

RISKCAT Els riscos naturals a Catalunya

Informe executiu

Los riesgos naturales en Cataluña
Natural Risks in Catalonia



RISKCAT

Natural Risks in Catalonia

Executive report

Note:

The CD-ROM contains:

1. Informe executiu (cat.)
2. Informe ejecutivo (cast.)
3. Executive report (eng.)
4. 7 Expert reports (cat.)
5. Legal framework report (cat.)

Presentation

The current year 2008, declared by the United Nations International Year of Planet Earth is unfortunately becoming known for catastrophes related to geological and meteorological phenomena around the world. Cíclon Nargis, that devastated the coasts of Burma, the earthquake in China or the eruption of the Chaitén volcano in Chile are, among others, good examples of this. In Catalonia, although we do not suffer from such serious episodes, we have also had phenomena of this nature, as this study documents.

Natural phenomena such as storms, avalanches, land collapses or earthquakes can't be avoided at this time. However, this does not mean that we have to admit them as a fatality but to act preventively and proactively: extending our knowledge on risks, setting the measures to prevent impacts and getting ready for action in front of disasters. Setting the necessary tools for natural risk prevention and management is one of the key points for sustainable development, both for the present and the future as well and territory planning is a key tool for prevention. Furthermore, as the report about the climate change in Catalonia published by the CADS in 2005 pointed out, climate change will make that some phenomena, such as strong storms –that can cause floods– be more frequent with a larger scope.

For all these reasons, the Consell Assessor per al Desenvolupament Sostenible (CADS) considered that it was necessary to undertake a study that allowed us to consider the importance of certain natural risks in Catalonia and, particularly, analyze the capacity of Catalonia to face them. RISKCAT focuses on the natural risks related with meteorology and geology that have a greater incidence (such as floods, coastal phenomena), incidents with local impact (avalanches, landslides and collapses) but also in others that we do not consider of prime magnitude but that we cannot forget (such as vulcanism or earthquakes)..

This is the executive report that gathers and points out the main conclusions and proposals of this more extensive work. By means of seven expertise reports (one for every studied phenomena), the analysis of the current legislation and a document database with the inventoried material, RISKCAT contains the knowledge base needed to assess the importance of natural risks, the events and damages of the past, the current point of knowledge and the measures that have been established.

A remarkable number of experts of our country have participated in the production of this report, under the

direction of Dr. Joan Manual Vilaplana, director of the research group of natural risks of the University of Barcelona. We want to stress that this is not a strictly academic work: the report considers strongly risks management and legal and institutional tools. The nine specialist authors have interviewed more than 50 experts (scientists, technicians and managers). The result exposes the high research level of Catalan universities and means a step forward not only as a pioneer exercise of diagnose and reflection that deals with a basic issue for sustainability in Catalonia but also because it puts together a great deal of information about natural risks and casts a design of a methodology for information management, as well as proposals.

The motive of the International Year of Planet Earth, "Earth Sciences for Society", reflects very well the vision of the CADS in relation to research and scientific knowledge and the improvement of government policies. Our task is to advise the Catalan government in those areas that are relevant for sustainable development, such as natural risks. RISKCAT allows us to have available quality information and proposals of action, a necessary starting point to give Catalonia the appropriate planning and action capacity in front of adverse phenomena.

The CADS will keep working in this area in the future, extending the kinds of natural risks (droughts, forest fires, etc.) that have been studied in the first phase and passing more defined proposals of action and management, targeted both to the government and the citizens. Furthermore, it is a field where it is very important to learn from the experiences of other countries that Catalonia can also help with the present work. The CADS has started a cooperation line with the United Nations Strategy for Disaster Reduction, within the Hyogo Framework for Action 2005-2015, which seeks to easy the transfer of knowledge between north-south countries in the reduction of disaster risks and that we hope will be very advantageous both for Catalonia and for the rest of local and regional governments involved.

Gabriel Ferraté i Pascual
President of the CADS

Ramon Arribas i Quintana
Director of the CADS

Prologue

The publication of a report such as this one must be good news for all persons interested in natural risks either for scientific reasons or because they try to undertake actions to mitigate their damage. The fact that the report comes to light in 2008, the year declared by the United Nations as International Year of Planet Earth (IYPE), gives it an extra value and opportunity, since the issue of natural risks has been designed as of special interest during this IYPE.

Natural risks constitute a considerable and growing problem for humanity. In the last half century, the number of natural catastrophes reported has increased ten fold and damage produced by them 20-25 times. Losses account for more than 1% of the world gross product annually. In the same period, the human population has increased 2.3 times, energy consumption 4 times and the gross product 7 fold. These figures reveal that, in spite that the efficiency of productive processes has improved, the management of natural risks is considerably poorer than in the past. Only this can explain that the number of catastrophes has increased much more than what could be expected from the variability of natural processes alone. This bad management is even more apparent when the growth of recorded losses is taken into account.

Natural risks arise from the threads or dangers due to natural processes, the exposure of human elements to them and their vulnerability.

For example, the number of catastrophes such as floods and landslides has increased 30 times in half a century. Those processes are very sensitive to human influence due to both climate change and geomorphological change, including the modification of the terrestrial surface, which increases the proportion of water rain that runs over it and reduces the resistance of the surface layer to the action of natural trigger agents.

The net result is an increase in the frequency and intensity of the mentioned processes (threads), joined by the growing exposure as a result of urban and infrastructure development, not suitable for a sustainable management of risks.

These facts show something that should be obvious: if a society wants to be in the appropriate condition to face the serious problem that natural risks mean, it has to face the management of the factors that cause the risk. This includes actions related to the general scientific knowledge, its application in a given region to characterize the nature of its threats and the implementation of

observation and alert programs. However, it also includes measures to minimize the negative effects of natural processes, ranging from legal norms and organisms with action capacity to programs addressed to educate the population in an appropriate culture to get along with risk and contribute to reduce its effects.

From my point of view, this report constitutes a remarkable example of action targeted to address the pool of factors to take into account in this issue. It analyzes systematically and separately, each of the processes that can represent natural dangers and the “state of the art” in Catalonia, as they relate with the factors that influence the extension, frequency and magnitude of their damage. It is noteworthy to point out the attention given to territory planning, a key aspect for good risk management.

The diagnose cast by this analysis has allowed us to identify the strengths and weaknesses of the whole system and, consequently, carry out a series of recommendations to improve the current situation. Then, a tool is put in the hands of the administrations that will probably allow setting priorities to address the improvement of the weakest points but, also, to maintain, strengthen and take advantage of existing strong points. All of this should help local administrations and the Generalitat –as well as the central administration- to achieve a reduction of future damages caused by natural processes and should also help to make an efficient use of the resources. Thus, following the route recommended by the IYPE, knowledge and consciousness to manage damages would be maximized.

In spite that the report, as it is obvious, is conceived and is of special interest for Catalonia, its utility goes beyond this territorial scope and, in my opinion, constitutes a model in itself and contains points of interest for other places. It would then be very desirable that the work is known also in other organisms that have some kind of responsibilities about natural risks, being either from other Spanish autonomous communities or from other European regions. This would contribute to answer the previous questions and to the achievement of the goals that spear the efforts in this field: the reduction of the toll that humankind pays in the form of human lives and material losses as a result of some disasters that are not “that natural”.

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1. Introduction

Motivation and context

Potentially dangerous phenomena are part of the regular development of natural systems. Today, their interaction with society generates increasingly higher human and economic losses and it has become necessary to reduce them as much as possible.

Reports on natural disasters by the United Nations (ISDR) and large insurance and reinsurance companies (Swiss-re, Consorcio de Compensación de Seguros, among others) conclude that the social and economic impact of Natural Risks, both in developed and developing countries have increased over the last few years and a similar trend is expected in the immediate future.

The causes of this fact are related both to the severity of natural phenomena and the physical and social vulnerability of the territory. Different studies point out that the vulnerability factor is the one which has increased more alarmingly. This can be directly related to the existence of weaknesses in the policies that determine the occupation of land.

Catalonia is no set apart of this problem. The growing occupation of land for new usages (specially housing development), the construction of large infrastructures and the new social habits (particularly related to the leisure industry), have the effect that more territory and more population are increasingly exposed to natural dangers.

Cultural and socioeconomic changes in Catalonia in the last decades have been very relevant and have shaped the society that we have in the present with a specific territorial distribution and have led to a behaviour towards the environment which is substantially different than the one we had not too long ago.

According to data from the Consorcio de Compensación de Seguros -Assurance Compensation Consortium- (CCS), Catalonia is one of the Autonomous Communities with more spending on natural disasters, being always among the top 3 communities in Spain. That spending is generated mainly by floods, with an annual average of 89.000.000 Euros.

In this context, the project RISKCAT comes to life as an initiative of the Consell Assessor per al Desenvolupament Sostenible -Advisory Council for the Sustainable Development (CADS) –an advisor agency of the Generalitat de Catalunya in the area of sustainable development- in order to discuss about the scope of a number of Natural

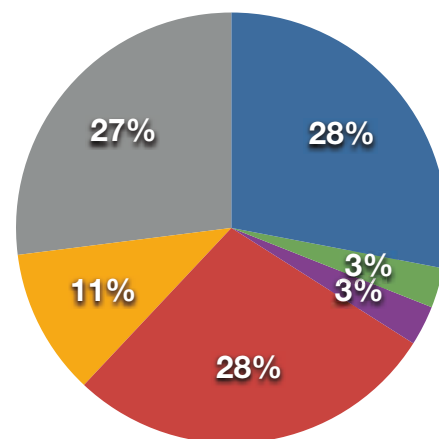
Risks in Catalonia, particularly those which have the greatest incidence on the territory.

Objective

The objective of RISKCAT is to carry out an analysis of the capacity to face natural risks in Catalonia. In order to achieve this objective, a number of geological and hydrometeorological phenomena have been analyzed and expertise reports have been produced, detailing what are the currently available tools for forecasting and analyzing natural phenomena with a spatial and temporal scope in mind.

The phenomena that have been analyzed are the following:

- Avalanches.
- Landslides and slips.
- Land collapses.
- Coastal phenomena.
- Floods (spates in large basins and in torrential basins and streams).
- Earthquakes.
- Vulcanism.



- Andalusia
- Valencia
- Catalonia
- Murcia
- Galicia
- Rest of Spain

Fig 1. Losses in Spain 1982-2002 caused by floods and earthquakes. In Catalonia 1.334.780.279 €.

Source: Consorcio de Compensación de Seguros

All of these phenomena happen suddenly, are short lasting and have a recurrent activity. They all can lead to a variable degree of damage to humans and goods and can

be of a variable geographical extension. A study of the current legislation linked to natural risks and territory is also included, since this legislation affects management strategies and limits or increases the efficiency of the whole process.

We consider that the knowledge of the current state of the situation is necessary in order to design a good management strategy of Natural Risks in Catalonia. Since we have been working for years in our country in the field of the knowledge and management of natural risks, RISKCAT undertakes an inventory of all those materials and actions related to risks, analyzing and evaluating what has been done and what is being done.

Finally, a number of actions are proposed to the Catalan Government and specially to those in charge of the management of natural risks with the objective of achieving effective risk management and a kind of land development which is more sustainable for the territory and more secure for humans.

In spite there are other natural risks that also affect Catalonia, it was decided that RISKCAT will not consider certain climatic or anthropic natural risks such as drought, desertification and forest fires, which are of great importance but have very different characteristics and incidence than the phenomena considered in the current study.

RISKCAT is not, by any means, a detailed analysis of the risks associated to each of the natural phenomena considered. Also, it is not an objective of this project to discuss the incidence of climatic change over the natural risks in Catalonia. We consider that this is a new research line that will soon be addressed by the Grup d'Experts en Canvi Climàtic de Catalunya –Expert Group on Climate Change of Catalonia- (GECCC). However, given the relevance of this issue, Annex I includes a brief article that highlights the main points about the relationship between climate change and natural risks.

Realization of the project and contents of the executive report

In order to undertake the study, the Grup de Recerca en Riscos Naturals de la Universitat de Barcelona – Research Group on Natural Risks of the University of Barcelona- (RISKNAT), has created a working team formed by nine specialists: seven experts in the different issues dealt with, a coordinator, a director and, as external help, 3 technicians who have carried out occasional work.

During the study they have introduced themselves to public and private organizations with the purpose of gathering information and more than 50 interviews have been done to people related to the issues discussed (aca-

demicians, investigators, technicians, managers, etc.) in order to gather data and opinions. In the final phase, an independent external expert has made a full review of the report.

The RISKCAT project has materialized in the form of 7 expertise reports (one for each natural risk), 1 legal report about current legislation related to natural risks, a document data base that includes all inventoried material and finally this executive report that summarizes the main evaluations and recommendations.

The executive report starts offering a global picture of the main problems in Catalonia for each of the phenomena considered; afterwards shows the document data-base and finally evaluates the strong and weak points of our current situation, to conclude with suggestions and recommendations of a number of actions.

In a separate chapter (Chapter 6) legal issues are dealt with. We extract the main conclusions of the analysis of current legislation in Catalonia in the field of natural risks. Finally, in Chapter 7, the report concludes with a discussion about the reduction of natural risks and with detailed suggestions to the Catalan Government in order to implement new actions and optimize the existing ones with the target of improving the efficiency of natural risk mitigation.

The RISKCAT project is a pioneer exercise of self-analysis and discussion that demonstrates that our Govern joins the international concern in relation to the improvement of natural risk management and that it has the willingness to consider this relevant issue in its strategic lines.

2. The natural phenomena considered and their impact

The objective of this chapter is to show the reader the scope, importance and consequences of each of the phenomena studied in Catalonia. In order to achieve this goal, a series of tables and maps at a regional scale have been produced, summarizing generically the impact of these phenomena.

Description of the tables

Data contained in the tables comes from the expertise reports and are completed with information obtained from other sources, mainly the database that the Consorcio de Compensación de Seguros (Assurance Compensation Consortium, CCS hereafter) has lent to the project. There is also information from the study “Pérdidas por terremotos e inundaciones en España durante el período 1987-2001 y su estimación para los próximos 30 años (2004-2003)” (Losses by earthquakes and floods in Spain during the period 1987-2001 and their estimation for the next 30 years (2004-2003)), carried out by the Instituto Geológico y Minero de España (Geological and Mining Institute of Spain, IGME hereafter) with information from the CCS, Civil Protection and articles in the national press. Interesting information has been also extracted from some studies of Catalan research groups, such as the Grup d’Anàlisi de Situacions Meteorològiques Adverses (Adverse Meteorological Situations Analysis Group) from the University of Barcelona (GAMA), among others.

In many cases it has been impossible or very difficult to obtain reliable data. It is especially difficult to obtain detailed quantitative information of the impact of most of the events. It would be advisable to have a deeper knowledge of this type of information. Generally, only qualitative data with more or less detailed descriptions of damage are obtained. This fact impairs the creation of an accurate post-event picture which would be very useful for technical and scientific studies of the phenomenon but also for the managers and administrations responsible of the mitigation of their effect.

Due to the lack of consistency of the quantitative information in the Catalan territory, it has been decided to describe or detail a particular event when this has been considered appropriate for better reader comprehension.

No data has been found about losses accountable to collateral effects of the events, such as indirect losses in agriculture production, job losses, decrease of tourism or business and so on...

The availability and homogeneity of the information about the damage caused by natural phenomena in Catalonia is a

non resolved problem that will have to be addressed somehow in the near future.

Table legend:

a) Event history

- Spatial distribution: location of events with damages.
- Time distribution: event record by date of occurrence.

b) Estimation of the recurrence of the phenomenon

From the event record described in the expertise reports, an approach to the recurrence of the phenomenon has been made. Recurrence is understood as the estimation of time that can elapse between events.

c) Impact estimation

- Social impact: number of missing and dead. If there was data, wounded, homeless or jobless people should be included and also epidemics or illnesses caused by the catastrophe.
- Direct economic impact: as a result of the lack of information and since in occasions it has been impossible to have access to quantified information but, on the other hand, there was descriptive information, column 2 has been split so as to offer as much information as possible.

Quantified: quantitative data of the damage produced by the phenomenon, such as costs for infrastructure repair and substitution, installations and properties, communication systems and electricity.

Descriptions: description of damages but no quantification.

Besides the fields described above, it would be very interesting to be able to include a field named indirect economic impact, that would reflect other indirect losses generated by the event and that could be of industrial, agricultural or cultural type. Good examples of this would be the reduction of the value of goods, losses in agricultural soil productivity, tax losses, costs of mitigation and preventive measures, losses in the quality of water, etc. Unfortunately, there are no useful studies or data and therefore this information is not included in the tables.

Description of maps

All maps shown here are at a regional scale and should allow, at a glance, to have an idea of the affected area in Catalonia and the percentage of the area where dangerousness and risk are high. Consequently, the maps are orientative and are not intended to be the base for decision making.

In some phenomena the cartography has been generated especially for this report, whilst in others existing maps have been used. The maps shown for each phenomenon show the susceptibility, dangerousness or risk, depending on the information available.



2.1. Avalanches

Impact status in Catalonia

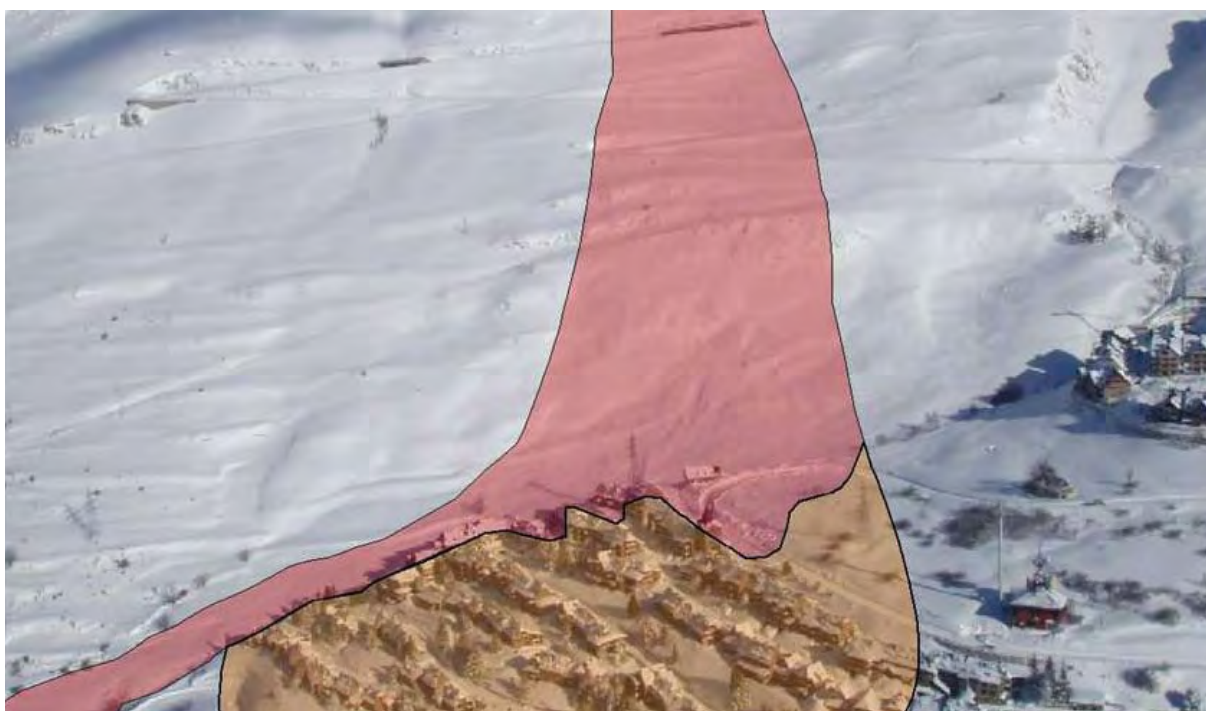
Avalanches have a great incidence in the Pyrenees in Catalonia, where the level of vulnerability and exposure has increased considerably in the last few years. Fortunately, there is a historic record of avalanches and a systematic inventory of avalanches in Catalonia since 1986 (http://www.igc.cat/web/gcontent/ca/allaus/igc_allaus_accidents.html).

