Compilation of FF & DF follow-up studies on damages and social impacts

Deliverable D5.1

Date	**28 - 01 – 2010**
Report Number	**D5.1-2009-12**
Revision Number	rev_1_0
Due data for deliverable:	12 – 2009
Actual submission date:	01 – 2010
Subproject Leader	**CETaqua**

IMPRINTS is co-funded by the European Community

Seventh Framework Programme for European Research and Technological Development

IMPRINTS is a Collaborative Project focused on Theme 6.1.3.3 - ENVIRONMENT: Preparedness and risk management for flash floods including generation of sediment and associated debris flow.

Start date 15th January 2009, duration 42 Months

Document Dissemination Level

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

DOCUMENT INFORMATION

Title	Compilation of FF & DF follow-up studies on damages and social impacts
Lead Author	Àngels Cabello (CETaqua)
Contributors	Lorenzo Alfieri (JRC), Isabel Escaler (CETaqua), Markus Gächter (Glarus Emergency), Alex Gracia (ACA), Ruud Hurkmans (WU), Arthur Marchandise (SCHAPI), Doris Primus (CETaqua), Antonio Santiago (EGMASA), Marc Velasco (CETaqua), Enric Velasco (ACA).
Distribution	CO
Document Reference	

DOCUMENT HISTORY

Date	Revision	Prepared by	Organisation	Approved by
28.01.2010	Rev_1_0	Àngels Cabello	CETaqua	

ACKNOWLEDGEMENT

The work described in this publication was supported by the European Community's Seventh Framework Programme through the grant to the budget of the Collaborative Project IMPRINTS, Contract FP7-ENV-2008-1-226555.

DISCLAIMER

RELATED DOCUMENTS

This report and others are available from the IMPRINTS Project Website at:

http://www.imprints-fp7.eu/

SUMMARY

Floods, including flash floods and debris flow events, constitute one of the most important hazards in Europe. Therefore, the main objective of this document is to develop a comparative analysis of the flood risk management information compiled for each one of the test-bed basins studied (Llobregat, Guadalhorce, Gardon d'Anduze and Linth basins). This task has identified what are the lessons learnt from past experiences occurred in the basins included in the project and also in other European basins (Northern and Eastern Europe and the Mediterranean region) in order to propose future strategies on risk management. Several sources of information have been assessed, from the specific surveys on the effectiveness of the implemented emergency plans and risk management procedures that were sent to the test-bed basin authorities that participate in the project to follow-up studies and research papers that detected relevant lessons learnt in other basins.

Table of Contents

List of figures

List of Tables

List of abbreviations

AAA: Andalusian Water Agency (Spain)
ACA: Catalan Water Agency (Spain)
AEMET: Spanish Meteorological Agency (Spain)
BMI: German Home Affairs Ministry (Germany)
CERFACS: European Centre for Research and Advanced Training in Scientific Computation (France)
CIS-WFD: Common Implementation Strategy for the Water Framework Directive
CME: Mediterranean Centre of Environment (France)
CTEI: Technical Commission for Flood Emergency (Spain)
CYPRIM: Cyclogenesis and Heavy Precipitation in the Mediterranean Region (France)
DDAF: Departmental Directorate of Agriculture and Forests (France)
DIREN: Regional Department of Environment Rhône-Alpes (France)
DF: Debris Flow
DWD: German Weather Service (Germany)
EC: European Commission
EDRINA: Education in Natural Risks (Spain)
EGMASA: Andalusian Environmental Management Company (Spain)
EHIMI: Integrated Hydrometeorological Forecast Tool (Spain)
FD: Floods Directive
FF: Flash Flood
FIC: Climate Foundation Research Centre (Spain)
FRMP: Flood Risk Management Plan
GCM: General Circulation Model
GWP: Global Water Partnership
ICP: Icelandic Civil Protection (Iceland)
IFKIS: Intercantonal Early Warning and Crisis Information System for Natural Risks (Switzerland)
IGC: Geological Institute of Catalonia (Spain)
IKSE: International Commission for Elbe's Protection (Germany)
INFOCA: Emergency Plan of Forest Fires in Andalusia (Spain)
INFOCAT: Emergency Plan of Forest Fires in Catalonia (Spain)
INUNCAT: Flood Emergency Plan in Catalonia (Spain)
IPCC: Intergovernmental Panel on Climate Change
LIDAR: Light Detection and Ranging
MEDCIE: Interregional and European Studies and Development Cooperation (France)
ORSEC: Rescue Organization Plan (France)
PAM: Municipal Action Plan (Spain)
PAPI: Program of Action for Prevention of Flooding in the Gardons Basin (France)
PCS: Municipal Safeguard Plan (France)
PEFCAT: River Area Planning in Catalonia (Spain)

PER: Risk Exposure Plan (France)
PMSH: Existing Building Safety Plans (France)
PPR: Risk Prevention Plan (France)
PPRI: Flood Risk Prevention Plan (France)
PREVAH: Precipitation-Runoff-Evapotranspiration HRU Model (Switzerland)
RBMP: River Basin Management Plan
RINAMED: Natural Risks in the Occidental Mediterranean Region
SAC: Flood Warning Service (France)
SAIH: Automatic Hydrological Information System (Spain)
SAMU: Urgent Medical Aid Service (France)
SCHAPI: French Central Service for Hydrometeorology and Flood Forecasting (France)
SGG: Swiss Public Welfare Society (Switzerland)
SMAGE: Gardons Basin Sustainable Water Management Association (France)
SMC: Meteorological Service of Catalonia (Spain)
SPC: Flood forecasting service (France)
SRES: Special Report on Emissions Scenarios
SSK: Saxon State Chancellery (Germany)
STARDEX: Statistical and Regional Dynamical Downscaling of Extremes for European Regions
USACE: United States Army Corps of Engineers (USA)
WMO: World Meteorological Organization
WWTP: Wastewater Treatment Plant

1 Introduction

Floods, including flash-floods and debris flow events, are one of the most important hazards in Europe regarding both, economic and life loss. Since 1998, floods have caused about 700 deaths across Europe, displaced about half a million people and led to at least €25 billion worth of insured damage in addition to uninsured costs (WISE website). Only in 2002, the direct costs of flooding amounted to €13 billion and it has been proved that the annual number of reported floods and damages in Europe increased during the 1972-2002 period (Guha-Sapir, Hargitt & Hoyois 2004).

The large-scale hydrological cycle has already been affected by climate change, being this related to the observed global warming during the last decades. Changes in precipitation patterns and intensity are very likely to increase due to climate change, raising the risk in areas that already are vulnerable to floods (IPCC 2008). Therefore, it is very important to carry out strategies to improve flood protection and this is why a new European directive was elaborated.

The Directive 2007/60/EC, on the assessment and management of flood risks, entered into force on 26 November 2007 and it required transposition into the European domestic laws by 25 November 2009. The Flood Directive (FD) prescribes a series of common steps across the EU to reduce the adverse consequences of flooding and introduces the integrated risk management as a new approach to cope with floods. By 2011 Member States are required to prepare preliminary flood risk assessments for all river basins as the first step to identify the areas with a significant flood risk, including flash-floods and debris flow events. This preliminary study has to include information on historical flood events (flood extents, conveyance routes and assessment of the impacts produced) confirming that learning from the past it is crucial to improve future flood risk management plans. By 2013 Member States will have to prepare flood hazard and flood risk maps for the areas previously identified. Flood hazard maps will include different scenarios, taking into account climate change, and flood risk maps will show the potential impact of flooding, summarizing the number of inhabitants affected, the type of economic activities in the area, the possible sources of pollution within the floodplain limits and the areas where floods can transport a high content of sediments and debris. Finally, by 2015 Member States will have to finish the Flood Risk Management Plans (FRMP) that will coincide with the 2nd cycle of River Basin Management Plans, implying that the two plans will have to be coordinated (EC 2007).

The first version of the FRMP will have to already incorporate probable impacts of climate change on the frequency and intensity of the precipitation causing the floods. They will focus on planning both, structural and non-structural, measures to reduce the likelihood of flooding. In the case of non-structural measures, the FD stresses the importance of sustainable measures for addressing flood risks, such as improving water retention through the use of natural floodplains and using spatial planning. Public awareness is also highlighted in the FD, Member States must consult the FRMP drafts with population and the plans have to be available when finished. Furthermore, the EU will provide Member States with financial support for prevention. Approximately €6 billion have been allocated as EU Structural Funds for risk prevention projects for the period comprised between 2007 and 2013.

Within the framework of the FD implementation, this report focuses on compiling past experiences that have led to improvements of the risk management policies throughout Europe. Follow-up studies on damages, economic and social impacts are usually carried out after major flash flood or debris flow events. If they comprise an integral analysis of the flood event management, they are extremely useful to assess the protection measures in order to check if they have accomplished their function, to review the emergency procedures that have taken place before and during the event and also to analyze the response and rehabilitation processes.

Identifying this type of studies and carrying out a comparative analysis is extremely important, but, unfortunately, it has not been done often enough. Frequently, the flood prevention and emergency plans are based only on hydrologic and hydraulic modelling and they do not take into account historical data. That is the reason why this report has compiled historical information, classifying the lessons learnt on the different phases of an emergency (prevention, preparedness, response and communication).

2 Objectives

The main objective of this document is to develop a comparative analysis of the flood risk management information compiled for several river basins where flash floods and debris flow (FF & DF) events have occurred or are likely to occur. This task has also the aim of finding out what are the lessons learnt from past experiences in order to propose future strategies on risk management.

The scope of the report includes those test-bed basins that have answered the questionnaire regarding the implemented emergency plans and management procedures. These are Llobregat, Guadalhorce, Gardon d'Anduze and Linth basins. The report also involves other European basins not tested in the project but analyzed through the inventory in a briefer way. The inventory includes basins from Northern and Eastern Europe and the Mediterranean region.

3 Methodology

The methodology followed in task 5.1 involves the analysis of several sources of information, from follow-up studies carried out in the test-bed basins to research papers that detected relevant lessons learnt in areas not included in the project. Therefore, this document will assess how the lessons learnt from those events have turned into improvements on the risk management practices and it will propose suggestions to make risk management procedures more efficient.

Next, there is an outline of the stages of work that have been carried out:

- ⇒ Specific survey on the effectiveness of the implemented emergency plans and risk management procedures has been sent to the test-bed basin authorities that participate in the project and to other European river basin authorities (reduced version of the questionnaire)
- ⇒ Analysis of the answers from the questionnaire and further research on the methodologies for risk evaluation and emergency plans currently implemented on the basins. The test-bed areas that have completed the survey are: ACA (Llobregat), EGMASA (Guadalhorce), SCHAPI (Gardon d'Anduze) and Glarus Emergency (Linth)
- ⇒ Compilation of available follow-up studies carried out in the selected test-bed areas after major flood events
- ⇒ Literature review of research papers on FF & DF events not belonging to the selected test-bed areas (also including other European projects)
- ⇒ Collection of the lessons learnt through a comparative analysis of the previous information
- ⇒ Recommendations for future strategies on risk management based on lessons learnt and management gaps detected through the process

⇒ Report (Deliverable 5.1) including all the previous information and the inventory of events carried out for Northern and Eastern Europe and the Mediterranean region

4 Analysis of the compiled information

4.1 Llobregat basin

4.1.1 Basin description

The Llobregat River (156,5 km) is located in Catalonia, in the Northeast of the Iberian Peninsula, and its river basin has a surface of approximately 5000 km². It has its source in the Pyrenees Mountains at an altitude of 1.259 meters, crosses quite densely populated areas and ends in the Mediterranean Sea, in the municipality of El Prat de Llobregat, near Barcelona (see Figure 1). The river flows usually through an irregular terrain, and at its last stretch it forms a delta, which is currently one of the most urbanised and industrially developed areas of the region. The main tributaries of the Llobregat are: Bastareny, Cardener and Anoia, in the right side, and Riera de Merlès, Riera Gavarresa, Riera de Rubí and Riera de Vallvidrera, in the left side.

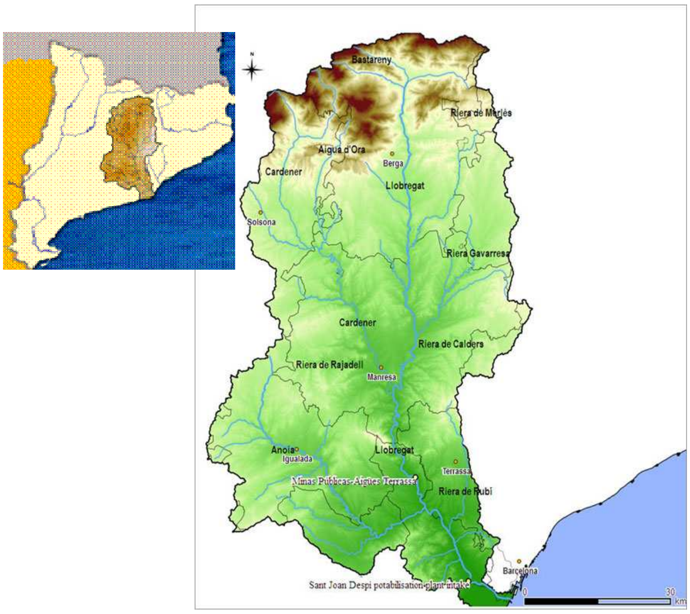

Figure 1. Llobregat River basin.

The Llobregat basin serves as a supply for a highly populated and urbanized catchment, with an estimated total population of more than 1.300.000 inhabitants. Water resources are used for different purposes, as drinking, agricultural irrigation, industry and hydro electrical energy production. This level of development makes Llobregat basin one of the most populated and industrialized areas of Catalonia and, as a consequence of it, the river is under several types of pressures. The river discharge has decreased over time due to urban and industry uses and, moreover, floodplains have been occupied by protection or transport infrastructures and settlements.

In relation to the climate, the average annual rainfall over the region is about 600 mm and one third of the average annual precipitation can usually fall in less than 48h. Due to its exposition to heavy rains and flooding, the weather forecast, the measurement of rain and the prevention of floods are subjects of major social interest in Catalonia.

4.1.2 *Historical floods*

Table 1 shows the most important historical events in terms of damages and social impacts identified in the Llobregat basin.

Table 1. Main historical floods in the Llobregat basin. *Sources: Barnolas & Llasat 2005 ; Cañellas 2000; Llasat et al. 2001, 2004; Milelli, Llasat & Durcrocq 2006; ACA questionnaire 2009*

Date	Max. Intensity (mm/h)	Total Precipitation (mm)	Discharge (m^3/s)	Economic loss (million €)	Deaths
October 1907	-	-	1500 (Martorell)	-	29
October 1940	-	-	2200 (Martorell)	0,7	300
September 1962	110 (1 h)	250	1550 (Martorell)	16	815
September 1971	82 (4 h)	400	1630 (Martorell)	42	19
November 1982	17 (24 h)	556	1600 (Martorell)	270	14
June 2000	100 (1 h)	225	1100 (Castellbell i el Vilar)	65	5

7-12. October. 1907

There were generalized floods all over Catalonia, but specially serious were the floods caused by the Ter River in Girona, the risen of the Llobregat River and the overflow of the Ebro River.

17-20. October. 1940

This flooding is considered one of the most catastrophic in the 20th century and affected northern and southern parts of Catalonia. Ter River raised its normal water level by seven meters and the Llobregat River caused severe flooding, too. The total number of deaths and disappeared exceeded the 300.

25. September. 1962

This was the worst registered flood of the 20th century in terms of human losses in Catalonia and also in Spain. It was a severe flash flood caused by a 250 mm precipitation fallen in less than 3 hours that provoked floods in the Besós River, the Llobregat River and numerous streams.

Damage inventory: 441 deaths: 374 missing, 213 injured. Total destruction of numerous houses, industries, bridges and other infrastructures (hydraulic, roads, train tracks). Cut off the water and electricity services. Losses on crops. Total estimated losses: 16 M€.

20-23. September. 1971

There were heavy rains all over Catalonia and these caused floods in Girona and Barcelona provinces. The Llobregat River experienced the largest discharge of the century, reaching the 3080 m^3/s.

Damage inventory: 19 deaths. Total destruction of some houses, bridges and hydraulic infrastructures. Cut off the water and electricity services. Roads and rail tracks interruptions. Serious damages on 450 industries. Total destruction of Llobregat Delta crops. Total estimated losses: 42 M€.

6-9. November. 1982

The floods affected mainly the Central and Oriental Pyrenees, but also Andorra and the South of France suffered the serious consequences of this event. These floods have been compared in many occasions to those of 1940. In several places, the rainfall exceeded the 500 mm in 48h and many rivers were overflowed. The Llobregat River caused floods in its higher part, due to the fact that the heaviest rains took place in the Pyrenees.

Damage inventory: 19 deaths. Total destruction of numerous houses, industries, bridges and transport infrastructures. Cut off the water and electricity services. Total estimated losses: 270 M€.

10. June. 2000

This specific event is one of the most analyzed by meteorologists and hydrologists in Catalonia. There are many research papers that evaluate its causes and consequences and the Water Authority Agency is currently finalizing two detailed hydrologic and hydraulic studies (River Area Planning, PEF) for two of the Llobregat tributaries that were severely affected, the Magarola and the Marganell (ACA 2001a, 2001b). ACA has authorized the authors to examine their last draft version in order to summarize the type of information that will be available.

In the frame of the general plan, the PEFCAT, there are several PEFs created, each of them focusing on a specific region of a main Catalan river or their tributaries. Most of these local plans have been developed as a result of a certain flood event. This is the case of the previously mentioned studies that were started as a consequence of the June of 2000 flood event that affected the Anoia and Baix Llobregat regions. Serious consequences were reported in the two mentioned streams, the Marganell and the Magarola, tributaries of the Llobregat River, close to the town of Esparraguera. Therefore, these studies were developed with the main aim of preventing and minimizing the consequences of a future similar episode.

The PEFs of Marganell and Magarola, elaborated by the ACA together with some civil engineering consulting companies, contain more or less the same information, but specified for each basin. First of all, all the data available is analyzed, starting with a precise study of the topography, geology, land-use, hydrology and some more characteristics of the basin. After all this information is analyzed, a hydraulic modelling of the river is carried out, using commercial software, such as HEC-RAS or FLOW-MASTER, to simulate different return period flood.

From these simulations, really detailed flood hazard maps can be obtained, containing different zones classified by return periods. Floods caused by 10, 100 and 500 years return period events are shown. In the Marganell River, the scale of the flood hazard maps is 1:2000, and for the Magarola River the scale is even finer, reaching the 1:500.

According to this zonification, the plan defines the land-uses allowed in each one of them. The river zone is the region between the river and the line corresponding to a 10 year return period flood, and it is still considered part of the river bed. Therefore, nothing can be built there, except for seasonal works on the riverbanks vegetation, always supervised by the ACA. The next zone, called the hydrological system zone, includes the area in between a 10 year and 100 year return period flood. In this zone some uses are allowed, as long as they do not modify the shape of the natural terrain, so agricultural uses, gardening, sports and similar ones are permitted. Finally, the flood zone is the one contained in between the lines corresponding to flood events of return periods among 100 and 500 years. Although in this case it is allowed to build, the constructions must take into account this situation, and locate the ground floor level at a certain elevation to reduce the effects of a possible flood. Amongst other restrictions, it is totally forbidden to locate camp sites in this zone, so catastrophes like the one that happened in Biescas (see Appendix 8.1) can be prevented. The problem is that some of these land-use regulations might not be followed nowadays because the constructions were already there before the new urban planning law.

Apart from the hazard study, the PEF studies also estimate the vulnerability and the subsequent risk associated to certain river stretches. The methodology followed for the risk analysis is similar to the one used in the INUNCAT flood emergency plan (Departament d'Interior de la Generalitat de Catalunya 2006). The potential risk is evaluated through an impact matrix. On one hand, it assesses the damage level by different categories (high, medium or low damage level) and assigns a numerical value for each of them. Then, the probability of the event is taken into account by a multiplying factor that is inversely proportional to the return period. Combining both values, a final impact value is obtained and a potential risk level is associated to each river stretch. Through this process, the PEF defines the critical areas in which specific measures should be implemented. The proposed measures have the aim of reaching a homogeneous maximum potential risk level defined as low for the whole basin, identifying integral actions that consider the basin in its totality. They can be either structural (doing the required construction works to reduce the risk) or non-structural (warning or installing some signs to make the population aware of the existing risk) and the PEF includes the budget estimation for all of them.

Regarding the meteorological information, during the first hours of the 10th of June 2000, Catalonia registered heavy rains that caused severe flash floods and debris flows in several municipalities. The rain was characterized by a high intensity, exceeding the 100 mm/h in different points.

The INUNCAT emergency plan was activated at level 1 and more than 500 people were evacuated (around 300 people were evacuated from the Montserrat mountain by helicopter). Some of the most affected municipalities, as Martorell, activated their Municipal Intervention Plan.

Damage inventory: 5 deaths (2 of them in a rescue action). Total destruction of numerous houses (Baix Llobregat and Anoia regions). Partial destruction of several infrastructures belonging to the Montserrat monastery. Total destruction of the most recent bridge of the N-II highway (the river rose its normal level by 4,5 m in this point). Cut off the water and electricity services. Total estimated losses: 65 M€.

4.1.3 Risk management plans

This section includes an analysis of the information provided in the questionnaire. In this particular case, further information related to the survey questions has been gathered through a phone interview with the person responsible for the flood emergency plan in the Civil Protection Department of Catalonia and through a meeting with the person in charge of the Telecontrol Centre belonging to the Water Resources Management Department of the Catalan Water Agency.

Map information

The first part of the questionnaire asks for general information of the selected river basin, including area, geomorphology, population and economical activities. In this case, as mentioned earlier, Llobregat basin is a highly populated and industrialized area and this is translated into pressures on the river water quality and quantity.

Regarding the detailed map information, there is a wide variety of data available as seen on section "2.2.1 Cartography" of the questionnaire. Summarizing, there are the following typologies of maps available: topography, land use, rainfall probability (see Figure 2), flood propagation speed, flood hazard and flood vulnerability.

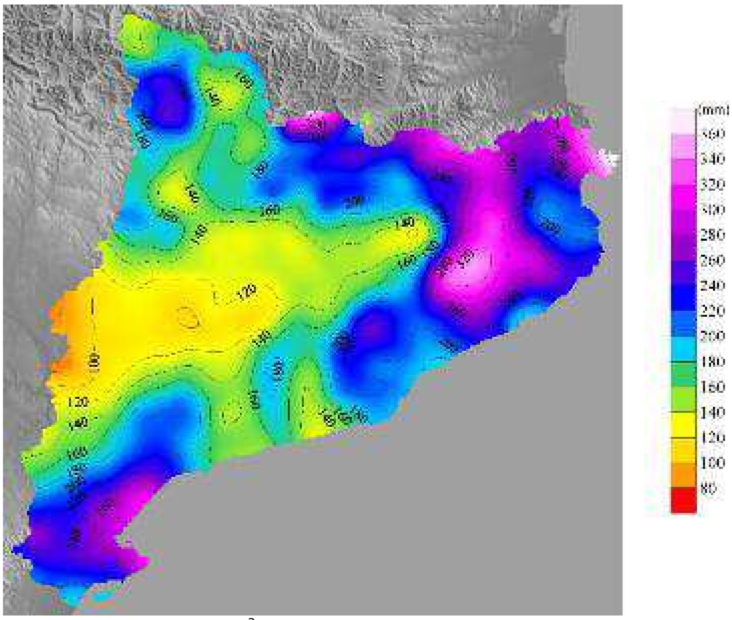

Figure 2. Estimated maximum daily rainfall (l/m²) for a 500 year return period. *Source: Departament d'Interior de la Generalitat de Catalunya 2006*

Improvements of plans and policies

Some of the events listed on section 4.1.2 led to improvements of the emergency plans and/or changes of policies or regulations. Further research has been conducted in order to identify which were the specific events that led to particular changes in the risk management procedures.

In the case of 1940 floods, a General Commission of Flooded Regions was created to compile all the actions proposed in Catalonia after the disaster. The Commission promoted the first comprehensive infrastructures plan for the region and several dams were built during the following years. This plan was reinforced after the 1962 events, and the construction of more dams and channelings started. Besides, it was decided to change some of the design parameters of bridges and viaducts. Summarizing, this period was characterized by the construction of infrastructural protection and prevention measures, but, on the other hand, some of the first control measures were also implemented (e.g. installation of limnigraphs).

Another event that constituted a shift in the risk management policy was the 1982 event. The first "Priority Intervention Points" (or "black spots") list was prepared and this led to urban planning improvements in several cities. This type of measures introduced by the first time the hazard concept in the flood management sector in Catalonia. Another important innovation was to propose for the first time "Local Emergency Plans" for those municipalities that suffered from certain level of risk.

The next step in time was the development of the first flood protection master plans: in 1992 the Flash Flood Protection Master Plan for El Maresme Area and in 1999 the Flash Flood Protection Master Plan for El Besòs River, two different Catalan regions with important flash flood problems.

In 1997, the first version of the Catalan Floods Emergency Plan, INUNCAT, was partially prepared but it was not until 2006 that this plan was finally completed and approved. This version of the INUNCAT is the one implemented nowadays and includes flooding maps at a 1:50.000 scale. Few years ago, the ACA started an ambitious project, the PEFCAT previously mentioned, that constitutes a detailed analysis of the rivers in Catalonia, including flooding areas at a 1:5.000 scale. At this time, there are 405 km of the Llobregat River and its tributaries already modelled of a total of 1.084 km (88% of the main river is already modelled). In the previous section, there is a brief summary of the information that these studies contain because a review was carried out for two specific cases, the PEFs of the Marganell and the Magarola Rivers.

Apart from hazard, another important aspect linked directly to the concept of risk is the presence of settlements in the floodplains and their associated vulnerability. Therefore, the urban planning laws should establish rules on what land uses are allowed depending on the different flood probabilities. The first urban planning law in Catalonia that specifically prohibits building in potential flood areas dates from 2002, but it was in 2006 (Regulation 305/2006) when the first guideline for protection against flood risks entered into force. This guideline defines the different flooding zones depending on the frequency of the event and establishes limitations in the land uses for each of them, constituting the first case in which urban planning is directly linked to the identification of flooding areas and their associated risk.

In the field of prediction and protection, important improvements have been made in the last years. From 1983 the "Automatic Hydrological Information System" (SAIH) is being implemented at a national level in different phases. In the case of the Llobregat basin, the installation finished in 1996 and it is working since then. This information system gathers hydrological, hydraulic and basic meteorological data in a real-time basis and sends it to the decision support centre. The SAIH also works as an alert system that monitors different variables and determines the water level through hydrological modelling. Furthermore, in the case of Catalonia, the "Integrated Hydrometeorological Forecast Tool" (EHIMI) is working since 2005 and constitutes an improvement compared to the SAIH. EHIMI incorporates radar images (from the Catalan Meteorological Service) to obtain optimized rain fields and combines them with rainfall data (from SAIH). The tool integrates them into a distributed hydrological model that provides a flow forecast in a real-time basis (for the Llobregat and Besòs Rivers, the model provides water levels and discharges rates with a 12 h lead-time). It is foreseen that by the end of 2009, ACA's website will contain a link to the EHIMI platform where real-time radar rain field information (updated every hour) will be available. It will also include real-time flood alerts for the whole Catalonia, with hourly and daily accumulated precipitation data.

