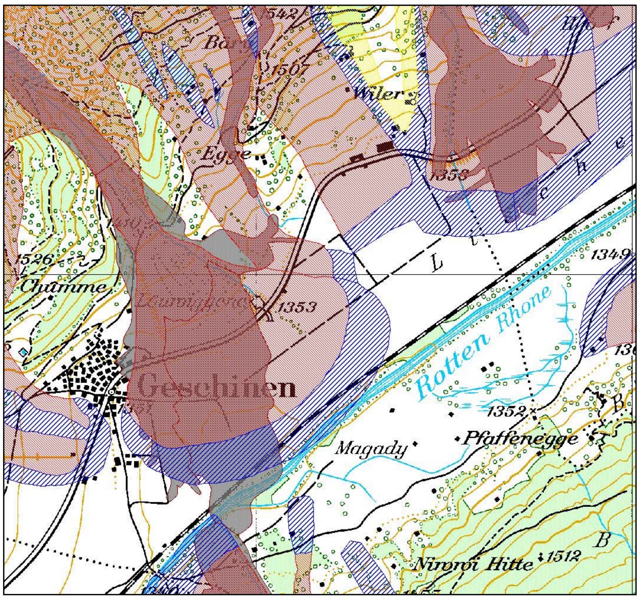

Figure 4.6 Avalanche hazard maps are very useful as base for land-use planning but also for intervention strategies in case of high avalanche danger. The shaded area represents avalanches which occurred in the winter of 1999 in Geschinen, Canton Valais, Switzerland

Many avalanches had enormous fracture heights and widths, often corresponding to the total potential fracture area. This led to transgression of the zone limits on existing hazard maps, particularly around 20 February 1999; in many cases the powder component of the avalanches transgressed the limits. Further improvements must be made in the following fields:

- Multiple avalanche events led to lateral overflow of dams and small or previously filled deviation dams were also overflowed. Multiple events must be weighed more carefully in future risk assessments and in the planning of means of protection.
- Although land-use planning proved to fulfil its function satisfactorily on the whole, the analysis showed that research is necessary for modelling flow avalanches and in particular combined flow/powder avalanches. It should be noted that about 40 avalanches overpassed the existing hazard zones, mainly due to powder snow avalanches.
- Only half of the avalanche prone communities in Switzerland have statutory avalanche hazard zones and a related land-use planning process. The implementation of hazard mapping in land-use planning has to be accelerated.
- Often the fracture height in the avalanche starting zone by far exceeded the basic assumptions for the mapping procedure. Nevertheless, the run-out distances remained within the limits. Reasons are not clearly understood.
- Avalanche dynamic measurements were taken on the SLF test site Vallée de la Sionne, canton Wallis (Figure 4.7). Speeds of up to 80 m/s at the front of the avalanche and around 110 m/s within the avalanche were recorded using Doppler radar. These measurements show that avalanche speeds in the avalanche track have been underestimated until present. For the first time these tests allow the validation of computer models being developed at SLF (Ammann, 1998; Ammann *et al.*, 2002).

Figure 4.7 Artificially triggered powder snow avalanche in February 1999 at the avalanche test site Vallée de la Sionne of the Swiss federal Institute for Snow and Avalanche Research (SLF), Davos

4.5.3 Technical measures

Inspection of many defence structures (snow supporting structures, wind fence structures, deviating structures, retention dams and avalanche galleries) during the winter allowed many interesting observations to be made. No large avalanches were triggered between snow supporting structures; they fulfilled their function efficiently. Despite the fact that these structures were completely filled in many places, they withstood the very high loads. Damages to structures amounted to 8 million Swiss francs (€ 6 million) and were relatively low. They occurred mainly in areas where avalanches overflowed the structures. Structures located on the ends of rows and in areas with strong snow gliding were found to be rather scarcely dimensioned (dimensions according to the BUWAL/WSL guidelines, 1990) and higher loads may have to be considered in future. Avalanche galleries also proved to be very efficient, and were only overflowed laterally by very large avalanches or in cases of multiple events (Figure 4.8). Further improvements however must be made in the following fields:

- Avalanche deflecting and catching dams suffered overflow in some situations. Avalanche dynamics calculation taking all kinds of obstacles into account are not at a level to model reality. A major effort has to be made to learn more about the interaction of avalanches with dams and to be able to quantify the effects.
- To maintain the effectiveness of paravalanche constructions, maintenance strategies for the avalanche defence structures become an important issue in the next decade (Bründl *et al*., 2000).
- The cost-effectiveness of the large investments in the past decades of more than € 1 billion will be argued and probably result in redistribution of credits. The pressure on politicians will increase to modify hazard maps after completion of technical measures.
- It should also be determined how the efficiency of defence structures and the residual risks can be quantified, and by which criteria rezoning can be undertaken when defence structures are built according to the official guidelines.

Figure 4.8 Due to many avalanche galleries, many avalanche-prone roads and railways could still be kept open in the 1999 catastrophic avalanche situation in Switzerland. The picture shows the Gotthard highway in February 1999

4.5.4 Eco-engineering and silvicultural measures

The absence of avalanche fractures in forests in winter 1999 was particularly striking. Only a limited number of avalanches occurred beyond the timberline. It is not clear how far the favourable snow cover conditions or the forests were responsible for this fact. Hardly any avalanches started in forests, even in potentially dangerous areas. The efficiency of forest structures cannot be established satisfactorily. One positive aspect for avalanche protection is definitely the constantly increasing surface area of forests and their growing density. Re-forestation supported by temporarily effective avalanche counter measures (wooden paravalanche constructions, gliding and creeping measures) proved to be efficient. The avalanches caused the formation of new potential dangers, for example, the presence of trees in stream beds. Clearing avalanche timber debris is not always meaningful or possible. However, priority should be given to the clearing of river beds which threaten to be dammed by timber.

4.5.5 Further lessons learnt

Finally, it appears that integral avalanche protection in the form of an optimal combination of various preventive and crisis management systems was successfully put to the test in February 1999. The catastrophic avalanche winter 1999 confirmed that complete protection is impossible due to technical, economic and ecological limitations. Existing avalanche defence structures should be completed wherever necessary. All efforts in this direction must therefore be pursued. The limited existing financial resources should be put to use in an optimal manner for integral risk management, i.e. for protection strategies which include the different and complementary methods of protection (organisational measures, technical measures, hazard mapping, eco-engineering measures). Risk assessment methods and methods for the evaluation of the economic efficiency of means of protection have priority (Wilhelm *et al.*, 2001). Integral risk management should be applied increasingly to other natural hazards such as floods and storms in future. Switzerland, like probably all other European countries, had to realise that during the last 10 to 15 years, the importance of individual mobility, information and communication has substantially grown. The dominance of these technologies in daily life was not adequately recognised, leading to an underestimation of the risk situation. In future, these risks have to be better integrated into an overall risk management process (Ammann and Stöckli, 2002).

In Switzerland, the cantons are responsible for the natural hazard crisis management. Based on the existing laws, the Swiss Federal government provides financial support to the cantons for the technical measures, the hazard mapping, the silvicultural measures and for the installation of the network of automatic snow and weather stations, but not for the service and maintenance of these stations and for the support of decentralised avalanche forecasting experts. Legal adjustments have to be implemented.

4.6 Research and development projects started at SLF after February 1999

The evaluation of the efficiency of the various measures during the 1999 avalanche winter have led to the definition of about 50 actions (SLF, 2000). Up to now, only a few of them have been started. They are briefly described hereafter.

a) Organisational measures

- To improve the level of qualification of the members of the avalanche commissions the SLF has established continuous education courses on snow and avalanches. Two different types are offered, according to the needs. Repetition courses are also offered. Since autumn 2000, more than 100 experts have been trained.

- To guarantee the exchange of information between the numerous decision makers and information sources and also to keep the public well informed (crisis management and information exchange tool) a pilot-project has been started in three different regions. The handling of the information exchange between the various decision makers is provided with a content management system (CMS).
- To improve the security level during artificial avalanche release actions, the existing SLF guidelines have been revised (Stoffel, 2001).
- To improve knowledge about the avalanche initiation process an extensive research programme has been started at SLF (fracture mechanics processes, etc.).

b) Hazard Mapping

- A pilot study has been performed to examine ways on how to evaluate executed technical measures in a hazard zoning revision process.
- An avalanche dynamics research programme concentrates on the numerical simulation of dense flow and mixed dense flow/powder snow avalanches. The project is underlined by extensive laboratory and field tests.

c) Technical measures

- A research project has been started to evaluate the efficiency of deflecting and retaining dams. Experimental work and numerical simulation will be performed to establish guidelines for the design of dams.

d) Integral risk management

- PLANAT, the National Platform for Natural Hazards is working on a national strategy to reduce risks due to natural hazards. The strategy states equality of prevention, preparedness, intervention and recovery (Figure 4.9). Measures should only be taken according to cost-effectiveness and no preference should be given in advance to technical prevention measures. The recent catastrophes in Switzerland have revealed that more weight should be put on organisational measures.

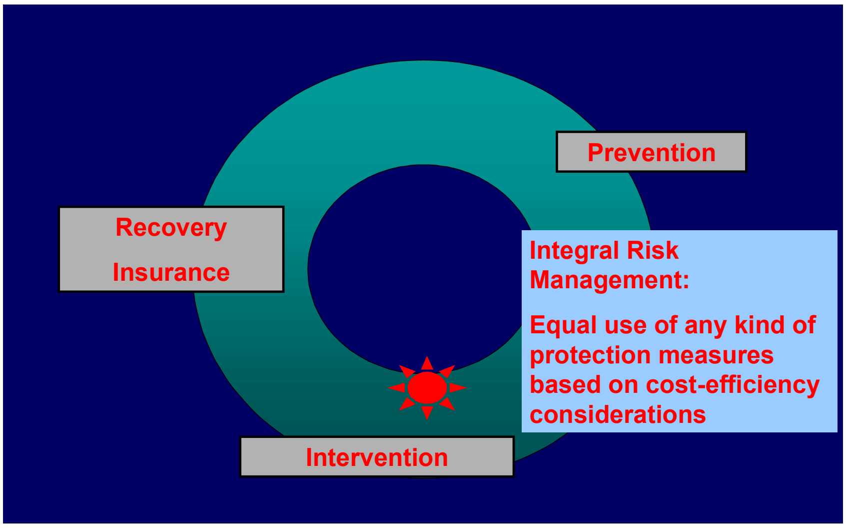

Figure 4.9 Catastrophic events always occur despite excellent prevention and preparedness work. Within the risk circle, besides prevention, it is therefore also very important to handle the intervention and recovery phase

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5. Hazard mapping and land use regulation in avalanche prone areas: Recent developments in Italy

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Abstract

This chapter briefly describes the state of the art of the Italian snow avalanche zoning tools with respect to legislation, hazard maps type and avalanche computational models. In particular, it presents a series of “guidelines” for hazard mapping and land-use regulation in avalanche-prone areas recently worked out by AINEVA (Italian Interregional Association for Snow and Avalanche) in collaboration with the Hydraulic and Environmental Engineering Department of the University of Pavia. These guidelines represent a first and preliminary attempt to define homogeneous criteria for the management of avalanche problems along the Italian Alpine Regions.