During the last 20 years there have been 36 deaths and 44 wounded. In most of the cases, these were minor avalanches, usually of reduced dimensions and that have mainly affected mountain sport lovers off the controlled zones.

Large avalanches in terms of extension and volume, called major avalanches, usually reach much lower elevations and have incidence in the destruction of woods, infrastructures, vital networks and some inhabited zones. Major avalanches can take place locally or in wider areas during intense snow falls that produce avalanches across the Pyrenees. During the last 20 years there have been 3 general and 4 local episodes with major avalanches that have resulted in important damage. Unluckily, we could not gather reliable quantitative data of damage but, instead, we were able to compile many descriptive information (see table 1).

It is important to note that there is not a high frequency of relevant avalanches but there is a constant occurrence of small and medium avalanches.

The preparation of people living in mountain areas and a good territorial management policy are key actions to avoid the increase in victims and damages. It should be taken into consideration that a minimum of fourteen exposed roads and sixteen recent urban developments have been affected totally or partially by avalanches (see expertise report on avalanches).



Area affected by the powder snow avalanche in Pleta de Vaquèira in January 2003. The dense area (magenta) and the spray area (orange) are shown. Photo: IGC.

Relevance of avalanches in Catalonia

Event history		Recurrence estimation	
Spatial distribution	Time distribution		
16 places affected by avalanches	Historical events (before 1975)	Severe avalanche episodes between 1 event every 10 years and 1 every 60 years.	
Alta Ribagorça: Sky station of Boí-Taüll, Senet	S XVI Tavascan	Spare avalanches 1 avalanche a year	
Alt Urgell: Cornellana	S XVII Senet		
Pallars Sobirà: Sky station of Tavascan, Tavascan	1855 Severe avalanche episode that affected Toran, Unha, Bahergue		
Ripollès: Rack Railway of Núria, Collada de Toses, Refuge Pasturia (Vallter)	1861 Bossost		
Vall d'Aran: Bagergue, Bonaigua, Bossost, Casarilh, Garòs, Pleta de Vaquèira, Unha, Toran	1937 Senet		
	Recent events (after 1975)		
	Avalanche episodes		
	1996 South slope of the Pyrenees		
	2003 North Slope of the Pyrenees		
	2005 Garòs		
	Sparse avalanches		
	1981 Bossost		
	1986 Núria and the Collada de Toses		
	1993-94 Road de la Bonaigua		
	2004 Tavascan		
	2005 Garòs		
	2006 Collada de Toses		
Impact estimation			
Social impact		Direct economic impact	
		Quantified	Described
1855	60 deaths	In and avalanche episode such as that of 1996, it is estimated that the direct losses can reach the level of hundreds of thousands euros.	1855 Destruction of 58 houses in la Vall de Toran
1886-87	1 death and 9 injured		1986 Service cuts in the rack railway in the Vall de Núria and the road of la Collada de Toses (Ripollès)
1987-88	1 death		1993 A car wiped out in the road of la Bonaigua
1988-89	1 death and 1 injured		1996 Evacuations in the residential areas of La Pleta de Vaquèira and El Nin de Bertet in the Val d'Aran. Destruction of houses and infrastructures Destruction of the Pasturia refuge in Vallter, with 2 injured.
1990-91	4 deaths and 3 injured		
1991-92	2 deaths and 2 injured		
1992-93	3 injured		
1993-94	1 death and 4 injured		
1995-96	2 deaths and 4 injured		
1996-97	1 death		
1997-98	2 injured		
1998-99	1 death and 3 injured		
1999-00	1 injured		
2000-01	4 deaths and 2 injured		
2001-02	4 deaths and 2 injured		
2002-03	1 death and 1 injured		
2003-04	3 deaths and 6 injured		
2004-05	1 death and 2 injured	2003 Houses and infrastructures affected in la Pleta de Vaquèira	
2005-06	1 death and 5 injured	2004 Cars affected in the parking lot of the sky station of Tavascan	
2006-07	1 injured	2006 Important extensions of devastated woods. Problems in the road of la Collada de Toses	
2007-08	1 injured		

Table 1. Summary of the scope and impact of avalanches in Catalonia.

The susceptibility or probability of the territory to generate avalanches according to zones is shown below (figure 2). The susceptibility classes have been based on elevation and slope criteria, as well as data from past avalanches (Avalanche Zone Map – Mapa Zones d’Allaus MZA and Avalanche Data Base – Base de Dades d’Allaus de Catalunya – BDAC).

The mentioned susceptibility has been classified in four levels:

High susceptibility zones, where the BDAC has recorded at least one avalanche in the last fifteen years.

Medium susceptibility zones, which are exposed sectors according to the MZA but there has not been any avalanche in the last fifteen years.

Low susceptibility zones, including areas above 1.500m but no avalanches have been recorded.

Undetected, non-exposed zones at elevations below 1.500m.

The medium and high susceptibility zones represent 4% of the territory and are restricted to the Pyrenees. Outside this area, only the high elevations of the Montseny are classified as low susceptibility. The rest of Catalonia belongs to the Undetected category.

This map also includes the major events with damage recorded some time in history.

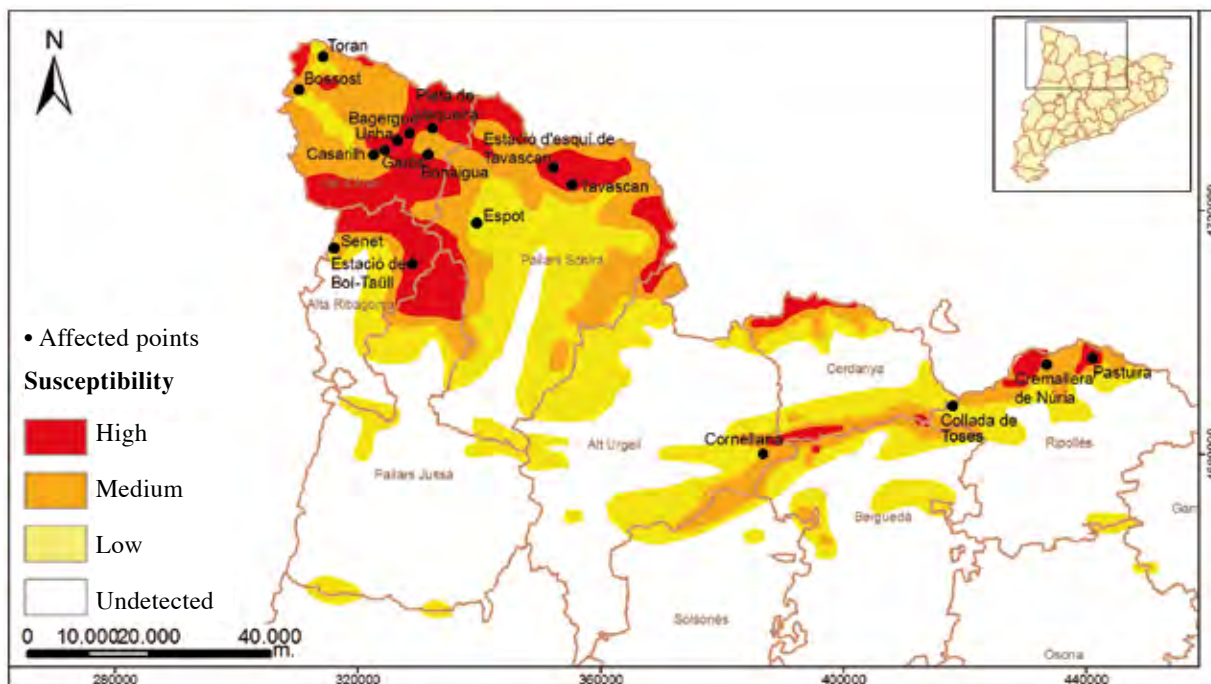


Fig 2. Zonification of avalanche susceptibility in Catalonia.



2.2. Landslides

Impact status in Catalonia

There is no systematic record of landslides and their damage. There exists quite a lot of information but it is irregular and sparse. This report has managed to compile a good number of events with damages in the last few years and in history.

From the information in table 2, one can see an increase in the number of landslides that cause damage and therefore there is an increase in risk. This fact is tied to the growing territory occupation and use, in other words, to an increase of exposure. However, we would like to mention the incidence of what has been called the “geomorphological footprint” and its relation with greater numbers of landslides. In the last 15 years, the economic development of our country has led to an extreme urban sprawl that, in many cases, has provoked ground instability and has reduced the resistance of the surface layer to the action of natural agents.

The most important landslides were associated to the large rainfalls in the years 1962, 1982 and 2000. Each of these caused numerous land movements with big damages. Unfortunately, the quantification of that damage has not been possible, since –in spite of the CCS paying important part of the assured goods- it has not been assigned to landslides but floods.

In 1987, the IGME carried out a study that estimated the approximate cost of landslides for the period 1986-2016 (table 2). Today, the CCS pays for landslide damage if it comes associated to large floods. Unfortunately, both concepts are not yet split but we have been informed that the cases are on the increase, particularly in housing development around slopes, since the soil has been modified and the action of rain leads to unstable ground.



Rock landslides in Malanyeu (Berguedà) in January 2006 (Photo J.M. Vilaplana).

Relevance of landslides in Catalonia

Event history		Recurrence estimation
Spatial distribution	Time distribution	
<p>Landslides that have affected exposed elements.</p> <p>Alta Ribagorça: Senet</p> <p>Alt Urgell: Bescaran, Organyà, Pont de Bar</p> <p>Bages: Montserrat</p> <p>Baix Empordà: l'Estartit, Sta. Cristina d'Aro</p> <p>Baix Llobregat: Castelldefels, El Papiol, Esparreguera, St. Esteve de Sesrovires</p> <p>Barcelona: Montjuïc</p> <p>Berguedà: Espinallet, Gòsol, Guixers, Malanyeu</p> <p>Cerdanya: La Molina, Martinet</p> <p>La Garrotxa: Castellfollit de la Roca, St. Esteve d'en Bas</p> <p>Les Garrigues: Juncosa</p> <p>Osona: Rupit</p> <p>Pallars Jussà: Capdella, Espui, Puigcerçós, Sant Salvador de Toló</p> <p>Pallars Sobirà: Boren-Isavarre, Caregue, Gerri de la sal, La Guingueta, Llavorsí, Sort</p> <p>Ripollès: Vall de Núria, Rocabruna</p> <p>Ribera d'Ebre: Tivissa</p> <p>Solsonès: La Coma</p> <p>Vall d'Aran: Arties</p> <p>Vallès Occidental: Barberà del Vallès, Castellbisbal, Ullastrell</p>	<p>Historical events <i>(before 1975)</i></p> <p>1845 Tivissa and Montjuïc</p> <p>1881 Puigcerçós</p> <p>End of 19th century Bescaran</p> <p>1907 Boren-Isavarre, Llavorsí and Espui</p> <p>1940 Rocabruna and Rupit</p> <p>1944 Ullastrell</p> <p>1962 Barberà del Vallès, Castellbisbal and el Papiol</p> <p>1963 Montjuïc, Arties and Senet</p> <p>Recent events <i>(after 1975)</i></p> <p>1979 Castellfollit</p> <p>1982 La Guingueta, Caregue, Gerri de la Sal, Capdella, Pont de Bar, La Coma, Gòsol, Maçaners i Espinallet, Vallcebre, Maçaners, Sant Salvador de Toló</p> <p>1984 El Papiol and St. Esteve Sesrovires</p> <p>1987 Guixers</p> <p>1990 Sort</p> <p>1995 Castellfollit</p> <p>1996 Martinet</p> <p>1998 St. Esteve d'en Bas</p> <p>2000 Esparreguera and Montserrat</p> <p>2003 Núria, Sta. Cristina d'Aro</p> <p>2004 L'Estartit</p> <p>2005 St. Esteve d'en Bas</p> <p>2006 Malanyeu, Organyà and Juncosa de les Garrigues</p> <p>2007 Castellfollit de la Roca, La Molina and Montserrat</p>	<p>According to the previous event record.</p> <p>Historical: between 1 event every 5 years and 1 event every 10 years.</p> <p>Recent: 1 event every year and a half.</p>



Destruction of the road N-260 by a landslide. El Pont de Bar during the heavy rains in November 1982 (Photo J.M. Vilaplana).

Impact estimation			
Social impact		Direct economic impact	
		Quantified	Described
Recent events		Expected losses for the period	1881
2003	2 deaths in Sta. Cristina d'Aro	1987-2016 442.747.789,88 €*	Slide of the whole village of Puigcerçós.
2005	1 death in St. Esteve d'en Bas		1982
2006	2 deaths in Juncosa de les Garrigues		Affected houses and damages in street furniture and infrastructures in la Guingueta d'Aneu and Pont de Bar. Cut in the access road to the village of Pont de Bar. Slide of the whole village of Pont de Bar (10 families). Castellfolit de la Roca, damages in the houses close to the scar.
			2000
			Since 1990 to 2007
			2007

Table 2. Summary of most relevant data about the scope and impact of landslides.

*Font: IGME 1987.

Soil and rock landslides have a great incidence and a wide territorial distribution in Catalonia.

In figure 3 the susceptibility or likelihood of the territory to generate landslides is shown. Susceptibility classes have been defined based on ground relief and its typology.

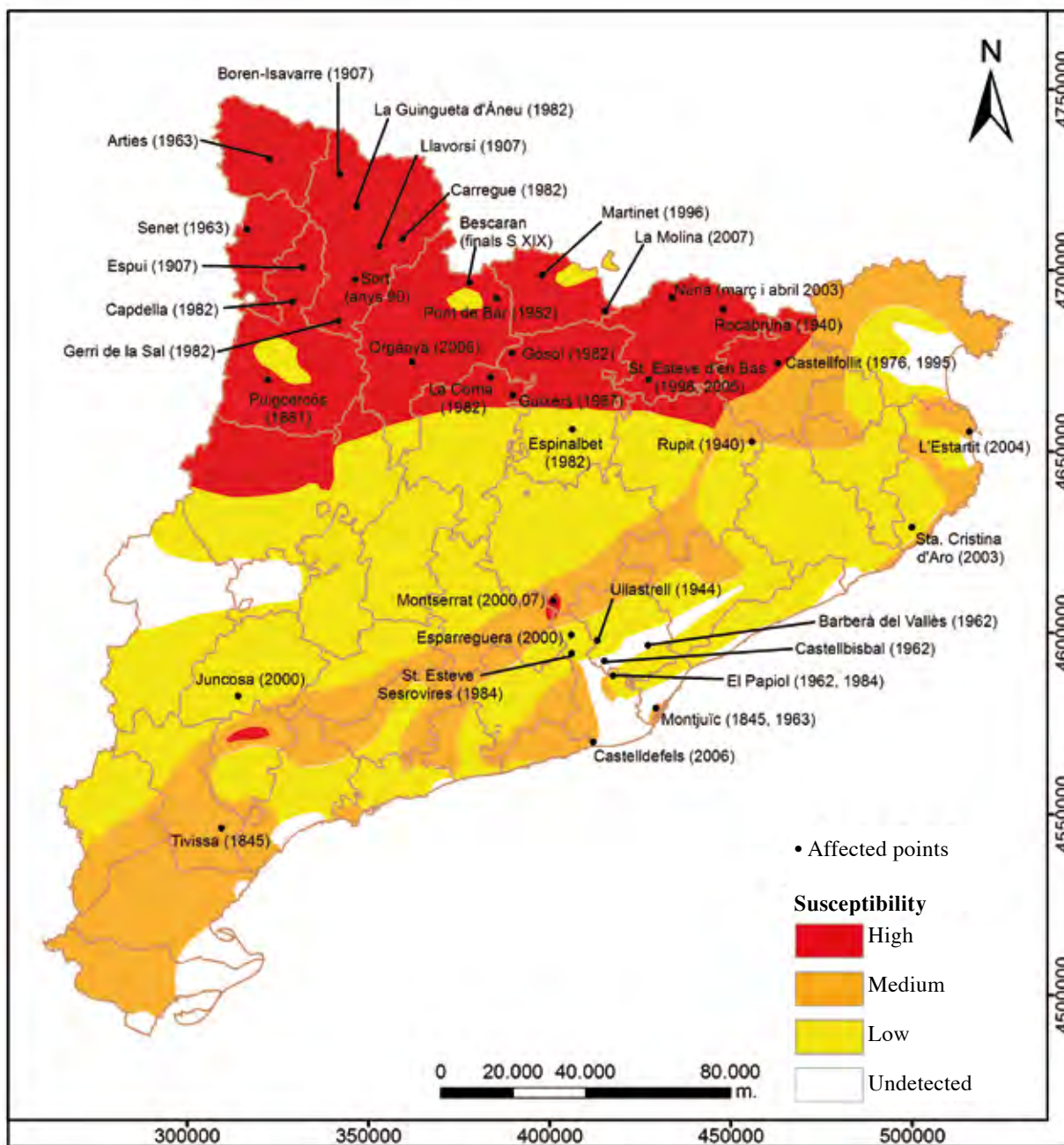


Fig. 3. Landslide susceptibility map in Catalonia with the localization of major events with recorded damage sometime in history.

In the previous map (figure 3), susceptibility has been classified into four levels:

High susceptibility zones. Those with a very steep relief and lithology prone to generate landslides. Their range is approximately 27% of the territory.