Currently, the Catalan Water Agency has different data related to water and the environment available to everyone in its website (http://aca-web.gencat.cat/aca/appmanager/aca/aca?_nfpb=true&_pageLabel=P38002452912118830426 87). Regarding their control networks, it is possible to download data from reservoirs, gauging stations and rain gauges. Moreover, all the flooding area maps of Catalonia will be available soon.

Implemented emergency plans and management procedures

The INUNCAT is the flood emergency plan that is currently implemented in Catalonia. The current version was approved in 2006 and it has not been updated since then. The actors involved in an emergency situation are: Civil Protection Department, Catalan Water Agency (ACA), Meteorological Service of Catalonia (SMC), Geological Institute of Catalonia (IGC), Police Department, Fire Department, managers of public basic services and the Regional and Local governments.

The INUNCAT contains the following information:

⇒ Hazard analysis (developed by ACA)

- Geomorphological / hydrologic-hydraulic analyses to delimit flooding areas
- List of "Priority Intervention Points"

- Calculation of propagation speed (indicator to classify floods by their response time and to detect flash flood areas, see Figure 3)

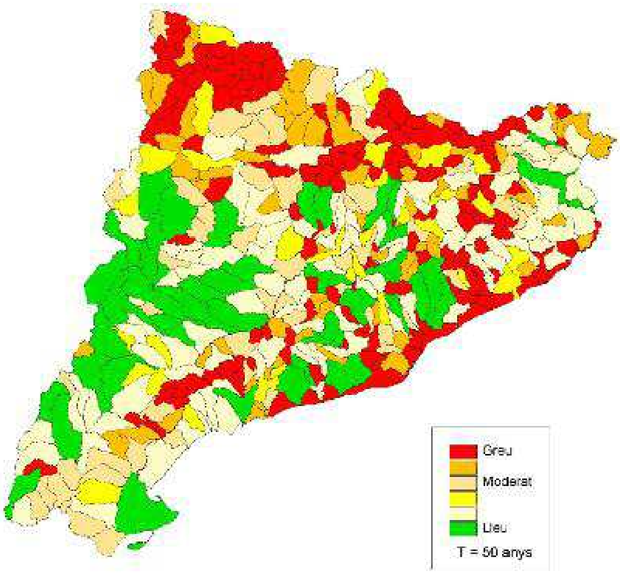

Figure 3. Basins hazard levels according to the propagation time for a 50 year return period. *Source: Departament d'Interior de la Generalitat de Catalunya 2006*

- Dam emergency plans
- Identification of geological phenomena (areas with mass movement probability)
- Hazard = Probability factor x Intensity factor

⇒ Vulnerability analysis (developed by Civil Protection Dept.)

- Definition of the minimum assessment unit as the municipality
- Economic loss evaluation through the USACE damage curves (see Figure 4)
- Estimation of population in flooding areas using statistical data
- Estimation of the length of transport infrastructures affected by floods

⇒ Historical data analysis

- Compilation of the major flood events (date, cause, river basin and affected municipalities)
- Meteorological description of some specific flood events

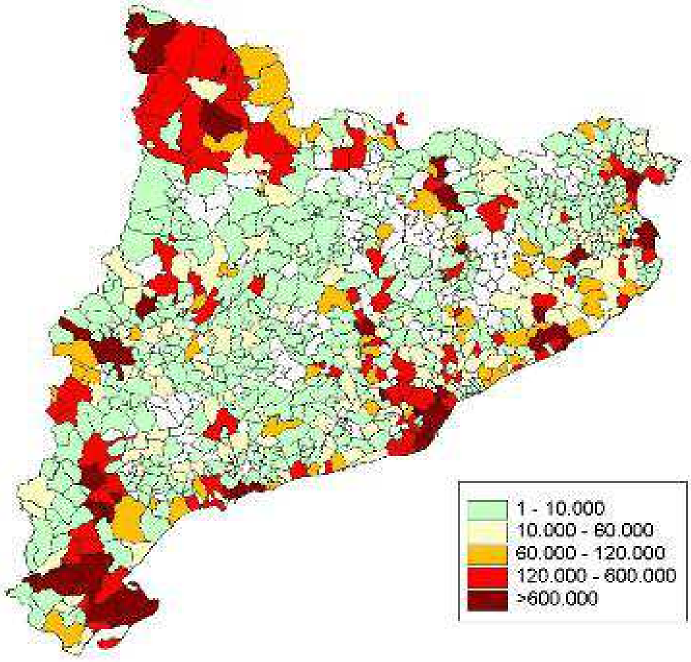

Figure 4. Estimated economic damages (in €) per municipality. *Source: Departament d'Interior de la Generalitat de Catalunya 2006*

⇒ Risk analysis

- Calculation of risk by element and municipality based on the probability of the event and the level of damages that may cause
- List of municipalities classified by their risk level. List of municipalities required to prepare a local emergency plan or Municipal Intervention Plan (PAM).

The emergency plan also contains the organization structure, the actors involved and the control centres that coordinate all the operational activities. See Figure 5 for the organization chart defined in the INUNCAT. Another section defines the emergency detection processes and the phases of the emergency plan activation. Finally, the INUNCAT describes the equipments and facilities needed when it is activated.

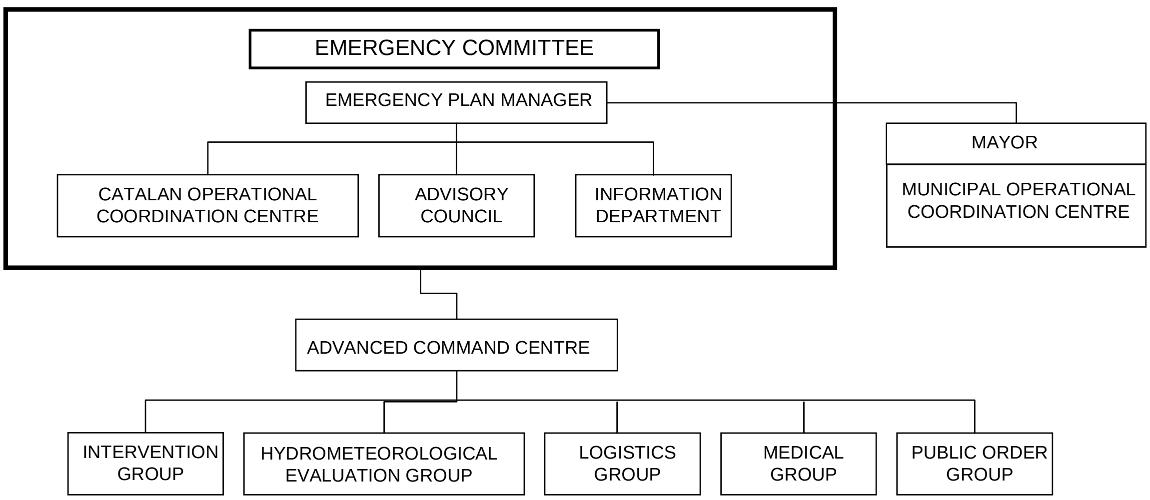

Figure 5. Flood emergency plan organization chart. *Source: Departament d'Interior de la Generalitat de Catalunya 2006*

Regarding forest fires, the INFOCAT is the emergency plan currently implemented (Departament d'Interior de la Generalitat de Catalunya 2007).

Existing information on the estimation of future changes

ACA and the New Water Culture Foundation, in collaboration with several universities and research centres, has recently published a book titled "Water and Climate Change" that includes a detailed diagnosis of all of the potential effects that may be caused by climate change throughout the 21st century. Chapter no. 12, "Effects on hydrological variability and extreme phenomena; examples of hydrological modelling of floods and droughts in future scenarios", deals with the existing projections on extreme precipitation in Catalonia (Manzano 2009).

The main conclusion of this analysis is that the information available until now has to be understood as a trend but not as specific results. Summarizing, it is likely that the frequency of extreme rainfall will double, with maximum discharge rates up to 20% more than the present values for return periods between 10 and 100 years. It is clear, then, that the current design guidelines used to build many infrastructures should probably be reviewed at some point. The report also highlights that the vulnerability will increase due to anthropogenic factors and it might imply a much more significant risk increment than the one climate change might cause.

4.1.4 Lessons learnt and future improvements

Several studies have been analyzed in order to extract the following lessons learnt (ACA 2009; Cañellas 2000; Escuer 2008).

Lessons learnt on prevention

⇒ In some cases, land use measures have been taken into account too late. It was in 2006 when the first "Guidelines for Protection against Flood Risks", as part of the Urban Planning Law, entered into force. This regulation is currently being applied to main rivers but it is not appropriate for secondary streams and/or alluvial fans. The review of the definition of land uses for each type of zone is a priority of the future River Basin Management Plan (RBMP) that is now under preparation. ACA is also planning to review and elaborate new technical recommendations on how to manage river areas, their occupation and the uses allowed. They have already published several guidelines to carry out small flooding studies but there is a need to standardize the different criteria used.

⇒ A more accurate calculation of vulnerability is needed. In the current emergency plan vulnerability is estimated by municipality, being this assessment unit too coarse in some cases. Population data has been extracted from statistics, as well as damages on buildings. A more precise calculation might be done in order to better evaluate what are the areas that are more exposed and may need more protection measures.

⇒ In the hazard field, the continuation of the PEFCAT project will imply having flooding maps at a much finer scale (1:5.000 instead of 1:50.000). This will mean that more accurate information will be available to calculate hazard levels. It would be also very useful to determine the uncertainty associated to this kind of studies by comparing their results to water levels produced by real events.

⇒ The implantation of a hydrometeorological alert system has been proved to be necessary to obtain forecasts with the maximum precision and lead time possible. This system (EHIMI) is currently under development and it will manage both, hydrologic (automatic water level, discharge) and meteorological data (rainfall data, radar data) in an integrated and centralized way. Improvements on the monitoring network are also planned (including sediment transport sensors). The system will generate the alarm warnings depending on these measures.

⇒ The Civil Protection Dept. is currently focusing on completing a "Priority Intervention Point" (or "black spots") database and proposing specific actions and infrastructure measures for these locations (e.g. install warning signals, fences). The objective is to work together with local authorities to detect additional problematic points and to define what is the action to implement, what is the urgency of it and who is the responsible of its execution. This involves a work of actions prioritization that is critical for improving the management procedures. Around 1.500 locations have been already identified. Regarding flash flood-prone areas, one of the priorities is to prevent vehicles from being dragged from low lying sections of road, because this constitutes one of the most frequent cause of accidents and, therefore, of human losses. Then, identifying these locations and putting traffic diversions around potentially flooded roads is crucial in these cases.

⇒ In the case of secondary streams that have an intermittent discharge, it has been detected that population has no risk perception. In relation to the previous point, these locations must be also detected and properly signposted.

⇒ Related to debris flow, ACA is currently analyzing more than 900 areas with potential problems of mass movements. This study is not published yet. ACA is also developing a specific study on "Flooding studies of the Lleida province camping sites" to identify potential debris flow hotspots.

⇒ Future research will have to take into account other aspects, like climate change or land use changes, in the analysis strategies that are currently in use. The Floods Directive 2007/60/CE asks to consider the potential impacts that these future changes can cause in the flood risk level. This need has been identified by the ACA and a study analyzing the climate change effects has been carried out in two small basins in Catalonia (ACA-INCLAM 2008). However this work is focused on the projected impacts of climate change in the water resources, not having evaluated its effect on the floods frequency and intensity.

Lessons learnt on preparedness

⇒ ACA is currently carrying out maintenance actions with the objective of guaranteeing an adequate flow in those stretches of the river where problems related to discharge capacity have been detected. This program of actions has been operating since 2004 and it includes riverbed maintenance measures that are carried out every year and emergency actions that are only implemented after a disaster.

⇒ The future RBMP will include structural measures to protect vulnerable areas and to improve the hydraulic capacity of some river stretches ("Flood Prevention Program" and "Morphodynamics and Sediment Management Program"). They will be classified by their priority. These measures will involve retention infrastructures, protection walls, bridges redesign and signs installation. These Programs are currently being developed with the aim of better detecting deficiencies in flood prevention, management and reduction of risks. A monitoring plan to control the right execution of the measures is also foreseen.

⇒ The need for reviewing and updating the emergency plans every certain periods of time has been detected by both, ACA and the Civil Protection Dept. Past experiences should be considered and lessons learnt from past events should be incorporated. At the moment, a meeting is held at least once a year (at the beginning of the campaign, in

September) with all the organizations involved in the emergency plan. The previous year events are analyzed and decisions are made in case there is the need of changing warning thresholds or any operational procedure. For example, it has been detected that there are small towns without any kind of local police and, then, it is necessary to provide mobile phones to the personnel that is involved in the operative actions of a flood emergency.

⇒ The current emergency plan contains a list of the municipalities that are forced to prepare a "Municipal Intervention Plan" (PAM) due to their risk level (very high, high or medium). At present, only between 20–30% of the approximately 500 required municipalities have implemented the PAM. Therefore, more human and economic resources are needed in order to help local authorities execute their PAM. This is especially problematic in the case of small towns that have no technical support or even without local police.

⇒ As a definitive measure for the next future, all the organizations involved in the flood management are preparing the Flood Risk Management Plan (FRMP) that the Floods Directive 2007/60/CE demands. FRMP will have to include flash floods and debris flow risks, the approximate number of inhabitants affected, the economic activities of the region, the installations that can cause an accidental pollution and the protected areas that might be affected. These plans are due by the end of 2015.

Lessons learnt on response measures

⇒ There is the need to evaluate the real effectiveness of the emergency plan. It would be very useful to carry out a follow-up analysis after an important event to detect response deficiencies (this is also applicable to prediction and prevention systems) and to propose improvements. It is also very important to analyze response actions in order to improve coordination among the different organizations that take part in the emergency management.

⇒ Maintenance and improvement of the protection, communication and control equipments is crucial to provide an effective response. For example, in the specific case of the floods in 2000, one of the control centres was left inoperative due to lightning, so the need for back-up centres was proved to be important in order not to depend on only one resource.

⇒ The future RBMP will include knowledge management measures in the flood prevention section. It will define roles and responsibilities of the different actors involved and it will help in the dissemination of information and educational programmes. It will also include a thematic network creation and expert commissions to debate topics related to floods. In Catalonia, there are initiatives like the Natural Risks Thematic Network, where many actors involved in the emergency management participate. The Network promotes discussion forums to debate about the different strategies on flood risk prevention.

Lessons learnt on dissemination and education efforts

⇒ The Civil Protection Dept. carries out dissemination programmes, especially at the beginning of the heavy rains period (September). They publish leaflets with recommendations and distribute them to public and private entities, they prepare interactive video-clips for their website, there are advertisements on the mass media and they e-mail information to local authorities.

⇒ The EDRINA website (Education in Natural Risks) contains information about natural risks, especially those related to meteorology, like floods, droughts or extreme temperatures. The promoter is a scientific group from the Astronomy Dept. of Barcelona University and their key objective is to reach the general public. There are other examples of websites, like the RINAMED project that also educates about how to face natural risks.

⇒ Traditionally, society usually has had the wrong perception of being under a non-risk situation because they were used to be protected by structural measures. Lately, population tends to accept a certain level of risk due to the equilibrium between structural and non structural measures, more sustainable with the environment. Education and dissemination of information should help to prevent a wrong idea of living under a non-risk situation.

4.2Guadalhorce basin

4.2.1 Basin description

The main river in the Malaga province is the Guadalhorce, which runs from north to south and collects water from almost half of its territory (3.157 Km^2, equivalent to 43% of the total Malaga's province area). Its main tributaries are the Turón and Guadalteba in Upper Guadalhorce (the two of them together with Guadalhorce River, flow into one of the most important sets of reservoirs of Andalusia: Guadalteba, Conde de Guadalhorce and Guadalhorce, three dams for volume regulation purposes) and other smaller rivers such as Grande, Fahala and Campanillas, in the lower part of the basin. The hydrographical map is completed by a series of endorheic basins (internal drainage areas not linked to the sea), being one of them the 'Fuente de Piedra' basin, which holds one of the most singular lakes in Spain, not only by its size but for its high ecological interest.

The Guadalhorce valley comprises 13 municipalities and it has a population of 132.928 inhabitants. Nowadays, the urban planning expansion is located in that zone, due to its proximity with the capital (Malaga) and the good communications, like the Malaga-Campillos Freeway.

Figure 6 shows the Guadalhorce basin with its main tributaries and towns.

The dominant climate in Malaga Region is described as warm-temperate Mediterranean. It is characterized fundamentally by a marked dry season, with hot summers and generally mild winters. The warmest months are July and August with an average of 23ºC maximum, and the coldest are December and February with an average of 13ºC minimum. The rainfall distribution of the area is well defined, being autumn and winter the wettest seasons.

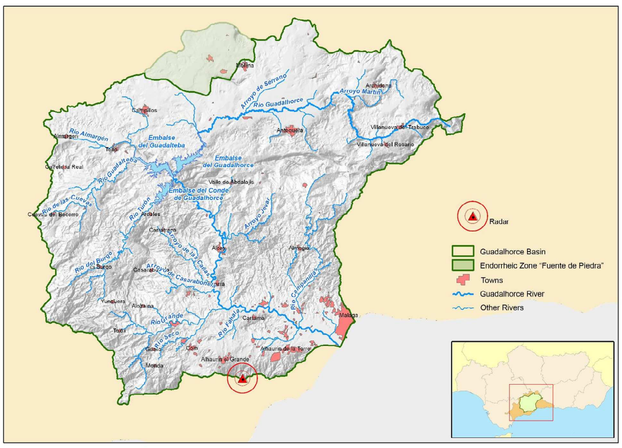

Figure 6. Guadalhorce basin. *Source: EGMASA questionnaire*

4.2.2 Historical floods

The information related to historical floods has been extracted from the technical datasheets included as an appendix in the "*Historical floods and Potential Risks. South Basin. Volume 2*" and from several issues of the Spanish journal, ABC. The mentioned datasheets have only qualitative information, but they do not contain detailed data about rainfall intensities, discharges or precipitations. In any case, these datasheets have been useful to search for more information in the journals of these dates. In the same way, the journals also tend to show only information about the caused damages.

All the events identified correspond to flash flood events, there has not been found any debris flow event. Table 2 shows the most important historical events in terms of damages and social impacts identified in the Guadalhorce basin.

Table 2. Main historical floods in the Guadalhorce basin. *Sources: ABC newspaper website; CTEI 1983*

Date	Total Precipitation (mm)	Economic loss (million €)	Deaths
September 1949	Approx. 100	-	0
October 1969	70-150 (depending on location)	-	0
January 1970	376	-	0
November 1989	(I_{max}=50 mm/h) 400	600	6
January 1997	-	-	0
February 1998	-	-	0

<u>11. September. 1949</u>

Damage inventory: Many houses and streets flooded in the town of Antequera. Cut off of several roads and rail tracks. Many agricultural fields flooded.

<u>5. October. 1969</u>

There were heavy rains all over Andalusia, with total precipitation amounts between 70 and 150 mm, depending on the location. In Malaga province, the overflowing of the Guadalhorce River caused the flooding of several roads, including the access to Malaga's airport, agricultural fields and several industries.

<u>14. November. 1989</u>

This event constitutes one of the most catastrophic episodes in the history of floods in the Guadalhorce basin. After several days of rain, accumulating more than 400 mm in twenty days, there was a large flooding that left six deaths and substantial economic losses. The discharge in the lower part of the river exceeded 2000 m^3/s.

The positive part is that the severe consequences of this event favoured a series of measures to protect population from the frequent floods of the Guadalhorce River. The two major actions planned were: the channelling of the lower part of the Guadalhorce River and the construction of the Casasola dam, in the Campanillas River. The works for the channelling took place along 7 km, with a total cost of 90 M€, and allowed the delta to have 300 ha instead of the 50 ha that had before. The river drainage capacity became 4500 m^3/s, more than double than before. The construction of the Casasola dam to retain the discharges from the Campanillas River allows not to increase the peak discharge of the Guadalhorce river and it contributes to enhance the control of the whole basin.

After this event, the Regional Environment Ministry started to program management and control actions in many rivers and streams in the whole Malaga province that are still being built today. These measures include two main types of actions. The first one includes the reforestation of large parts of the Guadalhorce's high basin, involving the plantation of 2,5 M trees and the restoration of several stretches of the river banks. The second action is included in the Correction Measures Program elaborated after the floods and it has involved the building of 370 protection dikes, with a total cost of 20 M€. All these efforts have made the Guadalhorce basin, especially its lower part, safer and more prepared to face events even worse than the 1989 one.

4. January. 1997

There were generalized rains in Andalusia, being Malaga province one of the most affected due to the overflowing of the Guadalhorce River. The major damages were concentrated in the lower part of the river, reaching a water level of 4 meters in the town of Cártama. Many families had to be rescued and evacuated and the town of Tolox was cut off during several days due to the collapse of its only road.

2-4. February. 1998

The flash flood occurred in February 1998 affected a large part of the South Basin and it constitutes an example of how a hydrometeorological model (SAIH Hidrosur) enabled an efficient management of an event.

The availability of the weather forecast for the next two days showed the possibility of a flash flood situation. It was decided to take the precaution of doing a generalized emptying of the reservoirs in order to increase the available reserve capacity. The Civil Protection centres involved received the SAIH data of the river levels with the intention of keeping those affected informed and taking the appropriate safety measures. There was not any victim and the economical damages were almost inexistent. The South Basin, through the SAIH Hidrosur, had meteorological forecasts available (from AEMET, the Spanish national meteorological office) and knew about the state of the basin (precipitation, flow rates, discharges, reservoir levels...) and this helped them to make the right decisions and keep all the municipalities affected under alert in a flood situation.

4.2.3 Risk management plans

Map information

The cartography available includes topography, geology, land use, ground water and rainfall probability maps at different scales, as shown in the corresponding section of the questionnaire. A special mention must be made to the existence of "extreme rain" maps that show the rate between the contribution of torrential rains and the total yearly precipitation.

In the study elaborated in 1983, "*Historical floods and Potential Risks. South Basin*" (CTEI 1983), there are historical flood maps which include the situation, the most probable season and the number of flood occurrences at different locations in the South Basin. This study also includes potential risk maps for the whole basin at a scale of 1:200.000. These risk maps were developed from the flooding area maps, also at a scale of 1:200.000 that show the flooded areas according to their return period. Apart from this information, the vulnerability level of the whole basin was analyzed. The vulnerability study was not specially detailed. It characterized, in a qualitative way, the potential damages that could be produced in each zone and it classified them into 7 types and into 3 levels of severity. This resulted in an impact matrix with numerical values for each type of damage that was translated into a vulnerability numerical mark for each zone. This mark was combined with a hazard coefficient, depending on the frequency of the event in that area, which gave the final numerical value which determined the risk level. This methodology is very similar to the one described for the Llobregat basin in the INUNCAT. Among the six Andalusian areas classified as "maximum risk" level, there is Vega del Guadalhorce zone, that includes several municipalities located along the Guadalhorce River (i.e. Cártama, Pizarra).

Currently, the Andalusian Water Agency (AAA) is working on a new series of flooding maps at a much finer scale, 1:2.000, elaborated through hydraulic modelling. When finalized, this work will be included in the "Flood Prevention Plan in Urban Areas" and it is foreseen to be completed by the end of 2015. The priority is modelling the rivers and streams nearer to the coast first, where the more vulnerable areas are located. The lower part of the Guadalhorce River is included in this initial phase of the work that is foreseen to be finished soon.

Improvements of plans and policies

The first measure that contributed to the prevention of flood effects was the construction of the "Conde de Guadalhorce" dam, back in 1914 (the dam was finished by 1921). In 1966 the Guadalhorce and Guadalteba dams were also started, constituting a three dams system that had three main purposes: hydropower generation, irrigation and water supply for Malaga city. Therefore, the initial objective of the dams was not the mitigation of the flood effects but it has shown to provide a significant use through time.

In 1980, the National Commission on Civil Protection was created to coordinate all the actions related to emergency situations. Later, in 1983 the Commission decided to constitute the Technical Commission for Flood Emergency (CTEI) to study preventive and corrective measures to minimize flood effects at a national level. Working groups 1 and 2 of this Commission elaborated the study "Floods in Spain. General Report", in which the flood problem was assessed and the historical data was inventoried.

After the General Report recommendations, the "Historical Floods and Potential Risks" report was written for each one of the Spanish hydrological basins, including the South Basin, in which the Guadalhorce river basin is included. The methodology used to elaborate the potential risk maps, which was the key objective of the study, still constitutes the base of the work that Andalusia is carrying out in the risk field nowadays. The methodology, which was common to all the hydrological basins in Spain, consisted on:

- ⇒ Compilation all the information available about historical floods
- ⇒ Selection of the main variables that defined those floods
- ⇒ Creation of a database with all the previous information
- ⇒ Analysis of the morphological aspects that determine the potential risk of flooding
- ⇒ Basin classification in different risk zones and identification of the black spots (especially hazardous locations)
- ⇒ Design of the potential risk maps

Chronologically, the next big improvement was the implementation of the South Basin's Automatic Hydrological Information System (SAIH Hidrosur, http://hidrosur.agenciaandaluzadelagua.es/webgis2/portada_1.html), which has been functioning since 1991 (AAA 2009). As explained in the Llobregat basin section, the SAIH is a network of remote stations with the objective of obtaining hydrometeorological data (discharges, water levels, precipitation...) in a real-time basis (hourly) at different locations. The system also receives meteorological forecasts from the AEMET (the Spanish meteorological service) and they generate risk alert warnings that are also available on-line (see Figure 7 for an example of a precipitation likelihood map). All data coming from the measurement stations is transmitted to the Control Centre, located in Malaga, where the information is analyzed and stored. These types of systems constitute a decision support system for both, flood and water resources management.