5.1 Introduction

This chapter provides a brief description of the snow avalanche zoning tools currently used along the Italian Alpine Regions. Although the attention for avalanche problems has grown sharply in the last few decades, at present in Italy there is neither a common legislation (see § 5.2.1) nor well defined technical criteria concerning hazard zoning in avalanche–prone areas. The various organisations which deal with avalanche hazard forecast and prevention were organically structured in 1983 to form an association called AINEVA (Peretti, 1992), which stands for “*Associazione Interregionale NEve e VAlanghe*” (Interregional Association for Snow and Avalanches). Nowadays, the Italian Regions which join AINEVA include Friuli Venezia-Giulia, Veneto, Lombardy, Piedmont, the Autonomous Region of Valle d’Aosta and the Autonomous Provinces of Trent and Bolzano. Each associated region has its own specific tasks, depending on their own regional and provincial regulations. However, AINEVA coordinates the activities and initiatives carried out by the various regional avalanche offices, particularly with respect to avalanche forecast and prevention.

In January 2001 a collaboration project between AINEVA and the Hydraulic and Environmental Engineering Department of the University of Pavia has started. Its aim is to define general guidelines for avalanche hazard mapping and land use regulation in avalanche-prone areas; these guidelines should serve as a reference common base to set up the specific legislation of the different Italian Alpine Regions. The collaboration project is currently in progress; however, in the frame of the present work the first results of this joint research project will be discussed (§ 5.3), especially with respect to their technical aspects. The results of an enquiry carried out over the different Italian Alpine regions concerning the availability of historical avalanche information and snowfall records are also presented (§ 5.4). Such an enquiry has provided useful information to set up feasible mapping criteria with respect to the degree of information presently available in the Italian context.

5.2 Hazard zoning principles in Italy

5.2.1 Legislation

As previously pointed out, at national level the legislation concerning land use in avalanche prone-areas is quite poor. Only very recently, in 1998, a national law concerning natural hazards (L.267/98) makes funds available for hazard mapping and defence structure design and construction, for those zones highly endangered by natural hazards (including also avalanches); therefore, for those avalanche sites included in this special disaster prevention plan, hazard maps were produced using the Swiss mapping criteria (cf. Salm *et al.*, 1990, and Table 5.1 below), and land use restrictions were adopted according to the degree of hazard evaluated and the relative law prescriptions (basically, no new buildings were allowed in high and moderate hazard zones). However, this kind of legislation is restricted only to a few avalanche sites, namely those included in the list of priority interventions considered by the L.267/98 law, and therefore does not include the majority of dangerous avalanche sites of the Italian Alps.

Nevertheless, at regional level the situation is quite heterogeneous. In some regions, such as Valle d'Aosta, a specific legislation on avalanche mapping and land use restrictions in mountain areas similar to the Swiss one has been recently produced (Pasqualotto, 1998; see Table 5.2 below). In other regions, such as the Autonomous Province of Trent, hazard mapping and land use restrictions have been based on historical avalanche data alone. In the remaining regions maps based on historical data are produced as well (the so-called C.L.P.V., see § 5.2.2). However, so far these maps have no legal liability, but are used solely as an aid in land use planning at local level (communes, provinces).

5.2.2 Type of maps

The avalanche hazard maps produced in the Italian Alpine Regions may be essentially divided in two general categories:

- C.L.P.V. (*Carte di Localizzazione Probabile delle Valanghe*, which stand for "maps of probable localisation of avalanches").
- P.Z.E.V. (*Piani delle Zone Esposte al pericolo Valanghe*, which stand for "plans of the zones exposed to avalanches").

C.L.P.V.

These maps are produced according to the French criteria for the C.L.P.A. maps (*Cartes pour la Localisation Probable des Avalanches*, which stand for "maps of probable localisation of avalanches") (De Crecy, 1980). The maps are drawn at 1:25,000 scale, with 25 m contours. At present such kind of maps cover about 50% of the Italian Alps (see Table 5.6 below), but in the near future they are expected to cover the whole Italian Alpine areas, as well as to be digitised. These maps contain two different types of information:

- Historically known avalanches, compiled from literature and documents, interviews and field work (indicated in the maps with purple areas);
- Information on hazard-prone areas identified by geomorphologic investigation in the field, use of topographic maps and aerial photogrammetry (indicated in the maps with orange areas).

A sample of this type of map is given in Figure 5.1.

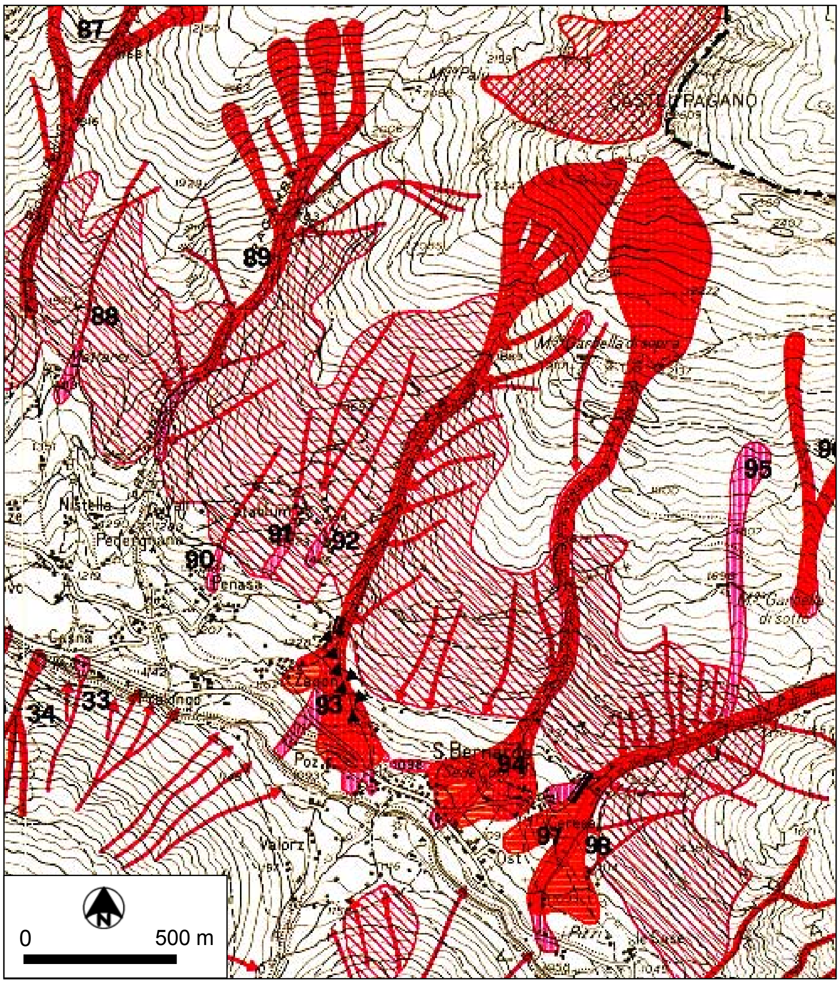

Figure 5.1 Sample of the C.L.P.V. map from the Rabbi Valley, Trent (by courtesy of the Avalanche Office of the Autonomous Province of Trent). Purple areas indicate historically known avalanches, whereas orange areas indicate avalanche identified by geomorphologic investigation in the field and aerial photogrammetry. The numbers identify each single avalanche path. The lines with arrows indicate sluffs, usually not numbered, and the dashed patterns sluffy areas

P.Z.E.V.

These maps represent "true" hazard maps, in which areas with different degree of exposure to the avalanche danger are defined on the basis of the application of computational models for avalanche dynamics and runout, as well as of known historic event analysis and geomorphologic investigation. These maps are usually drawn at 1:5,000 scale (or 1:2,000), with 5 m (or 2 m) contours. The hazard zones, which should correspond to the safety requirements in the national building regulations (so far still not univocally defined in Italy), are determined on the basis of proper frequency/magnitude relations (see Tables 5.1 and 5.2). To date, these kind of maps have been derived for only a few avalanche sites and, due to the lack of well defined and widely accepted criteria at national level, usually they are made on the basis of the Swiss mapping criteria (SLF, 1984; Salm *et al.*, 1990). A sample of this type of maps is given in Figure 5.2.

Table 5.1 The Swiss criteria for avalanche hazard mapping, widely adopted in Italy

Avalanche hazard zone	Definition
Red (high hazard)	Expected flowing avalanches will either have a return period of 30 years or a return period of up to 300 years and an impact pressure of 30 kPa or more.
Blue (moderate hazard)	Flowing avalanches with return periods between 30 and 300 years may occur, but the expected impact pressures are less than 30 kPa. Powder avalanches may also occur with return periods of 30 years or less and pressures less than 3 kPa.
Yellow (low hazard)	Flowing avalanches have return periods greater than 300 years, while powder avalanches with return periods of more than 30 years and impact pressures of less than 3 kPa may occur.
White (no hazard)	No avalanches are expected

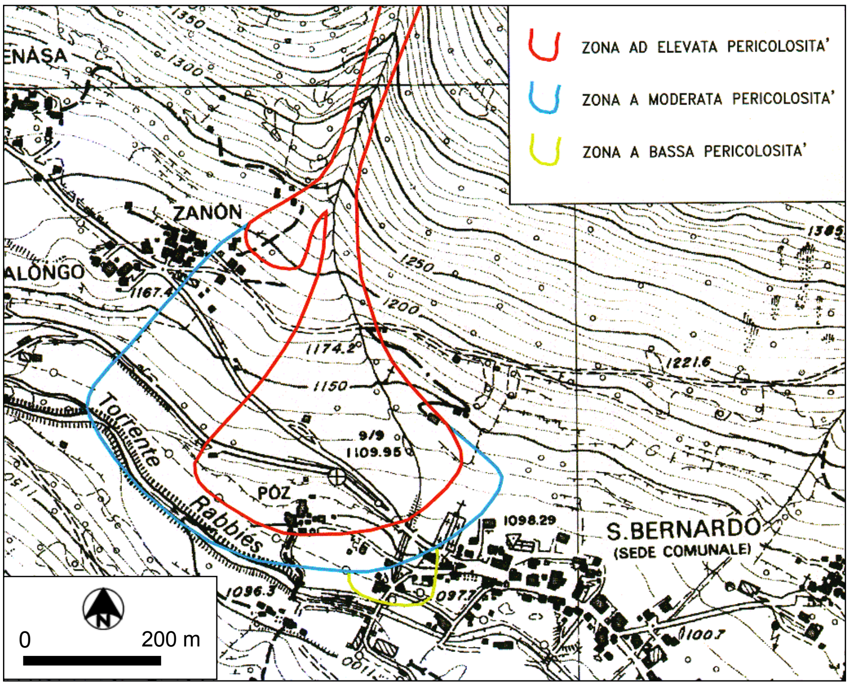

Figure 5.2 Sample of P.Z.E.V. map drawn according to the Swiss mapping criteria of Table 5.1, Val Nigolaia site, Rabby Valley, Trent. High hazard zones are portrayed in red, moderate ones in blue and low ones in yellow (by courtesy of Avalanche Office of the Autonomous Province of Trent)

The Only exception is represented by the Valle d'Aosta region, where the P.Z.E.V. are produced according to a specific legislation (see § 5.2.1), where both mapping criteria and land-use restriction in endangered areas have been clearly defined. The mapping criteria are presented in Table 5.2, whereas the related land-use restriction (Pasqualotto, 1998) are substantially similar to those stated in the Swiss Guidelines for Land Use in Mountainous Areas (SLF, 1984).