Medium susceptibility zones. Those with steep relief but a relatively low level drop. They take approximately 22% of the territory.

Low susceptibility zones. Mountainous areas of smooth hills and depressions with a certain topographic level drop. These account for 45% of the territory.

Undetected susceptibility zones. These are the great interior plains and coastal plains with practically horizontal relief that total 6% of the territory.



2.3. Land collapses and subsidence Impact status in Catalonia

Land collapses are vertical movements of the ground, more or less sudden, associated with the existence of subsoil cavities close to the ground surface. Subsidence is a process of slow, gradual collapse of an area of the ground.

Although there have never been casualties as a result of this risk, the economic and social impact that has generated a fact such as the collapse of the Estació neighbourhood in Sallent is very relevant. Also, in Súria the sudden

land collapses have limited the expansion of the urban area and in Cardona have made imperative to divert the Cardener River (table 3).

Once more, we observe a growing frequency of recorded events (table 3) that has to be attributed to the increment of exposed areas and to the acceleration of the vertical terrain movements as a result of certain activities (mining, subsoil water extraction, etc.)

Relevance of land collapses and subsidence in Catalonia

Event history		Recurrence estimation	
Spatial distribution	Time distribution		
<p>Places affected by land collapses: Besalú, Banyoles, Cardona, Sallent, Súria, St. Sadurní d'Anoia, La Bisbal del Penedès, Foix</p> <p>Places affected by subsidence: Delta del Besòs, Delta del Llobregat, Delta de l'Ebre</p>	<p>Events in the wetland basin of Banyoles 1904, 1908, 1978, 1982</p> <p>Catalan potassic basin Collapses since the beginning of the 20th century</p>	<p>During the 20th century 14 events recorded and 1 event every 7 years</p> <p>Recent events (after 1975) 8 events recorded and 1 event every 3 years</p>	
Impact estimation			
Social impact	Direct economic impact		
	Quantified	Described	
<p>Sallent episode: 224 families evacuated</p>	<p>By subsidence Unknown</p> <p>By collapses In the Sallent episode, 14.000.000 € are estimated to be given as a compensation for the 172 home owners affected</p>	<p>Damages in the road from Banyoles to Olot</p> <p>In Banyoles, problems with the infrastructures of the 1992 Olympic games.</p> <p>In the Sallent episode, in the neighbourhood of l'Estació, 333 affected homes; any of them have to be evacuated and demolish.</p> <p>In Súria, rustic soil affected limits the expansion of the urban zone.</p> <p>In Cardona, the Cardener river has had to be derived</p>	

Table 3. Summary of the most relevant data about the scope and impact of land collapses.

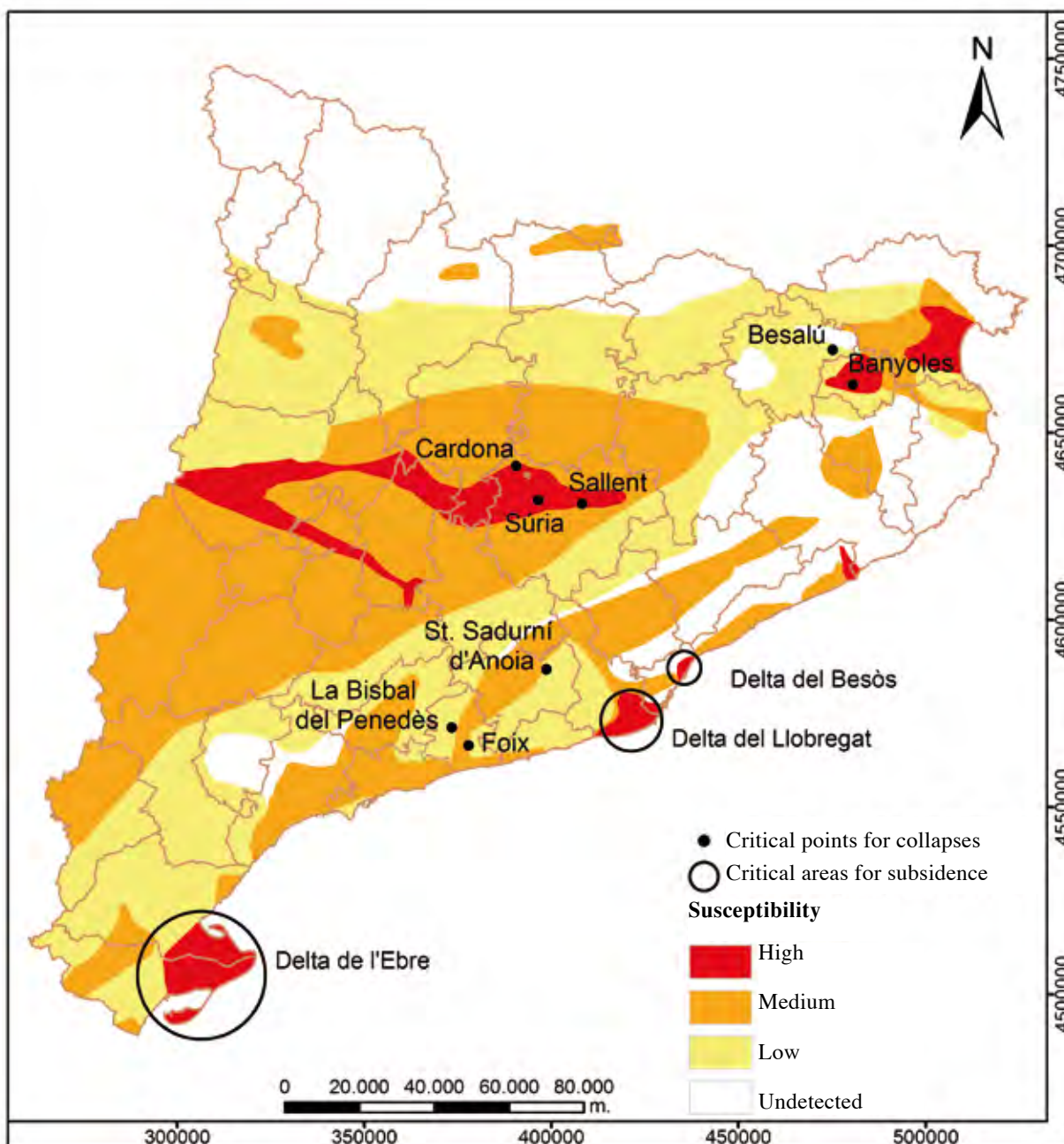


Fig 4. Susceptibility map to the collapses and subsidences in Catalonia. The most affected zones are highlighted.

The map in figure 4 represents in an informative manner the areas of the territory that are susceptible to the formation of collapses and subsidences, based on the lithological features of the ground.

Four levels of susceptibility:

High susceptibility zones. The chinks and/or salts of the Catalan potassium basin, in Banyoles and the anticlinal of Barbastro and the recent deltas: Ebre, Llobregat, Besòs, la Tordera and the Empordà plain. They occupy approximately 10% of the territory.

Medium susceptibility zones. Represent the areas of the terrain where powerful lutiticial formations occur. These areas are the central depression, the Vallès-Penedès depression, Alt Camp, Gironès, Cerdanya, Baix Camp, Maresme and Barcelonès, amongst others. They account for approximately 30% of the territory.

Low susceptibility zones, where powerful calcareous and conglomerate formations are found. These zones are the calcareous massifs in the pre-Pyrenees, a large part of the Prelitoral mountain range and the Garraf

massif, among some others. They constitute 40% of the territory.

Undetected susceptibility zones. They account for 20% of the territory, where granitic and metamorphic formations that will not produce land collapses and subsidences appear.

In this map (figure 4) the major events with damages recorded some time in history have been added. In Catalonia, the zones that have suffered -and still suffer- this phenomenon most are concentrated in the potassium basin of central Catalonia, the area Besalú-Banyoles and the deltas: Ebre, Llobregat and Besòs. In the areas of the Llobregat and Besòs, special attention is needed, since they are particularly vulnerable and risk is very high.



Large sink in the river bed of the Cardener River, 2003.
(<http://www.lasequia.org/montsalat/>)



2.4. Coastal phenomena Impact status in Catalonia

The Catalan coast is approximately 600Km long with a great morphological diversity and a high level of urban development. The tourism associated to beaches is and has been the main economical focus of our country, being this the reason why we have a highly humanized coast.

Data extraction related to the relevance of coastal phenomena has been particularly complex and time consuming. The Catalan coast has many actors and the interventions are diverse and constant in many fronts. There is a fragmentation of responsibilities and a great difficulty of coordination.

With table 4, in spite that scarce information has been got, we can have an idea of the magnitude and frequency of coastal storms, showing all the economical and environmental problems associated to erosion and beach maintenance.



Lloret beach during the easterly sea storm of 2004. (Photo J. Guillén).

Relevance of the coastal phenomena in Catalonia

Event history		Recurrence estimation
Spatial distribution	Time distribution	
Coast length 578Km	297 sea storms recorded in the last 14 years (1992-2006)	Erosion Continuous process, can't be characterized by a return period
Coast under erosion 192Km	147 Weak 82 Moderate 59 Significant 8 Severe 1 Extreme	Sea storms 20 / year (from weak to significant) 1 severe / 2 years 1 extreme / 14 years
Coast with infrastructures and artificial beaches 152Km		Tsunamis No records in the Catalan coast
Population in the coast zone affected by erosion 1.000.000 hab.		Giant waves, ripples and swells. No data available
Urban and industrial areas affected by erosion 123Km ²		
Areas of high environmental value affected by erosion 217Km ²		

Impact estimation		
Social impact	Direct economic impact	
	Quantified	Described
47 deaths as a result of sea storms in the last 14 years	Sea storms <i>As published in the media</i> 2001 13.000.000 €	Sea storms 2001 sea storm Damages in street furniture, damages in maritime avenues, leaks in defense works, flooding in deltaic areas, cuts in railway lines.
Erosion and floods Unknown	Loss evaluation <i>(CCS data)</i> 1996 684.921 € 1997 1.310.386 € 2001 6.241.975 € 2003 1.460.122 € 2004 1.852 € 2005 4.857.886 € 2006 1.115.812 € Erosion 2006 60.000.000 € Protection works in the beaches of Barcelona 1986-2006 110.000.000 € Minimum investment for artificial regeneration of beaches	Other damages caused by sea storms. Ecosystem degradation, poorer quality of water. Erosion Beach renourishment with 19.000.000m ³ of sand in 20 years

Table 4. Summary of information about the scope and impact of coastal phenomena in Catalonia.

Coastal vulnerability to erosion and flooding is usually high, especially in stretches of low sedimentary coast and in areas with high human pressure. The dangerousness map (figure 5) is intended to offer a general vision of the dangerousness associated to erosion and coastal flooding.

Due to the diversity of our coast and to the lack of data, it has to be stressed that the dangerousness map (figure 5) is orientative. The total volume of sand brought to beaches since 1986 is a good indicator of the areas where the risk associated to erosion is more intense.

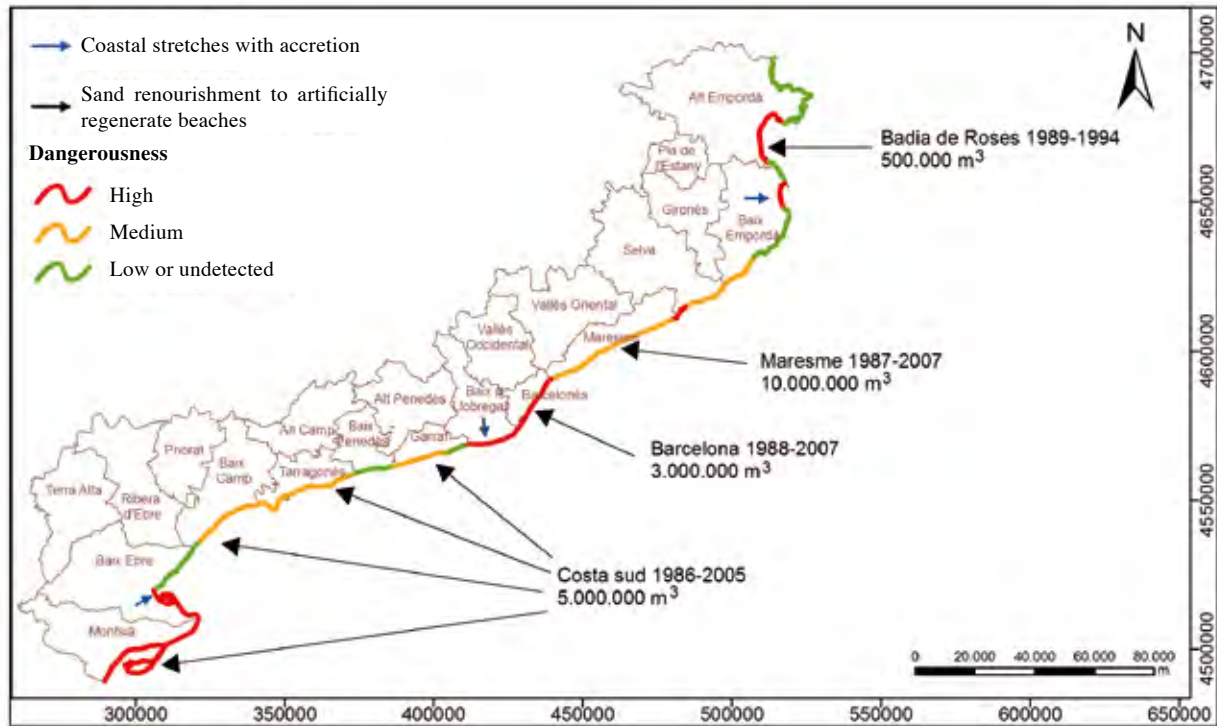


Fig 5. Map of dangerousness of erosion and flooding in the Catalan coast. Coastal stretches with accretion and quantities (cubic metres) of material intended to artificial regeneration of beaches are indicated.

Generally speaking, it is considered that dangerousness is highest in the mouth of large rivers and the city of Barcelona, medium in the stretches of highly humanized, sandy coast (Maresme, Costa daurada) and low or undetected in rocky coastal stretches.

last 14 years (1993 – 2006) prompted us to include the map in figure 6. In 14 years, 47 people have died in our beaches. All cases can be classified in two types: drowned bathers or passers-by that have been hit or swallowed by waves. It is important to point out that these accidents take place in summer during low magnitude storms.

The large number of victims attributed to storms in the

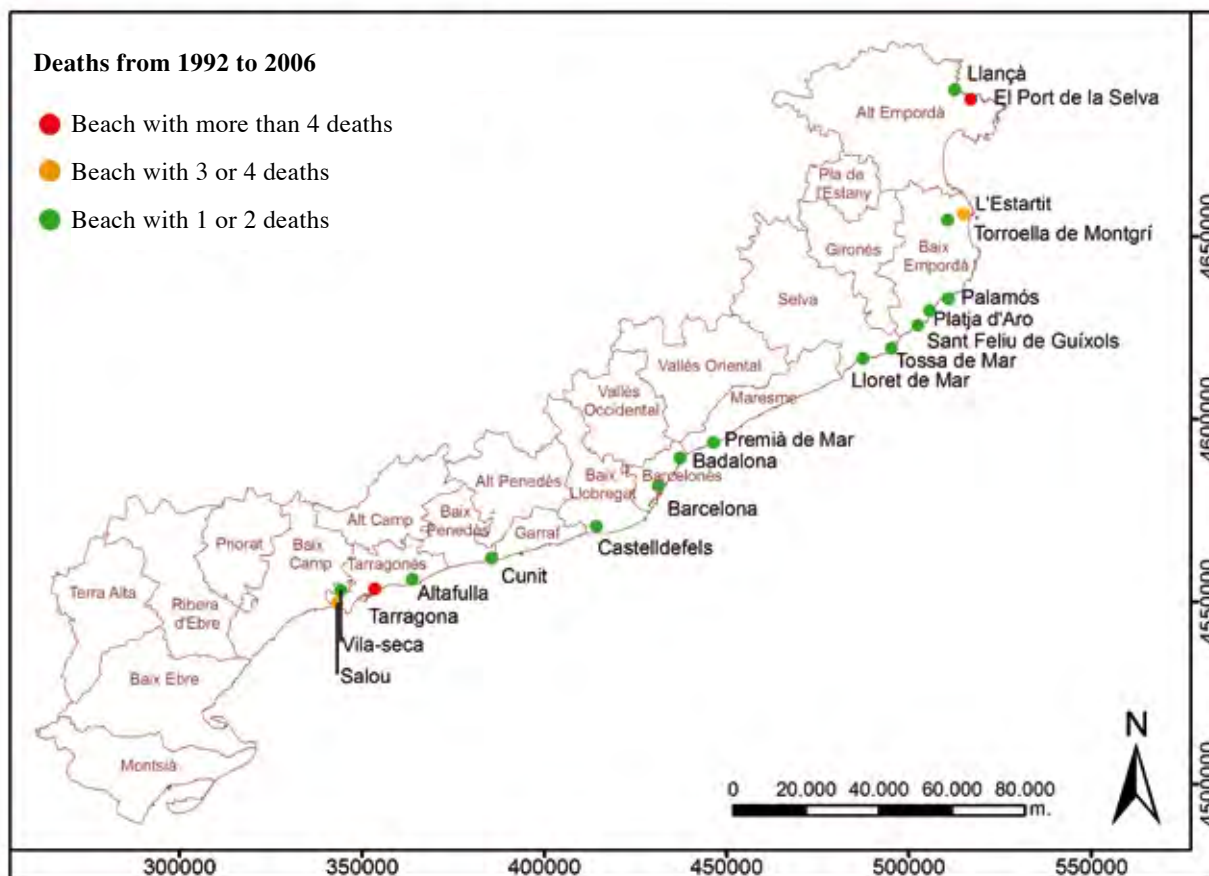


Fig 6. Number of deaths in the Catalan coast from 1996 to 2006.



2.5. Floods

Impact status in Catalonia

In Catalonia, floods have two typologies: on one side we find the large rivers, the Ebre tributaries and rivers in the internal basins, with a torrential behaviour in the river sources and a swelling pattern in the medium and low tracks and on the other side we find the fast and torrential swellings of coastal and mountain streams. Considering the floods that cause damages and, according to the records of the last 26 years, there are almost 3 of them each year. The summary shown in table 5 is significative.

The constant occurrence of mortal victims as a result of floods shows the relevance of the phenomenon. During the last few years, sudden floods -of the “fast flood” type- are those that have worried us most because of the difficulty of their prediction and because of their real fast effects. The population increase in Catalonia and its distribution have led to an increase of the vulnerability in front of this phenomenon.