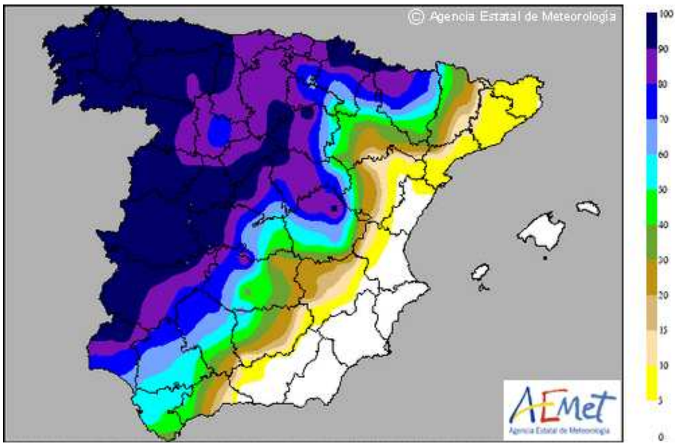

Figure 7. Map of the precipitation likelihood in the Iberian Peninsula. *Source: AEMET website*

In 1997, the Infrastructures Directive Plan of Andalusia established the following criteria to improve the safety conditions of the population and the economic goods in front of flood risks: build protection infrastructures, carry out forestry restorations prioritizing the areas under erosion risk and plan the construction works in order to limit their environmental impact and promote their integration into the urban areas. This plan sets the basis for the future Flood Prevention Plan.

In 2002, it was decided that a comprehensive risk diagnostic for the whole Andalusia region was a priority to later launch the flood prevention plan. This analysis detected the "black spots" (or high vulnerable flood-prone areas) and it classified them into four different risk level categories. The results were quite worrying because there were 428 municipalities classified as having a certain level of risk, which means that the 56% of Andalusian municipalities and 60% of population had flood problems, being those located near to the Mediterranean coast the more vulnerable ones (see Figure 8).

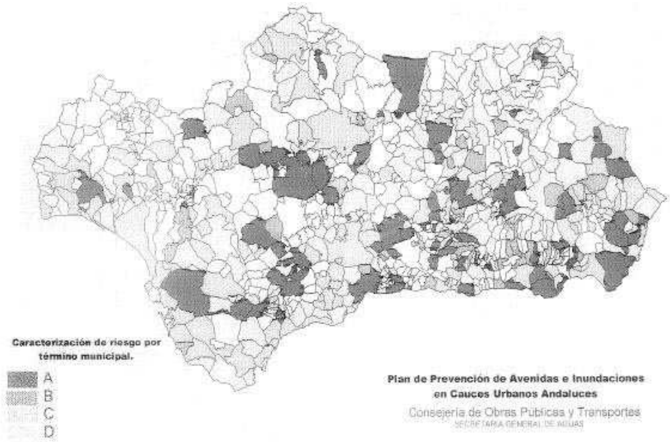

Figure 8. Level of risk by municipalities in Andalusia. *Source: Consejería de Obras Públicas y Transportes 2002*

This same year, in July, the "Flood Prevention Plan for Andalusian Urban Rivers" was approved due to the need of treating the flood problems from a global perspective and coordinating all the different public organisms involved in its management (Consejería de Obras Públicas y Transportes 2002). The main objective of the plan is the prevention and mitigation of the flooding risk in the urban areas through an integral management which includes the intervention in the urban planning processes. Besides, it promotes the execution of comprehensive actions at a basin level, meaning that actions must be carried out not only in the urban areas but also in the rural areas located upstream.

Related to the previous point, in December 2002, a new urban planning law was approved in Andalusia that limited the land uses allowed in every flood zone. Highlighting the most important aspects of the regulation, it is totally forbidden to build within the 50 year flood limits; it is not possible to build some types of industries within the 50 and 100 year flood limits or any kind of building if the water velocity reaches certain values; and finally, it is not allowed to install a polluting industry within the 100 and 500 year flood limits.

In 2004, the AAA started the execution of the hydraulic studies to delimitate the different return period flood areas. Currently there are 12 different river basin studies already finished or under development (see Figure 9). The stretch of land closest to the sea has been prioritized due to its high vulnerability, with a high urban development next to the rivers.

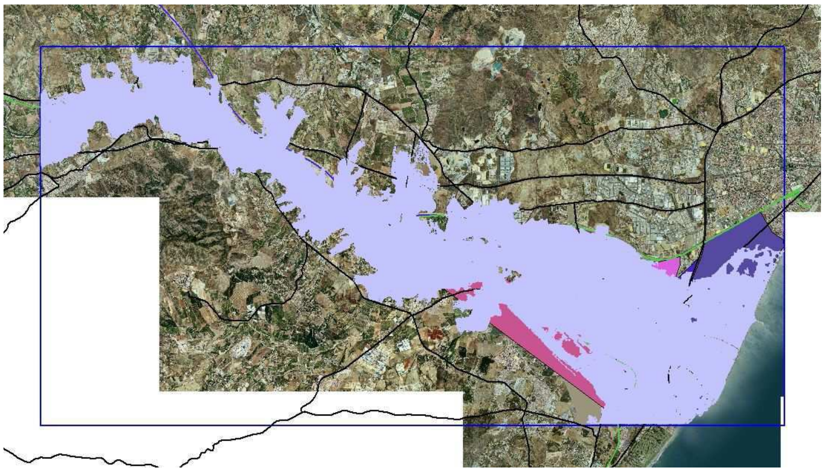

Figure 9. Simulation of the flooding areas for the lower part of the Guadalhorce River. Source: AAA website

Finally, in December 2004, the Flood Risk Emergency Plan of Andalusia was approved. The plan key objective is to establish the organization and the action procedures to provide an appropriate response during and after a flood event (Consejería de Gobernación 2004).

Implemented emergency plans and emergency procedures

As mentioned in the previous section, in July 2002, the "Flood Prevention Plan for Andalusian Urban Rivers" was approved. The main objectives of the plan are to promote integral actions (involving hydrometeorological, territorial, economic and environmental aspects) in order to reduce the flood effects, to establish priorities in the proposed actions program and to improve the coordination among the different administrations involved.

The methodology to be followed takes into account the participation of all the administrations involved, the compilation of all the previous studies and plans and the transparency of the process that should inform the population affected. The plan includes a series of measures that will have to be implemented at different phases and finished by the end of 2015. The main actions, involving both, structural and non-structural, measures are:

⇒ Delimitation of the flood zones

⇒ Inventories of infrastructures and buildings in flood-prone areas

⇒ List with the protection infrastructures needed in the locations classified as high risk prioritized by their urgency

⇒ Forestry hydrological correction measures

⇒ Riverbed maintenance

⇒ Urban planning regulation

On the other hand, in December 2004, the "Flood Risk Emergency Plan of Andalusia" was approved. Unlike the "Flood Prevention Plan" that focused on planning measures to mitigate the flood risk, this Emergency Plan contains the protocol that has to be followed when a flood emergency occurs. The main objective of the plan is to define the organization structure and the action procedures for a correct response in front of a flood emergency, including the definition of the alert levels according to the hydrometeorological information available. The plan also includes guidelines on how to improve the efficiency and coordination during and after the event. In relation with other emergency plans, it gives instructions to the municipalities on how to elaborate the Local Action Emergency Plans and it establishes the coordination procedures with the Dam Emergency Plans. It is also in the scope of this plan to promote and develop education and information programs to the population affected.

Regarding forest fires, the INFOCA is the emergency plan currently implemented in Andalusia. The first plan dates from 1985. However, the current plan is based on the one from 1993, when a new version of the plan was issued.

Existing information on the estimation of future changes

Regarding climate change, the Climate Foundation Research Centre (FIC) developed a study for the whole Andalusian region in December 2006, titled "Generation of climate change scenarios in Andalusia" (FIC 2006). This study was carried out within the Regional Climate Change Strategy framework and it aimed to evaluate the potential impacts of climate change in Andalusia. The results are based on a statistical downscaling with the analogues method that FIC previously tested in the EU project STARDEX. Two GCM were used and two different IPCC SRES were projected, A2 and B2. The variables obtained were temperature and precipitation, and for both of them, there are the 95% percentile values available, which can give an idea of their extreme projections.

In relation to land use changes, EGMASA attached a research paper (Ojeda & Villar 2007) to the questionnaire that presented the results of a study on the evolution of the urban land on the Andalusian coast during the 1998 – 2002 period using ortho-photography maps. The paper does not generate projections for the future but it is interesting to analyze the urban land use changes produced during the late years in order to identify the real evolution and have and idea of the projected trend for the next future. In fact, the results show a very clear increasing trend in terms of urbanization and intensification of already urbanized land, being respectively 7,8% and 6,3% in 4 years.

4.2.4 Lessons learnt and future improvements

Apart from the documents mentioned in the previous sections, several other studies have been analyzed in order to extract the following lessons learnt (Berga 1998; EGMASA 2006; Ojeda et al. 2008).

Lessons learnt on prevention

⇒ Even if there is an urban planning law that dates from 2002, this regulation only applies to new developments but not to the existing urbanizations. An additional difficulty related to urbanization is that this constitutes the main source of income of many municipalities, so it exists an increasing pressure to transform rural land into urban, leading to the transformation of flood-prone areas into urban.

⇒ The finalization of the detailed hazard maps (at a 1:2.000 scale) is crucial to have much more accurate information available related to the flood-prone areas. Making these maps available (for example on-line) is also very important in order to keep the population affected aware of the risk and also to establish restrictions when new urban and industrial developments are proposed.

⇒ Regarding the main protection infrastructures existing in the basin, the three dams system "Guadalteba", "Guadalhorce" and "Conde de Guadalhorce" have demonstrated to be really efficient in the reduction of the discharge peaks from the Guadalteba, Guadalhorce and Turon Rivers, respectively. An important inflection point in the protection infrastructure planning was the year 1989, when one of the most severe flood events took place. The Casasola dam, in the Campanillas River, a tributary of the Guadalhorce, was built allowing not to increase the peak discharges in the lower stretch of the Guadalhorce River. At the same time, the channelling of the lower part of the Guadalhorce River was built, and the river drainage capacity increased from 2.000 m^3/s up to 4.500 m^3/s. Even the cost of these measures is high, their benefits are significant and they have been planned through a global analysis, taking into account the nexus existing among water-territory-infrastructures.

⇒ As a result of those important regulation and protection infrastructures, the flood problem has been displaced from the main rivers (and main cities) to the secondary streams, and then, more efforts should be focusing on towns located near small rivers. In the case of Andalusia, Malaga is the only big city classified as being under a maximum flood risk.

⇒ The vulnerability was assessed in 2002 but since then, and according to the urban growth calculated in the previously mentioned paper (Ojeda 2007) during the 1998-2002 period, it might have changed significantly (more tourist and urban developments, more infrastructures…). Additionally, the damage costs have been calculated in a non precise way, being the minimum calculation unit the municipality, and from flood hazard maps at a very coarse scale (1:200.000). Therefore, the vulnerability information obtained is mainly qualitative, differentiating between rural, urban or industrial zones, and taking into account the main infrastructures and the number of people potentially affected. An updated vulnerability estimation should be done taking into account the more accurate flood hazard limits and newer statistics on population and buildings.

⇒ It is important to prepare historical flood databases in order to locate the areas that have been more frequently hit by flooding. Data should be summarized, classified and systematized to find out the main causes of the flood, the most frequent damages and their magnitude. This kind of database constitutes the basis to detect the "black spots" and to have information about the real cost of the damages. Another reason for creating a database is to provide real data of peak discharges and water levels during a flood event and compare them to the maximum values calculated empirically. It is also useful in order to have more information that enables to prioritize the actions to be carried out.

<u>Lessons learnt on preparedness</u>

⇒ The current Flood Prevention Plan (2002) already anticipates the budget for the continuous maintenance of the riverbeds (120 M€ for the period 2002-2015) to improve their drainage capacity and ensure their environmental integration.

⇒ The need for updating and reviewing the Emergency Plans has already been detected in the current one (2004). The plan gives general guidelines on how to update the plan and fixes that it should be updated every year, but it does not detail how it must be done, when it must be totally reviewed instead of updated or when the new versions will be available. It is essential to regularly check the efficiency of all the aspects involved in the plan: technical situation of the protection works, information flux, means and materials for intervention, organization of the groups and administrations involved.

⇒ The current Flood Emergency Plan establishes that all the municipalities must elaborate and implement their Local Flood Emergency Plan in order to protect the population affected with the local resources available. The emergency plan describes the minimum contents of the local plans, but there are some problems related to this point:

  - At the moment there is not any deadline to implement these local plans. Nowadays, only 106 municipalities have a local plan implemented, and this represents approximately the 25% of the 428 municipalities under a certain risk.

  - Many towns do not have enough economic and/or technical resources available to elaborate it or to implement it. It is true, however, that the current Flood Emergency Plan has detected some of these deficits and foresees to organize training sessions to local authorities and technicians.

Lessons learnt on response measures

⇒ As proved by the 1998 event, previously analyzed, the existence of a hydrometeorological system implemented in the whole basin constitutes a helpful decision support system that can improve and facilitate significantly the emergency management. This kind of systems allows estimating the flood magnitude with enough anticipation to activate the emergency plan and to reduce its impacts, provided that they are integrated within the civil protection operational procedures. The problem is that, frequently, in the case of flash floods the lead time is too short even with the help of an early warning system and the emergency plan can not be activated on time. In those cases, the plan is only used for the rehabilitation phase.

⇒ The coordination between all the administrations involved in the flood management is crucial, especially during and after the event. This aspect has already been considered in the Flood Emergency Plan for Andalusia (2004), where the coordination procedures between the national and local emergency plans have been established.

Lessons learnt on dissemination and education efforts

⇒ Promoting the continuous training of the technicians involved in any aspect of the flood management is needed. It is also important to carry out evacuation simulations to verify all the processes that take place in an emergency situation.

⇒ More dissemination and education campaigns to inform the population about the implemented prevention and emergency plans are needed. At present, the Andalusian regional government has a section in its website where the different types of natural risks are described. There are also recommendations on how to act before, during and after the emergency (http://www.juntadeandalucia.es/gobernacion/opencms/portal/SubdireccionEmergencias/ProteccionCivil/ContenidosEspecificos/Recomendaciones/3.B.1-RECOMENDACIONES_RIESGOS_INUNDACIONES?entrada=tematica&tematica=68)

⇒ The current Flood Emergency Plan has also identified the necessity of informing about the mechanisms and systems to communicate the alert levels to the population before and during the events. The warnings will be disseminated through different media (TV, radio, newspapers)

⇒ The development of follow-up studies after a serious event with an integral analysis of the management of the flood event: starting from assessing the protection measures and evaluating if they have accomplished their function, reviewing the emergency procedures that have taken place before and during the event and also analyzing the response and even the rehabilitation process. This kind of studies are useful for different dissemination purposes: it is important to make population and authorities involved aware about the means available to cope with floods, about the potential consequences of a similar event and to make a critical analysis of what parts of the emergency plans could be improved in the future and what parts can be used as an example for other basins.

4.3 Gardon d'Anduze basin

4.3.1 Basin description

The Gardon d'Anduze basin is located at the Northeastern part of the Languedoc and it is integrated in the system of basins of the Gardons. The Gardon d'Anduze River has a longitude of 30 km, and its basin has a surface area of 545 km^2. The basin extends from the Cévennes at 1500 m, which is its highest point and where the spring of the river is located, to the Gard River at 200 m, where the river discharges. The Gard River will later flow into the Rhône River, of which is one of its main tributaries and the last one before it arrives to the Mediterranean Sea. Figure 10 shows all this geographical information along with some relevant flood data. The Gardon d'Anduze basin is located in the Northwestern part of the map, upstream from the town of Anduze.

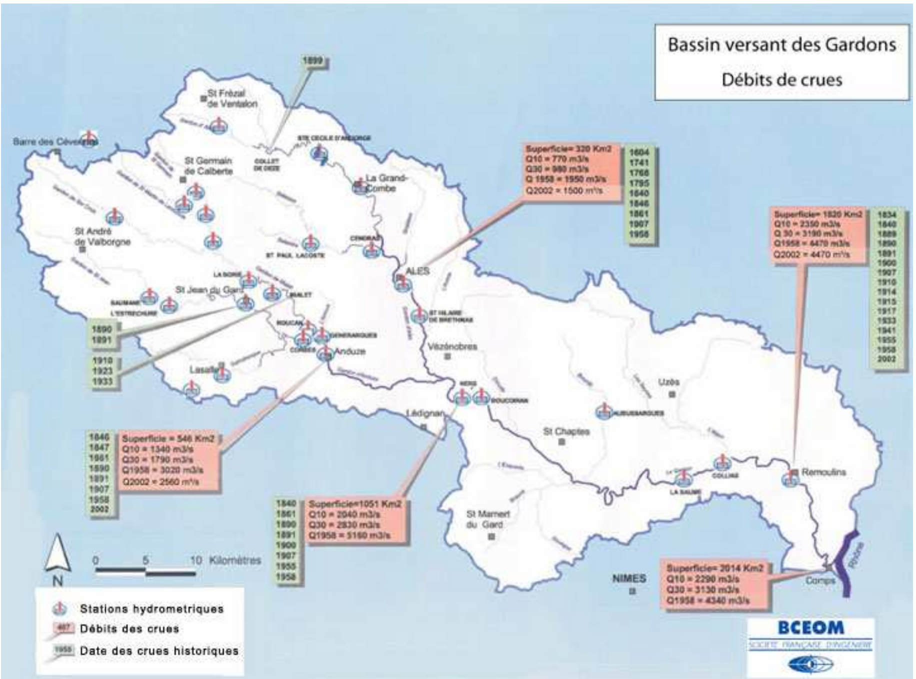

Figure 10. Exceptional floods and peak flow discharge values of Gardons basins. *Source: website of the 2002 flood*

The Gardon d'Anduze is a north west – south east oriented basin. Upstream of the town of Anduze, the river is divided into two main tributaries: Gardon de Mialet and Gardon de Saint Jean, which drain from other small streams, most of them also called Gardons. Therefore, the river network in the upper part of the basin is ramified going through very narrow valleys until, in the surroundings of Anduze, the bed widens forming an alluvial plain. The Gardon d'Anduze catchment area is covered basically by forest (80 % of the territory).

The river is often suffering from high risings, due to the climate situation, the geomorphological characteristics and, of course, the geology and land use of the region. The Gardon d'Anduze basin belongs to the Mediterranean region, and, thus, it is under the influence of its climate, with hot and dry summers and fresher and wet winters. Most of the rain is concentred in autumn and spring, and occasionally in summer, when there are very intense storms, that can lead to important accumulations of rain (sometimes even reaching 1/3 of the total annual precipitation). The top parts of the basin have a more extreme mountain climate, with colder temperatures, more rain and even snow in winter.

In relation to geology and soils, the majority (64 %) of Gardon d'Anduze soils consists on metamorphic rocks made up of schist, gneiss and mica schist. The basins of Mialet (220 Km^2) and Saumane (101 Km^2) are made up to 95% of these rocks.

As mentioned before, the Gardon d'Anduze basin is essentially a rural basin, where the urbanisation is only concentrated in few villages. The most important villages above Anduze are Saumane, Saint-Jean-du-Gard and Mialet, which make a total population of around 7.000 inhabitants in the whole basin.

Even though the Gardon d'Anduze is a rural zone, as it is flowing to the whole Gardon fluvial system, it is important not to forget about the influence that this can have. The Gardon basin (2.025 km2) crosses 150 cities, which represents 180.000 inhabitants. A lot of companies are located in flood-prone areas: 26 % of the companies located on the Gardon region, meaning that almost 1.5 million k€ are spent in transactions, for commerce, construction industry and services, (Chambre de Commerce et d'Industrie de Nîmes 2008). Therefore, flood management is a crucial issue for the economy the region.

4.3.2 Historical floods

As it can be seen in Figure 10, the torrential and intense rains lead to risings of remarkable level, showing high and pronounced peak flows on a regular basis. The discharge rate in the Anduze town gage is estimated at 1340 m^3/s for a 10 year return period and 1790 m^3/s for a 30 years return period.

However, there have been historical floods along time that have exceeded by far these limits. Taking a look to the historical data collected, the Gardon d'Anduze has shown extremely high risings in the years 1846, 1847, 1861, 1890, 1891, 1907, 1958 and 2002.

The two largest raisings of the last 50 years were on September 29th 1958 and September 9th 2002. In Table 3 a summary of the data collected is shown and, next, a brief analysis of the event can be found.

Table 3. Main historical floods in the Gardon d'Anduze basin. *Source: Bianciotto 2005*

Date	Discharge (m^3/s)	Rising of the river in Anduze (m)	P max total (mm)	Return period of the event (years)	Economic loss (million €)	Deaths
September.1958	3000	7,60	429	100	5	4
September 2002	3500	7,50	687	>100	1090	23

<u>*29-30. September. 1958*</u>

The rainfall event of the 29th and 30th of September 1958 was not only intense, but it also had a long duration. It was mainly localized in Cévennes, the highest point of the basin. The fact that most part of the rainfall was situated in the top of the basin had both positive and negative consequences. The advantage was that the lead time to detect the flood was larger, and then, the warning systems could be more effective. The problem was that, due to hydrological phenomena, the peak flow discharge was higher, because when the wave got to the discharge point, it was at its peak due to the fact that all the precipitation had been already accumulated.

The weather situation that created this event was as follows: an Atlantic depression was moving towards southeast, but was blocked by the high pressure coming from continental Europe. There was also a moist warm wind blowing from the Mediterranean to the North-Northwest. Finally, the overall situation made the cold and warm fronts converge right exactly over the Cévennes, creating the conditions that lead to that intense precipitation. The complete barometric situation of that day is shown in Figure 11.

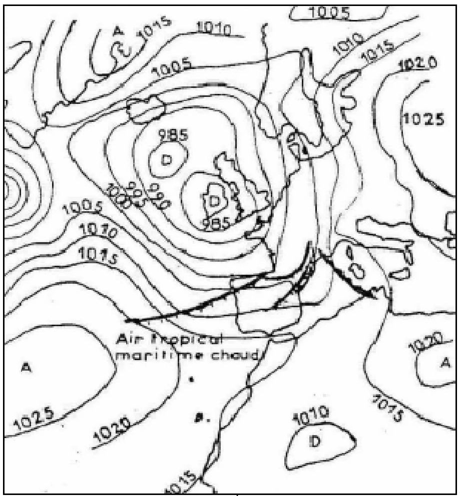

Figure 11. Barometric situation in Europe in 29th of September 1958. Source: Bianciotto 2005

The consequences of the rain event were devastating. The town of Anduze faced its worst situation ever, four people drowned and another person died in a fire caused by a short circuit produced by the flood. The quantification of the damage is very difficult because few documents exist, but some loss estimation can be found. The rehabilitation of municipal equipments that were partially destroyed and the cleaning and reconstructing of all the streets and roads cost around 3 million €. These were the first actions carried out in order to allow population to come back to their normal lives as fast as possible.

Later, more than 2 million € were spent in structural protection measures in order to increase safety in case of floods. Some defence works were done in the river bed, and some of the existing ones were repaired. Also a new bridge was built, making a total amount of more than 5 million € spent due to the flood.

8-9. September. 2002

During the 8th and 9th of September 2002, a rainy period of exceptional scale and intensity hit the northern part of the Languedoc region. There were anticyclones positioned over Scandinavia and France, creating a disturbance where a front was slowly moving from west to east. Because of that, upwelling of hot air from low levels of the Mediterranean area clashed with layers at a higher altitude engendering the formation of severe thunderstorms.

As it can be seen in Figure 12, the Gard region accumulated large precipitation amounts. Even though the total precipitation in Anduze was 687 mm, the Gardon d'Anduze basin was one of the less affected ones. The consequences of the flood were much smaller in that basin, in comparison with the rest of the region. For example, from the 23 people that died because of that event, none of them was in the Gardon d'Anduze basin.

Still, the magnitude of the flood in the test-bed area was huge, producing a much higher peak discharge than in the 1958 event. Then, the fact of having no casualties in the Gardon d'Anduze basin has to be justified by other reasons, like the increasing awareness of the population about the flood risk and the efforts that the administration put to have better risk management plans and policies.

The effects of the flood were visible in many different aspects. The riverbed changed completely, and the destruction of riparian forests, erosion of riverbanks, and destabilization of bank protection was clear in almost all beds. In addition, many houses and recreational areas were flooded and destroyed, as well as several infrastructures close to the river, which needed to be restored or rebuild after the event. This included bridges, embankments, dams, roads, pumping and purification stations, amongst others. The total estimated budget spent to recover from the flood effects reached the extremely high value of 1.090 million €.

In 1995 the Risk Prevention Plan (PPR) was created, in order to centralise all the existing regulations into one single document. The plan had a general scope, but it had to be adapted for each municipality by the prefects and local authorities. Besides providing a methodology to identify the zones prone to any hazard, it also provided a list of the measures to be undertaken, as well as the criteria for the land-use zoning.

As a response to the 2002 flood, the local Flood Risk Prevention Plan (PPRI) of many cities from the region was reviewed and improved, creating a better zoning related to the inundations, and more strict regulations to implement it.

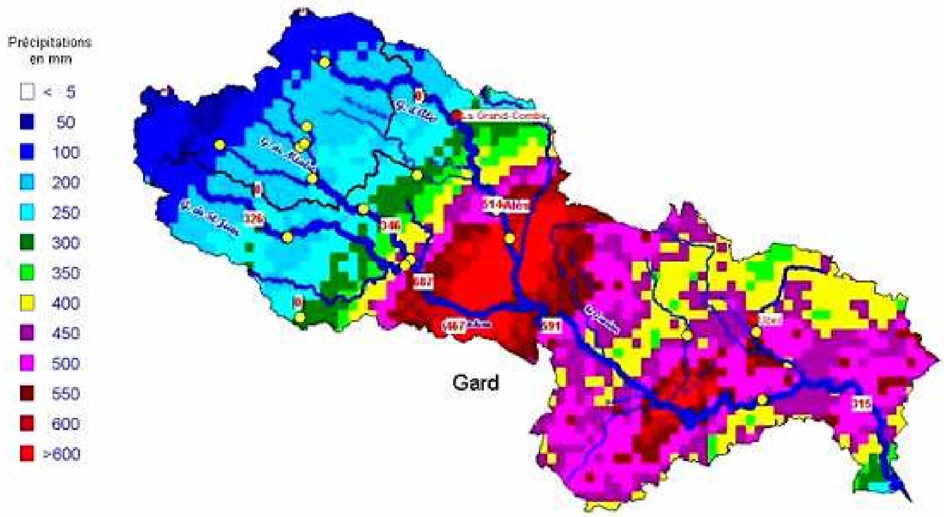

Figure 12. Total rain cumulated in the Gard region in 8-09-2002. *Source: Météo – France website*

In 1995, the Barnier Fund was created as a public national fund to provide economic support for the implementation of the PPRI through several measures (see Table 4). In France, damages caused by floods, avalanches and landslides are non-insurable, and, therefore, they must be covered by public grants. This is why initiatives like the Barnier Fund are required, because, apart from giving financial support for hazard prevention measures and, in general, for the implementation of the plan, it also considers extra funds to help recover those people that have suffered the consequences of a hazardous event.