Table 5.2 Criteria for avalanche hazard mapping from Valle d'Aosta legislation

Avalanche hazard zone	Definition
Red (high hazard)	Expected avalanches will have a return period of 100 years and an impact pressure of 30 kPa or more.
Yellow (moderate hazard)	Expected avalanches will have a return period of 100 years and an impact pressure between 30 kPa and 5 kPa.
Green (low hazard)	Expected avalanches will have a return period of 100 years and an impact pressure lower than 5 kPa.
White (no hazard)	No avalanches are expected

5.2.3 Methods of calculation

To date the computational model for avalanche dynamics calculations most widely employed by practitioners in Italy is undoubtedly the Voellmy-Salm model (Voellmy, 1955; Salm *et al.*, 1990). This is a quite simple model which may be termed as an "hybrid" of solid and fluid motion; actually, it considers an avalanche like a solid block sliding along the slope, but the momentum equation is completed with a fluid-like turbulent friction force to get a limit for the centre of mass velocity.

However, with respect to the Italian research in the field of avalanche dynamics modelling, it should be noted the research activities carried out since the early nineties at the Hydraulic and Environmental Engineering Department of the University of Pavia. At this Department avalanche computational models, named VARA models, have been developed (Natale *et al.*, 1994; Nettuno, 1996; Barbolini, 1998; Barbolini, 1999; Barbolini *et al.*, 2000). They use a hydraulic approach for the simulation of snow avalanche flows; the equations are in fact similar to those originally derived and commonly applied for free-surface hydraulic flow simulations. Consequently, these models are only applicable to dense snow avalanches. These models have been extensively calibrated and tested, and already applied to real world hazard mapping, mainly in the Central Italian Alps.

Furthermore, in some alpine areas, such as the Veneto and Lombardy regions and the Autonomous Province of Trent (Barsanti, 1990; Fellini, 1999; Castaldini, 1994) "statistical-topographical" models have been developed as well, based on the original ideas of the researchers of NGI (Norwegian Geotechnical Institute) (Lied and Bakkehøi, 1980). However, the use of such kind of model so far has been limited to research purposes only, and has not involved practical hazard mapping.

5.3 Recent developments

In the following paragraphs a series of general "guidelines" for land-use planning in avalanche-prone areas, recently worked out by AINEVA in collaboration with the Hydraulic and Environmental Engineering Department of the University of Pavia, are presented. These guidelines have been approved by the Technical Committee of AINEVA in March 2001. They represent only a first and preliminary attempt to define standard criteria for avalanche hazard management along the Italian Alps. The specific hazard mapping criteria have been defined in the frame of the same joint research project one year later (approved by the

Technical Committee of AINEVA in March 2002). They will be presented and discussed in § 5.3.2.

5.3.1 New Italian guidelines for the management of avalanche danger in land-use planning

Objectives

The management of avalanche danger in mountain areas is currently characterised at a national level by a general lack of common normative. Furthermore, at a regional level the problem is dealt with in a strongly heterogeneous way. The purpose of this document is to give the Italian Alpine Regions and Autonomous Provinces common guidelines for the elaboration of the technical and normative tools for land-use planning in avalanche-prone areas.

Avalanche danger

The avalanche danger has to be considered similarly to all the other dangers originated from calamitous events already regulated by the urban-planning tools.

Levels of planning

In land-use planning the prevention of avalanche danger should be made for progressive levels, in relation to the nature of the land-use plan and to its scale. Furthermore, the activities of prevention will be related to the degree of knowledge of the phenomenon and will be made with different approaches depending on the availability of data and information.

Land-use plans at a territorial scale and use of historical data

Properly documented avalanche historical data should be considered the basic source of information for land-use planning. In general, and if further knowledge about the nature of the expected avalanche events is lacking, in the zones historically affected by avalanches it must be avoided any modification of the territory involving an increase of the exposure of goods and people to the avalanche danger. For documented events is meant avalanches recorded in the Avalanche Cadastre and/or in the C.L.P.V. (see § 5.2.2). The use of historical avalanche data for avalanche danger evaluation has to be considered as the first step of a process of progressive improvement of the land-use planning tools. That is why its use should be regarded as appropriate only for land-use plans at a broad scale ("territorial" plans). The updating and completion of Avalanche Cadastre and C.L.P.V., as well as the inclusion of such information in GIS environments represent a priority for the Regions and Autonomous Provinces belonging to AINEVA.

Land-use plans at a local scale (urban plans)

In the community known to be threatened by avalanches the demand of a correct and detailed evaluation of the potential interaction between avalanches and urban development at local scale (communal scale) makes it opportune, in the preliminary phases of urban planning, the realisation of specific studies (i.e. hazard maps, see § 5.2.2) to identify the areas with different degree of exposure to the avalanche danger. In such studies, the evaluations of the different degree of exposure to the avalanche danger has to be based on the frequency and intensity of the expected avalanches. The realisation of these detailed studies (i.e. hazard maps) is necessary in all those situations in which it is possible a direct or indirect interference between avalanches and existing or planned buildings. The degree of exposure to the avalanche danger identified in these studies will be properly accounted for in urban planning by way of suitable land use restrictions.

Avalanche danger and infrastructures

If any modification of the territory interacts with avalanches documented in the land-use plans at territorial or local scale, in the preliminary phases of the design of infrastructures, specific avalanche studies must be carried out. Such studies will be strongly recommended in all those cases where the planned modification involves the exposure of human lives to the avalanche danger. The avalanche studies have the purpose of characterising the expected avalanche events in relation to their potential effects on the planned infrastructures.

Update of hazard mapping

The characteristics of the avalanche phenomena and the environment in which they occur could make it necessary to update the tools of § 5.3.1 (C.L.P.V., Hazard Maps and Avalanche Studies), in relation to possible modifications of the territorial and environmental context, such as the occurrence of larger avalanches with respect to those previously known, the reforestation of release zones, etc. However, with respect to the land-use planning tools and in relation to the land-use restriction in avalanche-prone areas, the possible presence of defence structural works (active and/or passive) should be regarded, in principle, purely as "making safer the existing ones”.

5.3.2 New Italian hazard mapping criteria

The purpose of the document was to define avalanche hazard mapping criteria according to the widely employed Swiss approach (hazard as a function of avalanche frequency and intensity; SLF, 1984), but with threshold values slightly modified according to the specific Italian situation in terms of data availability (see § 5.4). The new Italian mapping criteria are synthesised in Table 5.3, where the land use restrictions for the areas with different degrees of danger are also briefly indicated. Figure 5.3 shows a graphical representation of the criteria of Table 5.3 in a Cartesian plane frequency-pressure.

Some important points of these new guidelines that should be highlighted are the following:

- Static pressure should also be accounted for; that means that mapping is also based on the deposition depth.
- Monitoring and evacuation plans must be prepared to increase safety of people living in red, blue and yellow zones.
- Modification of hazard maps after realisation of defence works is allowed, under certain conditions (no new white areas, but only modification of the boundary between red/blue and blue/yellow zones; maintenance plan for the defence works must be operative; etc.)

5.4 Enquiry on data availability over the Italian Alpine Regions

5.4.1 Snowfall data

The result of the enquiry about the snow data availability is presented in detail for each region in Tables 5.4 and 5.5, for manual and automatic stations respectively. The graphical

Table 5.3 The new Italian avalanche mapping criteria (with an indication of the related land-use restriction) approved by AINEVA in March 2002

Avalanche hazard zone	Definition/Land-use restrictions
RED (high hazard)	Expected avalanches will either have a return period of 30 years and an impact pressure of 3 kPa or more, or a return period of 100 years and an impact pressure of 15 kPa or more. NEW CONSTRUCTIONS ARE NOT ALLOWED
BLUE (moderate hazard)	Expected avalanches will either have a return period of 30 years and an impact pressure of less than 3 kPa, or a return period of 100 years and an impact pressure between 3 and 15 kPa. NEW CONSTRUCTIONS ARE ALLOWED, BUT WITH "STRONG" RESTRICTIONS (low building indexes, reinforced structures, etc.)
YELLOW (low hazard)	Expected avalanches will have a return period of 100 years and an impact pressure of less than 3 kPa; the areas potentially affected by avalanches with a return period between 100 and 300 years are also allocated to yellow zones. NEW CONSTRUCTIONS ARE ALLOWED, WITH "MINOR" RESTRICTIONS (no public facilities, like schools, hotels, etc.)

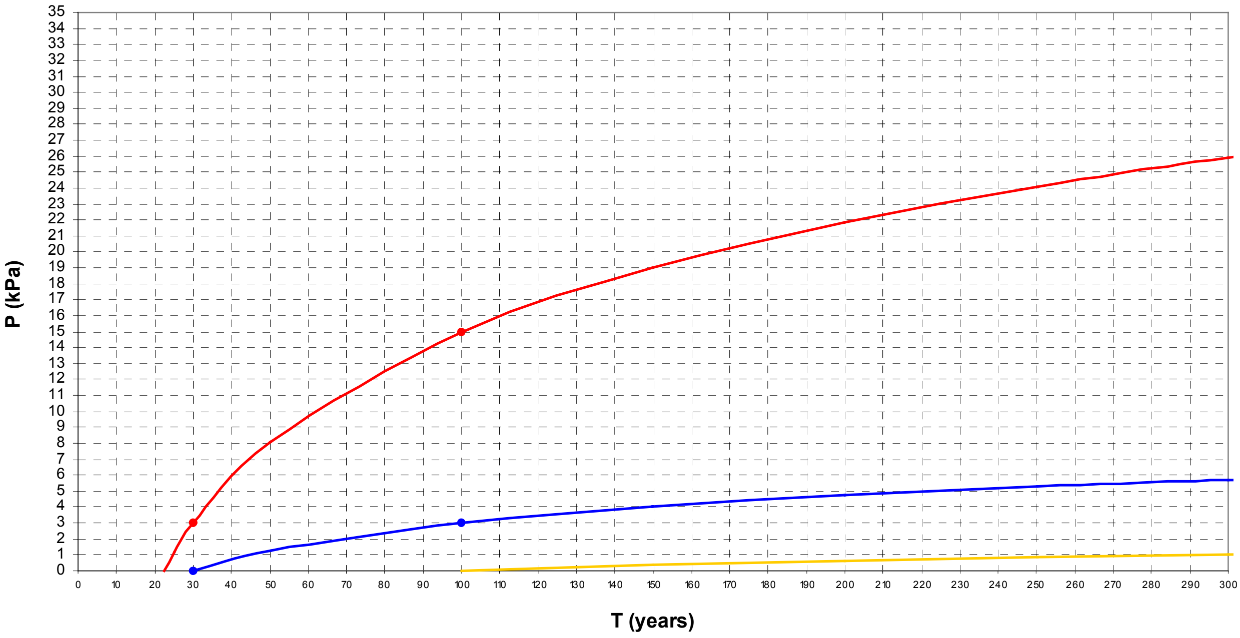

Figure 5.3 Graphical representation of the new Italian mapping criteria in a frequency-pressure diagram. The coloured lines define the boundary between the red-blue, blue-yellow and yellow-white zones; they are drawn based on the criteria of Table 5.3 (the solid circles represent the mapping thresholds there indicated) and using a Gumbel fitting

Table 5.4 Number of manual stations for each region, depending on the record length

Region	Daily record of new snow and overall snow cover depth No. of manual station			Length for the longest series
	<10 years	10-30 years	>30 years	years
Piedmont	0	40	0	17
Valle d'Aosta	2	13	0	29
Lombardy	1	24	1	33
Autonomous Province of Bolzano	0	19	0	19
Autonomous Province of Trent	5	29	1	44
Veneto	39	1	0	20
Friuli Venezia Giulia	3	15	0	28
Total	50	141	2	-