At the quantification level, it is remarkable the average of almost 100.000.000 € per year that the CCS points out (see data in table 5). We must remember that this value is just a minimum since it only takes into account insured goods, excluding those which are not and public

goods. Also, in most cases the final payment is lower than the actual insured good and franchises hide the real value of what has to be rebuilt.

Finally, the indirect economic impact –not shown in table 5- has to be considered, since it can be particularly relevant in many flood episodes that have taken place in Catalonia and that, very often, have posed difficulties to normal life, since they have disturbed transportation, communications, industry, agriculture and others for quite long.



Effects of a torrential flood in Salou, 2006. Photo: Internet.

Relevance of floods in Catalonia

Event history		Recurrence estimation	
Spatial distribution		Time distribution	
Records since the 19th century	Most important flood episodes in number of victims	1300 – 1900 period	Between 1 event every 50 years and one event every 15 years.
Most affected basins	1863 Llobregat basin	1900-1980 period	1 event a year
Ter basin	1874 Ebro, Francolí, Gaià and Llobregat basins	1980-2006 period	Almost 3 events a year
121 cases (between 1322-2000)	1907 General		
Llobregat basin	1940 North Catalonia and Eastern Pyrenees		
112 cases (between 1315 – 2000)	1962 Besòs and Llobregat		
	1971 Llobregat and Fluvià		
	1977 General		
	1982 Pyrenees		
	1987 Barcelona		
	1988 Llobregat		
	1994 Francolí and Siurana		
	1995 Barcelona, Eastern Pyrenees		
	2000 Baix Penedès, Anoia, Baix Llobregat, Bages		
	2004 Tarragona, Vendrell, Calafell, Baix Penedès, Ebro delta		
	2005 Baix Empordà		
	2006 Barcelona		
Impact estimation			
Social impact		Direct economic impact	
		Quantified	Described
1863 33 deaths	1987-2002 period in Catalonia	1874 700 houses destroyed	
1874 600 deaths	1.325.720.511€	1907 110 houses destroyed	
1907 29 deaths	By provinces:	1940 380 houses affected	
1940 90 deaths	Barcelona 979.131.709 €	1971 450 industries affected	
1962 700 deaths	Tarragona 258.992.207 €	1995 Floods in streets and under housing, severe damages in the crops.	
1971 35 deaths	Girona 62.782.627 €	Cuts of roads and railway lines	
1982 14 deaths	Lleida 24.813.968 €	2000 485 shops affected, 91 industries, 10 offices, 1.300 houses and more than 1.000 industrial vehicles.	
1987 10 deaths	2003 51.883.030 €	Important damages in the Montserrat monastery, break down of a bridge in the N-II road, cuts in roads and railway lines	
1994 10 deaths	2004 12.731.832 €		
2000 9 deaths	2005 77.662.356 €		
2004 3 deaths	2006 78.953.125 €*		
2005 5 deaths			
2006 2 deaths			
In every important episode there have been injured, displaced, and isolated people.			

Table 5. Summary of data about the scope and impact of floods.

* Data in Quantified Direct Economic Impact have been supplied by the Consorcio de Compensación de Seguros. Data for 2006 are still a minimum estimate.

It is then a first approach where 3 levels of risk have been defined:

Very high or high risk, covering 47% of the territory and 380 municipalities. These areas are characterized for having municipalities with a minimum of 50 and 250 people living in potentially flooding areas, quantified damages greater than 60.000 € and belonging to a high danger basin or, if lower, with otherwise high vulnerability.

Moderate and medium risk, covering approximately 36% of the territory and affecting 368 municipalities.

These zones are characterized for having municipalities with 5 and 50 people living in potentially flooding areas, quantified damages under 60.000 € and belonging to a low danger basin or, if higher, with otherwise low vulnerability.

Low risk, affecting 17% of the territory and 198 municipalities. These zones are characterized for having municipalities with less than 5 people in potentially flooding areas, quantified damages under 60.000 € and belonging to a low danger basin.



Effects of the raise of the water level of the river Segre in Martinet during the heavy rains of November 1982. (Photo J.M. Vilaplana).



2.6. Earthquakes

Impact status in Catalonia

In spite that the oldest information on earthquakes in Catalonia backtracks to the 6th century, reliable data start in the 19th century, when the most destructive earthquakes took place.

The historical earthquakes that caused the most important damages and had epicentral intensities in the range of VIII and IX, took place in 1373 and 1448 in the North of the country, with the exception of the 1448 earthquake in the Vallès Oriental (see table 6).

More recently, between 1986 and 2006, 16 earthquakes of magnitude higher than 4.0 ML have been recorded; among them, four series of earthquakes originated 20 – 30 Km off the coast can be highlighted. None of these produced relevant damages and only in 2004 an earthquake of magnitude 4.0 ML caused some light damages in an epicentral area in el Ripollès.

Earthquakes, especially in areas of moderate seismic activity such as Catalonia, do not show an event pattern that allows a calculation of their recurrence in time and an estimation of the average occurrence rate taken from the observed frequencies is used. Table 6 summarizes the

results of the estimation of recurrences from a model developed by the seismology unit of the ICC (ICC97).

The estimation of earthquake impact in Catalonia has several difficulties since there is no detailed information about the losses caused by the most destructive earthquakes because they have not taken place in recent times.

The information about direct losses from the most recent earthquakes can be found in the publications of the CCS and the Special Emergency Plan for Earthquakes of Catalonia (Pla Especial d'Emergències Sísmiques de Catalunya) SISMICAT, developed by the Catalan Geological Institute (Institut Geològic de Catalunya) IGC. This plan includes estimations of damages and victims at the municipal level, taken from: a) the map of seismic zones in annex 6 of the plan, which shows the maximum intensities that can be expected with an average return period of 500 years; b) a statistical evaluation of the vulnerability of the representative buildings of each municipality and c) the population and building census. Data from the referred sources have been summarized in table 6 and are described in more detail in the corresponding expertise report.

Relevance of earthquakes in Catalonia

Event history		Recurrence estimation	
Spatial distribution	Time distribution		
Activity mainly in the Pyrenees and the Coastal Ridge	<p>Most destructive earthquakes in Catalonia</p> <p>1373 La Ribagorça. Intensity VIII-IX (MSK scale)</p> <p>1427-28 Earthquake crisis in la Selva, la Garrotxa and el Ripollès. Intensity VIII-IX (MSK scale)</p> <p>1448 El Vallès Oriental. Intensity VIII (MSK scale)</p> <p>1923 Vall d'Aran. Intensity VIII (MSK scale)</p> <p>1927 Montseny. Intensity VII (MSK scale)</p> <p>Between 1300 and 1995, 900 earthquakes are detected</p> <p>Between 1996 and 2005, 4000 earthquakes are recorded, 19 of them of intensity IV (MSK scale)</p>	<p>According to the ICC97 model, earthquake average rate of intensity equal or greater than V (MSK)</p> <p>Western Pyrenees 1 event every 4 years and a half</p> <p>Coast and Eastern Pyrenees Between 1 event every 10 years and 1 event every 6 years.</p> <p>SW and Central Catalonia 1 event every 25 years</p>	
Minor activity in the Iberian Ridge, in the SW			
Very low activity inland			
Impact estimation			
Social impact	Direct economic impact		
	Quantified	Described	
<p>Earthquake of 1428 Death of 90% of the population in Queralbs, 25-30% in Camprodon, Castellfollit, Montagut, la Vall d'en Bas and la Vall de Bianya. In Barcelona, 20 deaths</p> <p>1448 earthquake 7 documented deaths</p> <p>Estimation of mortal victims by an earthquake with a return period of 500 years (according to SISMICAT) 95% of the municipalities between 0 and 10 dead In Barcelona, between 1000 and 2000 dead</p>	<p>Estimated losses for the period 1987 - 2001 9.000.000 €</p> <p>Extrapolation for the next 30 years 70.000.000 € (underestimation)</p> <p>Assessment of losses caused by earthquakes (CCS data)</p> <p>1997 Earthquake with epicentre in Perpinyà 31.642 €</p> <p>2004 Earthquake with epicentre in Queralbs 302.932 €</p>	<p>1923 and 1927 earthquakes Severe damages to infrastructures and housing</p> <p>2004 Light damages in the epicentral zone (Queralbs)</p> <p>Estimation of buildings left inhabitable by an earthquake with a return period of 500 years (according to SISMICAT) Between 10 and 100 in 50% of the municipalities. In Barcelona and Sabadell between 1.000 and 10.000</p> <p>Estimation of the population that could be left homeless by an earthquake with a return period of 500 years (according to SISMICAT) Between 0 and 10 people in 26% of the municipalities Between 10 and 100 people in 48% of the municipalities Between 100 and 1000 people in 21% of the municipalities In Barcelona, between 100.000 and 200.000 people</p>	

Table 6. Summary of data about the scope and impact of earthquakes in Catalonia.

The map below (figure 8) shows the epicentres of the earthquakes with damages of magnitude greater than 5.0 observed in Catalonia between 580 and 2003. It should be noted that earthquakes with epicentres outside Catalonia can generate impact in the Catalan territory as well.

With the goal of showing the seismic danger in Catalonia, the Map of Seismic Zonification of Catalonia by the SIS-MICAT has been used. This map (figure 9) has been elaborated considering the occurrence of earthquakes with an average return period of 500 years and the zonification of the estimated maximum intensities.

Since soil characteristics influence the intensity of the earthquakes on the surface, the map of seismic zonification of Catalonia also considers the effect of the soil, through the geotechnical characterization of the soils in the different municipalities (figure 9).

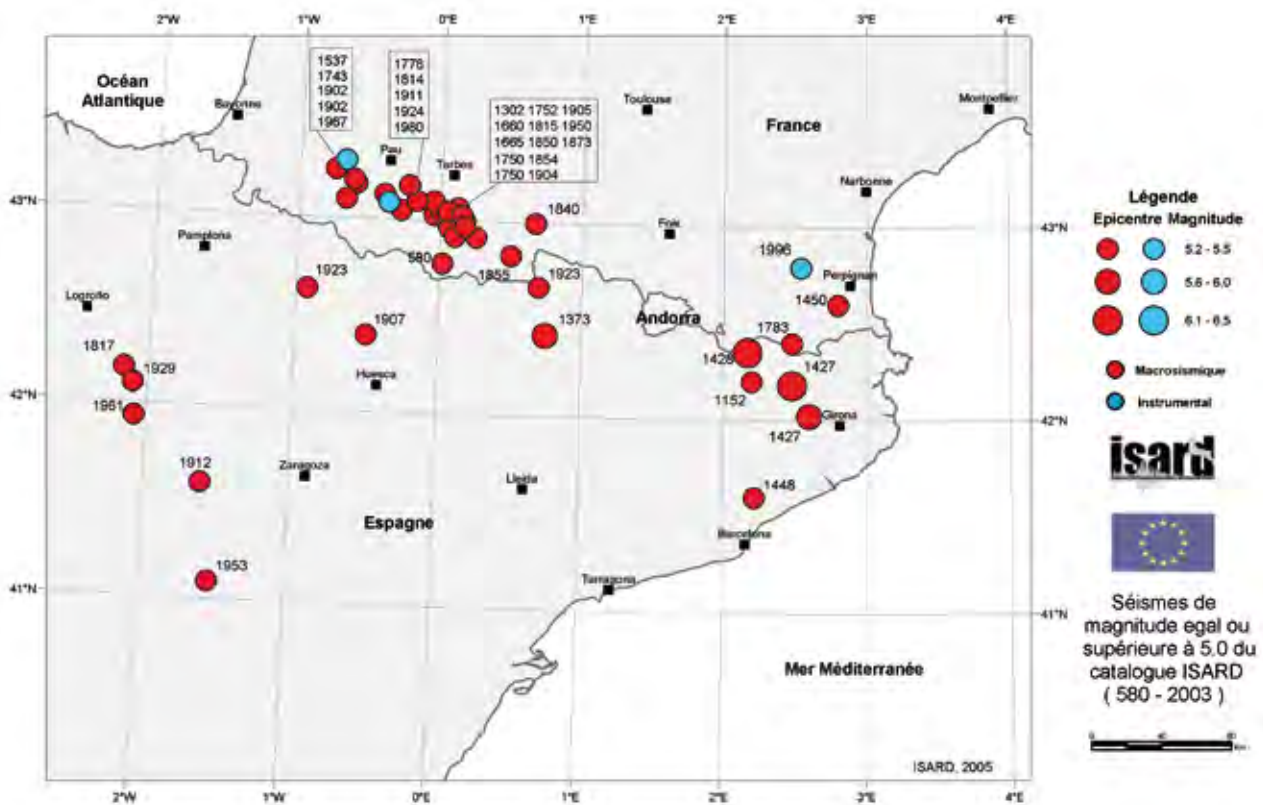


Fig 8. Seismic activity in Catalonia 580 – 2003 for magnitudes greater than 5.0 (earthquakes with observed damages). Unified catalogue in terms of magnitude of the ISARD project (<http://isard.brgm.fr>). In red: estimated magnitude from macroseismic observations; in blue: calculated instrumental magnitude.

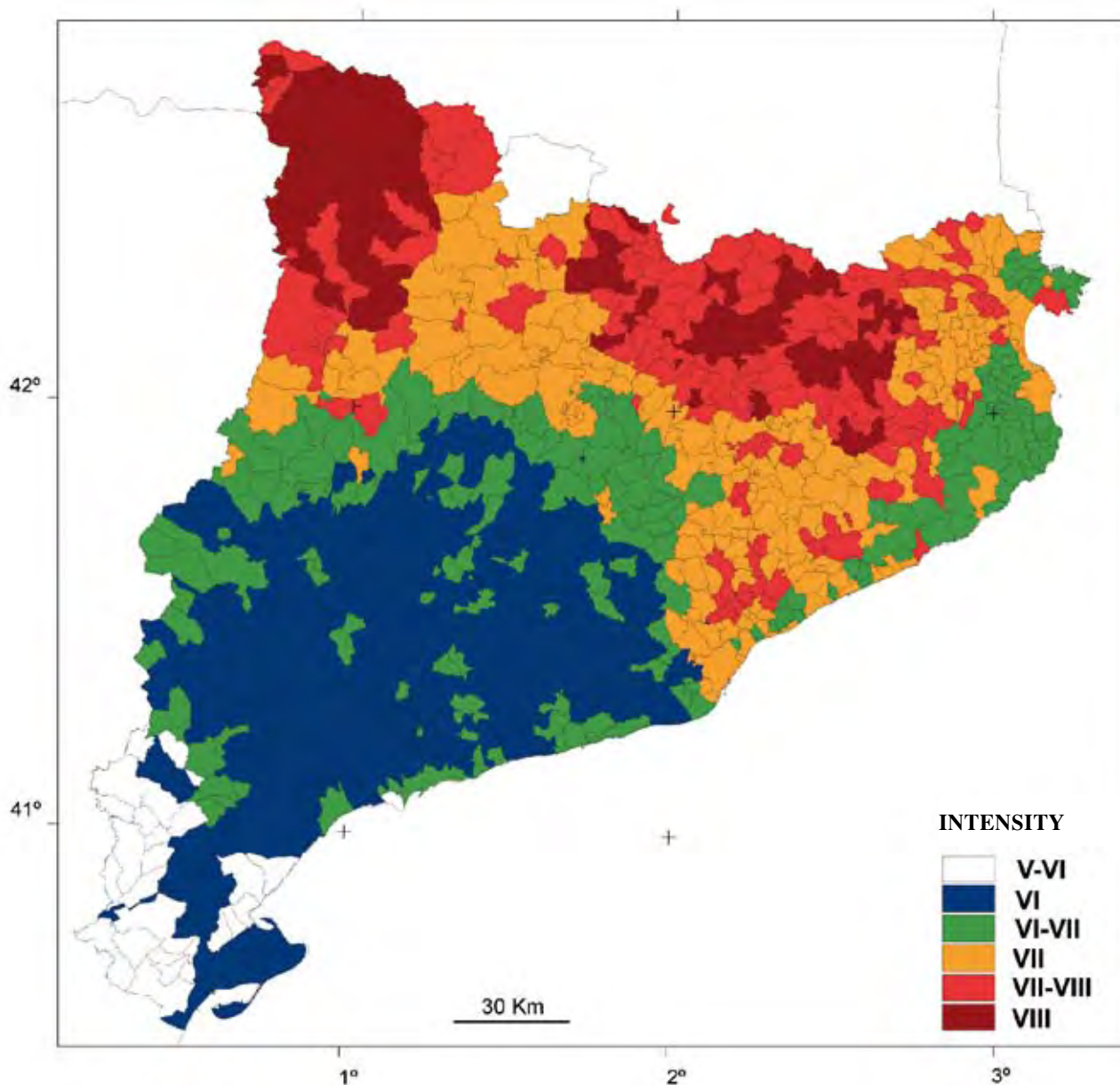


Fig 9. Map of seismic zonification of Catalonia considering the effect of soil, presented in the Special Emergency Plan for Earthquakes of Catalonia (SISMICAT) carried out by the ICC (2000).

In this map (figure 9), 6 seismic zones are characterized:

In white, zones where there can occur earthquakes with intensities between V and VI. They account approximately for 5% of the territory.

In blue, zones where there can occur intensity VI earthquakes. They cover approximately 32% of the territory.

In green, zones where intensity VI and VII earthquakes can occur. They correspond to 18% of the territory.

In orange, zones where intensity VII earthquakes can occur. They correspond to 23% of the territory.

In red, zones where intensity VII and VIII earthquakes can occur. They correspond to 12% of the territory.

In deep red, zones where intensity VIII earthquakes can occur. They correspond to 10% of the territory.

The areas where the highest intensities are expected are in the North third of the country, comprising the Pyrenees and pre-Pyrenees and the Catalan Coastal Ridge, whilst the lowest intensity areas are in the South and the inland in the Ebro basin. The seismic activity in the Pyrenees is more intense in the Western and Central Eastern part, decreasing in the Easternmost part of the ridge.



2.7. Vulcanism

Impact Status in Catalonia

Given the antiquity of volcanic eruptions in Catalonia, information on this phenomenon is scarce to allow a precise calculation of the ages of vulcanism and determine its impact. Table 7 summarizes the information gathered.

Since we do not have any historical record of any eruption, the quantitative estimates of its impact can only be potential and have to be made according to existing geological data combined with the application of predictive models.

Taking into account geological data, an eruption such as those that took place in la Garrotxa, defines two damage scenarios: one close to the immediate surroundings of the volcano by lava flows and ash rain and a second one with a local, highly destructive impact due to pyroclastic flows and also a regional impact at the atmos-

pheric level due to the dispersion of ashes cast by the eruptive column, with probable repercussion in the air space.