Table 4. Activities funded by the Fond Barnier 2003 – 2005 and previsions for 2006 – 2007. *Source: Agrawala 2007*

Expenses (EUR million)	2003	2004	2005	2006*	2007*
Expropriations	3.05	1.71	7.98	0.66	0.28
Funding of PPR development	8.39	3.47	6.96	16.00	16.00
Prevention measures and temporary evacuation	0.01	0.04	14.92	7.10	7.10
Local studies and planning	-	-	6.36	30.00	30.00
Extraordinary measures	5.6	-	-	2.00	5.00
TOTAL	17.05	5.22	36.22	57.76	58.38

4.3.3 Risk management plans

Map information

Section "2.2.1 Cartography" of the questionnaire, contains a list of the different types of maps available relevant to the flood risk management plans. The maps available in different scales include the following ones: topography, geology, soil use, soil depth, rainfall probability, and specifically related to risk management, flood and flash flood hazard, vulnerability and risk maps.

Improvements of plans and policies

French flood risk management policies have only been developed actively since the mid 1980s. Before, the existing regulations had a rudimentary 19th century base and they never ended in a successful document.

The real flood prevention policy started with the 1982 Compensation Law for victims of natural disasters. After that, in 1984, the state created the Risk Exposure Plan (PER), which combined risk zoning and associated prevention measures with land use planning and flood insurance.

More than 40% of the 36.500 French municipalities are concerned with flooding issues and, in fact, flooding is responsible for 80% of the damage related to French natural disasters. Until 1994, the resources allocated by central government to implement the PER regulations were insufficient to allow the system to reach the expected objectives and targets. In 1995, eleven years after the creation of the PER, only 396 municipalities had a PER approved, compared with over 2.000 which were known to be seriously exposed to some type of natural hazard.

In 1994, the state government asked its representatives in the provinces (prefects) to strengthen their floodplain policy. Therefore, in 1995 the Risk Prevention Plan (PPR) was created. Its main aim was to set a series of measures by the state authorities that later would be applied at the local level. Many of the PER aims and principles were still taken into consideration in this new risk plan.

Only the municipalities considered by the general PPR as being under the risk of flooding, must implement a local Flood Risk Prevention Plan (PPRI). The problem was that the mayor and prefect, who were the ones that should approve the document for every municipality, sometimes did not agree with the central government. They had differences in relation with the delimitation of the hazard maps and the implementation of the associated land use and control measures. Still, the implementation of the PPR has been much wider than the PER. By June 2003, 3.798 communes had a PPR approved, which means ten times the number of approved PER in 1995. By 2007, about 5.500 from the 11.000 municipalities exposed to flooding had an implemented PPRI and the rest had it under study.

In this plan, flood risk maps include the floodplain storage areas and the urbanized areas. The PPRI also contains the measures that have to be executed by the municipal authorities.

As the organization of the flood warning procedures remained handicapped due to a territorial dispersion distributed into 52 provinces, in 2002, the Ministry of Ecology and Sustainable Development initiated the reform of the flood warning structure. It consisted into two major measures:

⇒ The creation of the SCHAPI (Central Service for Hydrometeorology and Flood Forecasting Support) located in Toulouse

⇒ The creation of 22 new services for flood forecasting (SPC) to replace the existing 52 services for flood warning (SAC). Therefore, SCHAPI coordinates and provides support to the 22 flood local services.

At a local scale, the 2002 flash flood led to a review of the PPRI in many cities along the Gardon River. As a consequence of it, the description of the areas where urbanisation is allowed changed in comparison to the one established in 1995.

The catastrophic flood event from 2002 led to a further legislative review, and the Senate adopted a new law on 'Hazards, technological risks and damage compensation' in July 2003. Its aim is to enhance the compensation mechanisms and to encourage greater public involvement in risk reduction decisions. It also defines the legal framework for flood forecasting and promotes its development.

After that, in 2003, a new long-term plan to cope with flood risk at a basin scale was created. The Program of Action for Prevention of Flooding (PAPI Gardons) was assisted financially by the government (subsidy rates ranging between 20 and 50% depending on the actions) and it consists of a series of structural and non-structural measures for the entire watershed with the objective of mitigating the flooding risk of persons and property (Conseil Général du Gard and Le Syndicat Mixte d'Aménagement et de Gestion Equilibrée des Gardons 2003). The plan is supposed to be implemented and coordinated by the Gardon Basin Sustainable Water Management Association (SMAGE) but, nowadays, it does not have human and financial resources for achieving this, even if the Gard General Council and the State are also supposed to provide support.

The PAPI Gardons plan is focused on five main areas of action. After an analysis of the lessons learnt from the 2002 flood event, a list of general measures is proposed in each one of the following five topics:

⇒ Improving knowledge and strengthening risk awareness

⇒ Improving the monitoring devices and the forecasting and warning systems

⇒ Developing or improving flood prevention plans, implementing measures to reduce the vulnerability of buildings and activities located in areas at risk

⇒ Restoring the flood expansion areas and improving the rivers dynamics: reducing peak flows and water velocity

⇒ Developing collective protection facilities in populated areas

In the last part of the plan, those same measures are particularized for the Gardons basin, including tables with budget estimations for each of them and the public or private authority that is in charge of implementing them.

From July 2006, this reform led to the operational implementation of an information system that operates continuously and provides a constant surveillance of the potential floods. SCHAPI works together with Météo-France to improve the flood and flash flood forecasting and they have created a useful real-time tool, called "Vigicrues", which will be further explained later.

Implemented emergency plans and management procedure

The Gardon d'Anduze basin is one of the smallest test-bed areas studied in the project and therefore, it is very important to be able to increase the lead-time of the flood warning system. The French Ministry for the Environment developed, in 2001, a complete forecast and warning system for the main basins of the country, in cooperation with Météo-France. Later, with the creation of the SCHAPI, the whole system was modernised and improved to the one existing today, called Vigicrues.

Its purpose is to inform population in a simple, clear and fast way, because the response time in most of the basins is very small, going from 1 to 5 hours. Public authorities in charge of civil security (prefects and mayors) should use it to trigger the alarm when needed and mobilize the emergency resources, preventing by this important damages.

In the majority of the basins, the flood warning system only considers floods due to river overflowing, but the debris flow and the urban stormwater floods are not considered. However, this is not a critical issue for the Gardon d'Anduze basin because, usually, neither of them causes major problems. This is because, as seen before, the basin is mainly rural, so the urban runoff is not a problem, and the geological characteristics are not prone to debris flow.

Each stream included in the flood alert system is divided into several sections which have an assigned colour: green, yellow, orange or red, depending on the level of surveillance necessary to assess the flood risk in which the area might be within hours or days ahead. The map is accompanied by a newsletter that explains the global situation of the region selected and also contains an estimation of the possible consequences and behavioural advice suggested by the authorities.

The flood alert maps, newsletters and real-time data are available continuously. The map is updated twice a day, at 10h and 16h. When the risk of occurrence of a flood event is high, the map and bulletins are updated more frequently, every 3h or even less if needed.

The map, newsletters and general information of the system can be found in the following link: http://www.vigicrues.ecologie.gouv.fr/

In relation with Civil Protection issues, it is very important to have a good rescue and evacuation organization. The French Civil Safety and all the concerned organizations developed tools to anticipate, to manage and to assist to the decision making process. In 1952 the rescue organization plan (ORSEC plan) was established by a ministerial order, as a generic emergency plan to activate in case of any kind of disaster, flood, storm, earthquake, etc. The plan is aimed for extensive and/or long lasting disasters, no matter what the number of casualties is. It may even be activated, when there is not any casualty.

As a consequence of the 2002 floods, the Ministry realized that a better approach to this topic should be considered. The former National Plan ORSEC was modified in August 2004 in order to create a modernized civil security plan. A hierarchical system was created to replace the existing plan. In the new one the following plans coexist, working together to achieve better results (see Figure 13):

⇒ ORSEC National Plan (developed by the Home Affairs Ministry)

⇒ ORSEC Regional Plan (developed by the Prefect)

⇒ ORSEC Departmental Plan (decided by the Prefect of the province)

⇒ Municipal Safeguard Plan (decided by the town mayor)

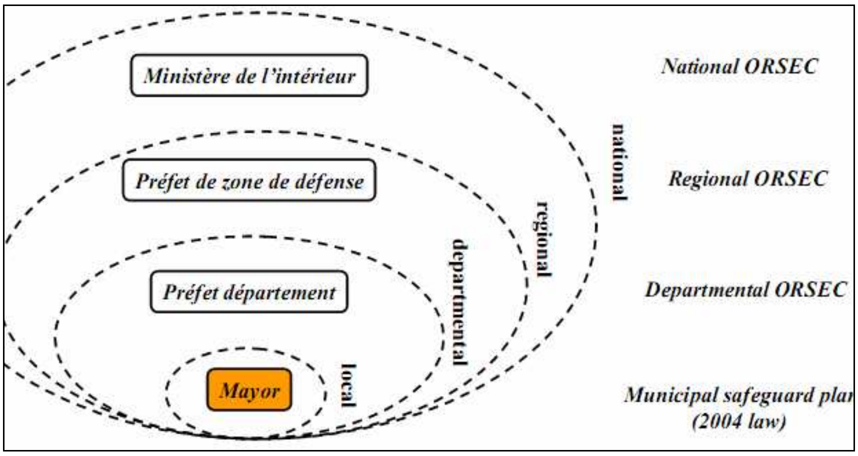

Figure 13. Rescue organization plans (ORSEC) in France. Source: Gaume 2007

The ORSEC plan is not a list of the things that should be done, but the description of the general organization, like who is in charge of what, which are the human resources and equipments available to develop the rescue and the methodology to follow in order to ensure that all the measures are implemented properly.

As seen before, the structure of the plan is clearly hierarchic, there is a management staff, and below it, in the disaster location, there is a double command. There is an operational team close to the disaster and a more distant logistics and reinforcement team (Figure 14).

The tasks that must be carried out in the plan are basically five, as the following list shows:

⇒ Maintenance of law and order, road traffic, identification of the victims: police

⇒ Search and rescue: fire-fighters, Urgent Medical Aid Service (SAMU), volunteers

⇒ Medical care and social aid: SAMU, hospitals

⇒ Transportation and work: civil engineering, public transport

⇒ Contact and signals (transmission)

In addition to this, there is always a public relations group to keep the population informed of all the news and actions that may be taking place.

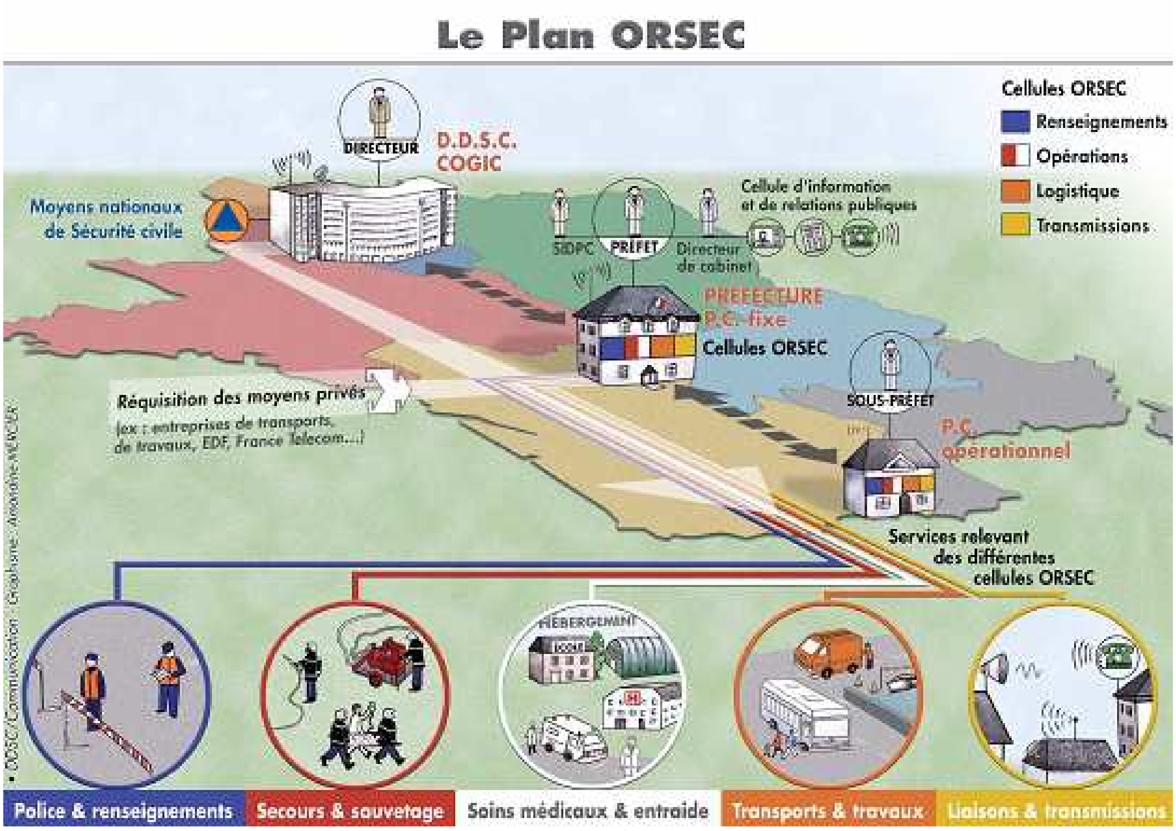

Figure 14. Structure of the ORSEC plan. *Source: Launay 2004*

In August 2005, the Municipal Safeguard Plan (Plan Communal de Sauvegarde - PCS) was created in order to further update the civil protection plans established. In September of that same year a decree made it compulsory for every municipality.

The objective of the plan was to prepare municipalities against disasters, by establishing the organizational structure and technical tools to cope with these situations. The mayor, together with some other local representatives, is the one that must prepare the PCS. It has to be highlighted, however, that the PCS is not specifically designed to deal with flash floods but to all types of disasters. In any case, every municipality has to identify their risks and particularize the plan.

The Ministry of Home Affairs provided guidelines, explaining all the topics that should be dealt with, depending on the size of the town, the number of actors involved in the plan and the level of detail the town wants to achieve (Direction de la Défense et de la Sécurité Civiles and Ministère de l'Intérieur et de l'Aménagement du Territoire 2004).

In summary, in order to compose a PCS, the following topics must be considered:

⇒ Diagnosing risk

⇒ Managing the plan

⇒ Inventory of resources

⇒ Maintaining operational system

⇒ Warning and informing people

⇒ Creating a municipal organization

⇒ Developing operational tools

In the case of the Gard region, in February 2004, a generic PCS was developed for all the municipalities to use in case they did not have their own plan (Conseil Général du Gard 2004). Nowadays, in the Anduze case, a more local and detailed PCS is being elaborated but, in the meantime, the generic one is used. This PCS is being developed under the guidance of a Municipal Committee and consulting to all local actors and it should be regularly tested and updated. Information campaigns to the local population will be also a crucial part to create a risk culture amongst them.

According to this plan, the mayor is responsible for the security of its citizens. He is required to take all the measures necessary to protect the population, like establishing prevention measures and alerting the population. Still, he can always claim for the intervention of the prefect when the effects of the disaster have exceeded the municipal level.

Regarding the forest fires prevention in the Gard region, the regulation currently implemented dates from May 2006 (Direction Départamentale de l'Agriculture et de la Forêt 2006). The mentioned law regulates the allowed activities during specific periods of the year at a certain distance from the forests. It includes a list of municipalities classified as being exposed to a certain risk of forest fire. In order to calculate the risk of forest fire, the DDAF Gard developed a methodology that allowed prioritizing the areas by their risk level.

Existing information on the estimation of future changes

Both the PAPI and the several existing PPRI are plans that are supposed to be continuously reviewed and updated, so they can still be effective if any changes occur. Therefore, they should be prepared to adapt to the new future scenarios that may come up in the next years.

In order to adapt the risk management plans, information about climate, socio-economic patterns and land-use changes must be considered.

Regarding climate change, in 2008, a report elaborated by MEDCIE, a research group of the French government, together with AlternConsult and ECOFYS, a consultant and research group specialized in renewable energies, was published. They analyzed the potential climate changes (mainly considering temperatures and precipitations) in the Languedoc-Roussillon region, consisting on a downscaling of the selected climate variables to a regional level and estimating general trends until year 2080 (ECOFYS and AlternConsult 2008). The study also included an assessment of the impacts caused by climate change in deferent sectors (energy, agriculture, natural resources, natural risks…) together with some socio-economic data.

There are also other projects that have studied climate change in this area before. The CYPRIM project (2005-2008) simulated the evolution of climate in the Mediterranean area for the next 100 years. Météo-France and CERFACS, participants in this project, can provide climate data at a spatial resolution of 8km for the whole country for research purposes.

Regarding socio-economic data, there is information on the evolution of vulnerability provided by different indicators (e.g. nº of inhabitants in flood-prone areas) that is available through the following link: http://orig.cg-gard.fr/orig/ori/tab/result

It would be possible to take this historical data from the last 20 years and extrapolate some socio-economic future scenarios (demography, industry, tourism, agriculture…) for the Gard region.

Concerning land use changes, as the Gardon d'Anduze basin is mainly formed by forests, the potential urbanization growth would be limited to the upper part of the municipality of Anduze due to the lack of economical activity in the rest of the basin. Land use changes might be based on the type of forest vegetation caused by a potential increase of the temperatures and changes in the precipitation patterns.

4.3.4 Lessons learnt and future improvements

As mentioned before, as a result of the 2002 events, the PPRI's of many municipalities in the Gard region were reviewed. The previous ORSEC plan was replaced by a new hierarchic system along with the Municipal Safeguard Plan (PCS), and the new flood prevention plan for the Gard region (PAPI), containing not only passive measures but also constructive ones, was created.

All this new regulations were done taking into consideration the several lessons learnt from the 2002 floods and some other previous experiences. Some of the issues that were considered in the new policies and some more that still have not been implemented can be found in the following section.

Apart from the documents mentioned in the previous sections, several other studies have been analyzed in order to extract the following lessons learnt (DIREN 2006; Huet 2003; Pottier et al. 2005).

<u>Lessons learnt on prevention</u>

⇒ The improvement of the flood warning systems is crucial in order to create fast channels of transmission for the alerts. A densification of the network of stations is still needed, even though a modernization of the Gardons flood alert system was carried out between 2001 and 2003. There are some areas with a lack of coverage, including some of the zones flooded by the 2002 event. Apart from the installation of new stations, new predictive models will have to be developed, especially focusing on an earlier forecasting of the potential flash floods, increasing the current lead-times.

⇒ One of the best ways to overcome risk is to promote actions in order to reduce vulnerability in the flood-prone areas. Two main measures have been identified to achieve it:

- o The relocation of certain activities and structures exposed has been considered (mainly housing and businesses). The previously mentioned Barnier Fund includes this situation and, thus, subsidies could be provided for those interested.
- o Thirty of the most vulnerable municipalities belonging to the basin have decided to promote Existing Building Safety Plans (PMSH). These studies, which will be under the municipal control, will include: those areas that can not be displaced neither further protected, the plan boundaries and the type of improvements that may be carried out by the owners. Owners will be able to apply for grants (up to a 40% of the total budget) and they will have to finish the works in a maximum of 4 years to achieve a higher level of protection in a reasonable short period.

⇒ The development of a comprehensive study to select and evaluate potential retention areas at the basin level would be very helpful to analyze the volumes that might be intercepted and, then, to calculate the peak flow reduction. This kind of measure intends to retain a significant volume of a low return period rainfall event (less than 50 years) but in a frequent time basis. The study should include a definition of the hydraulic context, determining the role of expansion areas, and a proposition of the potential retention areas according to different scenarios of development. In the Gardons case, the plan aims at intercept from 4 to 6 Mm^3 and to achieve it in a period of 15 to 20 years.

⇒ Also related with the previous measure, the role of agriculture land it is important to control the hydraulic dynamics. Several actions have been proposed in order to take advantage of the existence of crops within the flood limits, such as relocation of agricultural land, switching to crops compatible with flooding episodes, accounting for the reduction of water velocity and taking into account that agriculture collaborates into the maintenance of riverbanks and ditches.

⇒ It is needed to review the assumptions and calculations used in the sizing and design of the protection infrastructures (dams, dikes…) and, in that way, mitigate problems like flow obstruction or failure. This should be done for both, existing and new protection structures, and it is possible that re-sizing appears as an inevitable action.

⇒ In relation to the elaboration of the hazard maps, neither the construction companies, the scientific research groups of the region or the residents associations are involved in the process, but they should be.

⇒ Identify the Mediterranean areas with similar characteristics to the Gard region and, then, analyze the problems they face and the solutions they propose. In this way, by comparing with other areas with similar problems, some measures not identified before might be found suitable.

⇒ It has been proposed to establish a Risk Observatory with the purpose of following up the public actions in the field of prevention, including progresses in the municipal emergency plans, improvements in the dissemination of risk information, the level of awareness of the community, etc.

⇒ Considering a reduction in the number of regulations implemented could simplify the implementation procedures and favour the disposition of the actors involved to be aware of them.

Lessons learnt on preparedness

⇒ The elaboration of a study to analyze the hydraulic performance of the basin could help to understand the basin dynamics and, therefore, to prepare the municipal emergency plans. The document should include a catalogue of flood references with their consequential damages, a description of the functioning of the basin flooding (propagation time, water depth, water velocity…) and a guide of indicators located in the watershed (station network, websites with flood information…).

⇒ It is necessary to have an evacuation map of the potential flooded areas, including all the roads that may be used during a crisis, anticipating the possible cuts in some of the existing routes and planning the rehabilitation works. It has to be prepared jointly by the local and the state authorities to ensure that the overall road network is taken into account.

⇒ When a house is sold or rented, the seller must provide the new residents with information on the possible flood risk.

Lessons learnt on response

⇒ The implementation of the Municipal Emergency Plans (PCS) has to provide a higher level of protection to those municipalities that are the most exposed at risk. There are 60 municipalities in the Gardons basin that are supposed to have it implemented, but there have been some problems in getting the necessary means (both human and economic) to develop it. Thus, an annual meeting with the county has been planned to help the municipalities to implement the plan.

⇒ There is the need to improve the speed and effectivity of the procedure used to transmit the warnings. The audit carried out in 2000 already highlighted that the transmission chain used to communicate the alert information was slow and conditioned by a rigid procedure. In addition, there was a lack of surveillance by most of the mayors that exacerbated the problem.

⇒ The creation of a unit responsible for monitoring the post-crisis (reconstruction and implementation of the several recommendations validated) would be useful in order to control the effectivity and duration of the recovery works.

Lessons learnt on dissemination and education efforts

It is often found that, in some municipalities, there is a total absence of consciousness of the flood risk. There are still many people that ignore the violence of floods and underestimate the dangers for themselves and their property and, therefore, they do not follow the basic safety rules and they do not respond anymore after one or two false alerts. This is why more effort should be put in this issue, in order to create a risk culture and try to minimize he effects of the floods.

⇒ In 2006, a survey to the population of the Rhône River basin was carried out to check the population risk awareness. It was proved that in the September 2002 flood event, further information should have been given to the population. They did not have enough knowledge at their disposal and their perception of the flood risk was lower than desired. It seems reasonable that the municipalities located in high risk areas were more informed than those located in medium or low risk zones. The problem was that only the 31% of the interviewed people confirmed that they had received any kind of information. From these people, the most common information transmitted was instructions to follow in case of flooding (69% of those who received information), the town floodplains limits (55%) and the public safety means provided by the municipality in case of flooding (52%). In conclusion, the survey showed that the population was relatively uninformed about the flood risk and requested more information on particular matters like public safety and crisis management. PAPI proposes to conduct a sociological survey, like the one we have just mentioned, every two years in order to assess the population level of awareness to the flooding issue.

⇒ The mayor must install and maintain flood marks in public places around the city to remind people about the worst historical floods. Some additional information can be shown together with those marks to aware people about the flood risk (see Figure 15)

Figure 15. Historical floods sign and informational board. *Source: Gaume 2007*

⇒ In relation with the improvement of the flood alert systems, this should be accompanied by a proper training to mayors and municipal technical services on how to use it. They will attend a teaching program of 20 lessons a year, so they have a good knowledge level about river dynamics and flood warnings, as they are going to be taking decisions related to both topics. As this type of system constitutes a very powerful tool that provides lots of information, it is crucial to have appropriate trained personnel in order to further improve and exploit it.

⇒ As the average annual cost to help repair damage of natural disasters is very high, doing an information campaign of the actual costs to the partners that eventually pay it, public or private, should lead to changing attitude towards prevention.

⇒ Children will be taught about flood risk. In that way, from a very short age, they can develop a risk culture and increase their awareness. This kind of task will be successful only if it is planned for a long term, as a change in mindset requires working at least during one generation time period. Several tools have been created for this purpose:

- A board game about a flood event (Figure 16)
- An informational DVD based on the 2002 flood event
- A scale model showing the impact of the flood in the river surroundings
- A field visit, where a guide explains some the most emblematic situations occurred in the 2002 event, visiting 8 different villages in the basin
- School lessons (one day a year) to explain the contents of the municipal emergency plans, how to react and what precautions need to be taken before a flood emergency

Figure 16. Board game RIVERMED. *Source: CME website*

⇒ PAPI proposes to create a travelling exhibition that could be installed two weeks in each town to provide effective information about floods. In the towns with the highest level of risk, the exhibition should return periodically (e.g. every two years) and it might be accompanied by one or two public information meetings.

4.4 Linth basin

4.4.1 *Basin description*

The Linth basin is located in central Switzerland, in the Glarus canton, and has an area of approximately 600 km^2 that is drained by two main rivers: Linth (50 Km long) and Sernf. The highest point of the watershed is the mount Tödi with 3614 m, and the discharge point of the basin is located in Mollis (436 m), from where starts an artificial channel of 6 Km that discharges in the lake Walen (410 m) (Figure 17). Besides the two main rivers, the basin has about 150 small mountain streams, most of which can cause landslides due to the pronounced relief of the basin. The mountain slopes are steep and the densely populated valleys are very narrow, representing a potential high risk area.

Forests cover 20% of the basin. The portion of rocks and bare soil areas is 34%. Large parts of the watershed are used for pasture (31%). In the highest regions there are some small glaciers, which make about 4% of the total basin area. The 11% that remains belongs to the narrow valleys, which are the only populated zones of the basin. The Glarus canton has about 40,000 residents who live in 27 villages, being the city of Glarus the most populated one, with 6,000 inhabitants. Due to the limited living space, most of the villages are exposed to natural hazards. This is why the floods, avalanches, rock falls and mudflow processes, have been taken into account during the settlement development along history.

The discharge regime up to the gauge in Mollis is heavily affected by hydropower. Water stored in two big reservoirs (Limmerensee and Klöntalersee) during spring and summer is released for production of electricity at peak demand periods. The three largest power plants (KW Löntsch, KLL Linthal and KW Sernf-Niederental) can turbine together a daily outflow of 40 m^3/s of water.