Table 5.5 Number of automatic stations for each region, depending on the record length

Region	Daily record of overall snow cover depth No. of automatic station		
	<5 years	5-10 years	>10 years
Piedmont	12	22	20
Valle d'Aosta	2	2	0
Lombardy	0	7	0
Autonomous Province of Bolzano	7	0	0
Autonomous Province of Trent	5	1	5
Veneto	0	2	15
Friuli Venezia Giulia	9	0	0
Total	35	34	40

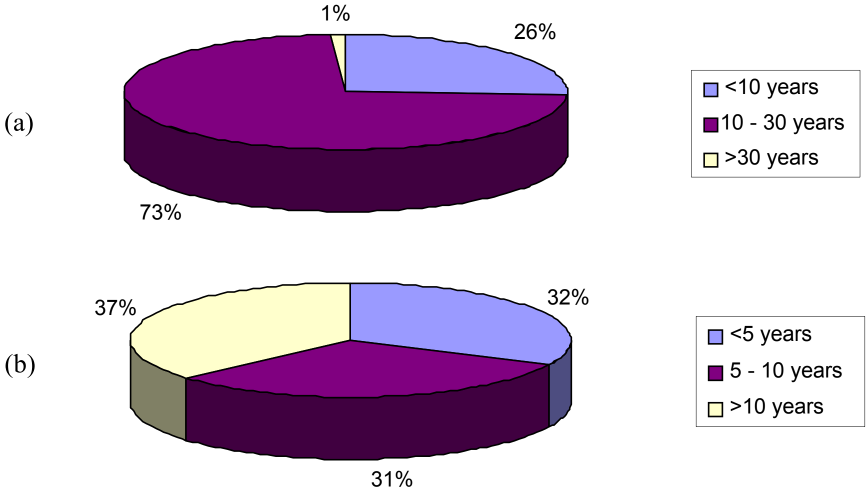

Figure 5.4a-b Percentage of manual (a) and automatic (b) stations over the Italian Alpine range depending on the record length

elaboration of Figure 5.4a-b summarises the results for the Italian Alpine context. The enquiry has shown that most (73%) of the manual stations for snow measurements represent an historical series of daily data about snow cover depth and new snow lasting between 10 and 30 years; about 25% of the stations have been recently installed and only 1% of the stations represent a data collection length longer than 30 years (and no longer than 50 years anyway). Regarding the automatic stations, their age is quite equally distributed over the three classes of record length represented; the oldest stations which have been providing data for a period longer than 10 years (but lower than 20 years in any case) are present only in the region of Piedmont and Veneto and in the Autonomous Province of Trent.

5.4.2 Avalanche data

The result of the enquiry is shown in detail in Tables 5.6 and 5.7, for maps of probable localisation of the avalanche (CLPV) and for avalanche cadastre data, respectively. The elaboration of the CLPV (at 1:25,000 scale) has been completed in Friuli Venezia Giulia and Veneto regions; it covers about 65% of the mountain territory in Lombardy and about 40% in Piedmont and in the provinces of Trent and Bolzano. In the Valle d'Aosta region this kind of maps has not been produced at all, because the regional law imposes the realisation of historical avalanche maps with higher detail (1:10,000 scale). Avalanche cadastres are more extended and complete in the north-eastern regions of the Italian Alps, then in the north-western one. This probably comes from the fact that in the former regions a traditional activity of avalanche damage reporting has been made in the past by the Forest Corp, which collected long series of data about damages to the wood heritage due to avalanches. This tradition was not diffused in the north-west region, so this kind of information is more scarce and not well organised.

The historical avalanche information is mostly referred to avalanches that occurred in the 20th century; an increase of the amount and quality of information is evident for the last 30-50 years. In Piedmont, information about historical avalanches in the Province of Turin from mid 19th century to present has been made available in a GIS at the website: http://gis.cis.it/meteo/valanghe/index.html.

Table 5.6 Percentage of the mountain territory covered for each region by the avalanche probable localisation maps (CLPV), and reference historical period of record

Region	CLPV % of mountain area covered	Reference historical period for available avalanche data
Piedmont	40	1885 - 2001
Valle d’Aosta	0	-
Lombardy	65	1970 – 2001
Autonomous Province of Bolzano	45	1900 - 2001
Autonomous Province of Trent	35	1900 - 2001
Veneto	100	1900 – 2001
Friuli Venezia Giulia	100	1950 – 2001

Table 5.7 Percentage of the mountain territory covered for each region by the avalanche cadastre, and reference historical period of record

Region	Avalanche Cadastre % of mountain area covered	Reference historical period for available avalanche data
Piedmont	10	1980 - 2001
Valle d'Aosta	75	1950 - 2001
Lombardy	10	Not continuous
Autonomous Province of Bolzano	100	1900 - 2001
Autonomous Province of Trent	100	1975 - 2001
Veneto	100	1970 – 2001
Friuli Venezia Giulia	100	1970 – 2001

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6. Recommendations for avalanche preparedness and response

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Abstract

Various recommendations have been made concerning preparedness and response in the face of avalanche risks which affect human lives. Preparedness is centred on characteristics of emergency plans, organisational structure and preparation of action groups. Differences are established between areas of high risk because of the existence of permanent population (towns, hotels and ski resorts), and permanent communication links. These areas need specific emergency plans that are different of the general action plans for areas only used by mountaineers and off-piste skiers. The response must be very quick for any possibility of finding victims alive. Training these groups, especially mountain doctors and rescue dog teams is very important. Likewise means of transport, especially helicopters, play an important role. Lastly a series of recommendations are made, which emphasise aspects of training, organisation, and institutional and crossborder cooperation.

6.1 Introduction

The organisation and development of preparative phases and intervention acquire their own dynamics in the face of situations of catastrophic avalanches. However, both planning and implementation are based upon and strongly conditioned by information and prediction, prevention and mitigation.

Firstly, avalanche hazard areas must have been identified and risk zoning must have been carried out, with identification of the most vulnerable points.

Since the concepts of hazard, vulnerability and specific risk do not always have the same meaning amongst those whose task is to study, evaluate and mitigate these phenomena, these concepts are here defined according to UNDRO (1979) and UNDP (1994):

- Hazard (H): Probability of occurrence of a potentially disastrous event in a certain period of time in a given place. Avalanche hazard zone is equivalent to a mountain zone with temporary or permanent accumulation of snow and / or ice. The danger increases under adverse climate conditions and favourable topographical factors.
- Vulnerability (V): Grade of loss of an element or group of elements under risk as the result of the probable occurrence of a disastrous event, expressed on a scale from 0 (no damage) to 1 (total loss).
- Specific risk (Rs): Grade of expected loss due to the occurrence of a specific event and as a function of hazard and vulnerability

The basic formula is as follows:

$$Rs = H*V$$

6.2 Definition of areas for avalanche preparedness and response

Avalanche risk zones are subdivided according to risk into areas of specific risk, of reduced dimensions, and a larger area of risk, of high vulnerability for sportsmen (table 6.1).

Table 6.1 Classification of avalanche risk areas from the viewpoint of preparedness and intervention

Specific Risk Zones	General Risk Zones
Towns, villages and residential developments Transport infrastructure Ski resorts Mountain refuges / huts	Zones with sporting activities

This zoning creates a series of areas of specific risk, depending on the existence of towns or villages (whether old or new) and infrastructure, with emphasis on transport and ski resorts. Each of these zones must be considered independently as to the active or passive protection measures which have been adopted.

The remaining territory, only accessible to sportsmen such as mountaineers and backcountry skiers, is considered to be at general risk.

Each of these areas has different characteristics (table 6.2)

Table 6.2 Characteristics of avalanche risk zones from the viewpoint of preparedness and intervention

General Risk Zones	Areas of General Risk
Permanently inhabited area	No inhabitants
Important seasonal oscillations	Visited sporadically
Land motor vehicle traffic	Without traffic (except snowmobiles)
(Possible) permanent defences	Lacking permanent defences
(Possible) active measures	Lacking active measures

High risk zones are increasing due to the growing demand for winter tourism. Visits to low risk areas are also increasing.

In both cases preliminary work always consists of the following steps:

- Risk identification and analysis, and evaluation of the consequences
- Risk zoning
- Designing and updating a plan of action
- Organisation of information system, previous to, during, and following an avalanche both for the local and temporary (tourist) population.

The first two phases are analysed in detail in previous chapters of this volume; the base of preparation is the Plan. The organisation of the information system is also dealt with in chapter 7.

Because of the difference in complexity, there will be differentiation between specific plans, for each particular zone of specific risk, and a general plan for the zone of general risk.

6.3 Emergency plans for specific high risk zones (towns or villages, transport infrastructure)

Each of the high risk zones, communities, transport infrastructures (road, rail, funicular) needs a specific emergency action plan for avalanches.

These plans, which are specific for each zone, have a common structure and a series of particular details. Their field of action is territorial, comprising a municipality, a valley or a ski resort. An example of this is Aguarta (2002).

The plan must include the following aspects:

- Organisational structure
- Action groups
- Phases of alert
- Preventive action: information and previous evacuation.
- Specific action in the event of catastrophic avalanche
- Specific means of rescue
- Implementation and maintenance of the Plan

6.3.1 Organisational structure of the emergency plan

The organisational structure in case of avalanches is similar to that needed to counteract any other catastrophe (Figure 6.1). Usually the political authority is in charge, with a crisis management team and an information unit. The crisis management team may be staffed by permanent technical personnel and temporary advisers. The Director and team should have a permanent centre of coordination and communications at their disposal (e.g. CECOP -*Centro de Coordinación Operativa*- in Spain and PCF -*Post Commandement Fixe*- in France).

6.3.2 Intervention groups

Rescue intervention groups are a basic element of specific plans. They may be professional, generally special police units, fire fighters or army personnel. They may also be voluntary, such as the Austrian ÖBRD (*Bergrettungsdienst Österreich*, Austrian Mountain Rescue). In ski resorts the intervention group is made up of employees and ski school instructors.

The role of dogs is vital. There should be support for the creation and training of dog and handler teams to work under winter conditions and in avalanche situations.

The basic medical requirement in intervention groups is the presence of mountain rescue doctors, with experience and equipment for the treatment of conditions resulting from the cold pathologies and injuries. Local doctors, public and private health centres, local units of the Red Cross, ambulance companies and other welfare organisations should also be borne in mind.

Law enforcement operatives are necessary to avoid robbery and looting. They are also necessary for legal formalities in case of fatalities and in the compilation of lists of missing persons.