In order to be able to understand the impact of what a volcanic eruption can mean today in la Garrotxa and given the fact that there is no historical record, an eruptive scenario has been defined taking as a model an eruption such as that of the Croscat. With the computer application VORIS2, designed by the Institut Jaume Almera of the CSIC, the evolution of this eruption and the areas occupied by its products has been quantified, indicating the nearby effects in the short term (location of lava washings, ash falls and pyroclastic waves) and more distant effects in the long term (eruptive columns and ash dispersion). In the expertise report this model is further described.

Relevance of vulcanism in Catalonia

Event history		Recurrence estimation
Spatial distribution	Time distribution	
Concentrated in the NE of Catalonia	<p>Oldest activity Alt Empordà 10.000.000 – 11.000.000 years</p> <p>Most recent activity In la Garrotxa, since 350.000 years ago until 9.000 years ago Traces of activity prior to 5.000 years ago</p>	<p>Estimated recurrence with insufficient data 1 episode every 15.000 or 20.000 years in La Garrotxa</p>
Isolated manifestations in the Baix Ebre and in the central marine bottom and in the Balearics		

Table 7. Summary of data about vulcanism in Catalonia.

There is not any evaluation of the danger or risk that this phenomenon can mean. However, we have to consider that volcanic activity has existed during the last 10 million years in Catalonia and, in spite the last events date from 10.000 years ago, it can be expected that this activity is going to follow the same pattern in the future.

According to the recommendations of the International Association of Vulcanology – IAVCEI, a volcanic zone is considered to be active when it shows or has shown volcanic activity during the last 10.000 years.

Applying the directives of the AVCEI to determine the dangerousness of recent vulcanism in Catalonia a mode-

rate degree of dangerousness is obtained, even if very conservative values are applied and the lack of existing knowledge is considered (see a more detailed description in the corresponding expertise report).

In the case of vulcanism in Catalonia and particularly in the area where these manifestations are recent (la Garrotxa and surroundings), the socioeconomic evolution of the area increases the risk from a low or very low one 100 years ago to moderate or high in present times. The following is a map with the localization of the volcanic cones and lava washings in the volcanic area of la Garrotxa, where the impact that those eruptions could cause to the population can be observed (figure 10).



Santa Margarida volcano Photo: Internet.

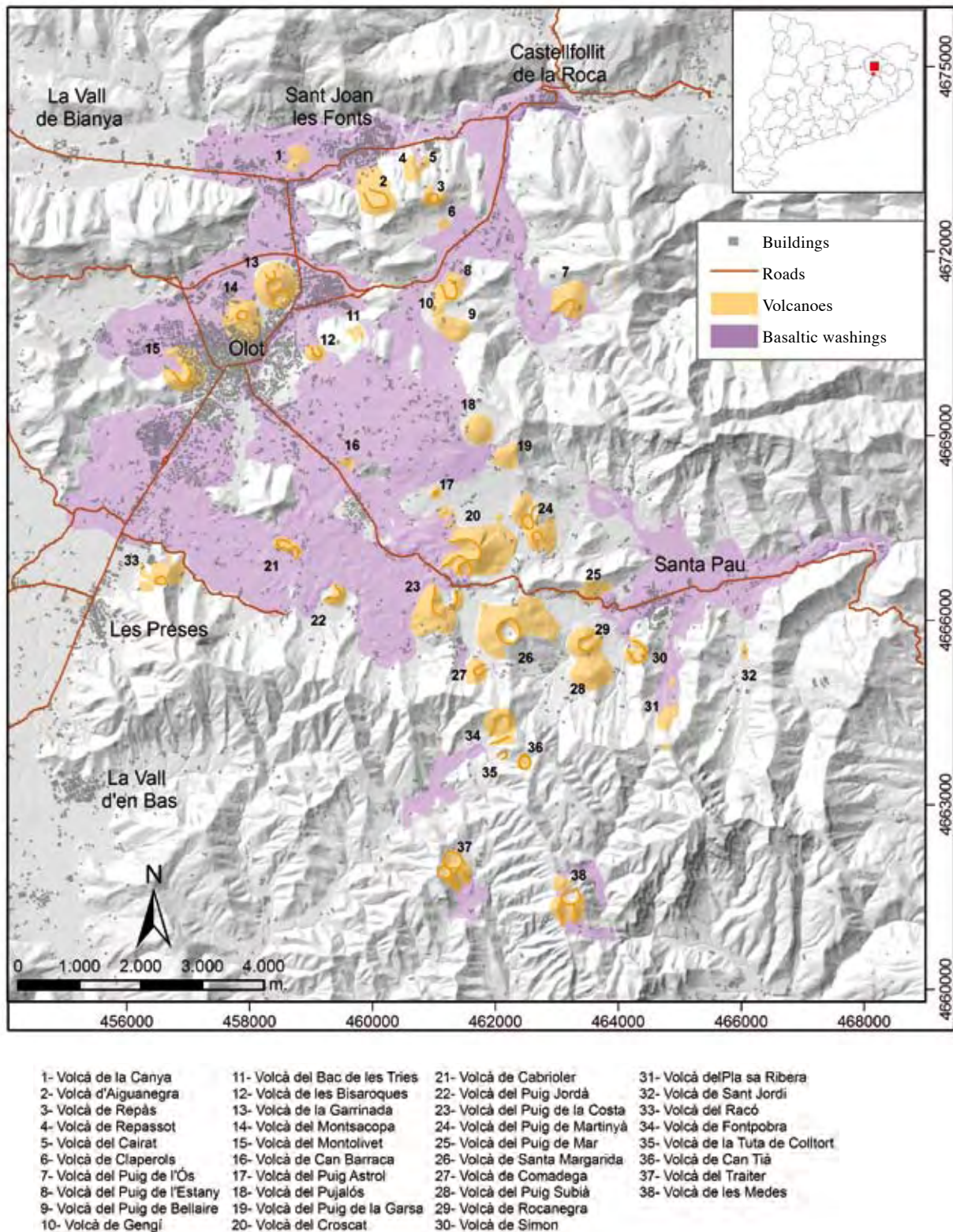


Figure 10. Localization map of volcanoes and lava flows in the volcanic zone of la Garrotxa (IGC2008).

3. Existing material related to the knowledge and management of natural risks

In the current report, with the goal of analyzing and evaluating the status of a number of natural phenomena in Catalonia, we have gathered products and actions made related to the knowledge and management of natural risks considered. All this material is now part of a catalogue in a document database.

Document database

This catalogue has the purpose of being an inventory of all material produced related to the knowledge and management of the natural risks that can be have taken place in the area of Catalonia during the last 30 years. This does not exclude older documents.

The material gathered is very diverse in terms of origin, format (reports, publications, maps, etc.), objectives or applications (academic, scientific, technical, public diffusion). Some of these products have been published, but some are not. Some are of public use, others are of restricted use. In many cases, the authors had to address directly to the sources (authors, organisms, companies), with the complexity and difficulty that this means. In some cases, the organism that generated the product is not –or should not be– the current owner. All material that has been accessed has been gathered.

Certain documents were very hard to obtain, sometimes due to the lack of inventories or systematic internal records and sometimes due to the particular characteristics of the products.

This fact has biased the catalogue in a certain way, has led to a lack of information or has provoked that information had to be grouped in the same record, with no detailed information on the contents, the place or the date of the report or project. This is the case of what has

been catalogued as report groups, where often we could not even detail the total number of reports gathered. All of this caused certain quantitative differences between the materials, distorting reality (see figure 11). For example, the fact that the number of reports collected about floods were half those that could be got about earthquakes is very surprising in a country where floods are much more frequent than earthquakes.

One should consider, however, that it is the first time that an initiative of such a wide scope is carried out in Catalonia and, in spite of the limitations listed above that come from particular situations, the catalogue shown in the report RISKCAT is a very valuable material and can be treated as the embryo of the future database of natural risks in Catalonia.

In this chapter, we want to present briefly the contents of the database but the content of the catalogue is further explained in depth in the expertise reports.

Structure

The information was classified according to the studied phenomena (avalanches, landslides, collapses, coastal phenomena, floods, earthquakes and vulcanism) and –on the other part– according to the legislation about natural risks.

For each of the phenomena, 5 types of records were defined: cartographies, reports, publications, data and projects. Thus, each product has a record that defines it (data, author, keywords, availability, etc.) and the type of information contained can vary according to the type of data. Apart from this, there are normative records that follow different patterns. The catalogue has 36 possible classes with a total of 943 records and 25 MB of information.

	Avalanches	Landslides	Collapses	Floods	Coastal	Earthquakes	Vulcanism	Legislation	TOTALS
Maps	2	4	0	36	3	36	1		81
Reports	39	33	9	67	24	133	0		305
Publications	51	48	18	91	32	111	13		364
Data	3	1	0	12	8	16	0		40
Projects	12	13	0	43	8	30	0		106
TOTALS	107	99	27	249	75	326	14	46	943

Fig 11. Distribution of the document database per phenomenon and record type.

In the following sections, the organization of the records for each typology is explained.

3.1. Avalanches

3.1.1. Reports, studies and constructive projects

- Academic studies (doctoral and degree thesis)
- Technical reports targeted to the proposal of defense measures to diminish the risk of vulnerable elements.
- Technical reports that produce zonifications at a detailed scale.
- Technical inventory reports and documentation of the avalanches occurred in avalanche episodes.
- Intervention Plans for the Preventive Induction of Avalanches (PIDA) in sky stations.
- Studies and constructive projects for protections

3.1.2. Data and databases

- Avalanche Database of Catalonia (BDAC) managed by the Geological Institute of Catalonia
- Data from the Meteorological Snow Stations Network of Catalonia, managed by the Meteorological Service of Catalonia; useful to elaborate the Bulletin of Avalanche Danger (Butlletí del Perill d'Allaus) BPA.
- Snow metrical data (profiles and stability of the snow mantle) useful for the elaboration of the BPA.

3.1.3. Cartography and zonifications

- Map of avalanche zones (MZA) at a 1/25.000 scale (14 sheets).
- Automatic map of avalanches at a 1/100.000 scale.
- Detailed and local maps about the natural danger at a 1/5.000 scale in some municipalities.

3.1.4. Research projects

Research projects have been grouped according to objectives:

- Propose analysis methods of the zones exposed to avalanche danger and/or evaluate the degree of exposure.
- Analyze the record and seismic signal of the avalanches in experimental zones.
- Modelling of avalanche dynamics, their scope or the sectors where wind driven snow accumulates.
- Analyze the role of vegetation and the application of dendrochronological techniques to study the dynamics, frequency and intensity of avalanches.

3.1.5. Publications

From 1986 to 2007, more than 45 scientific papers have been published dealing with the following issues:

- Cartographical techniques for the identification of avalanche exposed zones to develop the MZA.

- Application of sophisticated cartographic techniques to identify avalanche zones (use of empirical and numeric models, use of SIG to identify susceptible zones, use of botanical indicators to characterize avalanche zones, etc.)
- Study of snow transport by wind and associated avalanche danger.
- Analysis of the avalanche seismic signal for avalanche detection and dynamics study.
- Use of dendrochronology as a technique to evaluate avalanche frequencies and avalanche dynamics.
- Presentation to the scientific community of the cartographies and existing databases in the IGC.
- Works and notes presented in the Technical Workshops for Snow and Avalanches (Jornades Tècniques de Neu i Allaus) organized by the IGC.

3.2. Landslides

3.2.1. Technical reports, studies and constructive projects.

- Academic studies (degree and doctoral thesis)
- Emergency assessments by the IGC from warnings by firemen or the Emergency Centre of Catalonia (Centre d'Emergències de Catalunya) CECAT.
- Avalanche auscultation
- Preliminary assessments of danger identification for Plan of Municipal Urban Planning (Plans d'Ordenació Urbanística Municipal) POUMs.
- Zonification studies according to danger at a detail scale.
- Zonification studies according to the danger level at a detail scale. They are studies ordered by municipalities to develop their own POUMs.
- Hydrological corrections in rivers and streams to avoid landslides
- Description reports of the geomorphological effects of heavy rains.
- Constructive projects of protections against landslides
- Technical reports related to landslides.
- Studies related with zonifications and identification or risk areas.

3.2.2. Database

- Database Lliscat.

3.2.3. Cartography and zonifications

- Cartography of geological risks in the mountain counties of Catalonia from 1985 at a 1/50.000 scale.
- County Map of Geological Risk Prevention (Mapa Comarcal de Prevenció de Riscos Geològics) at 1/50.000 scale. Up to 2005, maps of 13 counties were made.
- "Theme cartography of Girona counties"; mapa nº 13 of geological processes at 1/200.000 scale.

3.2.4. Research projects

They have been grouped according to their main objectives:

- Studies of landslide dynamics and proposals of work methodologies with the goal of exposed zones evaluation.
- Analysis of the variations in landslide activity in relation to climate change, past or present.
- Auscultation of landslides to evaluate the influence of the conditioned factors.
- Analysis of the effectiveness of protection systems in front of solid charge in streams and currents with detritus.
- Studies of the effect of woods as a natural barrier in landslides.
- Analysis of the applicability and resolution of new techniques and model use.

3.2.5. Publications

Grouped by the following subjects:

- Analysis of the reactivation of landslides by rain episodes. A large part of these analyses are the result of the monitoring work of the landslide in Vallcebre.
- Analysis of the susceptibility of superficial landslide triggering by means of statistical and numerical methods.
- Analysis of threshold rains that cause superficial landslides and currents with detritus.
- Geomorphological effects and reactivated landslides by the rains of November 1982.
- Use of dendrochronological techniques to analyze the age of landslides and estimate the frequency of events.
- Proposals of methods and techniques to study the dangerousness of landslides.
- Numeric modelling or simulations of the falling of rocky blocks.



51 The large rock landslide in January 2007 in Montserrat (Photo IGC).

3.3. Collapses and subsidence

3.3.1. Studies, reports and technical projects

Report types have been classified as follows:

- Technical studies and reports dealing directly or indirectly with ground subsidence.
- Studies and technical reports that analyze the danger of ground collapse in the Catalan Potassic Basin.
- Technical reports related to the monitoring of ground sinking in the village of Sallent.
- Studies indirectly related to soil piping.
- Preliminary assessments for danger identification for POUMs.

3.3.2. Cartography and zonifications

- County Map of Geological Risk Prevention at 1/50.000 scale.

3.3.3. Research projects

They have been grouped according to their main goals:

- Analyze the reliability and possible improvements of the application of remote sensor techniques to monitor subsidence zones.
- RISCMASS.

3.3.4. Scientific publications

They can be grouped in two types:

- Analysis of the danger of landslides in the area of Banyoles and Besalú.
- Analysis of the application of the methodology of radar interferometry by means of satellite (DinSAR) for the detection of urban zones with subsidence.

3.4. Coastal phenomena

3.4.1. Reports

- Academic studies (degree and doctoral thesis).
- Reports from European projects.
- Technical reports about the evolution of the coastline.
- Technical reports about actions for artificial regeneration of beaches.
- Technical reports about the estimations of extreme wave conditions.

3.4.2. Data

- Wave series
- Marine level
- Tsunami records
- Document base of cartographies and images.
- Historical series of the coastline.

3.4.3. Cartography

- Erosion maps of the coastline.
- Maps of tracks of artificial coast and artificial regeneration of beaches.

3.4.4. Projects

Most of them correspond to current or very recent projects, mostly of European scope, dealing with the following issues:

- Coast erosion
- Historical series of wave patterns and sea level.
- Flood risks in the coastal zone from the perspective of coastal integrated management.

3.4.5. Publications

Basically, they are of scientific content and emphasize the morphological variations of the coast.

- Measure and analysis of the geomorphological and sedimentary dynamics of the coast.
- Evolution of the deltas.
- Storms and floods.
- Impacts on the coast.
- Tsunamis.

3.5. Floods

3.5.1. Reports, studies and technical projects

- Academic studies (degree and doctoral thesis).
- Technical reports. Some are targeted to the proposal of defense measures whilst others are intended to analyze the possibility of building development in exposed zones according to the available cartographies.
- Inventory technical reports and documentation of past floods in rainy episodes.
- Constructive studies and physical models to assess the dimensions and execute measures of structural defense.

3.5.2. Data and databases

- Meteorological data.
- Hydrological data.
- Database of critical points.

3.5.3. Cartography

- River Spaces Plan (Pla d'Espais Fluvials) PEF
- INUNCAT Plan, 1:50.000.

3.5.4. Research and administrative projects

- Delimitation of flooding zones.
- Public information and awareness
- Application of methodologies and techniques for meteorological forecast and meteorological analysis.
- Constructive and hydrological correction projects.

3.5.5. Publications

- Particular flooding episodes.
- Cartographic techniques for identification of exposed zones or zones affected by floods.
- Analysis of the general phenomenon of floods.

- Manuals, technical recommendations.
- Hydraulic works and hydrological restoration.
- Forecasting and emergency management.
- Works of scientific-methodology content.

3.6. Earthquakes

3.6.1. Reports

They can be grouped in different subjects:

- Seismic activity in Catalonia.
- Seismic zonation and microzonation.
- Active tectonics.
- Paleoseismology.
- Instrumentation and surveillance.
- SISMICAT Plan.

3.6.2. Data and databases

- Updated information about localization.
- Characteristics of instrumentation and seismic record.
- Historical seismic catalogues.
- Instrumental seismic catalogues.
- Monthly seismologic bulletins.
- Annual seismologic bulletins.

3.6.3. Cartography

- Seismic activity maps.
- Seismogenic zonation maps.
- Seismic zonation maps.
- Seismic danger maps.
- Seismic vulnerability and risk maps.
- Seismoresistant normative maps.
- Maps of seismic intensity distribution for individual earthquakes.
- Soil geotechnical characterization maps.

3.6.4. Projects

In general, they are of very diverse subjects. They can be grouped in different issues:

- Historical seismicity.
- Active tectonics.
- Paleoseismology.
- Earthquakes and tsunamis.
- Vulnerability analysis.
- Earthquake risk.

3.6.5. Publications

There are many publications and cover very diverse issues. Publications can be grouped in the following subject areas:

- Historical seismicity (catalogues, case analysis,).
- Seismic zonation and microzonation.
- Danger analysis.
- Vulnerability analysis.
- Seismic risk.
- Scenario simulation.

- Seismic engineering.
- SISMICAT Plan.
- Active tectonics.
- Paleoseismology.

3.7. Vulcanism

As far as vulcanism is concerned in Catalonia there is only cartographic material and publications

3.7.1. Cartography

- Vulcanism in la Garrotxa at 1:25.000.

3.7.2. Publications

- Petrology and vulcanic petrogenesis
- Geochemistry.
- Vulcanology.
- Geophysics.
- Public awareness.