This hydropower has been used since the early 19th century to develop the industrialization of the region, specialized in the textile sector. The settlements started to develop around these textile mills, creating the first important villages in the region. Nowadays, the main economic activity is still the industry, specially machinery and equipment construction, woodworking and building material industry. Agriculture plays also an important role. An increasing importance is being given to tourism, even though previously, the Glarus canton was already known for its spas. Today, the district is visited mainly for hiking, skiing and mountaineering.

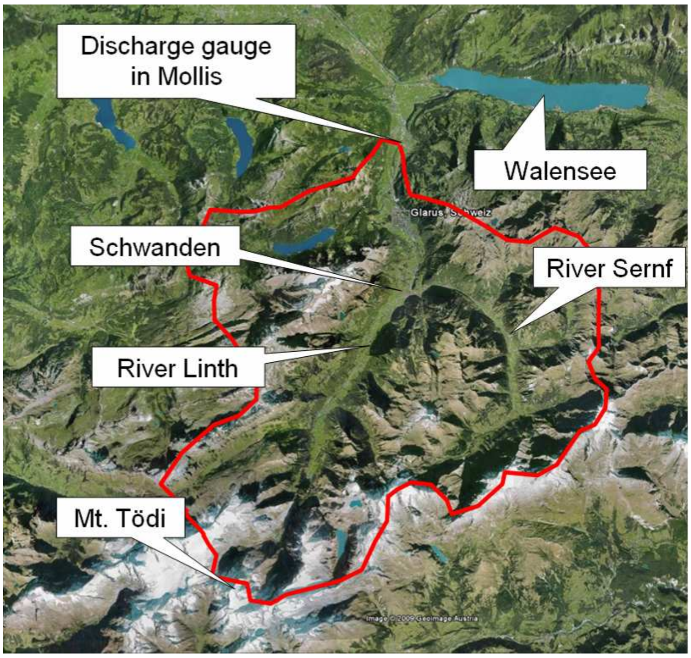

Figure 17. Linth basin. *Source: Glarus Emergency questionnaire*

4.4.2 *Historical floods*

As shown in Table 5, three historical events that caused important damage in the Glarus canton have been selected and subsequently analyzed in this section.

Table 5. Main historical floods in the Linth basin. Source: Glarus Emergency questionnaire 2009; Hilker et al. 2009

Date	FF	DF	Return period of the event (years)	Economic loss (million €)	Deaths
June 1910	yes	Yes	100	<5	0
August 1954	yes	Yes	30	<5	0
August 2005	yes	Yes	30	20	0

15. June. 1910

In 1910, Switzerland was hit by one of the most severe flood in the 20th century. Beginning on the 14th of July, 21 cantons were affected by a disastrous high water level. Eight power stations were not able to produce electricity, causing a blackout in Zurich for nearly 48 hours. The overall cost of this heavy flood is estimated at about 16 million Swiss francs, which corresponds to about 0.6 billion € of today's currency. Private losses were one third of the total amount and more than 10.000 citizens sent applications for loss compensation.

In the Glarus canton, it took a few months to repair all the damage produced in the infrastructures, which mainly included bridges and railways. The recovery cost was around 30 million €, and it was not until one year after the flood event, that the whole population of the region went back to a complete normal life.

In that period, there was not any direct emergency or victim relief provided by the Swiss state. Nevertheless in 1901, the non-profit company "Schweizerische Gemeinnützige Gesellschaft" (SGG) created a pool against non-insurable natural hazards (Gülden and Poliwoda 2008). The aim of the company was to build up a private financial pool for citizens who were heavily affected by a non insurable natural hazard. In the 1910 event, SGG was able to collect more than 1,5 million € from neighbours and international donors, whereas the national Swiss bank only gave a few thousands. The problem was that the distribution of this money was very heterogeneous, being able to cover more than the 60% of the damage in some cantons, and less than 5% in some others.

In the Glarus canton, where the help received was relatively small, people saw that something had to be done in order to reduce the damage in case of a similar future situation. Therefore, after this event some additional structural protections were built in the surroundings of the river in order to reduce the risk.

22. August. 1954

The flash flood and debris flow episode of August 1954, had a much smaller scale than the one in 1910. This was not only because the meteorological conditions were less extreme than in the other event, but also because the hard rain only affected a really small zone, focused basically in the Glarus canton.

However, the damage created in the region was comparable to the one of the previous event, with a value of approximately 5 million € in that period's currency. This damage mainly affected infrastructures, covering bridges, railways and roads. In order to repair all this, a few months were needed, which is more or less the same time that the general population of the region needed to come back to everyday life. The money spent in this reparation works, was around three times the damage cost (approx. 15 million €).

As this event did not affect the whole country, unlike the previous one, there was not such a campaign to collect money for helping the damaged zones. This is why in this case the help came basically from the same canton funds.

Again, it was proved that the infrastructures present in the river were not enough to provide protection in an extreme situation. Therefore, after the event, some more protections were added in the basin in order to reduce flooding risk.

24. August. 2005

Between the 19th and 24th of August 2005, heavy rainfall hit Central Europe, causing floods and landslides in Switzerland, Germany and Austria (Carpenter 2005). The event caused extensive damage in these countries, flooding thousands of properties and forcing hundreds of people to evacuate their homes. Furthermore, high waters in rivers and lakes reached record levels and the raging waters severely affected rail and road transport in the region. Reports said the flooding was the worst that hit Central Europe since 2002. Insurers estimate that in Switzerland alone, flooding caused damage of more than 1.7 billion €. A series of flood events also struck Eastern Europe between April and October of the same year. Overall, the floods across Central and Eastern Europe cost several billions of euros and killed more than 100 people.

Although the rainfall episode was pretty important, it was not an exceptional one. The problem was that there were several other factors that contributed to the resultant flooding:

⇒ The soil was waterlogged after a wet summer and was unable to absorb the precipitation, leading to surface run-off.

⇒ High summer temperatures raised the snowline to around 3.000 m above sea level so only a very small amount of precipitation was bound as snow.

⇒ Increased construction in the built-up regions of Switzerland, Germany and Austria reduced the amount of soil capable of absorbing the precipitation.

Switzerland experienced a large volume of rainfall during the 48-hour period from the 21st to 22nd of August, reaching the 200 mm in some places. The heavy rain caused increased discharges and even higher water levels in Swiss rivers and lakes. The gauge station in the Mollis discharge point measured a maximum flow of 327 m^3/s, which was the highest one since the 400 m^3/s of the 1954 flood episode.

Due to these high levels of water, flash floods and landslides were produced, which meant that road and rail transport was badly disrupted. Railway lines and several roads were closed, and even in some points, the flooding washed away parts of roads. Military personnel were deployed to support the civilian authorities, in order to help evacuating some people. As a result of all this, the estimated damage cost in the Glarus region was 20 million €. Even it is a big value, there were other regions in Switzerland that had much worse consequences, like canton of Bern, where around 5.000 properties were damaged and the overall cost in the canton was estimated in 188 million €.

After all this, the works that were carried out in order to recover all the infrastructures lasted one whole year. During the next three years after the flood event, several additional protection structures have been built not only in the main rivers, but also in the minor streams of the entire Linth basin. There are also several follow-up projects that are still being done, and will continue for five years after the flood event. Also, as a result of this flood event, a new alarm and warning system has been created, together with hazard maps that will be used to detect the zones with higher risk.

Even all these works commented above were planned for being developed in a long-term scale, the population managed to come back to normal life in just a few days after the event. It can be easily explained because of the more efficient equipment that is available nowadays plus the compensations system that is now implemented in Switzerland.

Whereas in the previous explained flood events, the financial compensation that the people got, was either voluntary help given as donations, or local help from the canton, nowadays the private insurance companies are the ones covering the main part of the loss (Gülden and Poliwoda 2008). Today, everybody in Switzerland has the buildings and other kind of properties covered by a private insurance that will pay all the damage provoked by no matter what kind of hazardous event.

4.4.3 Risk management plans

Map information

On section "2.2.1 Cartography" of the questionnaire, a list of all the existing cartography related to the flood risk management plans can be found. All the maps are available in ArcGis format, with scales that vary depending on the map, but all of them with a good resolution. There are available maps related to topography, geology, soil use, infrastructures, rainfall probability, flood hazard, flood vulnerability and also about flash flood and debris flow.

Improvements of plans and policies

One of the main problems of basins like this one is that, as their area is small, the lead time is also short. This means that the techniques to determine the flood risk on time will have to be more complex than in larger basins. In order to minimise missed events and false alarms, emergency managers need the best possible information.

This is a challenging situation that can be solved by a site-specific early warning system. In 2004, the development of an information and early warning system for hydrological hazards in smaller catchments started. This system was based on the existing avalanche warning system (IFKIS) in Switzerland and was named IFKIS-Hydro (Hegg et al. 2007).

During flood events in mountain areas, many different natural processes interfere: rainfall, wind, discharge, bed load transport, debris flows, etc. Therefore, different kind of information has to be collected and combined. Some of the processes can be measured with technical devices (mainly rainfall and runoff). In the case of other ones, just the impact can be observed. Few of these processes can be forecasted, but for most of them there are no such systems available.

This is why the IFKIS-Hydro system, proposes that the variables available for both, real-time information and forecasts, should be collected. In the case of other parameters, like runoff or bed load, direct observation should be carried out in some points as shown in Figure 18.

If the series of available measurements last for several years, the implementation of a hydrological forecast model is feasible. Up to now, the model PREVAH has been used as a part of the IFKIS-Hydro system. This is a model widely used in Switzerland that consists on interpolating values of the observed climatic variables in the zone of study, and at the same time it collects and integrates information from different observation networks like the Swissmetnet network of MeteoSwiss.

Figure 18. IFKIS-Hydro observation site. *Source: Hegg et al 2007*

Once every hour, the online PREVAH version downloads the newest information from a database, runs its spatial interpolation procedure and performs a model run over the last 13 days. At the end of the operational model run, the results are uploaded into a database, where the end-user can access them. Then, this data can be used to run a local model formed by a specific version of PREVAH that will give the forecasts. With this system it is possible to provide precise information in order to coordinate mitigation strategies, before and during alarm situations.

The system is currently implemented for the Linth basin up to the Mollis gauge and, in a mid-term period, it will be used in several small tributaries of this river, in order to warn all kinds of hazardous situations in the whole basin. Up to now this warning system has shown very reliable results for flash flood events.

Emergency managers can then assess this information and plan their decisions in advance. Even in the best of cases, the lead time will be too limited to carry out a full scale planning process in the case of an emergency. Therefore, a system like IFKIS-Hydro does not replace emergency plans, but the combination of both leads to a clear increase of each other's value.

This is exactly what has been done in the Glarus canton. The combination of contingency plans, together with the warning system, creates a very effective risk management system. In addition, in 1996 some hazard maps that have been used to increase the population's awareness of the possible dangers and also to support the administration decisions on the proper land uses were created.

Implemented emergency plans and management procedure

Combined with the hazard maps, the emergency plans also contain a set of intervention measures, like where to put sandbags or barriers, set up pumps, etc. The fire department units are the ones responsible for this type of actions. Then, when the forecasting team detects that a flood episode may occur, the cantonal fire chief is informed and he can start managing all the measures needed to deal with the emergency.

When the situation is too complicated to be dealt only by the firemen, the chief must contact other organizations that may be able to intervene, like the civil protection, some army divisions specialized in natural hazards or the canton police. Sometimes, when the situation requires it, the motorway maintenance team and some local construction companies may help providing heavy equipment that may be really helpful to build the temporary construction barriers or some other protection measures.

The complete risk management system in the Glarus canton is shown in Figure 19. Starting with the data collection and ending with the final intervention, it is a very clear structure that has proved to be very efficient.

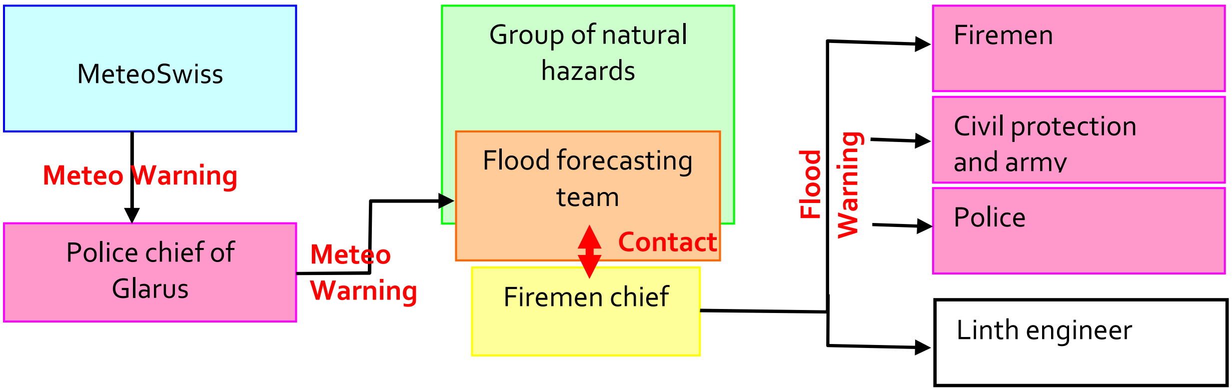

Figure 19. Scheme of the risk management system in the Glarus canton. Source: Glarus Emergency questionnaire

4.4.4 *Lessons learnt and future improvements*

Lessons learnt on prevention

⇒ Main structural measures:

In the early 18th century, the living conditions in the Glarus canton were hard. The industrialization process led to the cut down of the valley woods which meant that less soil was bound. Because of these, large quantities of gravel were going down with the yearly spring high discharges. This gravel was being deposited at the junction of Linth and Maag, at the outflow of the Lake Walen, in the plain located between Lake Walen and Lake Zurich. This caused frequent floods and made the level of Lake Walen rise several meters, turning the whole countryside into swamps. Agriculture was more and more difficult, the poverty increased and diseases like tuberculosis and malaria were every day more frequent.

This is the reason why the scientist Conrad Escher, from Zurich, designed and executed the plan of channeling the Linth River into Lake Walen, where the gravel could be deposited without causing any damage. A second channel was also built, the Linth Channel, which connected the lakes of Walen and Zurich (Figure 20), replacing the former Maag. This infrastructure was built from 1807 to 1823 and became one of the greatest engineering features of the beginning of the 19th century (Speich 2003).

Even though it was a big engineering project, the chief of the works wanted them to be integrated into nature. The use of original hydraulic engineering techniques like taking advantage of the old river bed in the parts where it was near the proposed channel track, allowed to turn the big construction plan into a simple change of the river bed, which meant lower costs, and more efficiency (Vischer 2003).

The river correction put an end to the floods, lowered the level of Lake Walen by five meters which greatly improved the living conditions of the population, and dried up the swamps, resulting in 20 km² of arable land in the Linth plain. It is clear that the authorities learnt from the previous flood episodes and decided to act with a prevention and protection plan. These were the most intensive works that the Linth basin has ever suffered, but of course not the only ones, because even though the yearly floods stopped, there were still some flash floods and debris flows.

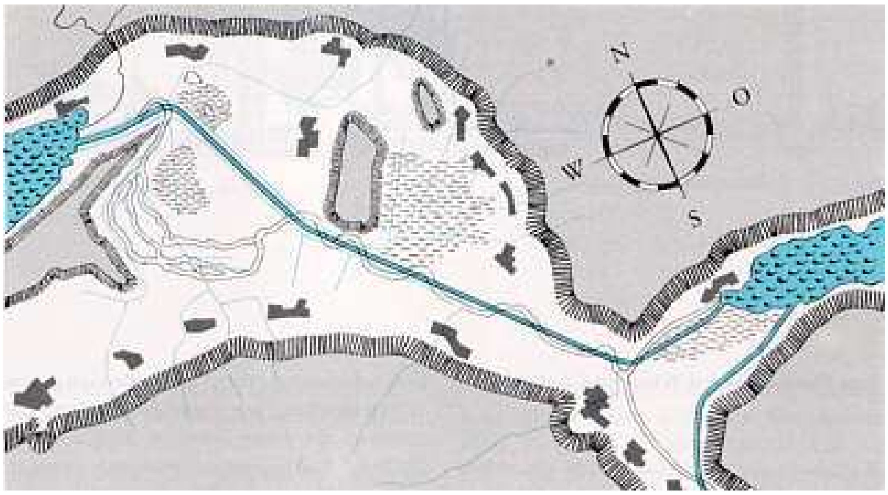

Figure 20. Plan of the Linth Channel, between Lake Walen and Lake Zurich. Source: Speich 2003.

⇒ There are a lot of protection structures in the Linth basin with the aim of reducing the effects of flood and debris flow that have been built along history, usually as a lesson learnt after specific flood events. The problem is that there is not a complete overview of all of them, and therefore, their influence can not be assessed properly. In order to keep track of all of them, the District will develop an inventory of all the protections in the coming years, collecting information of the type, location and condition of the infrastructure.

⇒ Most of the protection structures present in the basin are located in the main streams. Usually they consist on water locks, generally in the shape of staircase locks, so the peak flow can be reduced more efficiently, and the debris can be collected in the several steps. They have been proved to be effective for small events, but are insufficient for large events. The first reason is because these protections were actually designed for small hazard events, and the second one is that many of these old defence works have not been maintained for decades, which means that they may collapse in the case of a big rainfall event. This is why the canton is focusing on damage prevention techniques to avoid providing a non-risk perception to population.

⇒ According to the hazard maps that were elaborated in 1996, there are still many residential and industrial areas that are highly vulnerable to large floods. In these zones it is foreseen to do a big investment in the following years, in order to add the flood prevention and protection measures needed. These actions will be defined in an integral way and will consist on a mixture of structural, intervention and planning measures.

⇒ Another improvement that has already been taken into consideration is that the return period used for the infrastructure sizing is 300 years, instead of the 100 years used in the past. This change intends to take into account also the potential effects that climate change can cause in the region.

Lessons learnt on preparedness

⇒ The District is preparing a whole new strategy to cope with natural hazards. It will constitute an integral and sustainable management plan for natural hazards that will be implemented by 2011. This strategy is based on taking advantage from its own feedbacks, so it will create a loop that will build on experiences gained from the past events. Therefore, it will be continuously reviewed.

The cantonal natural hazards strategy will be based on seven pillars (Figure 21):

- Natural Hazards Organization: simply structured, strategically and operationally active cantonal specialized body that will coordinate several aspects.
- Risk basis: the canton will have comprehensive risk and hazard maps.
- Risk assessment: the District will be aware of its risks and it will know how to evaluate them. The population under an active risk will be kept constantly informed.
- Prevention and preparedness: the District will operate an integrated prevention plan, which will be composed of a regional planning and of structural and organizational measures. Early warning systems will play a central role.
- Event management: the District will have highly effective intervention units that will be an active part in emergency plans.
- Reconstruction: sustainable reconstruction will be promoted.
- Communication: there must be an active dialogue between the various actors, authorities and the population.

Figure 21. Scheme of the future natural hazards strategy. Source: Glarus Emergency questionnaire 2009

Lessons learnt on dissemination and education efforts

⇒ Whenever there is a flood event, the population is informed in a real time basis through newspapers, radio and TV. It is also important that once the event is finished more information is provided in order to give an overview of the event. The population is normally very interested in all this information.

⇒ The Swiss weather forecasting system is currently sending free of charge SMS to the population whenever severe weather conditions happen. Apart from the weather forecast, the potential consequences are also explained, so the people can be informed and know if a flood event may occur soon. In the Glarus canton, a similar system will be developed in the next few years and warning against floods will be available specifically for the Linth basin.

⇒ The hazard maps will be soon shown to the population, so they will be able to know exactly what may happen and where, and therefore, they will be prepared if a severe weather situation is forecasted. With this measure, the canton is trying to change to a new risk culture that can only be achieved if a new way of thinking is promoted. This means that the population should be kept informed about all the aspects of risk management.

⇒ As there are several regions in Switzerland that suffer from the same problems, a lively exchange takes place at various professional levels between the different cantons. Trainings are often offered and discussion groups are formed, so all the cantons can learn from the past experiences and promote a safer situation for the future.

4.5 Other basins

In addition to the extensive studies done about the test-bed areas, some more extra information about similar situations in other European basins has been compiled. By doing this, a broaden knowledge about the flash floods and debris flow events around Europe will be achieved. More lessons learnt may be identified, allowing to create a more exhaustive comparative analysis of the problem and, therefore, better recommendations for future risk management plans.

The inventory will be divided among the Northern European River basins, the Mediterranean River basins and the Eastern European River basins. Even though this last region was not considered in the original plan of the project, it has also been briefly studied, because a short version of the questionnaire was sent by the JRC to some other National Water Authorities and responses from Romania and Slovakia were received. Some events show a similar behaviour and interesting conclusions were extracted from their experiences that are worth taking into account.

4.5.1 North European basins

4.5.1.1 Analyzed information

An overview of flash-flood and debris flow events that were selected in Northern European basins is shown in Table 6. Note that debris flow events included have not been detailed because, in Norway, many events occur all the time and throughout the country. The nature of the flood events is quite different across all cases, although most of them result from extreme rainfall events. In Germany and the UK, the extreme precipitation was the most important reason. Here, despite the floods being characterized as flash-floods because of the water levels rising very fast (of the order of 1 m per hour), a huge area was impacted. In Germany, floods occurred throughout the Elbe and Mulbe basins and, in the UK, the entire country was affected. In Iceland and Norway, on the other hand, snow melt also played an important role. During these events, temperatures were unusually high causing rapid melting and, in Norway, the snow pack prior to the event was unusually large as well. The jökulhlaup event in Iceland is a very specific case, because it is caused by volcanic activity and it not related to any meteorological conditions. Forecasting of such events, therefore, should be based on entirely different systems (seismic).

In Norway, many landslide events also occur throughout the country, especially in the valleys and in the western fjord-landscape. However, they only cause harm occasionally. Similar to flash-floods, they are usually related to extreme precipitation events in combination with snow melt.

Table 6 shows a summary of the information of the events that were analyzed. For an extended review of any of these events, the complete datasheet can be found in Appendix 8.1.

Table 6. FF & DF events in Northern European basins. *Source: see appendix 8.1*

Country	Region affected	Date	Type of event	Return period of the event (years)	Deaths	Economic loss (million €)
Iceland	Myrdalsjőkull	1955 / 1999	Jökulhlaup	>30	0	-
Iceland	Patreksfjőrdur	January 22 1983	FF	>50	4	20 houses damaged
Norway	Glomma / Lågen	June 1995	FF	200	1	300 million US$
Poland	Vistula, Motlawa	9th July 2001	FF	>200	0	40
Germany	Elbe/Mulde basins	August 2002	FF	>150	0	11.600
United Kingdom	Entire country	May-July 2008	FF	250	13	3 billion GBP
Norway	Valleys and fjords	Regularly	DF	-	0	Harm is caused occasionally

4.5.1.2 *Lessons learnt*

Generally, a common response to the events is that the responsible agencies update their forecasting systems. In Germany, the DWD (German Weather Service) improved its forecast models and warning management. Moreover, stream gauges and their stage-discharge relationships were upgraded, so now, data is more reliable and accessible. In the United Kingdom, an improved flood risk map was created, based on high-resolution LIDAR. In Norway, plans currently exist for better flood risk maps and an improved warning system; however, there is a 24-hour flood forecasting system for flash-floods already that is provided by the Norwegian Water Resources Directorate for the entire country. In addition, a meteorological forecasting and warning system for landslide events is planned to be implemented nation-wide. Other infrastructural options to mitigate flood risk were employed in Iceland: a wide and deep channel was excavated to enable fast runoff without damage. Also in Iceland, large-scale evacuation plans already exist for jökulhlaup events by warning citizens with text messages or by telephone, based on seismic information prior to volcanic eruptions.

4.5.2 Mediterranean basins

4.5.2.1 *Analyzed information*

Table 7 shows a summary of the information of the six events analyzed. For an extended review of any of these events, the complete datasheet can be found in Appendix 8.1.

Table 7. FF & DF events in Mediterranean basins. *Source: see appendix 8.1*

Country	Region affected	Date	Type of event	Return period of the event (years)	Deaths	Economic loss (million €)
Spain	La Seu d'Urgell	7-8.11.1982	FF	>100	14	36
France	Nimes	3.8.1988	FF	100	9	-
France	Var	5.11.1994	FF	-	0	23
Spain	Barcelona	21.9.1995	FF	50	1	65
Spain	Biescas	7.8.1996	DF	500	87	50
Slovenia	Whole country	4-6.11.1998	FF/DF	100	2	145

As can be seen in the previous table, the consequences of these events differ a lot from one another but, all of them have aspects in common, like the driving mechanism that led to the flash flood and the basin conditions that exacerbated the effects.

The Mediterranean climate is characterized for being really dry most part of the year, but concentrating the main part of precipitation in short but very intense storms. These storms occur typically during the spring, summer and autumn almost every year in many Mediterranean regions. They are usually generated by convective systems that cause intense thunderstorms and extreme intense rainfalls for a short period of time. Depending on orography, human settlements and other factors, these rainfall events can produce catastrophic impacts.

Therefore, in addition to the heavy rains, the basin characteristics are also crucial in the triggering processes of these events. Although it may seem that some of the situations compiled in the table above are very different from one another, all of them lead to the same situation: a very low infiltration rate and the consequent generation of a high runoff. The urbanized area of Barcelona; the high heterogeneous thin soils that become saturated in a short period of time during rainfall events in the Var catchment; the previous rain episode that saturated the soil in Slovenia; etc., all of them had a reduced infiltration capacity, leading to an increase of the runoff and, therefore, making the peak discharge larger and more destructive. The high speed of the runoff produced is also another factor that makes the infiltration rates very low.

In the case of the debris flow events, the high slopes combined with the extreme precipitation intensities, caused the dragging of sediments, trees and other material.

4.5.2.2 Lessons learnt

In some cases, both the causes and the solutions for these catastrophic events are widely known, but it is very difficult to implement them, due to political, legal and economic reasons. This is the reason why identifying the lessons learnt from past experiences is useful to highlight this situation and to try to reach the people able to make political decisions.

In the following list, there are some of these lessons collected from the studied Mediterranean events, regardless of whether they have ever been implemented or not:

⇒ Locate the flood operation centres in a safe place, where the infrastructures cannot be affected by the flood.

⇒ Relocate some urbanized areas if necessary.

⇒ In urban areas, elaborate new sewage plans, involving the construction of retention tanks that reduce the peak flow.

⇒ The civil protection, firemen, police and army units must be efficient and be well coordinated, having planned in advance what to do in the affected zones. The municipal authorities and governments should provide the needed human and technical resources to deal with the situation.

⇒ Establish regulations to allow only certain land uses in flood-prone areas.

⇒ Take into account the professional opinion of water management experts and urban planners by the municipal authorities to make more effective the prevention and protection measures.

⇒ Mitigation measures should be executed after a flood event because, otherwise, the same sort of damage could be produced again after a similar event.