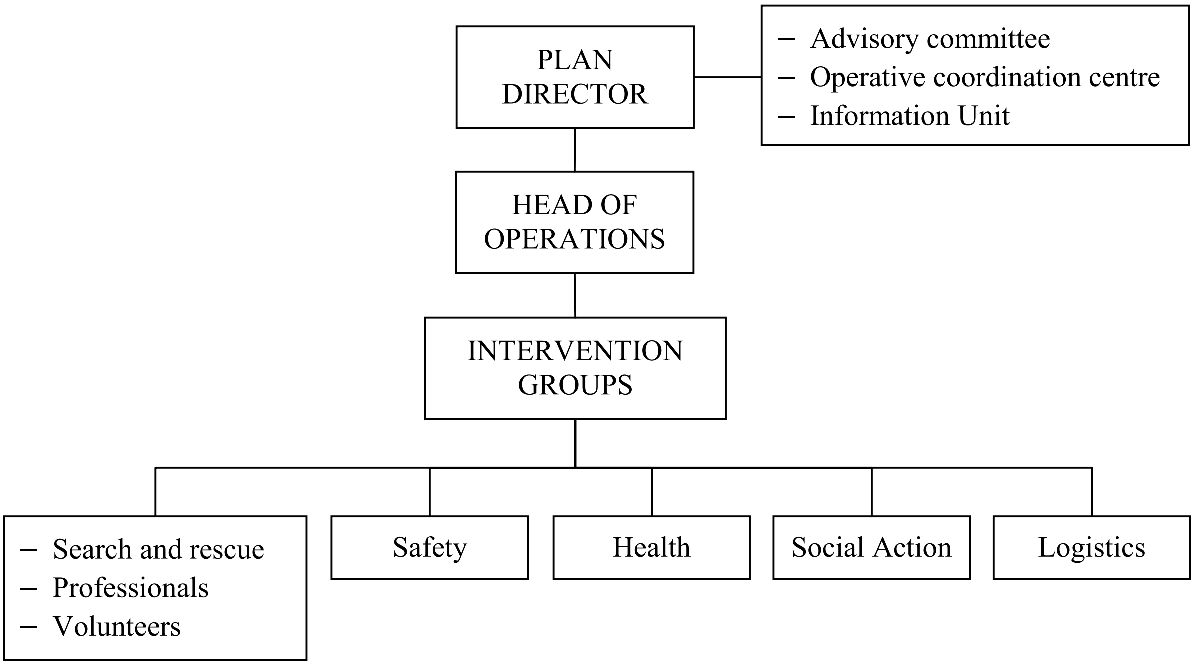

Figure 6.1 Emergency plan organisational structure

Another important topic is psychological attention to victims' relatives, both during rescue operations and later in the identification of victims, and in the processes of transfer and bereavement.

Lastly, in the event of evacuations and/or major catastrophes, it is important to organise the appropriate logistics of transport, accommodation and catering for a large number of people, both rescuers and evacuees. Transport is an important matter, since the very same atmospheric conditions which favour avalanches may impede helicopter flights and affect road traffic. It is important to have access to an updated inventory of public service snowploughs, and ski resorts' grooming cats and snowmobiles. In the last resort, army caterpillars may be used. At the same time it is necessary to know the numbers of coaches and conventional trucks available.

It is essential that these intervention groups have appropriate winter equipment and periodic training, especially the volunteer groups. An important aspect is that combined exercises should be carried out among the different groups with emphasis on coordination, cooperation and group technical training. In border areas, these types of activities should include units from the neighbouring countries.

6.3.3 Phases of alert

Emergency plans must foresee phases of alert and criteria for implementing each one of them.

The typical phases are:

- Phase 1. Level of low risk (alert)
- Phase 2. Level of high risk (alarm)
- Phase 3. Catastrophe

Phase 1 (alert) is usually established at the beginning of the winter season, with the first snowfalls.

Phase 2 (alarm) is usually established according to meteorological warnings (level 5 on the European avalanche hazard scale), the results of snow profiling, or the direct observation of avalanches outside the populated area.

Phase 3 (catastrophe) triggers off the immediate intervention of rescue teams, in order to localise victims and transport them to hospitals. Likewise it may be necessary to confine or evacuate part of the population, whether local inhabitants or visitors.

6.3.4 Preventive actions

With the establishment of phase 1 the management structure of the plan is reconstituted and minor details modified from the previous season are upgraded.

The final weeks of the phase 1 (alert) before the disappearance of snow in summer, provide a good opportunity for training exercises to be carried out, for a general analysis of the season, and for coordination meetings and revision of specific plans.

After each catastrophe meetings must be held for the analysis and evaluation of the measures deployed and the plans previously adopted, for a detailed written report to be compiled on the causes and effects of the catastrophe, as well as carrying out plans and recommendations for revision, if necessary.

With the setting of Phase 2 (alarm) the following measures are put into effect:

- Alerting intervention teams.
- Warning the population of the danger of avalanches, via the media. It is necessary to take special care to inform the temporary population such as tourists, and the high risk population (mountaineers, off-piste skiers).
- Restriction of access to roads and ski pistes, and closing mountain refuges / huts.
- Preventive confinement and/or evacuation.

In the event of high danger of avalanches, preventative confinement or evacuation of part of the population may need to be carried out. The plans must contemplate both possibilities, especially in those cases where access by road is easily cut off, and air rescue is impossible. The inhabited areas may be zoned, for evacuation purposes, depending on the level of snow and the information gathered on avalanches.

The areas which, thanks to appropriate structures or safe terrains, are suitable for confinement must be analysed by experts and calculated to hold the largest possible number of people.

The evacuee reception centres must be prepared to accommodate the population under very adverse atmospheric conditions of cold and snow. Several alternative reception centres must be available in the event of some communicating roads being impossible to use or for a high number of evacuees.

It is possible that there may be problems in convincing some of the population of the need for preventive evacuation. One of the reasons is the disbelief concerning the gravity of the forecasts. Another is that part of the visitors (tourists) are cut off from the normal media (telephone, newspapers, radio, television, Internet). Lack of information is greater among foreigners who do not understand the local language and are staying in rented apartments.

6.3.5 Specific actions in the event of catastrophic avalanche

An important part of the actions in the event of avalanches, similar to those of other catastrophes is that the work must be begun quickly in an orderly way; the coordination point "in situ" must be defined; the search territory must be zoned; a medical area must be defined; attention to accident victims must be given priority; uninjured parties and their families must be assisted; actions for the resumption of normal services carried out, etc. As in the case of flash floods**,** earthquakes and landslides, it is very difficult to establish the real number of accident victims.

There is a series of specific appropriate actions for avalanches:

- The necessary speed to rescue those buried unhurt alive in the snow, since the possibilities of rescue decrease dramatically after 20 minutes and are practically null after two hours.
- It is important to mark the surface of the avalanche and the areas which have already been searched appropriately, since fresh snowfalls and peoples' tracks may mask the search areas.
- The basic norms for dog and handler team work must be respected in order to avoid contaminate the searching areas with food, tobacco or other organic remains.
- The necessity to concentrate a large number of people, forming one or various avalanche probe lines, in a limited area.
- It is important that the risk of more avalanches that may affect the rescue teams should be born in mind. A warning system to detect new avalanches and/or to trigger controlled preventive avalanches must be organised.

Action timing should be carefully considered. Meteorological conditions may be bad and the hours of daylight limited.

6.3.6 Specific means of rescue

Specific means of rescue in avalanches, besides the use of dogs, include:

- Means of localisation:
  - Manual snow probes.
  - Metal detectors.
- Means of excavation:
  - Manual shovels.
  - Retro excavators.
  - Dynamic snowploughs.
  - Devices to produce hot water or vapour jets.
- Medical material
  - Thermal blankets.
  - Snow portable stretchers.
  - Specific medical material.

- Means of transport:
  - Helicopters.
  - Snowploughs and public works excavators.
  - Snowmobiles.
  - Grooming cat machines.
  - Cable cars and ski lifts in ski resorts.
  - Military caterpillar vehicles.

6.3.7 Drafting, implementation and maintenance of the emergency plan

The plan must be drafted at the initiative of the Director, with the advice and participation of the advisory committee, the head of operations and those responsible for the various intervention groups. The plan may be drafted with the help of an external group. It would be advisable that the initial plan to be drawn up by an authority with technical experience.

The plans must be flexible and they should be revised, preferably on an annual basis, according to experience gained from training exercises and the avalanches studied, whether catastrophic or without damage.

Training exercises should be carried out following the bases of each specific plan. They should be carried out in the areas of greatest risk and with complicated scenarios, so that intervention teams familiarise themselves with the terrain and useful information can be extracted for feedback regarding the plan. Likewise, new information and technologies must be adopted.

Every single catastrophic avalanche should be investigated thoroughly by experts, from different points of view, with the compilation of a written report containing conclusions and recommendations. The information should be collected on a database covering Europe. These reports and the content of the database should be widely distributed.

Specific plans for avalanches must tie in with plans concerning other risks for specific areas, whether natural or technological.

6.4 Recommended actions in areas of general risk (sport)

For areas of general risk, the danger may be high in very large areas without mitigation measures. They are only visited by a limited number of sportsmen and, occasionally, military detachments. Groups of mountaineers or mountain skiers rarely exceed 10 people, although there may be bigger groups in the vicinity of ski resorts or on some popular routes or peaks. Most of these journeys take place in high mountain areas, above the timberline.

It is advisable that mountaineers and skiers outside ski resorts have information on the danger of avalanches and what steps to take if there is one. Various useful documents exist, among them ANENA (2000), McClung and Schaerer (1993) and Rodés (2002).

Likewise, sportsmen should carry victim detection devices, known as ARVAS (*Appareil de Recherche de Victimes en Avalanche*), transceivers working at the frequency of 457 Khz. Some sportsmen know risk minimisation techniques as well as techniques in searches for victims. Rescue of people buried by avalanches is usually carried out by rapid intervention action groups of limited size, either professionals or volunteers (Figure 6.2 a,b,c). For reasons of urgency and risk, the action group enjoys great independence.

(a)

(b)

Figure 6.2 a, b, c Various phases of the rescue of a mountaineer buried by an avalanche by Guardia Civil's rescue services near Balneario de Panticosa (Huesca, Spanish Pyrenees) in April 2001. (Photographs by E. Torrijos)

(c)

Anticipatory action is the publication of the forecasted avalanche hazard level in the valleys or mountain ranges according to meteorological observations, preparing pits and modelling, using the European avalanche hazard scale. The scale is sufficiently clear and useful for preventive purposes. However, on a local scale it may be useful to highlight some frequent avalanche paths or to publish winter mountain guides which give information about the most dangerous areas.

The general plan of preparation / intervention for avalanches with victims in general risk areas consists of the following phases:

- Creation, equipment and training of rescue groups.
- Alert transmission system.
- Alert evaluation.
- Intervention of rescue teams.

Action groups must be in a state of permanent alert, have rapid transport systems and rescue dog teams at their disposal (cf. Figure 6.2 a,c).

Dogs are fundamental for the rapid rescue of buried people. Their training and motivation is essential, both for searches and for transport. Figure 6.3 shows a trained dog getting out of a helicopter. It is also important that rescue teams know certain basic rules to avoid any interference with dog teams' work.

It is highly advisable that these groups have doctors specialised in mountain interventions at their disposal. As well as their medical experience, they must have thorough knowledge of the sporting techniques necessary to meet winter conditions in the mountains, so that they are not dependent on rescuers. Figure 6.4 shows an image of the evacuation of a supposed victim during a training exercise for an avalanche with victims at a ski resort in the Spanish Pyrenees.

Figure 6.3 Trained rescue dog and handler getting down of a helicopter. (Photograph by Guardia Civil, Spain)

Speed in transmission of the alert is vital. Mobile telephones and portable radios are essential. In the case of the former, knowledge of the coverage of the various operators and operation of the different (analogue, digital) systems is important. In both cases it is important to have previous experience of operating under adverse meteorological conditions. In the event of an accident of some importance, it must be born in mind that phone lines may become saturated by the population in demand of information.

Organisation of telephone alert numbers (112) is essential for alerting rescue groups. In the event of avalanches that affect mountaineers, evaluation should be carried out by the nearest group of immediate intervention and/or the one which best knows the area.