3.8. Legislation

The collection of legal subjects related with natural risks in this report has been structured independently and following different criteria. The collection of information has been carried out taking into account the following premises:

- Typology of the product: law, decree, order, norm, directive, etc.
- Territorial scope of application: international, national, autonomous scope, etc.
- Subject scope: planning, management, execution, avalanches, earthquakes, etc.
- Place of publication: DOCE, DOGC, BOE, etc.
- Application to risk management: direct or indirect.

Each product has a corresponding record that collects all the characteristics mentioned here and some additional information are also included, summarizing in many cases the essential points of the inventoried normative.

46 records have been collected, including directives, laws, norms, decrees, sentences, legal texts and treaties.

4. Evaluation of the current status of risk knowledge and management

In this chapter, we take as a start point the evaluations that have been done about the current state of the knowledge and management of natural risks in Catalonia in the expertise reports.

The materials compiled in the document catalogue show the existence of a series of scientific and technical products, as well as a group of technical actions in the field of prevention and mitigation related with the natural risks that the report deals with. Their analysis and eva-

luation allows us to detect a series of strong points (and opportunities) and weak points (and challenges) that are collected in the present chapter; these will be the base for the recommendations contained in chapter 5 of this report. Strong points are based on products or actions that exist, that are consistent, need to be supported and, in many cases, mean an opportunity to improve our knowledge or management. Weak points indicate mainly a lack of information on knowledge and management.



Effects of the easterly sea storm in 2003 on the seafront avenue of Torredembarra. (Photo J. Guillén).

4.1. Avalanches

Strengths and opportunities Scientific and technical knowledge	Weaknesses and threats Scientific and technical knowledge
<p>The IGC has the competence in the evaluation of avalanche danger, risk and prevention.</p>	
<p>The IGC and the General Counsel of Aran CGA inventory and document avalanches systematically.</p>	<p>No quantification of damages, economic and cultural losses, etc.</p>
<p>Organisms and institutions of the Generalitat and other administrations carry out technical studies and projects dealing with avalanches.</p>	<p>No official technical guides that ensure and standardize work quality.</p>
<p>Avalanche Zone Map (MZA) at 1:25.000 scale (14 sheets).</p>	<p>No cartography about danger, vulnerability and risk at detail scales that give priority to urban developed and potentially developing areas.</p>
<p>Avalanche Database of Catalonia (BDAC), available in the web of the IGC. Good scientific and technical knowledge.</p>	
	<p>No in depth studies about the influence of climate change and the gravity and frequency of avalanches.</p>

Strengths and opportunities Risk management and mitigation	Weaknesses and threats Risk management and mitigation
<p>Since 2006 there exists a specific General Direction of Civil Protection.</p>	
<p>The Snow Emergencies Special Plan of Catalonia NEUCAT is an opportunity to include avalanche emergencies.</p>	<p>The NEUCAT Plan does not consider avalanches.</p> <p>An inventory of the critical points for avalanches is needed, in order to consider them in PAMs</p>
<p>The Urban Planning Law considers avalanches in POUMs.</p>	<p>A regulatory zonification of dangerous zones is needed.</p>
<p>The PIDA in some sky stations in winter.</p>	<p>A normative regulating the implementation of the PIDAs in all winter sky stations is needed.</p>
<p>The release of the highly used BPA.</p>	<p>No systematic validation of the bulletin results.</p>
<p>Experience in local predictions in some roads (case of the CGA in C-28 and C-142b).</p>	<p>There are critical points in roads and isolated buildings that do not have a local prediction.</p>
<p>Different organisms and institutions in the Generalitat install antiavalanche defense systems.</p>	<p>No coordinated action plan. No definition of residual risk.</p>
<p>The Law of Woods considers the qualification of protection woods as natural elements to reduce avalanche risk.</p>	<p>No systematic management of protection woods.</p>
<p>The issue of avalanche risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>
<p>Creation of the Association for the Knowledge of Snow and Avalanches (ACNA), that promotes the knowledge of avalanche risks.</p>	

4.2. Landslides

Strengths and opportunities Scientific and technical knowledge	Weaknesses and threats Scientific and technical knowledge
The ICG has the competence in the evaluation of landslide danger, risk and prevention.	
Cartographies of landslide danger at the county level 1:50.000	Restricted use. Partial cover of the territory.
Map of Geological Risk Prevention of Catalonia MPRGC 1:25.000. In starting.	Too long term project (2007 – 2019).
Some episodes are well documented.	No systematic documentation of episodes with collection of damage quantities and economic and sociocultural losses, etc.
LLISCAT Project (UPC-IEC), database in progress of collection.	
The General Direction of Roads has started and inventory of points affected by slope instability.	
Good scientific and technical knowledge.	No knowledge transfer to technical studies, projects and maps developed by the administrations.

Strengths and opportunities Risk management and mitigation	Weaknesses and threats Risk management and mitigation
<p>Since 2006 there exists a specific General Direction of Civil Protection.</p>	
<p>The INUNCAT plan considers landslides within the area of danger analysis.</p>	<p>Not all emergencies related to landslides get recorded in INUNCAT.</p> <p>No inventory of critical points with landslides that can be considered in the PAMs.</p>
<p>The urban planning legislation considers the geologic risks in the POUMs.</p>	<p>The scale of the MPRGC does not allow for a regulatory zonification of the danger that applies to POUMs or risk studies in the projects of public works.</p>
<p>Different administrations implement protections and take management actions.</p>	<p>No coordinated action plan.</p> <p>No official technical guides that ensure and standardize the technical quality of works.</p>
<p>The issue of landslide risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>

4.3. Collapses and subsidence

Strengths and opportunities Scientific and technical knowledge	Weaknesses and threats Scientific and technical knowledge
<p>The ICG has the competence in the evaluation of landslide danger, risk and prevention.</p>	
<p>There are some cartographies of collapse danger at the county level at 1:50.000 scale.</p>	<p>Restricted use. Partial cover of the territory.</p>
<p>MPRGC 1:25.000. In starting.</p>	<p>Too long term project (2007 – 2019).</p>
<p>Some episodes are well documented.</p>	<p>No systematic documentation of episodes with damage quantification and economic and sociocultural losses.</p>
<p>Several local administrations in the metropolitan area of Barcelona, order studies to minimize the risk of subsidences in new civil works.</p>	<p>No official technical guides that ensure and standardize the quality of works.</p>
<p>Good scientific and technical knowledge about methods of danger cartography and follow up of ground vertical movements.</p>	<p>Investigation targeted to analyze the dangerousness and risk is needed in order to use it in technical studies and zonifications.</p>

Strengths and opportunities Risk management and mitigation	Weaknesses and threats Risk management and mitigation
<p>Since 2006 there exists a specific General Direction of Civil Protection.</p>	
<p>Local emergency plan in Sallent</p>	<p>No emergency special plan that considers collapses.</p>
<p>The urban planning legislation takes into account geologic risks (collapses) in the POUM.</p>	<p>The scale of the MPRGC does not allow for a regulatory zonification of the danger that applies to POUMs or risk studies in the projects of public works.</p>
<p>The issue of collapse risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>

4.4. Coastal phenomena

Strengths and opportunities Scientific and technical knowledge	Weaknesses and threats Scientific and technical knowledge
<p>There exist different workgroups with knowledge and attributions.</p>	<p>It is difficult to have access to some information and it is sparse.</p> <p>Lack of cartography about coastal risks (erosion and flooding) with the appropriate accuracy.</p> <p>No systematic control of the evolution of the coastline and batimetry measures.</p>
<p>Acceptable hydrodynamic data monitoring and submarine seismograph.</p> <p>Some episodes are well documented.</p>	<p>Heterogeneity of formats and frequencies.</p> <p>No historical impact inventory of large storms, floods and tsunamis in the Catalan coast.</p> <p>Lack of quantified information about damages and economic and sociocultural losses.</p>
<p>Two projects in progress (Director Plan for the Sustainability of the Coast and State of the Coastal Zone in Catalonia) take into account the integration of coastal data and a definition of coastal risks.</p>	
<p>There are data to evaluate dangerousness in the short and medium term.</p>	<p>No data on vulnerability.</p>

Strengths and opportunities Risk management and mitigation	Weaknesses and threats Risk management and mitigation
<p>Since 2006 there exists a specific General Direction of Civil Protection.</p>	
<p>The INUNCAT plan mentions issues related to coastal risks.</p>	<p>No emergency special plan that considers the mentioned coastal phenomena.</p>
<p>Many administrations are involved in coast management and there are a number of initiatives.</p>	<p>Fragmentation of responsibilities and difficulties of coordination between organisms and parts involved.</p>
<p>The legal framework allows (and enforces in some cases) for action orientated to protection, prevention and sustainability.</p>	<p>The Catalan coast shows a growing trend of urban development and the possibilities of intervention in the territory are limited.</p> <p>There is a lack of transparent and sustainable criteria in decision taking in front of erosion.</p>
<p>Actions in the coast to fix definite problems.</p>	<p>No prevention measures in the short and medium term.</p>
<p>Measures of direct protection (dikes, piers, breakwaters, artificial generation).</p>	<p>No evaluation of environmental impact (moving the problem to other areas).</p>
<p>Continuous artificial regeneration of beaches.</p>	<p>No evaluation of environmental impact (sand extraction from the marine environment).</p>
<p>The strategies for the adaptation to climate change in the coastal zone must be an excellent opportunity to introduce the concepts of risks associated to erosion and flooding in the management plans.</p>	<p>The “risk” criterion is not taken into consideration in many actions.</p>
<p>The issue of coastal risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>

4.5. Floods

Strengths and opportunities Scientific and technical knowledge	Weaknesses and threats Scientific and technical knowledge
The Catalan Water Agency (ACA) has the competences in the determination and management of flooding zones.	
Cartography of flooding zones INUNCAT (hydraulic) 1:50.000	No integration of the hydraulic, hydrologic, geomorphologic and historical methodologies.
Cartography of potentially flooding zones INUNCAT (geomorphologic) 1:50.000	
Cartography of the River Areas Planning PEF (Planificació d'Espais Fluvials) 1:5.000	Territory cover still partial.
Existence of technical guides to evaluate flooding in river courses.	Lack of technical guides to evaluate floods in streams, alluvial fans or cones and urban floods.
Some episodes are well documented.	Lack of systematic and quantified collection of information on damages, and sociocultural and economical losses.
Good network of hydrometeorological measures and data collection.	
Good scientific and technical knowledge.	Lack of knowledge transfer between organisms. Lack of knowledge in the behaviour of flows with sediment transport. Lack of in depth studies about the influence of climate change in the gravity and frequency of floods. Lack of knowledge of vulnerability.

Strengths and opportunities Risk management and mitigation	Weaknesses and threats Risk management and mitigation
<p>Since 2006 there exists a specific General Direction of Civil Protection.</p>	
<p>The INUNCAT plan (2005) is a good management tool.</p>	<p>INUNCAT has not developed enough the phases of prevention and preparation.</p>
<p>There is a database of critical points of NUN-CAT.</p>	
<p>INUNCAT enforces the development of flood emergency plans for 488 municipalities (PAMS).</p>	<p>Only 20% have developed it.</p>
<p>The PEF are a good and necessary management tool.</p>	<p>No PEF in most of the exposed territory.</p>
<p>Several administrations and organisms carry out management actions.</p>	<p>No coordination between organisms.</p>
<p>The law or urban planning considers the risk of floods.</p>	<p>The law has some technical flaws. Exceptions can invalidate the normative.</p>
<p>The insurance policy in our country is of solidarity character and covers flood damages.</p>	<p>The insurance policy in our country generates a lack of risk perception.</p>
<p>The issue of flood risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>

4.6. Earthquakes

Strengths and opportunities Scientific and technical knowledge	Weaknesses and threats Scientific and technical knowledge
The IGC has the competence in danger evaluation, risk evaluation and prevention of earthquakes.	
There is a historical macroseismic catalogue updated until 1996.	No basic cartography at the regional level and detailed enough about the dangers of indirect earthquake effects (liquefaction, landslides, etc.)
There is an instrumental catalogue with a permanent network of seismic stations since 1986.	
There is a unified seismic catalogue of earthquakes greater than or equal to magnitude 3.0 for the period 588 – 2003.	More detailed information is needed about the effect of the most recent earthquakes with a quantified evaluation of damages and economic losses.
Earthquake activity is monitored and surveyed continuously by means of a seismic network.	The system must be more robust and with a redundant infrastructure to guarantee its operation in case of disaster.
A network of permanent accelerometers is available.	Reduced number of permanent accelerometers and heterogeneity both in their instrumentation and distribution.
There exists a permanent ocean bottom seismometer (OBS).	There is a lack of specific studies about earthquakes and seismic danger with marine epicentre.
There are some studies about paleoseismicity of some active divides in Catalonia.	
Good scientific and technical knowledge.	

Strengths and opportunities Risk management and mitigation	Weaknesses and threats Risk management and mitigation
<p>Since 2006 there is a specific general direction of civil protection.</p> <p>There is a permanent information system about the earthquakes that can affect population in Catalonia.</p>	<p>There is no critical definition of priorities in the evaluation and prevention studies on the side of the organisms involved in risk management.</p>
<p>There is a homologated Seismic Emergency Special Plan of Catalonia (SISMICAT).</p>	<p>Vulnerability and risk need to be updated, since they are based on 1990 data (building census) and 1996 (population census).</p>
<p>The municipalities in which a PAM is required (439 of 946) or recommended (480 of 946) have been identified.</p>	<p>There are only 27 municipalities with homologated PAM from the 439 that should have it.</p>
<p>There is the Seismoresistant Construction Norm, which applies to all Spain since 1962, updated in October 2002 (NCSE-02).</p> <p>There is a proposal to develop a reference normative for the design of seismoresistant structures (Eurocode 8) on the side of the European Committee for Standardization to unify criteria and norms at the European Union level.</p>	<p>There is no regularity in the update process of the normative of seismoresistant construction.</p> <p>The seismoresistant norm does not include a specific regulation or even recommendations for the consolidation of buildings and structures before the norm or built under lower restrictions than those active today.</p> <p>The seismoresistant construction norm does not cover a specific regulation or recommendations to protect monuments or buildings of historical heritage from earthquakes.</p> <p>The process to obtain updated information about dangerousness and risk is too slow.</p> <p>Few information is available for citizens in institutional Internet sites (Generalitat, municipalities) about earthquake risk.</p>
<p>The issue of earthquake risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>

4.7. Vulcanism

Strengths and opportunities	Weaknesses and threats
<p>The IGC has the competence in the evaluation of volcanic danger, risk and prevention.</p>	
<p>There is specific general direction of civil protection since 2006</p>	<p>There is no prevention or mitigation action of volcanic risk.</p>
<p>There is a potential of investigators on vulcanology in the country.</p>	<p>Lack of investigation about recent vulcanism.</p> <p>No numeric datings of volcanic eruptions in la Garrotxa.</p> <p>There is no current project to study volcanic danger, vulnerability and risk.</p>
<p>The issue of vulcanism risks is dealt with in ESO and it is a subject in one of the modalities in high school (batxillerat).</p>	<p>No implementation of the knowledge in the nearby geographical environment and no training on self-protection for the population.</p>
<p>Public information and documentation in the Volcanic Zone Natural Park of la Garrotxa.</p>	

5. Recommendations for a sustainable management of risks

This chapter proposes the main recommendations (classified according to the phenomena under study) that come to mind after considering the strengths and weaknesses collected in chapter 4. The recommendations are targeted to manage natural risks thinking in environment and social sustainability criteria. This means considering the following: minimizing and controlling exposed population, as well as their goods and infrastructures and finding the best relation of costs/benefits in the measures to mitigate the impact on the environment.

For each subject, the recommendations are grouped in two sets: those that must allow for a better scientific and technical knowledge of the phenomenon and those related to the improvement in management of that particular risk. In the bloc of risk management, prevention and protection actions

5.1. Avalanches

A Strategic Plan for Avalanche Risk Management in Catalonia is proposed, suggesting the integration of strategies that should lead to the improvement of knowledge, prevention and mitigation of avalanche risk.

5.1.1. Scientific and technical knowledge

- Integrate the Avalanche Data Base (BDA) and the Maps of Avalanche Zones (MZA) into the Geologic, Edaphologic and Geothematic Information System of Catalonia (SIDEG) of the IGC.
- Design a program for risk follow up consisting of the following:
 - Documentation of avalanche events.
 - Annual reports about the social and economic impact of avalanches.
 - Inventory of sectors with avalanche risk (critical spots).

5.1.2. Avalanche risk management

- Implementation of regulatory actions that lead to the following:
 - regulate the zonification of avalanche danger
 - regulate technical studies
 - regulate the PIDA
- Produce maps of danger zonification and regulatory zonification at a detail scale (1:2.000) for the POUMs.
- Produce maps of danger zonification and regulatory zonification at a detail scale (1:5.000) for the execution of infrastructures.
- Implement measures of structural defense in a planned and coordinated way between the different organisms and entities involved.



Impact of an avalanche on a building during the episode of February 1996 in the high Ter valley. (Photo Hostal Pastuira courtesy of the I'IGC).

- Develop a good management policy of protection woods.
- Publish the BPA, improving it and with systematic verification.
- Carry out local predictions of avalanche danger in high risk situations according to the inventory of critical spots.
- Integrate avalanche risk in the NEUCAT Plan, taking it into account in the design of the PAMs for mountain counties.
- Undertake public awareness actions of avalanche risks based on education and information.

5.2. Landslides

A Strategic Plan for Landslide Risk Management in Catalonia is proposed, integrating strategies for the improvement of risk knowledge, management and mitigation.

5.2.1. Scientific and technical knowledge

- Creation of a landslide database that will have to be integrated in the future SIDEG of the IGC.
- Creation of the maps with the landslide danger zones that will have to be integrated in the future SIDEG of the IGC.
- Design a program of risk follow up that should include the following:
 - Documentation of landslide events.
 - Annual reports on the social and economic impact of landslides.
 - Inventory of the sectors with landslide risk (critical spots).

5.2.2. Risk management

- Implementation of regulatory actions that lead to the following:
 - regulate the zonification of landslide danger
 - regulate technical studies



Damages to the road N-II in Esparreguera during the rain of June 2000. (Photo M.A. Marquès)

- Produce maps of danger zonification and regulatory zonification at a detail scale (1:2.000) for the POUMs.
- Produce maps of danger zonification and regulatory zonification at a detail scale (1:5.000) for the execution of infrastructures.
- Implement measures of structural defense in a planned and coordinated way between the different organisms and entities involved.
- Evaluate the need and viability of an emergency plan intended specifically for landslides.
- Undertake public awareness actions of landslide risks based on education and information.