⇒ An integral water law should be implemented, taking into account land use, prevention, protection and mitigation actions to be executed before, during and after a flood event.

⇒ More information must be provided to the public so they can know which the risks are and how they should react in case of a flood event. The communication procedures should be also improved. Most of the damage and mild injuries were reported during the impact phase of the flash flood, which means that it is crucial to be able to accurately detect the moment of the hit.

⇒ As the neighbours are always the first ones that arrive to an affected area, some training should be provided to the people living in a flood-prone zone, so they could start the rescue actions in an efficient way.

⇒ The channelling of the rivers and other protection structures present, in general, an appropriate functioning. However, the lack of maintenance may mean an inefficient performance or even the collapse of these structures. Therefore, the importance of a regular maintenance of the infrastructures must be highlighted.

⇒ When planning an infrastructure, a global analysis of the basin must be carried out because, eventually, it could worsen the situation. This is what happens when important amounts of debris are dragged by the flow; they can be blocked under a bridge and, by this, cause much larger debris flow event with extremely destructive consequences.

4.5.3 Eastern European basins

4.5.3.1 Analyzed information

Table 8 shows a summary of the information of the events analyzed. For an extended review of any of these events, the complete datasheets can be found in Appendix 8.1.

Table 8. FF & DF events in Eastern European basins. *Source: see appendix 8.1*

Country	Region affected	Date	Type of event	Return period of the event (years)	Deaths	Economic loss (million €)
Czech Republic	Vsetin	July 1997	DF	Precipitation >70% higher than annual	0	40
Slovakia	Malá Svinka and Dubovický Creek	28.7.1998	FF/DF	100	47	25
Romania	Crisul Alb river	6-11.4.2000	FF	>100	3	5,5
Czech Republic	Hluboče	April 2006	DF	Precipitation 67% higher than annual	0	0,35

The basins studied belong to an area under a humid continental climate, present in most of the regions of central and Eastern Europe. These regions, which are really far away from the sea and belong to the temperate regions of the mid-latitudes, show a changing weather pattern and large seasonal temperature variability. Summers are often warm and humid with frequent thunderstorms and winters can be very cold and snowy.

These climate characteristics led to catastrophic consequences. In the case of Romania in 2000 and Czech Republic in 2006, during the first four months of the year there were important floods because of the snowmelt and heavy rainfalls. Then, in April, a very intensive torrential rainfall occurred in both cases and the consequences were dramatic.

A similar situation occurred in Slovakia in 1998 and Czech Republic in 1997, but as it was later in the summer, what saturated the soil was not the water coming from the snowmelt, but the high level of humidity typical of this climate and some previous rainfall events.

4.5.3.2 *Lessons learnt*

As a result of these events, the authorities realized that some things must be done to prevent these catastrophes, because as it has just been said, the conditions that lead to them are normal and may happen year after year. In the following list, some of the ideas collected from the follow-up studies are listed:

⇒ The flood forecasting systems must be improved and modernised.

⇒ Long-term, mid-term and short-term preventive and protection measures must be implemented, both structural and non-structural. They should not be planned only after flood events.

⇒ The population must be appropriately informed and warned. Policies and regulations should be promulgated in order to prohibit to build-up houses within the flooding area limits.

⇒ The government must provide the local authorities with defence means against flooding. They should provide them with operative materials and establish the intervention teams.

⇒ To prevent this kind of events, detailed hazard maps must be created based on topography and land use.

⇒ Research and development projects related to flood protection should be publicly funded.

5 Lessons learnt

This section aims to summarise the lessons learnt compiled throughout the analysis of the questionnaires answered by the different River Basin Authorities from several European countries. The return of experience identified through the elaboration of the inventory of events in Northern, Mediterranean and Eastern European basins has also been taken into account. Finally, several other studies related to flood risk and disasters management have been also incorporated in order to further complete this section.

The lessons learnt have been grouped according to the management phases of a flood crisis: prevention, preparedness and response. Lastly, lessons learnt concerning dissemination through the three previously mentioned phases and also related to education initiatives have been included.

5.1 Lessons learnt concerning prevention measures

Improving risk estimation:

⇒ A more accurate calculation of vulnerability is needed. In many cases, vulnerability is estimated by municipality, using statistics to estimate both, population and damages on buildings, therefore, the information obtained is mainly qualitative. A more precise calculation is needed in order to better evaluate what are the areas most exposed and those that may need more protection measures.

⇒ Some regions are developing a new generation of hazard flooding maps, using LIDAR or ortophotography to elaborate maps at a much finer scale (e.g. 1:5.000 instead of 1:50.000). This means that more accurate information will be available to calculate hazard levels. It is also crucial to make these maps available (e.g. on-line) in order to keep the population affected aware of the risk.

⇒ In relation to the elaboration of the hazard maps, often neither the construction companies, the scientific research groups of the region or the residents associations are involved in the process, but they should be because they may have a good knowledge of the analyzed basins.

Land use planning:

⇒ Urban planning regulations have been taken into account too late in many cases. Even if, frequently, there is an implemented urban planning law, the policy only applies to new developments but not to the existing urbanizations, which means that zones where nowadays it is not allowed to build, already have urban settlements. This is why sometimes, it will be unavoidable to relocate some urbanized areas to reduce the vulnerability in the flood-prone areas.

⇒ An additional difficulty related to urban planning is that urbanization constitutes the main source of income of many municipalities, and, therefore, there is an increasing pressure to transform rural land into urban, leading to the transformation of flood-prone areas into urban developments.

⇒ The urban planning regulations are often being applied only to the main rivers but they are not appropriate for secondary streams and/or alluvial fans. Thus, a review of the current policies should be carried out because, especially in the case of flash floods, many events take place in this kind of streams.

Alert systems:

⇒ The implantation of a hydrometeorological alert system has been proved to be necessary to obtain forecasts with the maximum precision and lead time possible. Potential improvements of the warning systems analyzed include: densification of the meteorological and gauging stations network, developing of new predictive models especially focused on flash floods forecasting, installation of sediment transport sensors, etc.

Structural measures:

⇒ Long-term, mid-term and short-term protection measures must be implemented, but they should not be planned only after flood events. Especially in the case of high cost infrastructural measures, an early planning is needed in order to favour the implementation of non-regret measures. By this, together with a global analysis and not forgetting about the nexus existing among water-territory-infrastructures, their implementation is going to be successful.

⇒ When planning an infrastructure, a global analysis of the basin should be carried out because, eventually, this could mean an improvement in a specific location but it could worsen the overall situation in the area. This is the case when important amounts of debris are dragged by the flow and they are blocked under a bridge; this may emphasize the problem, causing a much larger debris flow event.

⇒ Dams, together with some other regulation structures present in the main rivers have demonstrated to be clearly efficient in the reduction of the discharge peaks from the rivers. As a result of these important regulation and protection infrastructures, the flood problem has been displaced from the main rivers (and main cities) to the secondary streams, and then, more efforts should be focusing on towns located near small rivers.

⇒ Sometimes, the problem with the protection infrastructures is that there is not a complete overview of all of them, because they have been built along history. In order to keep track of all of them, it would be useful to elaborate an inventory of all the existing protections, collecting information of the type, location and condition. This measure would assist to monitor the maintenance state of these infrastructures and identify the ones that need an urgent intervention.

⇒ It is needed to review the assumptions and calculations used in the sizing and design of the protection infrastructures (dams, dikes…), and, in that way, minimize problems like flow obstruction or failure. This should be done for both, existing and new protection structures, and it is possible that re-sizing appears as the only possibility. In addition, using a larger return period for the infrastructure design may be a measure to consider in order to take into account the potential effects of climate change.

⇒ In the case of urban floods, the elaboration of new sewage plans, involving the construction of retention tanks that reduce the peak flow and avoid combined sewer overflows, can be considered in order to mitigate their negative effects.

⇒ It is necessary to start designing the flood warning gauges in a flood-proof manner and to equip them with back-up data collection, transmission and power supply systems.

Non-structural measures:

⇒ Property owners should also be involved in the implementation of some prevention measures in their own lots. They should be advised to clear periodically the drains in their property, to minimise the water accumulation on it or even to avoid flooding neighbouring properties.

⇒ Evaluate the potential retention areas at a basin level would be very helpful to analyze the volumes that might be intercepted and, then, calculate the peak flow reduction. Related to the previous point, the role of agriculture land it is important to control the hydraulic dynamics. It is possible to take advantage of the existence of crops within the flood limits to reduce the water velocity for example.

Operational procedures:

⇒ Setting up a permanent emergency management team, which should have the control of the situation all year round may be very useful. This permanent team should be in contact with the other actors involved, such as the Civil Protection authorities and weather forecasting institutions on a daily basis.

⇒ Planning the location flood operation centres in a safe place, where the infrastructures cannot be affected by the flood, to ensure that the coordination work will be carried out without problems during a crisis.

Planning the response:

⇒ There is a requirement for forward planning and risk assessment when it comes to evacuation. This should focus on the actions that need to be carried out during an evacuation and compare them with the amount of resources available. The goals would be:

- o Understanding at what point a disaster turns into a crisis and external help is deemed to be necessary
- o Considering what tasks and activities need to be carried out and how these should be prioritized under different circumstances.

⇒ Planning should include the possibility of persistence of flooding for significant periods in specific areas. The recession time of flood waters can vary from a few hours to a few days and it could persist for even longer periods, which inevitably leads to a greater and sustained demand on emergency services, including need for support and shelter for people displaced by floods.

Risk perception:

⇒ In the case of secondary streams that have an intermittent discharge, it has been detected that population has no risk perception. These locations must be detected and properly signposted to raise people awareness.

Learning from the past:

⇒ Local authorities should review past flooding experiences in order to identify vulnerable areas and associated sources of flooding, and consider what procedures might be adopted to mitigate the effects of flooding. It is important to promote the creation of historical flood databases in order to locate the areas that have been more frequently hit by flooding. Data should be summarized, classified and systematized to find out the main causes of the flood, the most frequent damages and their magnitude. This kind of database also constitutes the basis to detect the "black spots" (also called Priority Intervention Points) and to have information about the real cost of the damages. Another reason for creating a database is to provide real data of peak discharges and water levels during a flood event and compare them to the maximum values calculated empirically. It is also useful in order to have more information that enables to prioritize the actions to be carried out and the locations.

⇒ Expert meetings might be held to discuss about the lessons learnt on flash flood management, some very positive results can be achieved:

- o Raising awareness of the similarities and differences in the approach of coping with disasters in the different countries of the European Union.
- o Exchanging of the lessons learnt in the disaster risk management area.
- o Creating a roundtable discussion regarding disaster risk management at various scales: international, national, regional and local.

Future changes:

⇒ Future research will have to take into account other aspects, like climate change or land use changes, in the analysis strategies that are currently in use. The Floods Directive 2007/60/CE asks to consider the potential impacts that these future changes can cause in the flood risk levels.

Simplifying procedures:

⇒ Considering a reduction in the number of regulations implemented could simplify the implementation procedures and favour the disposition of the actors involved to be aware of them.

Debris flow:

⇒ Related to debris flows, it is particularly important to identify precipitation thresholds that trigger the event in order to define alert levels (e.g. attention, warning and alarm).

⇒ In general, landslides are often recurrent, hence, knowledge of past landslide occurrence in an area can be effectively integrated with other relevant information to create specific hazard maps, and, therefore, to identify the most dangerous zones.

⇒ Taking into account specific non-structural measures, such as reforestation of hill slopes, can help to reduce the occurrence of dangerous debris flows.

⇒ As in the case of flash floods, there is the need of setting up a permanent monitoring network equipped with the latest technology to detect major active landslides that can imply danger to population. Automatic warning and alarm systems connected to headquarters of emergency intervention bodies should be implemented, so that they can evacuate the area in time.

5.2 Lessons learnt concerning preparedness measures

Plans implementation process:

⇒ The need for reviewing and updating the emergency plans every certain periods of time has been detected. A meeting should be held at least once a year with all the organizations involved in the emergency plan to evaluate its real effectiveness. The previous year events are analyzed and decisions are made in case there is the need of changing warning thresholds or any operational procedure. Reviews should include coordination issues between the different organizations involved in the response.

⇒ In most of the cases analyzed, the current Flood Emergency Plans establish that all the municipalities must elaborate and implement their Local Flood Emergency Plan in order to protect the population affected with the local resources available. The main problem is that many towns do not have enough economic and/or technical resources available to elaborate it or to implement it. It is true, however, that this difficulty has already been detected and it is foreseen to organize training sessions to local authorities and technicians.

⇒ The elaboration of a study to analyze the hydraulic performance of the basin could help to understand the basin dynamics and, therefore, to prepare the municipal emergency plans. The document should include a catalogue of flood references with their consequential damages, a description of the functioning of the basin flooding (propagation time, water depth, water velocity…) and a guide of indicators located in the watershed (station network, websites with flood information…).

⇒ As the definitive measure for the next future, all the organizations involved are preparing the Flood Risk Management Plan (FRMP) that the Floods Directive 2007/60/CE demands. FRMP will have to include flash floods and debris flow risks, the approximate number of inhabitants affected, the economic activities of the region, the installations that can cause an accidental pollution and the protected areas that might be affected.

Maintenance measures:

⇒ Planning river beds maintenance measures in a regular basis (e.g. yearly, before the beginning of the most frequent flash flood season) should be done in addition to ordinary infrastructural measures. The usual measures carried out are: vegetation removal, recovery of the bridges flow capacity, stabilization of riverbanks, etc.

Preparedness information:

⇒ It is crucial that real time information concerning the following topics is available during a flood episode:

  - Magnitude and extent of the flood event.
  - Elements at risk (population affected, economic activities…).
  - Characterization of a critical level, e.g. a pre-determined threshold that, if exceeded, still allows for safe clearing of an emergency zone.
  - Damage assessment and calculation of costs.

⇒ It is recommended that information is prepared and made available to the public, particularly in areas with a history of flooding, setting out advice on measures to reduce the effects of floods, actions to be taken in the event of flooding, and recovery from a flooding event, including reoccupation of buildings and reinstatement or repairs.

⇒ When a house is sold or rented, the seller must provide the new residents with information on the possible flood risk.

Evacuation preparedness:

⇒ It is necessary to have an evacuation map of the potential flooded areas, including all the roads that may be used during a crisis, anticipating the possible cuts in some of the existing routes and planning the rehabilitation works. It has to be prepared jointly by the local and the state authorities to ensure that the overall road network is taken into account.

5.3 Lessons learnt concerning response measures

Response and post-crisis procedures:

⇒ Knowledge of the road network, location of the vulnerable elements at risk and evacuation times is the key to evacuation planning. Roads and bridges for re-establishing the circulation to isolated areas should be temporarily reconstructed if it is reasonably possible.

⇒ When necessary, it is important to call a state of emergency at an early stage so the local disaster protection authority can take over the centralised direction of emergency.

⇒ The creation of a unit responsible for monitoring the post-crisis (reconstruction phase and implementation of recommendations) would be useful in order to control the effectiveness and duration of the recovery works. It is also important to ensure that the allocated funds for the recovery phase are really used for this purpose.

⇒ Developing follow-up studies after a serious event with an integral analysis of the management of the flood event is useful for different dissemination purposes: it is important to make population and authorities involved aware about the means available to cope with floods, about the potential consequences of a similar event and to make a critical analysis of what parts of the emergency plans could be improved in the future and what parts can be used as an example for other basins.

Alert systems:

⇒ In the case of the response phase, the existence of a hydrometeorological system implemented in the whole basin constitutes a helpful decision support system that can improve and facilitate significantly the emergency management. This kind of system allows to estimate the flood magnitude with enough anticipation to activate the emergency plan and to reduce its impacts, provided that they are integrated within the civil protection operational procedures. Sometimes the lead time is too short even with the help of an early warning system and the emergency plan can not be activated in time. In those cases, the plan is only used as a rehabilitation plan.

⇒ There is the need to improve the speed and effectiveness of the procedure used to transmit the warnings. The timing, speed and method of communication of reports are critical for an efficient emergency management during a flood event. In too many occasions, the transmission chain used to communicate the alert information is slow and conditioned by a rigid procedure and, hence, more robust and integrated communication links between the organisations involved is needed. In addition, it has been detected that in some cases there was a lack of surveillance by the mayors that exacerbated the problem.

Coordination between the actors involved:

⇒ As also mentioned in other phases of the risk management, the coordination between all the administrations involved in the flood management is crucial during and after the event. This aspect has already been considered by most of the Flood Emergency Plan assessed in this work. They establish the coordination procedures between the national and local emergency plans or among the different organizations working during this phase of the emergency.

⇒ The cooperation between the emergency services and voluntary organisations is a positive aspect when responding to an inundation event. Their commitment and professionalism in providing a continuous response in different disasters could enhance the service received by affected communities. In a similar way, as in many occasions neighbours are the first ones that arrive to an affected area, thus, some training should be provided to the people living in a flood-prone zone, because by this they will be able to start the rescue actions in an efficient way.

Specific training:

⇒ Promoting the continuous training of the technicians and other personnel involved in any aspect of the flood management is needed. It is also important to carry out evacuation simulations to verify all the processes that take place in an emergency situation and to improve its effectiveness in a future real case.

Maintenance measures:

⇒ Maintenance and continuous improvement of the protection, communication and control equipments is crucial to provide an effective response. It is very important to have back-up means available in case something unexpected happen (e.g. it is not recommended to depend on only one control centre). It is also necessary to ensure that there are enough receivers to attend the emergency number callers asking for assistance, so that they do not queue up during a flood crisis.

5.4 Lessons learnt concerning dissemination and education initiatives

Alert communication:

⇒ More information must be provided to the public so they can know which the risks are and how they should react in case of a flood event. The communication procedures should be also improved. Most of the damage and mild injuries were reported during the impact phase of the flash flood, which means that it is crucial to be able to accurately detect the moment of the hit.

⇒ There is the need of diversifying the mechanisms and systems to communicate the alert levels to the population before and during the events. The warnings may be disseminated through different media (TV, radio, newspapers, SMS, internet).

⇒ In relation with the improvement of the flood alert systems, this should be accompanied by a proper training to mayors and municipal technical services on how to use it. As this type of system constitutes a very powerful tool that provides lots of information, it is crucial to have appropriate trained personnel in order to further improve and exploit it.

Risk perception:

⇒ Traditionally, society usually has had the wrong perception of being under a non-risk situation because it was used to be protected by structural measures. Lately, population tends to accept a certain level of risk due to the equilibrium between structural and non-structural measures, more sustainable with the environment. Education and dissemination of information should help to prevent a wrong idea of a non-risk situation. It is often found that, in some municipalities, there is a total absence of consciousness of the flood risk. There are still many people that ignore the violence of floods and underestimate the dangers for themselves and their property and, therefore, they do not follow the basic safety rules and they do not respond anymore after one or two false alerts. This is why more effort should be put in this issue, in order to create a risk culture and try to minimize the effects of the floods.

⇒ Some plans propose to conduct a sociological survey, approximately every two years, in order to assess the population level of awareness to the flooding issue.

⇒ Flood marks in public places around the city should be placed, in order to remind people about the worst historical floods, enhancing this way the creation of a risk-culture.

Dissemination programmes:

⇒ Many Civil Protection authorities carry out dissemination programmes, especially at the beginning of the heavy rain period, especially focusing in the flood-prone areas. They publish leaflets with recommendations and distribute them to public and private entities, prepare interactive video-clips for their websites, put advertisements on the mass media and e-mail information to local authorities. However, more dissemination and education campaigns to inform the population about the implemented prevention and emergency plans is still needed.

⇒ The hazard maps should be shown to the population, so they will be able to know exactly what may happen and where, and therefore, they will be prepared if a severe weather situation is forecasted.

⇒ Once the event is finished, more information should be provided in order to give an overview of the event. The population affected is normally very interested in all this information and, then, they can achieve a better awareness on flood prevention.

⇒ As the average annual cost to help repair damage of natural disasters is very high, doing an information campaign of the actual costs to the partners that eventually pay it, public or private, should lead to changing attitude towards prevention.

⇒ Press conferences would be useful to disseminate information to a broad public; however, they must be well prepared beforehand via meetings between the several concerned actors.

⇒ The need to establish a notification centre and to appoint an information manager to inform both, the people and the media, is essential in the management of the disasters. In remote disaster areas, this must be complemented with the improvement of telephone and radio communication systems.

⇒ Creating a travelling exhibition that could be installed two weeks in each town to provide effective information about floods may be a good dissemination technique. In the towns with the highest level of risk, the exhibition should return periodically (e.g. every two years) and it might be accompanied by one or two public information meetings.

Sharing information:

⇒ As there are several regions that suffer from the same problems, it is crucial that a lively exchange takes place at various professional levels between the different actors. Trainings should be offered periodically and discussion groups should be organized, so everybody can learn from the past experiences and create a better situation for the future.

Education:

⇒ Children will be taught about flood risk, in that way, from a very short age, they can develop a risk culture and increase their awareness. This kind of task will be successful only if it is planned for a long term, as a change in mindset requires working at least during one generation time period. Several tools can be used for this purpose:

- A board game about a flood.
- An informational DVD.
- A scale model showing the impact of the flood in the river surroundings.
- A field visit, where a guide explains some the most emblematic situations occurred in previous events.
- School lessons (once a year) to explain the contents of the municipal emergency plans, how to react and what precautions need to be taken before.

⇒ There are several websites specifically focused on education about how to identify and face natural risks: EDRINA (http://gama.am.ub.es/edrina/) and RINAMED (http://www.rinamed.net/) are two good examples.

6 Conclusions: recommendations for future strategies on flood risk management

As the Floods Directive (FD) states, "Floods have the potential to cause fatalities, displacement of people and damage to the environment, to severely compromise economic development and to undermine the economic activities of the Community". In fact, floods are the type of natural disaster that causes most human and economic losses in Europe. This is the reason why it is crucial to carry out strategies to improve flood protection and, therefore, there was a need to elaborate a new EU Directive to establish a framework for the assessment and management of flood risks.

The FD states that different types of flood occur across Europe and identifies flash floods as one of them. This means that every Member State will have to determine which are the types of flood that take place in each region and evaluate the risks according to this assessment.

The FD highlights among other factors the importance of the role of the Civil Protection organizations to provide an appropriate response to affected populations and to improve their preparedness and resilience. It also establishes the EU Solidarity Fund to grant rapid financial assistance when a major disaster occurs. The Directive promotes the development of regulations referred to the potential impacts that water and land use changes might have on flood risk.

These flood risks should be assessed through the elaboration of Flood Risk Management Plans (FRMP) with tailored solutions for each basin, evaluating their flood mitigation potential, promoting environmental objectives and increasing the efficiency of the already adopted measures. FRMP should focus on *prevention* (and *protection)*, *preparedness* and *response*, they should be periodically reviewed and updated taking into account the potential impacts of climate change. These three main risk management phases of a flood crisis have been assessed when extracting the lessons learnt for the four test-bed basins.

As mentioned before, the flood risk management procedures of the four basins from three different European countries have been analyzed in order to compare them and understand which are the needs and difficulties found in each case.

Starting with the similarities, a common response to most of the events described in this document is to upgrade the meteorological and hydrological forecasting systems. Making the forecasting lead-time as large as possible, in combination with detailed risk maps, gives time for evacuation of people in the risk areas. This is, of course, the exact goal of IMPRINTS.

As the risk for catastrophic events always exists, they also agree that it is not wise to accumulate much value in the risk areas. Bans on building in those areas, perhaps in combination with subsidizing people or companies moving to safer areas should be promoted. As this is not always possible, infrastructural measures like upstream storage reservoirs, or large channels that can be used during flood peaks could be used to prevent or reduce catastrophic flooding.

All the basins have also detected that structural measures are needed to increase the population's protection level. However, the traditional approach to flood protection has been generally characterized by a safety mentality. Protection was based on design criteria without an integral analysis of the whole basin, the different possible events, failure scenarios and protection objectives. This traditional safety mentality has to be replaced by a risk culture based on a comprehensive analysis of the flood risk and an evaluation of the potential risk-reducing measures. This new risk culture approach has already been identified by Glarus Emergency, the Linth's basin authorities, which are preparing a new strategy to cope with natural hazards that is based on taking advantage of the experiences gained from past events.

The four basins studied have also highlighted the importance of collect information when flash floods and debris flow events occur and create historic databases that will provide extremely useful information in the future.

Finally, they agree on the need for periodic reviews and updates of the FRMP as the FD already demands. Nowadays, the flood emergency plans usually do not have a fixed schedule on when an update is necessary and, therefore, the new versions might be delayed indefinitely.

Even if the four test bed basins analyzed have identified similar lessons learnt from past events and recommendations for future flood risk management strategies, each one of them has put its focus on different issues. In the following text boxes there is a brief summary of which are the main strategies on flood risk management that the four basins are currently carrying out:

Llobregat basin (Catalonia, Spain)

- Working on the detection of high risk debris flow areas.
- Developing EHIMI, an integrated hydrometeorological forecasting tool that will work on a real time basis and it will be available on-line soon.
- Continuing with the PEFCAT program: new hazard maps through hydrologic and hydraulic modeling, comprehensive list of measures for each basin (structural and non-structural)

Guadalhorce basin (Andalusia, Spain)

- Developing new hazard maps at a much finer scale (1:2.000 instead of the current ones at a 1:200.000)
- Implementing a comprehensive prevention plan including structural and non-structural measures during the 2002 to 2015 period

Gardon d'Anduze basin (Gard, France)

- Putting a lot of effort on simplifying and clarifying the structure of the emergency management organizations and plans
- Focusing on education and dissemination measures through a wide variety of different ideas and media to transmit the information: board games, traveling exhibitions, visits to sites, school lessons, marks in public places...

Linth basin (Glarus, Switzerland)

- Finishing an Integrated Flood Risk Management Plan to be implemented by 2011 that will be based on the promotion of a new risk culture and that will favor a sustainable reconstruction if this is the case.
- Due to the importance of risk awareness, providing information before, during and after a flood event will be crucial in the new FRMP.

In addition, as one of the main objectives of this report was to identify the lessons learnt by the River Basin Authorities of different European countries (including the four test-bed basins) to assess which ones could be used as recommendations for future flood risk management, here are presented the measures selected grouped according to the management phases of a flood crisis. Each text box corresponds to a different phase and a fourth one has been added to include ideas concerning dissemination of information and education initiatives.