The use of helicopters is essential for immediate access of action groups to the avalanche area. Because rescuers must be brought as close to the site as possible and because of difficulties with mountain flights, especially under adverse conditions, it is important that helicopter pilots should have specific training and that their equipment is prepared for their functions (skids).

Rescuers must have appropriate means (cf. Figure 6.2 c). They must have appropriate clothing for adverse winter climatology, as well as portable material for localisation of victims: manual shovels, avalanche probes, ARVAS, and metal and electromagnetic radiation detectors. Figure 6.5 illustrates two avalanche probe lines in a rescue training exercise in the Spanish Pyrenees.

The plan has a complement in training and informing mountaineers, possible victims, in avalanche risk evaluation, sensible behaviour, selection of safe routes, acquisition and training in use of ARVA, as well as procedure in the event of accident both for giving warnings and in the initial search for missing people. This equipment consists of a fixed

Figure 6.4 Rescue of a supposed avalanche victim during a training exercise in the Spanish Pyrenees. (Photograph by E. Leo)

Figure 6.5 Avalanche probe lines during a rescue training exercise in the Spanish Pyrenees. (Photograph by E. Leo)

frequency transceiver. It is usually kept in transmitter position. When someone in possession of an ARVA is buried under the snow, their companions or rescue teams place their ARVAS in reception position. This allows the buried person to be located. Since time is a decisive factor, it is necessary to follow systematic search protocols. The use of ARVA is limited by its cost, between € 180 and 300; by the need for certain training for its use in detection; and because of interference problems when there is more than one person buried. It would be very helpful if a special rescue ARVA was designed to detect the existence of more than one buried device and indicate their locations as quickly as possible.

6.5 Conclusions and main recommendations

- It is necessary to compile, revise and to improve emergency plans on local, regional and national scales and on an international scale where appropriate.
- It is important that training sessions should be organised on a regular basis, for varied situations and under non ideal conditions, for different action groups, especially if these come from different bodies: police, fire fighters, volunteer groups, the Red Cross, private companies, ski resort employees and public works employees.
- It would be useful to improve evaluation systems for training exercises, so that their objectivity is increased and the acquired experience is assimilated both as to the level of training of personnel and as to improvement of specific plans in a continuous feedback process.
- Given the importance of their function, it is necessary to continue and improve helicopter pilots' mountain training systems.

- For the same reasons it is necessary to encourage training of rescue dogs and handler teams. Helicopter transport should be among the abilities to be developed in training.
- Training of mountain doctors must be encouraged, continued and improved, in regular courses. For example, in Spain, in the so-called CUEMUM courses (*Cursos Universitarios de Especialización en Medicina de Urgencia en Montaña*, Specialist Mountain Medical Emergency University Courses) offered by the University of Saragossa.
- Cross-institutional coordination must be improved among the different organisations upon which the execution of plans and action in the event of catastrophic avalanches depend.
- International cooperation mechanisms must be improved, in the case of cross-border mountain ranges, to cope with episodes such as the crisis of 1999 in the Alps.
- New technology in the fields of planning and intervention must be incorporated, such as systematic use of geographical information systems, extension of telecommunications and development of new instruments for detecting people buried under the snow.
- It would be of interest to study the possibility of incorporating use of decision making tools to support rescue actions in the event of avalanches.
- Compilation and publication of studies both at national and at European level is important. An example of this is SLF (2000) and Colombo (2000).
- An easily accessible European database on snow avalanches should be organised.

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7. Recommendations on dissemination of information to the public in case of avalanches

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Abstract

Continuous and reliable information flow between the responsible authorities and people in the event of avalanches is essential for people to take the appropriate actions. The relevant information to be issued varies between the periods prior, during and after the event, as well as between the different types of targeted public, with a main distinction being made between domestic people and foreign tourists. In this chapter this information is described together with the main dissemination systems and most useful tools. Finally, the collaboration between the competent authorities and the media is emphasised. The appointment of a focal person for media contacts and a media information centre is recommended, and guidelines so as to ensure that the information transmitted to the public is accurate are provided.

7.1 Introduction

The recommendations on dissemination of information to the public in the event of avalanches provided in this chapter are mainly based on the experience gained over the years in Vorarlberg, the westernmost state of Austria, as well as in the neighbouring state of Tyrol. Historically and statistically this very mountainous region has had the highest incidence of alpine disasters, including avalanches.

One of the worst avalanche disasters happened in 1954 when more than 150 people died in Blons in the Großwalsertal Valley, Vorarlberg. This was one of the main reasons for the establishment of the first official Austrian avalanche warning systems. Based on this experience, additional avalanche commissions were established in every municipality of this high-risk area. A second serious avalanche took place at Galtür, Tyrol, in 1999 (Figure 7.1). Because of this disaster, the authorities and rescue organisations started further information sharing programmes.

7.2 Current trends in society in general

The period from the end of the last century to the beginning of this one could be called the “information era”. Information sharing technology is one of the fastest growing technologies and social products of our time. This entails:

- Modern society heavily depends on information
- People are mobile
- Complexity of emergencies
- Great demand for information
- Different needs of people
- Growing individuality
- Competing solutions

Figure 7.1 Rescue operations after the catastrophic avalanches of February 1999 in Western Austria. (Photograph by the Government of the State of Tyrol, Austria)

7.3 Information prior to the event

Continuous information flow is very important. The population must know the information sources, experts and addresses. In case of emergencies, people can automatically contact the correct sources. Main information consists of:

- In general, knowledge about the country, avalanche risks, self-protection measures, etc.
- In particular, knowledge about the avalanche tracks, emergency numbers, traffic problems, etc.

7.3.1 Public awareness strengthening

Activities to strengthen public awareness are to focus mainly on the general public. In case of snow/avalanche situations the activities can also be specific for special groups (tourists, domestic people). The policy of public sensitisation requires actions prior, during and after the event. It includes knowledge about special information sources, self-protection measures and warning signals. Prior to the event, measures must be set up on education, awareness and effectiveness response schemes. During the event, measures for effective self-help and self-protection actions must be set up. Following the event, measures for self-help actions and, for example, insurance priorities must be set up.

7.3.2 European "information TV channel" (radio, TV)

Regarding a European information system it might be important to have one information source for all European citizens. For example, it could be very easy to get information about weather conditions, traffic situation, blocked roads and hostage.

7.3.3 Information regarding alert/warning infrastructure

There has to be a continuous flow of information between the responsible authority and the public. Snow and avalanche alerts and warnings should be carried out by the responsible authority with clear connections to the government departments and the involved organisations.

7.4 Information during the event

It must be differentiated between periods of heavy snowfall only and periods in which avalanches could happen. Very serious problems are to be expected if these avalanches are combined with dead and injured people. One of these problems is, for example, the risk of stampede due to panic.

7.4.1 Strong snowfall period without avalanches

- Information for domestic people: Usually without problems because of their local special knowledge; normality.
- Information for foreign people (tourists): Need for information about blocked roads for planning their travel back arrangements, for information about weather forecast and closed ski lifts, etc (Figure 7.2).

Figure 7.2 Directly informing tourists

7.4.2 Strong snowfall period with avalanches

- Information for domestic people: It is necessary special information about the situation and its expected change.
- Information for foreign people (tourists): People with lodging in the affected area need the same information as domestic people.
- People on the way to their holiday resort need information about alternative ways to reach lodging or alternative lodging.
- People staying home need information about possibilities to reach holiday lodging.

7.4.3 Avalanches happened with serious damage, dead and injured people

- Information for domestic people: Same special information necessary as for every disaster situation.
- Information for foreign people (tourists): Special information necessary about situation, losses, expected behaviour, evacuation, information points, support, etc.
- Information for affected people and relatives: Set up call centre with information service

7.5 Information after the emergency

The most important information after the emergency is to tell people about what has happened and what is being done. In addition, people should be informed about restoration measures and progress. Main information thus includes:

- Affected population/people
- Destroyed and damaged buildings
- Destroyed and damaged infrastructure
- Insurance situation
- Reconstruction action / timetables
- Infrastructure restoration
- Travel back arrangements
- Moving back into buildings

7.6 Information outputs

Snow and avalanche information must be packed in a closed information system. The responsible authorities with governmental departments have to be involved. Information has to be issued at European level with tools like radio, TV and Internet. Relevant information, recipients, information systems and tools are listed below.

7.6.1 The information

- Meteorological forecast maps
- Weather radar maps
- Snowfall data
- Predicted snowfall data
- Temperature data
- Warning signals
- Alert signals
- Contact phone numbers
- Contact addresses
- Evacuation plans
- Danger zone
- Hazard zoning plans
- Traffic situation
- Lodging possibilities
- Alternative lodging possibilities
- Blocked roads
- Measures of authorities
- Measures of rescuers
- Responsible organisations

7.6.2 The information recipients

- Local people
- Foreign people
- People speaking different languages
- Elderly people
- Children
- Young people
- Physically disadvantaged
- Mentally disadvantaged
- Ethnically different people
- Socially different people
- Economically different people

7.6.3 The systems

- Digital, cable and state TV (Figure 7.3)
- Internet and Intranet
- Fax
- Radio
- Traffic radio
- Call outs
- Fact sheets
- Flyers

Figure 7.3 TV teams at work after an avalanche disaster

7.6.4 Useful tools

- Press conferences (Figure 7.4)
- Situation reports
- Assessment reports
- Briefings to representatives
- Media interviews
- Telephone conferences
- Correspondence, e-mail, fax
- Fact sheets, flyers
- Press communiqués
- The World Wide Web.

Figure 7.4 Press conference following a disaster

- Tourist information systems
- Maps
- Photographs
- Video materials
- Contact lists
- Charts

7.7 Handling of the media

The media are most important for wide information flow. The authorities and the population have high expectations in the accurate reporting in case of disaster. The correct teamwork between the authorities, rescue organisations and media is the base for optimised reporting (Figure 7.5a).

7.7.1 General

Whenever there is a newsworthy situation, the media will be there. Media assistance plays a vital role in a disaster or pre-disaster situation. It is therefore important to keep the media well informed. Keeping good relations with the media has frequently resulted in sympathetic coverage by journalists. However it must be accepted that discrepancies may exist between the media presentation and the reality.

7.7.2 Policy

The responsible media contact person sets, in arrangement with general politics, the guidelines for relations with the media. This person is normally the focal point for all media contacts (Figure 7.5b) and responsible for setting up the media/information centre.

Figure 7.5 a) The media at work in an avalanche devastated area. b) Focal point person for media contacts. (Photographs by the Government of the State of Tyrol, Austria)

7.7.3 Rules regarding the media

- Prepare press pack to provide media representatives with background information on snow and avalanche situation.