5.3. Land collapses and subsidence

A Strategic Plan for Land Collapses Risk Management in Catalonia is proposed, integrating strategies for the improvement of risk knowledge, prevention and mitigation.

5.3.1. Scientific and technical knowledge

- Creation of a land collapse database that will have to be integrated in the future SIDEG of the IGC.
- Creation of the maps with the land collapse danger zones that will have to be integrated in the future SIDEG of the IGC.
- Design a program of risk follow up that should include the following:
 - Documentation of land collapse and subsidence events.
 - Annual reports on the social and economic impact of land collapses and subsidences.
 - Inventory of the sectors with land collapse and subsidence risk (critical spots).

5.3.2. Risk management

- Implementation of regulatory actions that lead to the following:
 - regulate the zonification of land collapse danger
 - regulate technical studies
- Produce maps of danger zonification and regulatory zonification at a detail scale (1:2.000) for the POUMs.
- Produce maps of danger zonification and regulatory zonification at a detail scale (1:5.000) for the execution of infrastructures.
- Implement measures of surveillance and instrumental monitoring.
- Regulation of the activities that can increment the risk of land collapse and subsidence.
- Evaluate the need and viability of an emergency plan intended specifically for land collapses.

- Undertake public awareness actions of landslide risks based on education and information.

5.4. Coastal phenomena

An overview of natural risk due to the impact of coastal phenomena in the Catalan coast shows a very complex picture. The knowledge is found in very sparse sources, there are many administrations involved in its management and there have been very diverse actions. The Catalan coast has a very high degree of urban sprawl –with a growing trend- and the possibilities of intervention in the territory are limited.

The following recommendations are suggested:

5.4.1. Scientific and technical knowledge

- Creation of maps at a detail scale (1:5.000) for the whole Catalan coast that integrates erosion and flood risk. These documents will be the base for risk estimation in a scenario of climate change and a key element for the management of the coast.
- Systematic collection of data after storms with the objective of evaluating their impact and feed the risk analysis system with real data.
- Increase the collection of hydrodynamic and geomorphological data, by means of increasing both in frequency and number of observatories.
- Grouping of all data and documents about coastal phenomena in one single and public information system.

- Support and promote basic and applied research to improve the following:
 - The knowledge about the response of the coast and its infrastructures to the natural processes.
 - The procedures to evaluate the risk associated to coastal phenomena.
 - The modelling of coastal phenomena.
 - The study of alternatives for the protection of the coastal zone.

5.4.2. Risk management

- Promote those initiatives that allow an integrated and sustainable management of coastal zones and provide means of communication between the existing working groups, the administration and those in charge of risk management at all levels.
- Specialists from different fields must be provided with an environment that allows knowledge transfer in order to generate synergies and that the tasks in progress contribute directly to the management of risk in the coast. Promote working groups and specialist information networks.
- Implement action protocols in front of coastal phenomena, improving prevention in the medium and long term:
 - Erosion: it is necessary to establish clear action criteria and deepen in the optimization of sand resources, particularly in the transport from accretion zones to erosion zones.
 - Flooding: action protocols must be defined in front of events of long return periods (500 years or mo-



Barceloneta beach during an easterly sea storm in 2004. (Photo J. Guillén)

re) both from the point of view of structures design, early alert systems and action coordination during and after the event. These protocols must be integrated in the plans for civil protection (improvement of INUNCAT) in floods resulting from sea storms or floods in the coast resulting from the combined effects of heavy rains and river overflows.

- Promoting the acquisition by the Administration of specially sensitive land tracks in order to set natural protection land strips.
- Reduce mortal accidents associated to storms. The updated information targeted to beach users in the most affected beaches, explaining previous accidents and the processes that provoke them (waves, currents), would have a discouraging effect of bad practices.
- Undertake public awareness actions to explain the risks of coastal phenomena, based on public education and information.

5.5. Floods

In the area of floods we find that there is an elaborated plan and a lot of work done, that's why our recommendations refer mainly to point actions o specific improvements about what is being done or what has been done.

The following recommendations are suggested:

5.5.1. Scientific and technical knowledge

- Systematic collection of data after storms in order to evaluate their impact and be able to feed the risk analysis system with real data.
- Promote the work with models and real scenario simulations that allow us to evaluate the level of damages to exposed elements and increase our knowledge on danger and vulnerability.
- Promote the work with integrated methodologies that incorporate historical, geomorphologic, hydraulic and hydrologic analysis.
- Introduce improvements in the estimation of the intensity of phenomena, alert thresholds and return periods.

5.5.2. Risk management

- Promote those initiatives that allow a comprehensive treatment of flood problems and facilitate the communication between existing working teams, the Administration and those responsible of risk management at all levels.
- It is necessary that the specialists are provided with an environment that allows knowledge transfer to generate synergies and that the tasks have a direct incidence in flood risk management. Promote working teams and specialist networks.

- Convert PEF maps in zonification of regulatory danger, accelerate their production and edition and give priority to those municipalities with sectors of most vulnerability to use them in urban planning.
- Promote the creation of maps that identify damage zones, where zones with their degree of flooding risk is described, including the risk of environment contamination as a consequence of flooding.
- We must be aware of the initiatives developed in our neighbour countries with more experience. In particular, we propose to consider the model of the French PPR (Plans de Prévention aux Risques).
- Production of technical guides to characterize the danger of torrential dynamics, alluvial cones or fans, currents with detritus and urban flooding and include those in the regulatory body and in the management of the phenomenon.
- It is necessary an INUNCAT update that adds the detail maps (PEF) and the review of the inventory of critical spots.
- Promote, facilitate and suggest a schedule for the immediate carrying out of the PAMs in all municipalities that must have it as compulsory.
- Maintain the natural conditions in river spaces (alluvial plains) or allow for their restore with the maximum surface and width, both for the effects of lamination and the benefits of the ecosystems.
- Manage the natural risk from a comprehensive view at basin level (integrated in the PAMs) where prevention, protection, reaction and preparation are considered. Consequently, it is necessary an absolute synergy between Civil Protection, the Environment Department (ACA) and the Territorial Policy Department (IGC).
- Undertake public awareness actions of flooding risks based on education and information

5.6. Earthquakes

5.6.1. Scientific and technical knowledge

- Reinforce the system for earthquake emergency detection (seismic network), both in instrumentation (accelerometers) and in measures targeted to guarantee a basic action in front of any event, originated by the emergency itself of by external factors.
- Develop specific studies about earthquake activity with marine epicenter that can affect Catalonia and its potential in the determination of seismic danger.
- Evaluate the influence of the population and building census update carried out by the INE in 2001 within the SISMICAT, taking advantage of its biannual update and, in any case, before the validity term of the current version (2008).

- Carry out the basic cartography at a regional and detail level, of the danger of indirect earthquake effects (for example, liquefaction and landslides).
- Investigate in more detail the effects of the most recent earthquakes with damages and include the quantitative estimation of losses.
- Incorporate the most recent knowledge in the map of earthquake danger that accompanies the regulation of seismic resistant construction, according the standards from other countries in the European Union (for example, Italy) and as a preparation for the Eurocode 8, scheduled to come into effect in 2010.
- Critical evaluation of the methodology used for the elaboration of earthquake zones included in SISMICAT, comparing it with the practice in other European countries and with special attention to the criteria considered to define the factors of amplification according to soil type.
- Critical evaluation of the available methods for estimating earthquake vulnerability and risk at a regional and urban scale, comparing them with those of other European countries and with the current maps of SISMICAT.
- Carry out a critical analysis of the probability levels (return periods) that are most appropriate in the determination of the earthquake danger both for common structures (buildings) and structures of special importance (for example, hospitals, fire stations, dams, etc.) or vital lines or, alternatively, proceed to the application of increment factors in seismic classification.

5.6.2. Risk management

- Promote the development of municipal action plans for earthquake emergencies, especially in those municipalities with compulsory development as defined in SISMICAT that have not yet elaborated them or haven't had them homologated.
- Develop effective actions targeted to improve knowledge transfer about earthquake danger and risk between the scientific and technical organisms responsible of risk management and potential users.
- Propose priorities and implement regular financial sources for specific studies related with the evaluation and prevention of earthquake risk.
- Evaluate the importance of including in the Regulation for Earthquake Resistant Construction a specific regulation or recommendations for the reinforcement of buildings and structures built prior to the existence of specific regulations or built under regulation with lower requirements than those in effect today.
- Consider a specific regulation or recommendation to reinforce monuments or buildings of historical heritage.
- Regulate the update process of the Regulation for Earthquake Resistant Construction.

- Include appropriate information about the areas with seismic risk in institutional web sites (Generalitat, local councils).
- Evaluate the interest of public access to all contents of SISMICAT, including the public information (for example, in municipal web sites) about the content of the homologated PAM-SISMICAT.

5.7. Vulcanism

The perception of volcano risk is non-existent in the population as a result of the lack of events in historical records. The high return period of an eruption makes that the estimated danger of the volcanic phenomenon in Catalonia is relatively low, but this does not allow us to affirm that the probability of an eruption is zero. In spite of the probability being low, the structural and social vulnerability of the territory exposed to damages is high. Consequently, the risk needs to be considered.

It should be taken into account that volcanic activity can be forecast and the measures to undertake must be mainly preventive rather than reactive. This is the reason why we believe absolutely necessary to consider volcanic risk in the territorial planning of the zones and very especially in areas close to the focuses of probable volcanic activity.

A design of a program for volcanic risk prevention in Catalonia is recommended, incorporating the following:

- Mechanism to improve the basic knowledge and eruptive dynamics, as well as vulcanism age.
- Evaluation of the danger of volcanic eruption in la Garrotxa and close areas.
- Evaluation of different vulnerability scenarios related mainly to large infrastructures, such as airport, vital lines, transportation network, large industrial complexes, hospitals and other sensitive buildings.
- Setting of a surveillance and geophysical monitoring plan (seismic, gravimetric and magnetic).
- Implementation of a systematic information and educational program about volcanic risk, taking advantage of the potential of the Volcanic Zone Natural Park of la Garrotxa.
- Develop a Volcanic Emergency Special Plan fed with the above actions in order to face a hypothetical volcanic crisis.

6. Natural risk legislation in Catalonia: evaluation and proposals

The whole set of regulations collected in the document catalogue has been analyzed and evaluated in the expertise report with a comprehensive revision of the legal situation, regulation and planning of natural risks in Catalonia.

In this chapter a summary is shown but it contains only some –we think that those that are more relevant- of the many considerations that are made in the extensive Legal Report. Thus, here the final considerations are shown as a conclusion, as well as a set of proposals intended to improve natural risk management and reduction.

6.1. Final conclusions

The conclusions or recommendations introduced below take into account the following aspects in the regulation of natural risks: current state in matters of legislation, normative, administration, planning, management and prevention.

General

1. Catalonia has a legislation that, in general terms, contains an appropriate regulation of natural risks.
2. This regulation includes multiple dispositions, sparse in numerous laws and regulations that cover many sectorial aspects that have influence in the subject (civil protection, urban planning, water, forests, territory planning, environmental evaluation, etc.)
3. A comprehensive and complex planning system is available but it is made of a great diversity of plans and planning tools of different nature (civil protection plans, territory planning, urban development plans, hydrological planning, etc.)
4. There are several public organisms and different departments in the Generalitat de Catalunya affected by the issue of natural risks, having sectorial and concurrent competences on the same areas (the Department of Territorial Policy and Civil Works with the Geological Institute of Catalonia and the Cartographic Institute of Catalonia, the Department of Environment and Housing with the Catalan Water Agency and the Meteorological Service of Catalonia, the General Direction of Civil Protection, among others).

5. The coordinated action of all these public organisms and departments would optimize the prevention policy of natural risks in Catalonia and speed the integration of the regulatory zonifications of natural risks in urban and territory planning.

Risk and territory

6. The prevention in the issue of natural risks must be a priority of the Catalan Government and territory planning must be an essential element to achieve this goal.
 7. A remarkable progress has been recently made in Catalonia in the attempt to fit urban planning in the prevention of natural risks (promulgation of the Urbanism Law and Urbanism Regulations, approval of the Law of Geographical Information, elaboration of hydrological planning, the Law of the Geological Institute of Catalonia, etc.).
 8. Guarantee the urgent incorporation to urban planning of the regulatory zonification of natural risks with a regime of soil use restrictions adequate to its nature, degree of danger and vulnerability of the territory. On the other hand, the immediate availability of official maps in the matter of delimitation and zonification of the territory exposed to natural risks must be guaranteed.
 9. The pace of urban planning approval in Catalonia and the redaction, elaboration and approval of official cartography is not coordinated adequately in the issue of natural risks.
- #### Specific
10. In Catalonia, the regulatory zonification of the territory affected or exposed to natural risks is not, as of today, complete nor it is regulated in all risks.
 11. The risk map scales that have been elaborated for civil protection (sales 1:50.000 or 1:25.000) are neither compatible nor appropriate to allow their direct incorporation in the urban planning and ordination system of the territory, which use maps at scales of 1:1.000, 1:2.000, 1:5.000 and 1:10.000

6.2. Proposals for action

For the development and implementation of the set of conclusions and recommendations collected in the legal report, the following action proposals are suggested. They have been classified in three groups: legislation, administrative organization and management.

6.2.1. Legislation and normative proposals

General

1. Incorporate within the attribution of functions of the **Directorate of Civil Protection** in the Article 13 of the **Decree 479/2006 of 5 December**, the faculty to inform urban and territory planning processes, establishing the binding character of the report made by the competent organism in the matter of civil protection, as related to urban and territory planning.

2. The promulgation of a holistic and specific norm that regulates the natural risks in Catalonia from an integral point of view could be an adequate instrument to facilitate the best knowledge, information, the taking of a step forward and the application, by the whole set of public administrations in Catalonia and society, of the prevention in the issue of natural risks.

Risk and territory

3. Incorporate in the **urban legislation**, in the regulation of the compulsory technical documentation in the POUMs (Plan of Municipal Urban Planning) and within the information maps, the one relative to the delimitation of the natural risk zones in the municipality, at a 1:2.000 scale. This map must be elaborated including the risk zonifications derived from the hydrological planning, civil protection planning, and territory planning available and, if not available, by means of the realization of flooding studies and geological studies. Guarantee the incorporation in the POUM map that defines soil classification, the areas under threat of natural risks with the qualification of non urban soil. Incorporate the requisites mentioned above in the article 59 of the Legislative Decree 1/2005 of 26 July and partially amend the text in article 79 of the Urbanism Regulation to intensify the regime of guarantees.

4. Review the contents of **article 5 of the Urbanism Regulation** which in the regulation of the preservation directive in front of natural risks has incorporated exceptions to the general banning of building and urbanizing in areas under threat of natural risks set in article 9 of the Law. And, with that purpose, remove the requirement of “total incompatibility” set in the regulation and also eliminate or limit the scope of the exceptions that foresee the possibility of urban development and building in those risky areas in the assumption of works linked to risk prevention and protection.

5. Review the **Law 23/83 of 21 November of Territorial Policy of Catalonia** to incorporate the perspective of natural risks as elements of general and supralocal interest to take into account in the elaboration and approval

of territory planning (Territorial General Plan of Catalonia, partial plans and others).

Specific or technical

6. Set a technical normative (technical guides), applicable in matters of official cartography in the fastest term available

7. Amend the article 2 of the **Law 16/2005 of 27 December** that regulates geographical information in order to incorporate in the theme maps, the specific mention to “natural risks cartography”.

Risk and floods

8. Modify the Urbanism Regulation (**Decree 305/2006 of 18 July**) and guarantee the banning of setting buildings, installations and works in flooding zones of return periods never below 100 years, and remove the current exceptions regime set in the article 6 of the norm.

9. Review the regime of exceptions to the use limitations introduced in the **Urbanism Regulation**, intensifying the imposition of conditions, requisites and guarantees with the goal of restricting as much as possible its application, increase legal security and guarantee the application of the prevention principle in that matter. In particular, it should incorporate the requisite of non altering the flooding conditions of the rest of terrains, in the exceptions of use limitations in flooding zones with a return period of 500 years.

Risk and environmental evaluation

10. Incorporate in the **Normative of Environmental Impact Evaluation in Projects** in effect in Catalonia (**Decree 114/88 of 7 April**), the perspective of natural risks. Modify the articles in the decree in order to incorporate the minimum contents in the Environmental Impact Studies the specific description about the affection of natural risks of the area, degree of affection and risk level, as well as the foreseen corrective measures to correct and eliminate the risk.

11. Incorporate in the **Normative of Environmental Impact Evaluation in Projects** in effect in Catalonia (**Decree 114/88 of 7 April**), in relation to the study of alternatives of the projects, in the declaration of environmental impact and in the definitive resolution of the project, the need to take into account the perspective of natural risks and the consideration of the alternatives of the project with the least incidence in soils affected by natural risks

12. The future promulgation of the **Catalan Law of Strategic Environmental Evaluation of Plans and Programs**

must constitute an opportunity to incorporate the perspective of the prevention of natural risks in all of its contents.

6.2.2. Administrative organization

1. Appointment by the Government of a **Special Commissioner for Natural Risks in Catalonia** with the goal of promoting policies of prevention of natural risk, the urgent elaboration of natural risk maps and the implementation of a road map for an efficient and sustainable management of risks.

2. Promote the production of official technical guides for the evaluation and zonification of danger.

3. Ensure that high priority is given to the making of risk maps and the zonification in matter of natural risks at scales compatible with urban planning in those areas of most vulnerability in a term not greater than 4 years.

4. Modification of the program contract signed with the Catalan Water Agency with the goal to guarantee the urgent elaboration of the PEFs and, with these, get the precise outlines of the flooding areas in the whole Catalan territory. The appropriate financial support for this task must obviously be given.

5. Inclusion in the **program contract** between the Department of Territorial Policy and Public Works with the Cartographic Institute of Catalonia of the official cartography of natural risks, as well as the appropriate financial support.

6.2.3. Management and administrative actions

Specific

1. Ensure that Catalonia is urgently supplied with an official **cartography of natural risks** duly registered in the Cartographic Register of Catalonia, with the necessary formalities and requisites of the Law 16/2005 of 27 December.

2. Provide the **Geological Institute of Catalonia** with the funds, human, technical and material resources that are necessary to be able of prioritizing as much as possible the elaboration of the cartographies of natural risks and the corresponding technical guides, accelerating the processes of making official those cartographies and risk maps.

3. Urgently incorporate to the **Infrastructure of Spatial Data of Catalonia** all theme data relative to natural risks in order to ensure the general knowledge and guarantee their availability to all public administration, particularly to local entities and the society and citizens.

Risk and floods

4. Urgently complete the **delimitation of flooding zones** promoting the approval of the river spaces planning (PEF) and ensure that it comprises all rivers and river basins of Catalonia.