Recommendations for the prevention phase

- Improve risk estimation by a more accurate hazard and vulnerability calculations.
- Implement and accomplish the land use regulations, even in areas close to secondary streams. A real understanding of flood risk is very important in the planning stages of new developments.
- Improve the hydrometeorological forecasting systems and develop new predictive models in order to increase the lead-times as much as possible.
- Elaborate an integral analysis when planning a protection infrastructure: considering the nexus among water-territory-infrastructure.
- Create an infrastructure inventory to help in their maintenance schedule. Involve also the property owners in the maintenance of their private drains.
- Promote the maintenance and restoration of natural floodplains, improve the water retention and/or controlled flooding of certain areas. Analyze the retention potential at a basin level.
- Learn from the past through the creation of historical flash flood and debris flow databases to help identify the high risk areas. It can constitute an excellent source of information about real damages cost and real values for peak discharges.
- Take into account potential future changes such as, climate and land use, in the Flood Risk Management Plans as the Floods Directive already demands.
- Specifically for debris flows:
    - identify precipitation thresholds
    - have a good knowledge of past landslides occurrences
    - create specific hazard maps for debris flows
    - set up a permanent and specific monitoring network
    - promote specific measures such as the reforestation of high risk hill slopes to stabilize them

Recommendations for the preparedness phase

- Set up a schedule for the review and update of the emergency plans. Evaluate the real effectiveness of the plan through a yearly meeting.
- Plan river bed maintenance measures regularly.
- Plan the response and evacuation in advance. Prepare an evacuation map of the potential flooded areas.
- Promote training to those involved in the different phases of a flood emergency and plan evacuation simulations.

Recommendations for the response phase

- Improve the coordination between the different flood emergency plans and among the organizations involved in this phase of the emergency.
- Create a unit to monitor the post-crisis to control the appropriate allocation of funds, the time of reconstruction...
- Elaborate follow-up studies after an important flood event to make population and authorities involved aware about flood consequences.
- Improve the speed and effectiveness of the procedure used to transmit the warnings.
- Promote the use of the hydrometeorological systems as decision support systems to facilitate the emergency management, allowing to activate the emergency plans with enough anticipation.
- Take into account the continuous maintenance and improvement of the response equipment.

Recommendations for dissemination of information and education initiatives

- Promote the exchange of information between experts and technicians from different European countries.
- Diversify the mechanisms to disseminate alert levels to population: TV, radio, newspapers, SMS, internet...
- Create a risk culture in which society accepts that it is and it will remain vulnerable to flood damage, to a certain extent. It is crucial to fight against the wrong perception of being under a non-risk situation with measures such as:
  - carry out sociological surveys every certain periods
  - put flood marks in public places around the city
  - distribute leaflets with recommendations
  - broadcast mass media advertisements
  - show hazard maps
  - organize travelling exhibitions
- Start education programmes at schools: it must be planned for a long term period because a change in mindset requires working at least during one generation.

Finally, regarding the issue of taking into account the potential climate change impacts in the FRMP, as the Floods Directive already demands, this will have to be gradually incorporated in each one of the FRMP cycles. The just released "Guidance document on River Basin Management in a Changing Climate" from the CIS-WFD (2009) states that including climate change effects in the new FRMP will require both, to monitor and to understand, climate-driven impacts. Due to the large uncertainties related to climate projections, robust and flexible measures should be incorporated. Those measures should be valid for a wide range of climate models and emission scenarios to implement, in that way, low regret solutions.

7 References

Llobregat basin

ACA, 2001: Planificació de l'Espai Fluvial (PEF) – Riera de Marganell (in progress)

ACA, 2001: Planificació de l'Espai Fluvial (PEF) del torrent Mal i la Riera de Margarola (in progress)

ACA-INCLAM, 2008: Avaluació de l'impacte produït pel canvi climàtic sobre els recursos hídrics a les conques de capçalera de la Muga i el Francolí

ACA, 2009: Programa de mesures del Pla de gestió del districte de conca fluvial de Catalunya.

Barnolas, M., M.C. Llasat, 2005: Aplicación de una herramienta SIG en el estudio en el estudio de las inundaciones en Catalunya, 1901-2000. ***Revista del Aficionado a la Meteorología***, 28.

Cañellas, A., 2000: Informe extraordinari del Síndic de Greuges al Parlament de Catalunya sobre l'actuació de l'Administració Pública en matèria de prevenció i intervenció davant el risc d'inundacions i avingudes. ***Butlletí Oficial del Parlament de Catalunya***, VI legislatura, tercer període, 114.

Departament d'Interior de la Generalitat de Catalunya, Relacions Institucionals i Participació, 2006: Pla d'emergència especial per inundacions – INUNCAT.

Departament d'Interior de la Generalitat de Catalunya, 2007: Pla Especial D'emergències Per Incendis Forestals De Catalunya – INFOCAT.

Escuer, J., 2008: El risc d'inundacions a Catalunya. ***Projecte RISKCAT***.

Llasat, M. C., J. de Batlle, T. Rigo and M. Barriendos, 2001: Las inundaciones del 10 de Junio del 2000 en Cataluña. ***Ingeniería del Agua***, 8, 1.

Llasat, M.C., M. Barnolas, M. Ceperuelo, M. Llasat, M.A. Prat, 2004: Algunos aspectos del impacto social de las inundaciones en Catalunya. ***Revista del Aficionado a la Meteorología***, 20.

Manzano, A., 2009: Effects on hydrological variability and extreme phenomena; examples of hydrological modelling of floods and droughts in future scenarios. ***Water and Climate Change (ACA)***, 153-165.

Milelli, M., M. C. Llasat and V. Durcrocq, 2006: The cases of June 2000, November 2002 and September 2002 as examples of Mediterranean floods. ***Natural Hazards and Earth System Sciences***, 6, 271-284.

Web Sources

Agència Catalana de l'Aigua. http://aca-web.gencat.cat/aca/

Guadalhorce basin

AAA, 2009: Distrito Hidrográfico Mediterráneo, Red Hidrosur: Descripción breve del sistema.

Berga, L., 1998: Dam Safety. ***A. A. Balkema, Rotterdam/Brookfield***, Vol. 1, 2.

CTEI, 1983: Inundaciones históricas, cuenca del Sur. Las inundaciones en España. Informe General.

Consejería de Obras Públicas y Transportes, 2002: Plan de prevención de avenidas e inundaciones en cauces urbanos andaluces.

Consejería de Gobernación, 2004: Plan de Emergencia ante el riesgo de inundaciones en Andalucía.

EGMASA, 2006: Estrategia de defensa ante inundaciones en Andalucía. FLORISPRE : encuentro de especialistas en prevención, protección y mitigación de las inundaciones, Sevilla, 18 – 19 Octubre 2006.

FIC, 2006: Generación de escenarios de cambio climático en Andalucía.

Ojeda, J. and A. Villar, 2007: Evolución del suelo urbano/alterado en el litoral de Andalucía (España): 1998-2002. ***Geofocus***, 7, 73-99.

Ojeda, J., J. I. Álvarez, D. Martín and P. Fraile, 2009: El uso de las tecnologías de la información geográfica para el cálculo del índice de vulnerabilidad costera (CVI) ante una potencial subida del nivel del mar en la costa Andaluza (España). ***Geofocus***, 9, 83-100.

Web Sources

ABC's Newspaper Library. http://hemeroteca.abc.es/

AEMET. http://www.aemet.es/es/eltiempo/prediccion/avisos

Agencia Andaluza del Agua. http://www.juntadeandalucia.es/agenciadelagua/

Hidrosur. http://hidrosur.agenciaandaluzadelagua.es/

Junta de Andalucía: Consejería de Gobernación. *http://www.juntadeandalucia.es/gobernacion/*

Gardon d'Anduze basin

Agrawala, S., 2007: Climate Change in the European Alps. Adapting winter tourism and natural hazards management. ***Organisation for Economic Co-operation and Development***.

Bianciotto, L., 2005 : Les crues du Gardon sur la commune d'Anduze: approche historique et enjeux. Université Paul Valery – Montpellier III.

Chambre de Commerce et d'Industrie de Nîmes, 2008: Analyse de la vulnérabilité des entreprises face au risque inondation suivant les bassins versants.

Conseil Général du Gard and Le Syndicat Mixte d'Aménagement et de Gestion Equilibrée des Gardons, 2003: Projet de plan de prévention des inondations sur le bassin des Gardons (PAPI).

Conseil Général du Gard, 2004 : Plan Communal de Sauvegarde.

Direction de la Défense et de la Sécurité Civiles and Ministère de l'Intérieur et de l'Aménagement du Territoire, 2004 : Plan Communal de Sauvegarde: Guide pratique d'élaboration.

Direction Départementale de l'Agriculture et de la Forêt, 2006: Arrête préfectoral nº 2006-131-4 du 11 mai 2006 relatif à la prévention des incendies de forêts.

DIREN, 2006: Le risque inondation dans la Vallée du Rhône de la frontière Suisse à la mer.

ECOFYS and AlternConsult, 2008 : Etude des effets du changement climatique sur le grand sud est. Etape 1. Rapport Languedoc-Roussillon. ***Mission d'Etude et de Développement des Coopérations Interrégionales et Européennes***, p. 34.

Gaume, E., 2007: Flood crises preparedness: the French case study. ***Laboratoire Central des Ponts et Chaussées, Flood Site project***.

Huet, P., X. Martin, J. L. Prime, P. Foin, C. Laurain and P. Cannard, 2003 : Retour d'expérience des crues de septembre 2002 dans le Sud Est. ***La Houille Blanche***, 6, 107-113.

Launay, P., 2004: The role of civil safety in the management of the floods, ***Colloque Franco Marocain***, 4 - 5 October 2004.

Pottier, N., E. Penning-Rowsell, S. Tunstall and G. Hubert, 2005: Land use and flood protection: contrasting approaches and outcomes in France and in England and Wales. ***Applied Geography***, 25, 1, 1-27.

Web Sources

CME – Centre Méditerranéen de l'Environnement. http://cme-cpie84.org/

Météo – France. *http://france.meteofrance.com/*

VigiCrues project: Ministère de l'Écologie, de l'Energie, du Développement durable et de la Mer. *http://www.vigicrues.ecologie.gouv.fr/*

Website of the 2002 flood: Inventaire Cartographique des inondations des 8 et 9 septembre 2002. http://www.languedoc-roussillon.ecologie.gouv.fr/risques/gard_2002/gardons/

<u>Linth basin</u>

Carpenter, G., 2005: European Flood Report 2005 – Central and Eastern Europe.

Gülden, J. and G. N. Poliwoda, 2008: Financial Adaptation to Floods in Switzerland in the 20th and 21st Century - A historical and economic investigation.

Hegg, C., H. Romang, F. Dufour, N. Hilker, M. Zappa and J. Rhyner, 2007: IFKIS-Hydro - a flood hazard information and warning system for smaller catchments.

Hilker, N., A. Badoux and C. Hegg, 2009: The Swiss flood and landslide damage database 1972-2007. ***Natural Hazards and Earth System Sciences***, 9, 913–925.

Speich, D., 2003: Die Linthkorrektion. Ein Projekt zur Verbesserung von Mensch, Natur und Gesellschaft. ***TEC21***, 16-17/2003.

Vischer, D., 2003: The Tricky Question of Equilibrium. ***23rd international meeting of the Working Party on Mountain Watershed Management***, Davos, Switzerland.

<u>Other basins</u>

Barrera, A., M. Barriendos and M. C. Llasat, 2005: Extreme flash floods in Barcelona County, ***Advances in Geosciences***, 2, 111–116.

Bird, D. K., G. Gisladottir and D. Dominey-Howes, 2009: Resident perception of volcanic hazards and evacuation procedures, ***Natural Hazards and Earth Systems Science***, 9, 251–266.

Colombo, A., I. Prezelj and A. Vetere Arellano, 2002: Nedies project : lessons learnt from flood disasters. ***Ispra, Joint Research Centre, EC***.

Duclos, P.J., O. Vidonne, P. Beuf, P. Perray and A. Stoebner, 1991: Flash flood disaster: Nimes, France. ***European Journal of Epidemiology***, 7, 4, 365 – 371.

Ganyet R., 1999: La canalización y el parque olímpico del Segre en La Seu d'Urgell. ***Revista del colegio de ingenieros de caminos, canales y puertos***, 47, II.

Guinot, V. and P. Gourbesville, 2002: Modelling Flash Floods in Mediterranean areas: Should we attempt to calibrate physically-based models? ***5th International Conference on Hydro-Science & Engineering***, Warsaw, Poland.

Haven, J., 2008: Redrawing the landscape, ***Sustainable Business***, 144, 47-48.

Klimeš, J., 2008: Analysis of preparatory factors of landslides, Vsetínské Vrchy highland, Czech Republic. ***Acta Research Reports***, 17, 47-53.

Klimeš, J., I. Baroň, T. Pánek, T. Kosačik, J. Burda, F. Kresta, and J. Hradecký, 2009: Investigation of recent catastrophic landslides in the flysch belt of Outer Western Carpathians (Czech Republic): progress towards better hazard assessment. ***Natural Hazards and Earth System Sciences***, 9, 119-128.

Kreibich, H., M. Müller, A. H. Thieken, B. Merz, 2007: Flood precaution of companies and their ability to cope with the flood in August 2002 in Saxony, Germany. **Water Resources Research**, 43, W03408.

Krejči, O., I. Baroň, M. Bíl, F. Hubatka, Z. Jurová, and K. Kirchner, 2002: Slope movements in the Flysch Carpathians of Eastern Czech Republic triggered by extreme rainfalls in 1997: a case study. ***Physics and Chemistry of the Earth***, 27, 1567-1576.

Majerčáková O., M. Makeľ, P. Šťastný, M. Kupčo and P. Rončák, 2004: Report of Selected Flash Floods in the Slovak Republic. ***Global Water Partnership – Slovakia***, Bratislava.

Majewski, W., 2008: Urban flash flood in Gdansk - 2001; solutions and measures for city flood management. ***International Journal of River Basin Management***, 6, 4, 357-367.

National Institute of Hydrology and Water Management, Bucharest, 2005: Study of historical floods in central and Eastern Europe from an integrated flood management viewpoint – Romania. ***WMO/GWP Associated Programme on Flood Management.***

Tomas, R. and O. Moravcova, 2008: Portal of geohazards in the Czech republic – information services for disaster prevention. http://www.geology.cz/geohazardy

Tómasson, G.G., E. Hestnes, 2000: Slushflow hazard and mitigation in Vesturbyggd, northwest Iceland, ***Nordic Hydrology***, 31 (4-5), 399-410.

White, S., J. García-Ruiz, C. Martí, B. Valero, M. Errea and A. Gómez-Villar, 2004: The 1996 Biescas campsite disaster in the Central Spanish Pyrenees, and its temporal and spatial context. ***Hydrological Processes***, 11, 1797-1812.

Wold, B., 1998: Norwegian spring flood disaster 1995: Experiences and consequences. ***Proceedings of the Institution of Civil Engineers: Municipal Engineer***, 127 (4), 192-195.

Other sections

Colombo, A. G. and A. L. Vetere Arellano, 2002: Lessons Learnt from Flood Disasters. ***NEDIES Project***, EUR 20261 EN.

EC, 2007: Directive 2007/60/EC of the European Commission of 26 November 2007 establishing a Floods Directive on the assessment and management of flood risks. http://ec.europa.eu/environment/water/ flood_risk

EC, 2009: River basin management in a changing climate. Guidance document No. 24. ***Common implementation strategy for the Water Framework Directive (2000/60/EC).***

Guha-Sapir, D., D. Hargitt and P. Hoyois, 2004: Thirty years of natural disasters 1974-2003: the numbers, Centre for Research on the Epidemiology of Disasters (CRED), ***Presses Universitaires de Louvain***, Belgium

Hervás, J., 2003: Lessons Learnt from Landslide Disasters in Europe. ***NEDIES Project***, EUR 20558 EN.

Hilker, N., A. Badoux and C. Hegg, 2009. The Swiss flood and landslide damage database 1972-2007. ***Natural Hazards and Earth System Sciences***, 9, 913-925.

IPCC, 2008. Bates, B. C., Z. W. Kundzewicz, S. Wu, and J. Palutikof, Climate change and water. ***Technical Paper of the Intergovernmental Panel on Climate Change***, IPCC Secretariat, Geneva, p. 210

Lumbroso, D., N. Asselman, P. Bakonyi, E. Gaume, C. Logtmeijer, A. Nobis, B. Woods-Ballard, 2007: Review report of operational flood management methods and models. ***FloodSite Project***.

WMO-GWP, 2007. Guidance on flash flood management: recent experiences from Central and Eastern Europe. ***Associated Program on Flood Management.***

Web Sources

WISE – Water Information System for Europe. http://water.europa.eu/

8 Appendix

8.1 Inventory of events: Mediterranean, Northern and Eastern Europe basins

8.1 Inventory of events: Mediterranean, Northern and Eastern Europe basins

Northern Europe basins

Country: Iceland

Catchment/River basin: Mýrdalsjökull

Date of the event: Unconfirmed volcanic activity may have created the jökulhlaup which occurred in 1955 and 1999 from the Kötlujökull and Sólheimajökull catchments, respectively (Bird et al. 2009).

Details/Driving mechanism: The Icelandic term "jökulhlaup" is defined as a sudden burst of meltwater from a glacier and may occur for a period of several minutes to several weeks (Björnsson, 2002). All confirmed historic eruptions of Katla, the volcano underlying the Mýrdalsjökull ice cap in southern Iceland, have produced jökulhlaup (Thordarson and Larsen, 2007). A Katla eruption can melt through the ~400m of ice covering the Katla caldera in 1–2 h, producing a catastrophic jökulhlaup with a peak discharge of 100 000–300 000 $m^3 s^{-1}$ (Björnsson, 2002). All historic jökulhlaup have emanated from the catchment areas of Kötlujökull and Sólheimajökull while none have come from the Entujökull catchment.

Severity/Return period: Since settlement in the 9th century, Katla has erupted approximately 1–3 times per century (Thordarson and Larsen, 2007). At least 21 eruptions have occurred during this time with the last confirmed eruption in 1918 (Larsen, 2000).

Reported damage: In the July 17th-18th 1999 event, a meltwater flow destroyed power lines, oversplashed a bridge on Iceland's main road and transported ice blocks 8 km into the sea Expected damages due to an eventual catastrophic jökulhlaup are: within 3 h Highway 1 would be inundated and the entire outwash plain surrounding the Markarfljót would be flooded within 10 h. With a maximum flood depth of up to 2 m, low lying regions could remain submerged for over 24 h.

Measures taken: In view of the potential future hazard presented by jökulhlaup, the Icelandic Civil Protection organisation (ICP) developed regional evacuation strategies based on a worst case scenario as described in the report edited by Guðmundsson and Gylfason (2005).

Further info/key sentences: If an eruption is imminent, residents would be notified via a text message to their mobile phone. If residents do not have a registered mobile phone number, a recorded message would call through to their landline. Upon receiving this message residents have 30 minutes to prepare to evacuate. However, if an eruption occurs without precursory activity, residents will be instructed to evacuate immediately. Before leaving, they are required to hang the evacuation sign outside their house to indicate that they have left. Certain residents in each region have volunteered to 'sweep' their local area to ensure their neighbours have left for the evacuation centres located in Hella, Hvolsvöllur and Skógar. In order to reach these centres some residents must evacuate via the roads that parallel the Markarfljót and along Highway 1.

Eventual feedback: To test the proposed evacuation plan the ICP conducted a full scale evacuation exercise on 26 March 2006 in Rangávallasýsla. Approximately 1200 residents live within the hazard zone and for the purpose of fully testing the evacuation plan residents were not informed of the timing of the eruption scenario.

Field observations were made during the evacuation exercise, semi-structured interviews with key emergency management officials were held after the evacuation exercise, and questionnaire survey interviews were conducted with local residents.

<u>*Source:*</u>

Bird, D. K., G. Gisladottir and D. Dominey-Howes, 2009: Resident perception of volcanic hazards and evacuation procedures, ***Natural Hazards and Earth Systems Science***, 9, pp. 251–266.

Björnsson, H., 2002: Subglacial lakes and jökulhlaups in Iceland. ***Global Planet. Change***, 35, 255–271.

Thordarson, T. and G. Larsen,2007: Volcanism in Iceland in historical time: Volcano types, eruption styles and eruptive history. ***J. Geodyn.***, 43, 118–152.

Larsen, G., 2000: Holocene eruptions within the Katla volcanic system, south Iceland: Characteristics and environmental impact. ***Jökull***, 49, 1–28.

Guðmundsson, M. T. and Á. G. Gylfason, 2005: Hættumat vegan eldgosa og hlaupa frá vestanverðum Mýrdalsjökli og Eyjafjallajökli. ***Ríkislögreglustjórinn Háskólaútgáfan, Reykjavík***, 210 pp.

Country: Iceland

Catchment/River basin: Patreksfjördur

Date of the event: 22nd January 1983.

Details/Driving mechanism: The release of slushflows – flowing mixtures of water and snow – is associated with cyclonic activity during autumn and winter as well as spring break-up periods. The slushflows in Patreksfjördur were released due to a cyclonic warm front passage. The synoptic station Kvigindisdalur located across the fjord, recorded 123 mm of precipitation within 24 hours on the day of the accidents. Comparing the records with the time of the events, an estimated 100 mm of rainfall fell prior to the slushflow occurrence. Due to the high humidity, an average wind of approximately 10 m/s and temperature above 5°C for at least 15 hours, the amount of snowmelt is estimated to have been 70-80 mm. Thus, the total water supply received by the snowpack per unit area before the slushflow release was probably 170 mm or more.

Severity/Return period: The slushflow records, the climatic data and the age of the houses in the area, indicate that slushflows comparable in size with the event in 1983, may have a return period of 50-100 years or more. This estimate should, however, be taken with great caution, given the very limited underlying data.

Reported damage: The catastrophic slushflow from Geirseyrargil in Patreksfjördur occurred at 15:40 in the afternoon of January 22nd, 1983. Sixteen houses were damaged or destroyed and ten people were caught in the slushflow, causing three fatalities. Less than two hours later, at 17:15, another slushflow came down the nearby Litladalsá, leaving four damaged houses and one victim.

Measures taken: The proposed defences in Geirseyrargil consist of a wide channel excavated in the alluvial fan straight down from the mouth of the gully and lined by earthfill dams. In addition, the gully itself is straightened and widened below 130 m a.s.l. to provide a uniform track from the gully into the excavated channel.

Further info/key sentences: Although the main purpose of the protection works is to secure the residential area against slushflows, it will also serve as a defence against avalanches, rockfalls and debris flows from the gully.

Source:

Tómasson, G.G., E. Hestnes, 2000: Slushflow hazard and mitigation in Vesturbyggd, northwest Iceland, ***Nordic Hydrology***, 31 (4-5), pp. 399-410, 2000.

Country: Norway

Catchment/River basin: Glomma and Lågen River.

Date of the event: June 1995.

Details/Driving mechanism: The flood occurred due to several factors, which in themselves were not out of the ordinary. The snow accumulation in the mountains (above 1000 m), and in the forest areas 300-1000 m above sea level, was larger than normal at the beginning of May and increased further throughout the month due to solid precipitation and low temperatures. A sudden change in the temperatures at the end of May caused rapid melting in the low-lying areas as well as in the mountains, and combined with heavy rainfall, produced the century's largest flood.

Severity/Return period: The return period for the flood has in some areas been estimated to be 200 years.

Reported damage: The level of dykes was exceeded in many areas, which led to their breaching due to overtopping or hydraulic fracturing. During the three weeks of flooding, more than 130 km^2 of agricultural land was covered with water. Approximately 7000 people and a large number of domestic animals had to be evacuated. Roads and railways were blocked for several days and in some instances for several weeks.

The total costs associated with the flood were estimated to be US$ 300 million. Insurance payments amounted to about US$ 170 million, while the remaining US$ 130 million was covered by the authorities. Costs relating to loss of production and diversions of traffic are not included in these figures. The costs associated with emergency and prevention work and cleaning up during and after the flood were estimated to be US$ 52 million.

Fortunately, there was only one fatality.

Measures taken: Immediately after the flood, the Government set up a special commission on Flood Protection Measures. The commission's terms of reference were, in part, to investigate the causes of the flood and assess the flood warning system and the flood information provided by the central authorities. However, the commission's main objective was to propose measures that would reduce the country's vulnerability to the hazards and damage caused by floods.

One of the most important recommendations adopted by the Norwegian government was that the design requirements for flood protection should be reconsidered. Where large urban areas or important infrastructures are threatened, it seems reasonable to base safety planning on 200-500-year return periods. A classification of flood protection measures was recommended, based on the consequences arising from potential flooding.

Flood zone maps will be produced for the most important parts of Norwegian rivers, estimated to be approximately 3500 km in length. These maps will mark the various flooded areas in detail for floods of different return periods.

A research program (Hydra) was started by NVE immediately after the flood with a view to assessing whether land-use changes and other physical impacts, such as dikes, erosion protection, etc., have increased the risk of flooding.

Further info/key sentences: The commission's work was based on the assumption that floods are natural occurrences associated with climate and topography, and that society to a certain extent must accept that it is, and will remain, vulnerable to flood damage.

Eventual feedback: The new increased awareness and emergency measures were successfully put to the test during a large spring flood in northern Norway in 1997. Although, in some respects, this flood was worse than the 1995 flood in southern Norway, the damage was less severe due to the sparsely populated areas in that part of the country.

Source:

Wold, B., 1998: Norwegian spring flood disaster 1995: Experiences and consequences. ***Proceedings of the Institution of Civil Engineers: Municipal Engineer***, 127 (4), pp. 192-195, 1998.

Country: Poland

Catchment/River basin: Vistula River, Radunia Channel, Motlawa.

Date of the event: 9th July 2001.

Details/Driving mechanism: On the 9th of July practically the whole catchment area of the Radunia Channel received 80 mm of precipitation within only 4 hours. The daily amount of precipitation in Gdansk on 9th July 2001 was estimated to be between 110 and 120 mm. The upper part of the catchment received 120 mm and the lower part, including the channel and its right hand area, 110 mm.

A dramatic situation in the city was caused by the fact that flooding started within a very short time from the beginning of rainfall and the city infrastructure made impossible to apply any technical measures of protection.

Severity/Return period: Precipitation distribution over the city of Gdansk on the 9th July 2001 indicates that the catchment of the channel was in the centre of the maximum precipitation area. This value was estimated to have a probability of 0.5 to 0.3% (once in 200–300 years).

Reported damage: More than 300 families were affected by the flood (damaged houses, loss of property). It was necessary to rescue people and their property from complete loss and destruction. Basements of numerous houses were flooded and required draining and drying. About 5000 people received the special calamity status, which allows them to benefit from social assistance. Total flood damage of the city infrastructure was estimated at about 40 million €.

Measures taken: After the flood of 2001, the local authorities (Regional Board of Water Management in Gdansk) decided that it was necessary to undertake steps to improve flood protection in the Gdansk area in the future, especially in the region of Radunia Channel (Majewski et al., 2003, 2004).