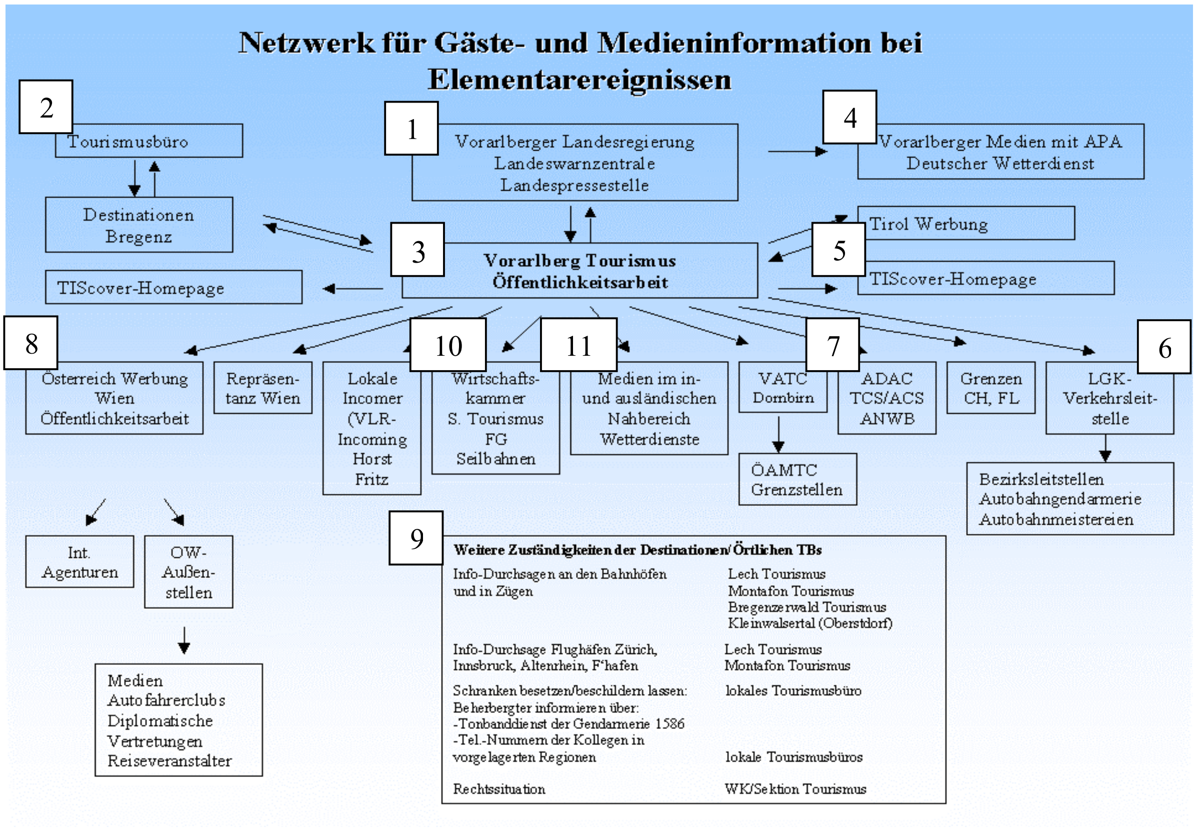
- Try to be the first to supply information thereby establishing the media responsible contact person as the useful source of information.
- Try to have an updated description of snow and avalanche situation related activities.
- Know the main points you want to make clear before you carry out an interview or press release.
- Know what you want to say (and what you do not want to say) before starting talking.
- Do not favour one media; all are entitled to similar treatment.
- Know whom you are talking to. Make a media log with journalists' name, newspaper, radio/TV station, addresses and telephone numbers.
- Provide full and accurate information on a regular basis.

7.7.4 Information handling

The responsible persons should consider using the following tools to facilitate availability, dissemination and sharing of information. These tools will be particularly useful as part of the output of a press/information centre established for information handling.

- Situation reports.
- Assessment reports.
- Media interviews and press conferences records.
- Press releases and fact sheets.
- Maps, charts, contact lists, photographs and video material.
- Actions/organisations overview - logbook.
- Weather forecasts.
- Traffic situation information – forecasts.
- Visitors/VIPs programme.
- Build up a media centre with the necessary infrastructure.

Annex - Austrian network for tourist and media information in case of heavy snowfall



Legend:

1	State of Vorarlberg government office; Regional alarm centre
2	Tourist office
3	State tourist agency
4	Local media, Weather service
5	Tyrol tourist agency
6	Police dispatch centre
7	Road services; Vehicle emergency services
8	National tourist agency
9	Local and regional tourist offices
10	Commercial agency
11	Local, regional, national and international media

8. Conclusions and summary of recommendations

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In this publication relevant issues regarding snow avalanche prediction, prevention and mitigation, preparedness and response and information to the public have been discussed, and recommended measures and actions to cope with avalanches have been presented. Although each chapter has focused on a specific avalanche management domain based mainly, but not only, on the experience gained in a particular country, these recommendations are considered useful to any avalanche-prone country or region in Europe. An attempt has also been made to draw recommendations that can be applicable for a European dimension, including strengthening of cross-border collaboration, creation of a European avalanche database and EU-funded research.

It should be noted that despite individual chapters having focused on specific domains of avalanche disaster management, it has been shown that they are often inter-linked. Hence, developing an integral strategy for disaster management accounting for all these phases is highly recommended.

Below is a summary of recommendations grouped by major disaster management phases.

8.1 Prediction

Avalanche prediction strongly relies on timely information regarding past, present and future weather, the accumulation and transport of snow, the layering of the snowpack and its strength and weaknesses and also the past history of avalanches in the area concerned. Although prediction can be considered as an integral part of prevention, the main recommendations specific to avalanche prediction can be summarised separately as follows:

- The prediction should be divided in nowcast and forecast, especially for inhabited areas. The nowcast is necessary in order to warn the general public of imminent danger and the need to take preventive actions immediately. It has to specify individual avalanche paths and possible runout distances or class of avalanche. The forecast needs to stipulate what could possibly happen in the near future so as to enable the authorities to prepare for a possible action and the public to plan in accordance with the forecast. It needs to specify the general aspect of slopes and the elevation ranges that are unstable and thus likely to avalanche.
- Information about the possible runout distances within individual avalanche paths in inhabited areas is very important to divide the areas at risk into predetermined evacuation areas depending on the magnitude of the predicted event. Such a plan should be in place before a crisis occurs so as to precisely determine the buildings to be evacuated, the evacuation means and route, and the destination of the evacuees.
- It is also important to evaluate the conditions at avalanche starting zones. To this end, in these areas it is necessary to collect precise information on key weather parameters, snow depth and snow drift by means of automatic stations. Instrumentation that can better cope with the severe weather conditions typical of these areas needs to be developed. Also, in order to extrapolate the point measurements thus obtained to a larger area to get an estimate of a possible slab, it is important to develop methods and models to accurately predict the thickness of that slab and the flow of snow into the starting zone.

- Models of snow stability and avalanche release are necessary to estimate snow accumulation in the starting zone and model the redistribution of snow due to wind and erosion, as well as the settlement of the snowpack and the metamorphism within the snow, to estimate the probability of an avalanche release, and especially to predict possible runout distances. Existing models have to be improved and new ones have to be developed.
- Since the design of defence structures is largely based on modelling results, it is also important to collect data for individual events regarding the effectiveness of the structures that have been constructed.
- It is recommended that all the data collected for avalanche prediction be integrated in a geographical information system (GIS), in order to map the areal extent of avalanche runouts and starting zones, to coordinate data collection and to correlate the data.
- The persons (snow observers) employed for monitoring the conditions of the snowpack in avalanche-prone areas should be provided with good working conditions and necessary tools to properly support the prediction and the improvement of the models used.
- Collaborative research, standardisation of data collection and sharing of information and data at European level should be promoted. It is thus particularly recommended to create a central European data centre for avalanches, to be fed, amongst others, by data and results of the research projects funded by the EU. It is also recommended that the EU funds projects focusing on providing solutions to specific avalanche prediction problems, rather than funding a large, probably unrealistic project to provide solutions to all problems.

8.2 Prevention and mitigation

Although different classification schemes are possible, avalanche prevention measures can be divided into non-structural and structural measures. The former consist mainly of organisational measures such as daily avalanche hazard bulletins and artificial release of avalanches, and hazard and risk mapping. The latter include mainly technical measures, like defence structures (snow supporting structures, wind fences, deviating structures, retention dams and protection sheds for roads and railways) and forests.

8.2.1 General recommendations

- Measures should be adopted according to cost-effectiveness. To this end, more emphasis should be placed on organisational measures. Applying new structural or non-structural measures should always be accompanied with a cost-effectiveness study.
- Optimisation of financial resources by integral risk management, which considers complementary structural and non-structural measures, should be pursued. Risk assessment methods should have priority. Also, factors like individual mobility, information and communication should be better integrated in the overall risk assessment process.
- It is recommended to perform a global and periodic safety audit in a given area in order to evaluate the whole avalanche risk management system. The central part of this audit should be an analysis of the whole mitigation system impacted by extreme conditions.
- Central or federal governments should provide financial support to regional or local administrations for the implementation of the necessary avalanche measures wherever these administrations cannot cope with.
- Avalanche databases should be completed for all avalanche-prone areas in Europe. A minimum degree of homogeneity and level of accuracy for the maps should be defined. It

is also suggested that databases are made available to citizens and that these can themselves provide alternative information, which can be separated from that officially provided.

- Exchanges between responsible persons and bodies in neighbouring countries should be intensified with the aim to improving the European avalanche mitigation procedures and also to develop a European expertise in this field.

8.2.2 Recommendations on non-structural measures

- The avalanche bulletin information is essential to early warn the crisis management teams and enables them to take the necessary emergency actions, such as people evacuation and closure of roads and railways. Funding to run this service should thus be guaranteed.
- Regulations and security procedures regarding artificial release of avalanches have in general to be re-examined so that this measure does not further endanger inhabited areas and roads.
- Avalanche hazard mapping is an essential tool for land use planning. Its harmonisation and legal implementation in land use planning in all endangered communities should be enforced.
- Legislation for providing funds for avalanche hazard mapping should be extended to all endangered communities.
- Availability of historical avalanche information and snowfall records is fundamental to establish adequate criteria for hazard zoning maps. Properly documented avalanche historical data are also essential for land use planning at a territorial (coarse) scale.
- Specific studies to identify areas with different degree of exposure to avalanche danger (based on the frequency and intensity of the expected avalanches) are necessary for land use planning at a local (communal) scale, and therefore to establish land use restrictions.
- It is important to determine the most dangerous avalanche paths using the same criteria, with a same relative weight, for all paths rather than on a small territory. Use of both hazard and vulnerability related data should be involved in this procedure.
- Production of avalanche risk maps (i.e. taking also into account vulnerability) is highly recommended in inhabited areas.
- It is suggested to make red zones (i.e. high hazard zones) clear of permanent inhabitants. This procedure should be adequately planned and given a realistic deadline. It should also entail provision of indemnities, withdrawal of exposed property from the market and acquisition of the property by public authorities for seasonal use for environmental related purposes. A law regulating this process should also be ensured. It should also be considered to include these provisions in a possible European directive.
- It is suggested to leave properties located in blue zones (i.e. zones of moderate hazard) in the property market, although transferring, and updating if necessary, the risk information in case of a new transaction.
- Hazard and risk zoning maps should be reviewed after completion of structural measures. In particular, residual risk must be assessed in order to counteract foreseeable demands for building rights after new defence structures have been built.
- Funds, including EU funds, should be provided for research aimed at properly modelling flow or combined flow-powder avalanches that run beyond the hazard zones, as well as for more suitably weighing multiple events which may largely increase the level of hazard.

8.2.3 Recommendations on structural measures

- Technical measures are often proved to be very efficient against avalanches and should therefore be completed wherever necessary.
- Existing structures should be inventoried and systematically checked up and maintained.
- Avalanche risk should be reassessed after new structural measures have been implemented.
- It is important to improve avalanche dynamics calculations so as to account for all kind of obstacles in their path. In particular the efficiency of retention dams should be further investigated to improve their design.
- Although the efficiency of forests has not yet been properly determined, forests are recognised to be important to prevent avalanches from starting. More research on this subject should thus be promoted. Also, reforestation assisted by eco-engineering (wooden) structures is particularly recommended. Riverbeds should also be kept clear of timber debris.