5. Review **hydrologic planning** to adapt it to the new technical criteria derived from the Directive 2007/60/CE and the Royal Decree 9/2008 of 11 January. It should be considered the possibility of extending to 200 m. the zone of water policy, the definition and outlining of flooding zones, the recuperation of alluvial plains and the evaluation of the possible effects of climate change.

6. Incorporate to the Program of Measures and the Management Plan of the District of the River Basin of Catalonia, the measures related to prevention and defense in front of floods that result in highest priority according to their vulnerability and exposure to danger.

7. Incorporate to the **Financial and Economic Program of the Hydrologic Planning of Catalonia**, the funds and resources and the appropriate schedule of the timing of the prevention and defense works as far as the existing critical spots inventoried in INUNCAT.

Risk and coast

8. Promote the incorporation of the definition of traffic servitudes, protection zones (200 m. instead of 100 m.) and influence zones (above 500 m .) defined in the **Law of Coasts** (22/88 of 28 July), in the review processes of the territorial and urban development plans of Catalonia.

9. Guarantee the verification, checking and eventual revision of the current urban development plans in the **deltaic zones of Catalonia**. All this, with the goal of following a policy that protects the soil with most natural value, having its effect, at the same time, in a better prevention and security to face natural risks.

Risk and territory

10. Once natural risk maps are available at the appropriate scale, promote the revision or modification of **urban plans** in those municipalities in which the expected soil qualification does not fit risk zonification. It will be necessary to guarantee the classification of affected soil as non urban soil and the incorporation in the planning of the limitations and restrictions to the allowed uses.

11. Link and coordinate the policies of natural risk prevention with territory and urban planning, using the po-

tentiality of its tools. We must incorporate the perspective, zonification and regulation of the areas affected by natural risks in all the territory plans that are being developed, in process and approved.

12. Review the **General Territorial Plan of Catalonia** approved on 16 March 1995 by the Parliament of Catalonia with the goal of incorporating the zonification and delimitation of natural risk areas in all Catalonia, their consideration in the reports, the diagnosis and other documents that are part of the plan and in the large public works for defense and prevention of risks that are deemed necessary to execute.

13. Incorporate in the **General Territorial Plan of Catalonia** the definition at a scale under 1:10.000 of the areas under natural risk that should be excluded of any urban transformation process and the areas to allow for infrastructures.

Risk and civil protection

14. Evaluate the advisability of having a specific **Planning for Civil Protection** regarding geological risks (landslides, land collapses, avalanches), volcanic risk and the risks linked to coastal phenomena, both at the autonomous and local level.

15. Adapt the **Map of Civil Protection of Catalonia** (that should incorporate all the documents of the special emergency plans) to scales compatible with those of territory and urban planning.

16. Use the potentiality of the **Security Charge** and of the **Security Fund**, set in the Law of Civil Protection of Catalonia, to allow for resources and funding for the future undertaking of works of natural risk defense, prevention and protection.

17. Study if the **Security Charge** and **Security Funds** are enough for the goals indicated above and, if necessary, modify or amend what can be improved.

18. Give the **General Direction of Civil Protection** the funds and human and technical resources necessary to promote the extension of civil protection planning in all the country and, at least, in the municipalities that have compulsory plans. Also, articulate the corresponding promotion measures and financial support, grants and appropriate technical support for local bodies.

7. Considerations and final proposal

In this chapter a series of fundamental thoughts related to natural risk mitigation is shown, followed by a proposal of defined action that comprises the priority recommendations of this study.

In the expertise reports and in the legal report, specific evaluations and conclusions grouped by subject and management scope are presented. All of them have been the base to collect the recommendations contained in chapters 5 and 6, where 80 of them are related to the improvement of knowledge and management and 34 for the improvement of the legal context.

The objective of the recommendations is that the Catalan government is supplied with a set of proposals that will allow the optimization of current actions and implement new ones that improve the efficiency of natural risk management and, consequently, achieve a reduction of their impact.

To reach this objective we believe it is necessary to make a proposal that incorporates a vertebration and coordination element of the risk management system. We are confident that the proposal will make it possible to establish a road map to initiate and lead immediately and with the maximum efficiency a better govern of the natural risks in Catalonia.



Damages to the rack railway in Vall de Núria caused by a rock landslide in 2003. (Photo J.M. Vilaplana)

General considerations

Risk and sustainable development

In the framework of sustainable development, the coexistence with natural risks has an important role. It is vital to develop useful tools in order to coexist with risk, since it is clear that risk zero is non-existent. Our society must decide the levels of tolerable risk that is ready to accept and coexist with them. In this sense, it is basic to start a process of understanding between existing social agents: institutions, administration and civil society.

Natural risks are not that natural

The increase in damages of what we call natural catastrophes is attributed mainly to the increase of the exposed population but also to the increase in intensity and impact of some phenomena (particularly floods) due to inappropriate development practices. The modification of the natural space that has experienced Catalonia in the last few decades makes that today the gravity of natural phenomena has an anthropic dimension.

Risk and territory management

The best way to avoid risk is not to occupy exposed zones. In this sense, planning is fundamental: we must incorporate the delimitation of natural risk zones territory and urban planning. The consideration and contemplation of natural risks should be part of all public processes of territory planning, urbanism, soil planning, scheduling of infrastructures, equipments and other public policies.

Risk and prevention

The efficient mitigation and the adequate regulation of natural risks require that prevention is given priority. The inversion in prevention is more profitable, both in economically and socially, than the costs of rehabilitation and recovery after the disaster.

Risk and public awareness: information and education

It is important, by means of the correct public information and education, to reach a level of public awareness that will allow to both citizens and politicians to evaluate the level of shared responsibility in decision taking in relation to natural risks.

Proposal for action

This report highlights the extraordinary complexity of the legal, normative and planning framework for the management of natural risks in our country.

It has been clearly shown that this is an absolutely interdisciplinary issue that involves professionals and special-

lists of very different subjects and their execution implies necessarily several administrations and organisms that have the competence on education, research, environment and different natural phenomena, territory, housing, urbanism, public works and civil protection, among others.

The creation of a Commissioner for the Reduction of Natural Risks in Catalonia is proposed. This body should have decision and management capacity and should report to the Parliament of Catalonia, having the presidential role of an interdepartmental commission consisting of a high representative and a technical expert from each of the Departments of the Generalitat involved in the knowledge, management and mitigation of natural risks.

The main functions and actions that the Commissioner should have in the short term are proposed below:

Essential functions

1. Help the Catalan Government of the Generalitat de Catalunya to promote and prioritize the prevention policy of natural risks.
2. Prepare the road map with the recommendation contained in the RISKCAT report and elaborate the action schedule to carry out in order to ensure the sustainable and efficient management of risks.

Actions of administrative organization

1. Provide the General Direction of Civil Protection (and local entities) with the funds and technical and human resources that are necessary to prioritize and accelerate the preventive strategies and civil protection plans.
2. Help the IGC to promote and prioritize the management actions 2, established in its program contract.
3. Review the program contract of the ACA to provide it with funds so that it can prioritize and accelerate the development of all of the PEFs, following the actions of management 2 and 3.

Management actions

1. Ensure that Catalonia has, in the shortest possible time and with maximum priority, a cartography of natural risks that is official and duly registered in the Cartographic Register of Catalonia, with the formalities and requisites of the Law 16/2005 of 27 December.
2. Help the IGC promote and prioritize the actions of management 2, established in their program contract.
3. Carry out the zonification of the regulatory danger at a scale of 1:2.000 for urban planning and 1:5.000 for infrastructure planning in the shortest possible term, giving priority to those zones with most vulnerability, so that they can be implemented in to the POUMs.
4. Immediate incorporation of the regulatory zonifications in the territory and urban planning.
5. Promote a structural and non structural defense plan in the areas exposed to natural risks where urban development has already taken place.

Annex 1

Meteorological risks and climate change

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In the latest report of the Intergovernmental Panel on Climate Change (IPCC, 2007) some conclusions are included about observed tendencies, as well as consequences that the future scenarios can have on natural risks and, in particular, about those issues linked to precipitations, temperature and severe weather. In general terms, the observations point towards an increase of extreme situations such as droughts, heavy rains, heat waves and tropical cyclones. In spite that the considered periods are not the same for all regions and for all risks, the common period would start around 1970. The report indicates, in general terms, that an increase in the intensity and duration of droughts since 1970 has been observed, particularly in tropical and subtropical zones. This would be linked to the increase in temperatures, the decrease in rain levels, the changes in the sea temperature (SST), winds and decrease of the snow mantle. The report also concludes that the frequency of episodes of strong rains has increased in some regions, positively correlated with the heating and increase of water steam in the atmosphere. As far as extreme temperatures are concerned, a mention is made about the changes observed in the last 50 years with a decrease in the number of cold days and frosts and, on the other side, a higher frequency of hot days and nights, as well as heat waves. In both cases, according to the IPCC, the magnitude of the change would be of around 10% both in the increase of hot days and the decrease of cold ones. In the case of tropical cyclones, even if it has been an increase in their intensity since 1970, related to the highest SST, nothing can be stated about their frequency. The report notes that there is not enough evidence of change in small scale risks such as tornados, hailstorms, lightning and dust storms. As far as future scenarios are concerned, the report states that it is very likely that heat waves, extreme heat situations, heavy rain episodes and intensity of tropical cyclones will be on the increase.

The IPCC report makes no comments about other risks that could be associated to meteorological or climate conditions. Such would be the case of landslides, forest fires, avalanches or wind storms. However, intuitively one can assume an increase in landslides linked to the growing number of strong rains or an increase of forest

fires as a consequence of the decrease of rains and the expected higher temperatures. Also, in spite that in the whole text of the report floods are mentioned, no conclusions are presented. On the other hand, the conclusions relative to already detected trends and scenarios are found in a framework of climate change at a global scale that in certain occasions can differ from the results obtained at a regional or local level. Therefore, two factors must be taken into account when we talk about the impact of climate change on natural risks.

Firstly, the complex character of natural risks must be considered. The "risk" concept itself contains a component of what we consider dangerousness and another component linked to vulnerability. The latter, furthermore, includes by itself or a result of external factors, other aspects such as exposure, emergency management, public awareness and education and damage evaluation. The climate and its variations can affect, at first, the level of danger, both in frequency and return period and in magnitude or intensity as well. If the relationship between the increase of gases that cause the greenhouse effect and the danger level of strictly meteorological risks (for example, strong rains, storms, etc.) is usually non-linear, the analysis of the impact gets complicated when we talk about non strictly meteorological risks that must be addressed from a multifactor perspective. Floods can be a good example: any frequency or magnitude study would require taking into account the geomorphologic, hydrologic or hydraulic aspects of the area and its possible expected changes. The second aspect is related to the social and ecologic impact, much more complex if we consider that the range of adaptation or acceptance to risks is neither static nor homogeneous in all regions. A certain increase of risk can hide an increase of poverty in the region and their inhabitants or, on the contrary, an increase in the evaluation of the goods susceptible to be damaged. At the same time a change in the climate can involve human displacement and, consequently, a change in vulnerability or changes in population behaviour that can alter also the level of danger. In fact, however there is not unanimous agreement about the increase of dangerousness, there is indeed about the increase of risks, due essentially to an increase in vulnerability and exposure.

The second main factor to take into account is the regional problem. The uncertainty of many projections, particularly those related with rainfalls, is still very high when treated at the regional scale and in certain seasons of the year. The Mediterranean is considered one of the most complex regions and of more difficult estimation. The Progress Report of the First Phase of the Project for Generation of Regionalized Scenarios of Climate Change, published by the Spanish Ministry of Environment, highlights these uncertainties found when rain patterns in Spain are analyzed. These are especially relevant in the Mediterranean sector, where conflicting results are observed depending on the global model and regionalization used. Also, in the report about Impacts of Climate Change in Spain, natural risks are dealt with in chapter 12. Regarding the Mediterranean area, this chapter concludes that between the decades of the 70's and 80's an increase of heavy rains has been observed in comparison with previous decades. Some have generated extraordinary grows with maximum records greater than those of the first half of the 20th century. The chapter insists in the increase of vulnerable zones as a consequence of the growing exposure of more areas and, consequently, that the best adaptation consists in the improvement of prevention studies and in a better territory planning, pointing out also that the prediction systems in operation in some basins should be improved. This report states that there is no defined trend in the frequency and magnitude of landslides and avalanches but that an increase in the torrential character of rains would lead to an increase in landslides. However, a better inventory of landslides is needed and it is necessary to consider risk zones in territory and urban planning. Finally, regarding forest fires, the report shows that the average index of danger has increased during the 20th century. However, since this is a mixed risk in which the role of man as a trigger of the ignition and the abandoning of crops are key factors, it is difficult to relate it with climate change, in spite of it being obvious that the highest temperatures expected and drought conditions are favourable factors for an increase in danger levels.

In this context, the CADS has promoted the creation of the Climate Change Experts Group of Catalonia (GECC). One of the activities and studies that this team will carry out is the analysis of the influence of climate change on natural risks. With this study, a deeper knowledge will be got about all the factors that have been pointed out in this introduction.

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Annex 2

Glossary

Exposure · Exposició

Exposición · Exposition

Indicates the location of the whole set of elements that occupy and/or use the territory that is potentially affected or threatened by a certain natural danger (when we speak of territorial elements we refer to persons, edifications, communication networks, diverse infrastructures and in general to the different soil uses).

Mitigation · Mitigació

Mitigación · Mitigation

Any strategy for the reduction or minimization of risk. This can be achieved acting individually or in a combined form over the factors of risk: danger, vulnerability and exposure.

Natural danger · Perill natural

Peligro o amenaza natural · Danger naturel

Potentially destructive natural phenomenon. An earthquake, volcanic eruption, landslide, river flood, storm, etc.

Natural disaster · Desastre natural

Desastre natural · Désastre naturel

Natural catastrophe · Catàstrofe natural · Catástrofe natural · Catastrophe naturelle

Event generated by some natural danger that causes intense alterations to people, goods, services and the environment, exceeding the response capacity of the affected community.

Natural hazard · Perillositat natural

Peligrosidad natural o grado de amenaza · Aléa

Probability of occurrence of a natural danger in a particular place and period of time.

Natural risk · Risc natural

Riesgo natural · Risque naturel

Probability of damages due to a natural phenomenon in a particular place and period of time. The natural risk is understood as a product of the danger caused by the vulnerability of the elements under exposure.

Prevention · Prevenció

Prevencción · Prévention

Whole set of techniques and actions that are necessary to eliminate, reduce or avoid natural dangers over people, goods and the environment.

Resilience · Resiliència

Resiliencia · Résilience

Capacity of recovery or regeneration of the vulnerable element to get back to the previous situation before being affected by the dangerous phenomenon.

Susceptibility · Susceptibilitat

Susceptibilidad · Susceptibilité

Tendency or ease of the territory to be affected by a certain natural phenomenon.

Sustainable development · Desenvolupament sostenible

Desarrollo sostenible · Développement durable

Process of natural, economic, social, cultural and institutional transformations that have as a goal the improvement of living conditions of human beings and their productive system, without deteriorating the environment or compromising the bases to get a similar development for future generations.

Vulnerability · Vulnerabilitat

Vulnerabilidad · Vulnérabilité

Vulnerability expresses the percentage of the value (economic and/or social) of the exposed elements that can be lost as a consequence of a certain natural phenomenon. (It is also known as the degree of potential losses, within a range from 0 and 1).

Annex 3

Acronyms

CCS	Consortio de Compensación de Seguros (Assurance Compensation Consortium)
CECAT	Centre d'Emergències de Catalunya (Emergency Center of Catalonia)
CGA	Consell General d'Aran (administrative body of the county of la Val d'Aran)
CSIC	Consejo Superior de Investigaciones Científicas (Spanish Superior Counsel of Scientific Investigations)
DinSAR	Interferometria de Radar mitjançant Satèl·lit (Radar Interferometry via Satellite)
DOCE	Diario Oficial de la Comunidad Europea (Official Diary of the European Community)
DOGC	Diari Oficial de la Generalitat de Catalunya (Official Diary of the Generalitat de Catalunya)
GAMA	Grup d'Anàlisi de Situacions Meteorològiques Adverses de la Universitat de Barcelona (Analysis Group for Adverse Meteorological Situations of the University of Barcelona)
GECCC	Grup d'Experts en Canvi Climàtic a Catalunya (Experts Group on Climate Change of Catalonia)
IAVCEI	Associació Internacional de Vulcanologia (International Association of Volcanology and Chemistry of the Earth's Interior)
ICC	Institut Cartogràfic de Catalunya (Cartographic Institute of Catalonia)
IGC	Institut Geològic de Catalunya (Geological Institute of Catalonia)
IGME	Instituto Geológico y Minero de España (Geological and Mining Institute of Spain)
IGN	Instituto Geográfico Nacional (National Geographical Institute)
INE	Instituto Nacional de Estadística (National Institute of Statistics)
INUNCAT	Pla Especial d'Emergències per Inundacions de Catalunya (Special Emergency Plan for Floods of Catalonia)
ML	Magnitud local d'un terratrèmol (Local magnitude of an earthquake)
MSK	Escala Medvedev-Sponheuer-Karnik per estimar la intensitat d'un terratrèmol (Medvedev-Sponheuer-Karnik scale to estimate the intensity of an earthquake)
MPRGC	Mapa de Prevenció de Riscos Geològics de Catalunya (Map of Geological Risk Prevention of Catalonia)
MZA	Mapa de Zones d'Allaus (Map of Avalanche Zones)
NCSE	Norma de Construcción Sismoresistente (Regulation for Earthquake Resistant Construction)
NEUCAT	Pla Especial d'Emergències per Nevades de Catalunya (Special Emergency Plan for Snowfalls of Catalonia)
PAM	Pla d'Actuació Municipal (Municipal Action Plan)
PEF	Planificació d'Espais Fluvials (River Spaces Plan)
PIB	Producte Interior Brut (Gross National Product)
PIDA	Plans d'Intervenció per al Desencadenament Preventiu d'Allaus (Intervention Plans for the Preventive Induction of Avalanches)
POUM	Pla d'Ordenació Urbanística Municipal (Plan of Municipal Urban Planning)
RISK NAT	Grup de Recerca en Riscos Naturals de la Universitat de Barcelona (Research Group for Natural Risks of the University of Barcelona)
SIDEG	Sistema d'Informació Geològica, Edafològica i Geotemàtica de Catalunya (Geologic, Edaphologic and Geothematic Information System of Catalonia)
SISMICAT	Pla Especial d'Emergències Sísmiques de Catalunya (Special Emergency Plan for Earthquakes of Catalonia)

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