8.3 Preparedness and response

Emergency planning is directly linked to prediction, prevention and mitigation measures. In particular, evacuation procedures are closely associated with avalanche hazard and risk zoning, hence the importance of this measure.

Preparedness and response plans are differentiated between areas of specific risk (of reduced dimensions) including villages, ski resorts and transport lines, and a larger area of general risk, which is distant from the above-mentioned areas, of high vulnerability for sportsmen. There should also be a different emergency plan for each particular zone of specific risk. Some general recommendations follow.

- For both specific risk and general risk areas it is necessary to compile, revise and improve emergency plans at local, regional and national scales and at an international scale where appropriate. Also, cross-institutional coordination should generally be improved as well as international cooperation mechanisms, the latter especially in cross-border mountain ranges.
- New technology in the fields of planning and intervention must be incorporated, such as systematic use of GIS, extension of telecommunications and development of new instruments for detecting people buried under the snow. It would be helpful if a special ARVA was developed to detect the existence of more than one buried device and indicate their locations as quickly as possible. Use of decision-making tools to support rescue actions should also be investigated.
- Combined training exercises should be carried out among the different intervention groups. In border areas, these exercises should include units from the neighbouring countries.
- Studies both at national and at European level should be promoted.

8.3.1 Recommendations in specific risk areas

- The emergency plan must include aspects such as an organisational structure, rescue intervention groups, phases of alert, preventive actions, specific action in the event of catastrophic avalanches, specific means of rescue and implementation and maintenance of the plan.
- It is recommended that the initial emergency plan be drawn up by an authority with technical experience. The plan should be revised, preferably on an annual basis, according to experience gained from training exercises and the avalanches analysed,

especially those catastrophic. The report drafted for each of these avalanches should contain also lessons learnt and recommendations.

- The evacuation orders, issued by the responsible person or committee, should preferably be recorded and documented. This is necessary in view of possible litigation after a disaster.
- Creation and training of dog and handler teams to work under severe avalanche conditions should be supported.
- In addition to the support from standard welfare organisations, it is required the presence of rescue doctors with appropriate experience and equipment.
- Psychological attention to victims' relatives is also recommended.
- When organising intervention logistics it is important that experts analyse the areas suitable for confinement and that the evacuee reception centres be prepared to accommodate the population under very adverse weather conditions.
- The emergency plans must foresee phases of alert (e.g. alert, alarm and catastrophe) and criteria and measures to implement each one of them. While the alert phase mainly entails the set up of the management structure and the revision of the plan, typical actions during the alarm phase include alerting intervention teams, warning the population, restricting access to roads and ski pistes, closing mountain refuges and preventive confinement and/or evacuation. In the event of catastrophic avalanches, in addition to actions common to other disasters recommended actions include speediness of rescue of people buried alive in the snow, marking appropriately the surface of the areas which have already been searched, facilitating dog and handler team work, concentrating a large number of people forming probe lines and organising a warning system to detect new avalanches that might affect the rescue teams.

8.3.2 Recommendations in general risk areas

- It is recommended that mountaineers and skiers are informed about the danger of avalanches (e.g. through daily avalanche bulletins using the European avalanche hazard scale, signals on frequent avalanche paths and winter mountain guides) and the actions to follow in their event.
- The general plan for preparedness and intervention in the event of avalanches should make complementary provisions for training and informing mountaineers, as possible victims, on avalanche risk evaluation, sensible behaviour, selection of safe routes and acquisition and training in the use of victim detection devices (ARVAs).
- Mountaineers and backcountry skiers should move in groups and carry both ARVAs and manual shovels.
- Intervention groups should be in a state of permanent alert. These groups should consist of rescuers equipped with portable material for localisation and release of victims, doctors trained in mountain interventions and trained rescue dogs with developed ability for helicopter transport. They should have rapid transport systems, including also helicopters.

8.4 Dissemination of information to the public

Main targets of information related to avalanche danger or disaster are both local people and tourists, including also foreigners. In the information flow, the role of the media is considered particularly important.

8.4.1 Recommendations on information and people

- It is recommended that the information be provided by the crisis management team or avalanche commission established to deal with the crisis.
- When providing information to people, factors such as age, social and economic differences, possible physical or mental problems, and especially the fact that they may speak different languages must be considered. When informing people of the need of evacuation special attention should be paid to foreigners staying in rented apartments.
- It is recommended to establish a press/information centre and an information network. Continuous information flow should be provided.
- People must know the information sources, experts and addresses so that they can quickly contact the right sources in case of emergency.
- Prior to the event or emergency, main information should regard the characteristics of the area, avalanche hazard (via daily avalanche bulletins and weather forecasts), self-protection measures, avalanche paths, emergency numbers and possible traffic problems. In this phase it is also important to strengthen public awareness.
- During the event, information should be differentiated according to periods of heavy snowfall only, periods with high avalanche danger and periods with avalanches causing serious damage and victims. In general, information should focus mainly on the actual danger, blocked roads and weather forecast, accommodation possibilities or leaving the area, damage and losses in case of catastrophic avalanches, expected behaviour and evacuation, information points and support. A call centre with information service should also be set up for affected people and relatives.
- After the event, people should be informed about affected persons, damage to buildings and infrastructure, recovery measures, insurance situation, accommodation and travel back arrangements.
- Main information tools should include traffic radio, TV, telephone help lines, warning signals and the internet. Setting up a European TV channel or radio station could be useful as a common information source, especially for tourists.

8.4.2 Recommendations on the media

- A person responsible for relations with the media and for setting up the media/information centre should be appointed.
- A good relation between authorities, rescue organisations and media should be established.
- It is recommended to prepare press releases with general information on snow and avalanche situation, to provide accurate updates for the media on a regular basis, to anticipate other possible information sources and not favour a particular media.
- The information responsible person should use tools such as event/crisis situation and assessment reports, media interviews and press conferences, press releases and fact sheets, maps, charts, photographs and video material, weather forecasts and traffic situation information.

Annex 1 - European avalanche hazard scale

DEGREE OF HAZARD	SNOWPACK STABILITY	AVALANCHE PROBABILITY	EFFECTS ON OFF-PISTE AND BACKCOUNTRY ACTIVITIES; RECOMMENDATIONS	EFFECTS ON TRAFFIC AND RESIDENTIAL AREAS; RECOMMENDATIONS
1: LOW	The snowpack is generally well bonded and stable.	Triggering is generally possible only with high additional loads** and few very steep extreme slopes. Only a few small natural avalanches (sluffs) possible.	Virtually no restrictions on off-piste and backcountry skiing and travel.	No hazard from avalanches.
2: MODERATE	The snowpack is moderately well bonded on some steep slopes* otherwise generally well bonded.	Triggering possible with high additional loads**, particularly on the steep slopes indicated in the bulletin. Large natural avalanches not likely.	Generally favourable conditions. Routes should still be selected with care, especially on steep slopes* of the aspect and altitude indicated.	Virtually no hazard from natural avalanches.
3: CONSIDERABLE	The snowpack is weakly bonded in most steep slopes*.	Triggering possible, sometimes even with low additional loads**. The bulletin indicates many slopes which are particularly affected. In certain conditions, medium and occasionally large-sized natural avalanches may occur.	Off-piste and backcountry skiing and travel should only be carried out by experienced persons able to evaluate avalanche hazard. Steep slopes* of the aspect and altitude indicated should be avoided.	Traffic and individual buildings in hazardous areas are at risk in certain cases. Precautions should be taken in these areas.
4: HIGH	The snowpack is weakly bonded in most steep slopes*.	Triggering probable even with low additional loads** on many steep slopes. In some conditions, frequent medium or large-sized natural avalanches are likely.	Off-piste and backcountry skiing and travel should be restricted to low-angled slopes; areas at the bottom of the slopes may also be hazardous.	Avalanches may be of high magnitude.
5: VERY HIGH	The snowpack is generally weakly bonded and largely unstable.	Numerous large natural avalanches are likely, even in moderately steep terrain.	No off-piste or backcountry skiing or travel should be undertaken.	Extensive safety measures (closures and evacuations are necessary).

(*) Generally described in more detail in the avalanche bulletin (e.g. altitude, aspect, type of terrain, etc.)

- Steep slopes: slopes with an inclination of more than about 30°
- Steep extreme slopes: particularly unfavourable in terms of the inclination, terrain profile, proximity to ridge, smoothness of underlying ground surface

(**) Additional load:

- High: e.g. group of skiers, piste machine, avalanche blasting
- Low: e.g. skier, walker

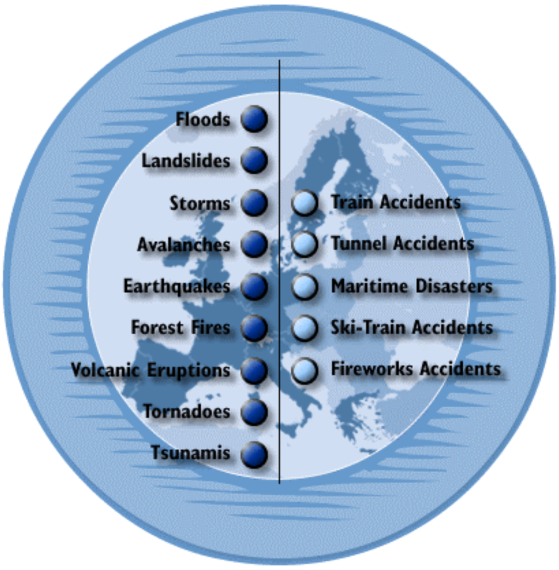
Annex 2 - Selected websites on avalanches

European:

- AINEVA: Associazione Interregionale Neve e Valanghe (Snow and snowfall interregional association of Italian Alpine regions)
  http://www.aineva.it
- ANENA: Association nationale pour l'etude de la neige et des avalanches (National association for the study of snow and avalanches, France)
  http://www.anena.org
- Austrian avalanche warning services
  http://www.lawine.at
- Cemagref (National research centre for agricultural and environmental engineering, France)
  http://www.grenoble.cemagref.fr/grenoble/etgr/etna.html
  http://clpa.grenoble.cemagref.fr
- European Avalanche Services
  http://www.avalanches.org
- ICC: Institut Cartogràfic de Catalunya (Cartographic Institute of Catalonia, Spain)
  http://www.icc.es/allaus
- IMO-ICM: Icelandic Meteorological Office
  http://www.vedur.is/english/avalanche.html
- Lawinenwardienst Bayern (Bavaria's Avalanche Warning Services, Germany)
  http://www.bayern.de/lfw/lwd/
- SLF-WSL: Swiss Federal Institute for Snow and Avalanche Research, Davos
  http://www.slf.ch
- SnoSKRED.no: Snøskred ved friluftsliv i Norge (Norway's NGI avalanche page)
  http://www.snoskred.no
- SAIS: SportsScotland Avalanche Information Service
  http://www.sais.gov.uk
- SVI: Servizio Valanghe Italiano (Italian Avalanche Service of the Italian Alpine Club)
  http://www.cai-svi.it

International (including European) and non-European:

- Canadian Avalanche Association
  http://www.avalanche.ca/
- CISA-IKAR: International Commission for Alpine Rescue
  http://www.ikar-cisa.org/
- CyberSpace Snow and Avalanche Center
  http://www.csac.org/
- International Glaciological Society
  http://www.igsoc.org/
- WestWide Avalanche Network: US Avalanche Centers (including US Forest Service's)
  http://www.avalanche.org/



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