On the basis of the hydraulic calculations and the analysis of all the circumstances, it was decided to construct 18 small artificial storage reservoirs on all the streams discharging into the Radunia Channel, in order to decrease the inflow in case of intensive precipitation. This will retain water in the channel catchment temporarily. Their total volume is $420 \cdot 10^3$ m^3 and this is not sufficient to accommodate all water from intensive rainfall. Therefore, it was proposed to also construct 4 control outflows from the Radunia Channel to the Radunia and Motława rivers to diminish the flow in the channel in case of high precipitation. Two flood polders are planned, which can be operated in case of an extremely strong storm surge and simultaneous high water level in the Motława River.

It is also proposed to install automatic precipitation and water level gauges net in order to create, together a with meteorological radar, a flood warning system.

Further info/key sentences: The storm gates Brama Zuławska and Kamienna Grodza play a very important role in the Gdansk Water Node. Depending on water levels in Martwa Vistula caused by storm surges and the inflow into Motława Moat, two situations are possible: closure of the gates and impoundment of Motława Moat and Motława River upstream. In the second case, storm surge does not result in the closure of the storm gates, but it increases the water level in the Motława Moat.

Source:

Majewski, W., 2008: Urban flash flood in Gdansk - 2001; solutions and measures for city flood management. ***International Journal of River Basin Management***, 6 (4), pp. 357-367.

Country: Germany

Catchment/River basin: Elbe and Mulde River (Saxony).

Date of the event: August 2002.

Details/Driving mechanism: Floods of short duration with a relatively high peak discharge (*UNESCO* 2006), in this case caused by very intense rainfall, were defined as "flash floods" in this study (Kreibich et al. 2007). In the village of Weesenstein, on the banks of the Müglitz River, the water level rose by 1 m between 9:30 and 10:30 a.m. local time on 12th of August 2002, and continued to rise at a rate of 0.5 mh-1 until the telemetry transmissions failed at 3:45 p.m. (*Ulbrich et al.* 2003). This situation was caused by intense rainfall, e.g. 312 mm of rain within 24 hours were measured on the 12th of August at the Zinnwald-Georgenfeld station, which is located at the headwaters. This is the highest amount of daily precipitation ever measured in Germany.

Severity/Return period: The flood was an extreme event with discharge return periods of 150-200 years at the Dresden gauge, in the Elbe River, and 200-300 years at the Erlln gauge, in the Mulde River (*IKSE* 2004).

Reported damage: The total flood damage in Germany is estimated to have been 11.6 billion €, with an estimated 8.6 billion € of damage in Saxony, the most affected federal state (*BMI* 2002; *SSK* 2003). About 13,000 companies were affected in Saxony, causing direct damages of 1.9 billion € (*SSK* 2004), and incalculable losses due to business interruptions and limitations.

Measures taken:

Country-regional level - After the 2002 flood, many initiatives were introduced to improve the flood warning system. For instance, the German Weather Service (DWD) has been further developing and improving its numerical weather forecast models and its warning management. The federal states have started to design the flood warning gauges in a flood-proof manner, and to equip them with back-up data collection, transmission and power supply systems. The flood routing model "ELBA" has been updated with new stage-discharge relationships and new model components. In addition, a new flood forecast model, "WAVOS", has been developed for the Elbe River in Germany and the schedule of releasing warnings has been upgraded. In Saxony, the four existing regional flood centres have been integrated into one state flood centre (Landeshochwasserzentrum LHWZ, www.hochwasserzentrum.sachsen.de) and the water levels measured at the gauges are automatically collected and transferred to that centre.

Private measures - The flood motivated a relatively large number of companies to undertake private precautionary measures. As was the case before the flood, building precautionary measures were most popular: 39% of the companies had undertaken building precautionary measures after the flood and an additional 6% were planning to undertake such measures within the next six months, at the time of the interview. The service sector had best improved its building precautionary measures, so that it is now on a comparatively high level together with the agricultural and manufacturing sectors. Also, quite a few companies in the financial sector undertook building precautionary measures, but this sector still remains the one with the lowest proportion of companies with building precautionary measures. 15% of the companies undertook behavioural precautionary measures after the 2002 flood, 12% were still planning to do so. However, behavioural precautionary measures remained quite unpopular, with 61% of the companies not intending to undertake such measures. The highest percentage of companies utilizing behavioural precautionary measures was in the manufacturing sector. The flood insurance coverage of companies improved after the 2002 flood, but 25% of the companies stated that their company was not insurable and 29% did not intend to take out insurance. The least popular measure was the relocation of the company (the flood endangered branch) to a flood safe area. Only 5% of the companies decided to do this after the 2002 flood and 3% were still planning on it. In the financial sector the companies were most mobile, with 10% of companies relocating after the 2002 flood and 8% planning to relocate. Generally, simply the knowledge of the potential flood danger had stimulated companies to invest in precautionary measures before the 2002 flood, but it is not as effective as flood experience by far, as demonstrated by the relatively high number of companies that undertook precautionary measures after the 2002 flood.

Further info/key sentences: In Germany, the traditional approach to flood protection was generally characterized by a safety mentality. Protection was aimed at design criteria (for instance, the 100-year flood), without a detailed analysis and debate about the complete spectrum of possible events, failure scenarios and protection objectives. This traditional safety mentality or promise of protection is slowly being replaced by a risk culture. Such a risk culture is based on a comprehensive analysis of the flood risk and an appraisal of potential risk-reducing measures.

Eventual feedback: In order to gain more knowledge about precautionary measures taken by companies and their abilities to cope with the adverse effects of floods, a survey was undertaken among companies in Saxony affected by the August 2002 flood. Specifically, the aim of this study is the identification of improvement potential in the flood management of companies. The companies were divided into sectors to reduce data variability within the subgroups and to identify differences between sectors. Hence, the sectors with the largest improvement potential will be identified and recommended for specific measures and programs.

Source:

BMI, 2002: Bundesregierung zieht vorläufige Schadensbilanz der Hochwasserkatastrophe: bisher finanzielle Hilfe im Umfang von über 700 Millionen Euro geleistet. **Press release (6 November 2002)**, www.bmi.bund.de/dokumente/Pressemitteilung/ix90912.htm

IKSE, 2004: Dokumentation des Hochwassers vom August 2002 im Einzugsgebiet der Elbe, IKSE, Magdeburg.

Kreibich, H., M. Müller, A. H. Thieken, B. Merz, 2007: Flood precaution of companies and their ability to cope with the flood in August 2002 in Saxony, Germany. **Water Resources Research**, 43, W03408.

SSK, 2003: Augusthochwasser 2002 – Der Wiederaufbau in Sachsen ein Jahr nach der Flut, Dresden.

SSK, 2004: Tillich: Die Sachsen haben den Wiederaufbau weitgehend bewältigt, Dresden.

Ulbrich, U., T. Brücher, A. H. Fink, G. C. Leckebusch, A. Krüger and J. G. Pinto, 2003: The central European floods of August 2002: Part 1 - Rainfall periods and flood development. ***Weather***, 58, 371-377.

UNESCO (2006): International Glossary of Hydrology, www.cig.ensmp.fr/~hubert/glu/aglo.htm

Country: Great Britain

Catchment/River basin: Whole country.

Date of the event: May to July 2008.

Details/Driving mechanism: Flash flooding from "tropical-style" downpours brought a level of destruction that caught everyone by surprise.

Severity/Return period: It was the wettest May to July period for 250 years.

Reported damage: Thousands of homes and businesses were flooded, 13 people were killed and around 7000 were rescued from the flood waters by the emergency services. The Association for British Insurers estimates the total cost of the June and July floods to be around £3B.

Measures taken: New flood risk maps with higher spatial resolution, made with LIDAR units and J Flow controls (2008). Features of the landscape such as small water courses, which would never have shown in the old maps because of their size, are now clearly visible thanks to these new modelling techniques.

Further info/key sentences: The purpose of sequential testing is to help steer new development to the lowest-flood-risk zone appropriate to the proposed use.

It has been agreed a small amount of land rising can take place providing there is no overall loss of storage to the flood plain.

Eventual feedback: The new maps are already having an impact on how flood zone areas are categorized. Because details such as watercourses are now clearly visible, this may well have the effect of pushing an area into a higher flood risk zone than had previously been the case, and this will have an immediate impact on developments.

Only a month since their introduction, the new flood maps are already having ramification for developers. And this serves to highlight why a real understanding of flood risk is so important in the planning stages of new developments.

Source:

Haven, J., 2008: Redrawing the landscape, ***Sustainable Business***, (144), pp. 47-48, 2008.

Country: Norway

Date: Across Norway, different types of landslides/debris flow often occur. Most Norwegian valleys, as well as the fjord landscape on the west and north coast, do have debris flow problems, but only occasionally they do any harm.

Details/Driving mechanism: Most often landslides are related to extreme, local precipitation, often combined with snow melt.

Measures taken: The NVE (Norwegian Water Resources and Energy directorate) is in charge of prevention of damage caused by landslide, avalanche and rock fall. This organism deals with mapping and information, protection and mitigation measures, land use planning, emergency preparedness, monitoring and early warning. Nowadays there is no warning system in Norway for landslides/debris flows. The hydrology department of NVE runs a 24 hour flood forecasting service for the entire country and it will be possibly in charge for an early warning system for flash floods and landslides in the future too.

A methodology to use forecasted precipitation and snowmelt in combination with data on groundwater and soil moisture to provide regional warnings for landslides is still under development.

In cooperation with the meteorological institute, NVE is developing a Web- and GIS-based system (www.seNorge.no) used to distribute information on water and snow conditions for all Norway with 1 km2 grid (i.e., precipitation, air temperature, evapotranspiration, snow-water equivalent, groundwater, soil water deficit, soil frost and stream flow). This data can be used for hazard mitigation for flood, drought, energy supply shortages, avalanches and landslides and climate change. In addition, a website is available where all the historical avalanches, debris slides, slushflows, and rock slides are registered: http://www.skrednett.no (this website is only in Norwegian).

Relevant websites:

http://www.met.no

http://www.ngi.no/en/

http://www.nve.no/en/

http://www.geohazards.no

http://www.senorge.no

http://www.ngu.no/en-gb/

http://www.skrednett.no

Mediterranean basins

Country: Spain

Catchment/River basin: La Seu d'Urgell.

Date of the event: 7th-8th November 1982.

Details/Driving mechanism: A long storm that lasted more than 40 hours hit the whole Segre River basin, generating in some points accumulations of 408 mm of rain. As the watershed area affecting the city of La Seu d'Urgell is quite extensive and most of the soil was already saturated, the discharge flow at this section was around 3.600 m^3/s.

Severity/Return period: More than 500 years.

Fatalities: 14 deaths were reported

Reported damage/ Economic losses: Estimated at 36 million €

Additional information: As a result of the flood event, the river shape changed significantly and both, the owners and the authorities, were worried about the possibility of a similar event happening again. Therefore, a reorganization of the property was done, so the river could be channelled all along the urban zone. The works started in 1983 and they had another objective apart from being used to prevent the floods in the region. The channel was used as an Olympic facility, which reported big economic profits to the region during the Olympic games of Barcelona in 1992.

Preventive measures after the event/lesson learnt: The channelling of the river has shown really good results, the riverbanks remain stable through time and the drainage capacity of the channel is approximately 1.250 m^3/s, associated to a return period of 500 years.

Effectiveness of measures: The Canadian engineer that designed and built the channel in the Segre River has recently declared that if nowadays a rainfall event like the one in 1982 occurred again, it is possible that some catastrophic consequences would happen again. He thinks that the lack of maintenance of the structure might entail their collapse in a extreme situation.

Source:

Ganyet R., 1999: La canalización y el parque olímpico del Segre en La Seu d'Urgell. ***Revista del colegio de ingenieros de caminos, canales y puertos***, No. 47, year 1999, RÍO Y CIUDAD, Volumen II.

Country: France

Catchment/River basin: Nimes

Date of the event: 3rd October 1988.

Details/Driving mechanism: During the night of the 3rd of October, there was a really heavy rainfall episode, with a total amount of 263 mm (measured in a urban meteorological station), and a maximum of 467 mm in another part of the basin. Because of this, and considering that main part of the basin is urbanized, a flash flood occurred at 7:45 am.

Severity/Return period: 100 years.

Fatalities: 9 deaths were reported.

Reported damage/Economic losses: The homes of 45.000 people were damaged, more than 1.100 vehicles were destroyed, many bridges and other infrastructures were damaged and the traffic lines were interrupted.

Additional information: The flash flood was very severe because of the rainfall characteristics and the basin morphology. However, the consequences could have been more dramatic (apart from the 9 deaths, there were only 3 injured persons), because when it happened, the 93% of the people living in the affected areas were still at home. Besides, there could have been more fatalities in the roads but, luckily, the traffic heading into the city was stopped by some access roads being flooded. The rescue operations were set up within the framework of the French disaster plan and the civil protection response was effective.

Preventive measures after the event/lesson learnt: In a survey done after the flood, only the 17% of the population living in the area affected was aware of the situation. More information must be given to the public so they can know which the risks are and how they should react in case of a flood event. The communication procedures should be also improved. Most of the damage and mild injuries were reported during the impact phase of the flash flood, which means that it is crucial to be able to accurately detect the moment of the hit.

Further info/key sentences: Because of the fast occurrence of the event, the first people that were able to help were the neighbours (40%), followed by the family members (20%). Later, the professional help arrived and conducted the proper rescue operations leaded by fire-fighters (12%), the Red Cross (10%) and military personnel (8%).

Source:

Duclos, P.J., O. Vidonne, P. Beuf, P. Perray and A. Stoebner, 1991: Flash flood disaster: Nimes, France. ***European Journal of Epidemiology***, Vol. 7, No. 4, p. 365 – 371.

Country: France

Catchment/River basin: The Var Catchment, Southern France (next to the city of Nice).

Date of the event: 5th November 1994.

Details/Driving mechanism: The average cumulated rainfall over the catchment between the 2nd and the 5th of November was about 200 mm. High rainfall intensities occurred on the 5th where the peak value of the discharges was estimated at 3.770 m^3/s at Napoleon III bridge, next to the catchment outlet. The Var catchment is characterized by a geological background of high heterogeneous thin soils that saturate quickly during rainfall events, producing high water runoff. The highly urbanised region has also altered the river morphology to meet human needs.

Severity/Return period: Considered as the most spectacular hydrological events recorded for the Var catchment. The return period remained inferior to 50 years for the river and most of its large tributaries.

Fatalities: No death reported

Reported damage/Economic losses: Estimated at 23 million €.

Additional information: The Nice local operation centre for flood crisis management located at the basement of the administrative building next to the river was the first area to be flooded. Therefore, communication, warning and in general, the activation of the emergency plan was not able to be carried out effectively. The international airport of Nice (which was located at the original outlet course of the river) was flooded and closed for one week. A number of national roads were destroyed, some bridges were washed away and numerous buildings were severely damaged.

Preventive measures after the event/lesson learnt: The following suggestions were made by the engineering community but yet to be implemented due to political (local authorities) and community (because they may affect their income and livelihood) objection:

⇒ Removal or lowering down of most dams in order to re-establish the sediment transport in the river (prevent sediment deposits build up within the dams, which with time increases the bed height of the river)

⇒ Relocation of the local flood operation centre to a more safer place

⇒ Relocation of some urbanizations out of the flooding area

Further info/key sentences: Currently, there has not been any flood mitigation measures implemented in response to this flood due to the reasons mentioned above.

Effectiveness of measures: No measures implemented.

Source:

Guinot, V. and P. Gourbesville, 2002: Modelling Flash Floods in Mediterranean areas: Should we attempt to calibrate physically-based models? ***5th International Conference on Hydro-Science & Engineering, Warsaw, Poland.***

Country: Spain

Catchment/River basin: Barcelona County

Date of the event: 21st September 1995.

Details/driving mechanism: The flood was caused by a sudden thunderstorm that was not forecasted by the meteorological model and that produced a high rainfall (145 mm in less than 45 minutes). It mostly affected the central coast of Catalonia. It was the typical summer / autumn storm that almost every year occurs in the North-eastern part of Spain, due to convective events characterized by extremely high intensities during a short period of time. Depending on orography, human settlements and other factors, these rainfall events can produce catastrophic impacts.

Severity/Return period: 50 years

Fatalities: One death was reported

Reported damage/Economic losses: Estimated at 65 million €

Additional information: As the main part of the rainfall fell in an urban region, the infiltration value was almost zero, and, therefore, this high rainfall turned a lot of streets into rivers. The lower parts of the city, where the littoral lagoons existed in the past, were flooded.

Preventive measures after the event/lesson learnt: In order to avoid this situation in the future, a new sewage plan was created, which involved the construction of underground tanks to collect rain water. The construction of the first one started in 1997 and nowadays there are 8 of them working together, covering the whole city of Barcelona. A new warning system was also created and some pumps were installed where needed.

Further info/key sentences: The retention tanks, do not only reduce the peak flow and avoid floods in the city, but also have an environmental advantage. They avoid combined system overflows that might be highly polluted and retain the storm water to later be carried to the WWTP.

Effectiveness of measures: In 2005, a similar rainfall event occurred without creating any consequences due to the effective work of the tanks. Since they were installed, no more urban floods took place in Barcelona and it will be difficult that they ever happen again, because of the huge water volume that the tanks can retain.

Source:

Barrera, A., M. Barriendos and M. C. Llasat, 2005: Extreme flash floods in Barcelona County, ***Advances in Geosciences***, 2, 111–116.

Country: Spain

Catchment/River basin: Biescas, Aragon Pyrenees

Date of the event: 7th August 1996.

Details/Driving mechanism: The typical convection summer storm, with some extremely high intensity periods, produced an accumulation of 250 mm of rainfall in 6 hours with a peak flow of 400-600 m^3/s. As the basin, belonging to the Pyrenees, had really steep slopes (average of 14%), the water speed was really high, which meant that wood, big stones and other kinds of debris were dragged by the flow. Because of that, several locks were destroyed, creating a really big debris flow episode that in few minutes was able to destroy a whole camping site located in the alluvial fan at the outlet of the catchment. The fact of having a saturated soil from previous rain episodes contributed to make the situation worse, because less water could be infiltrated.

Severity/Return period: 500 years

Fatalities: 87 deaths reported at the camping site

Reported damage/Economic losses: Approximately 50 million €. Of course the 87 deaths also contributed in a significant way; in 2005, the Ministry of Environment finally had to pay more than 11 million € as a compensation to the families.

Additional information: The camp site was located in a zone were the flood hazard was obvious, and there were already some studies elaborated by technicians in 1986, before the camp site was built. Still, the Ministry and the town hall allowed the owner to build it there. This is why in 2005 the judge concluded that it was not the owner's fault, but the Ministry, because it is its duty to not allow this kind of situations.

Preventive measures after the event/lesson learnt: The catastrophe of 1996 is still present in everyone's minds in that region. This is why since then, every time that an important rainfall episode occurs, the civil protection units and the police evacuate the camp sites and other potential affected zones.

Further info/key sentences: The problem is that there is still not a specific plan, containing hazard maps to avoid building in the most dangerous zones and coordinating the warning and evacuation actions during flood events in this area.

Source:

White, S., J. García-Ruiz , C. Martí, B. Valero, M. Errea and A. Gómez-Villar, 2004: The 1996 Biescas campsite disaster in the Central Spanish Pyrenees, and its temporal and spatial context. ***Universidad de Zaragoza e Institución Fernando el Católico.***

Country: Slovenia

Catchment/River basin: The whole country

Date of the event: 4th-6th November 1998.

Details/Driving mechanism: The whole country was under a process of gradual and continuous saturation of the ground, keeping the groundwater levels high. On the 3rd of November a strong precipitation began, and it spread out to all the country. The most affected area was the western mountains one that was exposed to a total rainfall of 200 to 300 mm. After that, many rivers were overflooded, especially in the western part of the country. As the rainfall episode continued until the 5th, it was not until the 6th that the water levels started to decrease gradually. All together, 703 landslides were triggered, which were mainly debris flow events in the western mountains.

Severity/Return period: 100 years

Fatalities: two deaths were reported

Reported damage/Economic losses: Estimated at 145 million €

Additional information: It was considered the worst natural disaster in Slovenia in 1998. It was an event that impacted the whole country and apart from the two deaths, there were lots of houses destroyed, bridges demolished, traffic lines interrupted and the entire country was paralysed for a few days.

Preventive measures after the event/ lesson learnt: Although the professional opinion of water resource experts and urban planners is clear, usually it is not taken into account by the municipal authorities. If it were, the prevention measures would be more effective and, for example, houses would not be destroyed. In addition, mitigation measures should be executed after a flood event because, otherwise, the same sort of damage could be produced again after a similar event. The response actions carried out by the civil protection units and in some case by the armed forces, even if effective, were in some cases not enough due to the lack of human or technical resources.

Effectiveness of measures: All these measures need to be improved and coordinated. An integral water law should be implemented, taking into account land use, prevention, protection and mitigation actions to be executed before, during and after a flood event.

Source:

Colombo, A., I. Prezelj and A. Vetere Arellano, 2002: Nedies project : lessons learnt from flood disasters. ***Ispra: European commission: joint research centre***.

Eastern Europe basins

Country: Czech Republic

Date: July 2007.

Details/Driving mechanism: In July 1997, the best-documented historical landslide event occurred, along with severe flooding. The Outer Western Carpathians mountain chain in the Czech Republic typically receives 900-1000 mm of precipitation per year. Heavy precipitation (257 mm in 5 days; in some stations the July precipitation was over 70% of the annual mean) caused more than 1500 landslides of different types (Klimeš et al., 2009).

Reported damage: In 1997, most slope movements occurred in the District of Vsetin (1143 km^2). The landslides damaged houses (villages Mikulůvka and Růžd'ka), roads, railways, forests, and a water reservoir. The total damage was estimated to be about 40 million USD (Krejči et al., 2002).

Measures taken: See event of April 2006 (see page 91).

References: See event of April 2006 (see page 91).

Country: Slovakia

Catchment/River basin: Malá Svinka and Dubovický Creek

Date of the event: 28th July 1998.

Details/Driving mechanism: On July 28th 1998, there was a very unstable air mass due to high air humidity, high temperature of the lowest layer of the atmosphere. This, added to the orographic characteristics, culminated into an important thunder activity. A torrential precipitation occurred in two isolated areas, which led to several flash floods. The most catastrophic ones were located in two tributaries of Svinka River: Malá Svinka and Dubovický Creek. The thunderstorms, associated to the most damaging flash floods, lasted approximately 1,5 to 2 hours. On both creeks, the flood waves were produced at the same time because the lengths and areas of both watersheds are very similar. In the confluence of both tributaries with the main stream the maximum peak flows were combined creating a very destructive discharge wave.

Severity/Return period: In this region the total 24-hour precipitation for a 100 years return period is approximately 80 – 90 mm. On the 28th of July, the precipitation values reached approximately 100 - 130 mm during 150 min.

Fatalities: 47 deaths were reported

Reported damage/Economic losses: Estimated at 25 million €

Additional information: In addition to the hard rain event, several other negative factors occurred simultaneously. The soil saturation level of the catchments was already at its maximum due to previous precipitation. The high slopes, especially in the upper parts of the catchments, enhanced the effect of the discharge wave, adding it more energy. In the upper parts of Malá Svinka catchment there were evident effects of an intense debris flow. This created a series of consecutive waves and caused debris to be blocked behind the existing artificial barriers, like bridges that crossed the streams. By the later destruction of these barriers, very energetic waves were produced, exacerbating the destructive consequences of the flood.

Preventive measures after the event/ lesson learnt: The great impact that caused this flash flood event made the Slovak Government implement, in 2000, a strategy document called the Programme of Flood Protection until 2010. It consists of the following parts:

⇒ Implementation of a group of long-term, mid-term and short-term, both structural and non-structural measures

⇒ Promotion of research and development projects related to flood protection

⇒ Upgrading and modernisation of the flood warning and forecasting system

Source:

Majerčáková O., M. Makeľ, P. Šťastný, M. Kupčo and P. Rončák, 2004: Report of Selected Flash Floods in the Slovak Republic. ***Global Water Partnership – Slovakia, Bratislava.***

Country: Romania

Catchment/River basin: Crisul Alb river

Date of the event: 6th-11th April 2000

Details/Driving mechanism: The forestation degree in the basin is only 30%. In addition, along the river there are a lot of towns which are often flooded. Year 2000 could be divided into two different periods, each one characterized by different hydrometeorological phenomena. During the first four months of the year, the soil was continuously saturated because of the snowmelt due to positive temperatures. The second period was characterized by heavy rainfalls and this is when the most important and destructive flood event happened. The torrential rain that fell from the 3rd to the 6th of April aggravated by the pre-existent conditions of the basin was the one that caused the worst impacts.

Severity/Return period: In this case, it is more appropriate to talk about the magnitude of the peak discharge more than the rainfall values themselves, due to the great influence of the previous basin conditions. The basin was already saturated and with important flow levels. The maximum discharge recorded by the hydrometric network in the Crisul Alb was 586 m^3/s. Meaning that the return period was clearly higher than 100 years.

Fatalities: 3 deaths were reported

Reported damage/Economic losses: The flood affected 336 houses, arable land, several roads, bridges and many other assets. The total estimated value of the damages was 5.5 million €.

Additional information: The solid runoff was very important and its maximum value was produced before the maximum flood discharge, increasing the destructive effects of this event.

Preventive measures after the event/ lesson learnt: In order to reduce the impacts of floods, the Ministry of Environment decided to implement an action plan on flood protection by improving the flood forecasting system. Some more measures were decided: the maintenance of the river beds in the cross sections close to bridges and drainage ditches was planned. Towns were asked to be responsible for warning the population and elaborate plans with regulations to avoid building houses within the flood-prone areas. The Ministry will be responsible for providing the local authorities with defence and operative means for intervention to cope with floods.

Source:

National Institute of Hydrology and Water Management, Bucharest, 2005: Study of historical floods in central and Eastern Europe from an integrated flood management viewpoint – Romania. ***WMO/GWP Associated Programme on Flood Management.***

Country: Czech Republic

Date: about 80 events at the end of March/ beginning of April 2006.

Details/Driving mechanism: High cumulative precipitation in March (67% higher than the average) and the beginning of April caused the soil to be saturated. In addition, the very thick and long-lasting snow cover, caused by abnormally cold winter 2005/2006, melted abruptly after sudden warming during the first days of April.

Reported damage: The 2006 landslides occurred at Hluboce, in the Bíle Karpaty Highlands near the town of Brumov-Bylnice, 3.5 km west of the border with Slovakia. Although it did not develop over a densely inhabited area, it completely destroyed three buildings and damaged an electric powerline, unpaved roads and part of the forest. Total damage was estimated at 350.000 € (Klimeš et al. 2009).

Measures taken: As a response to the events in 1997 (Krejči et al. 2002), the Czech Ministry of Environment launched the project "Slope deformations in the Czech Republic" to provide a detailed landslide inventory of the most hazardous areas and landslide susceptibility maps. The latter maps were created using GIS-software to classify the land into "stable", "conditionally stable" and "unstable" areas (Klimeš 2008).

Part of this project was to disseminate information to a broad public by making available a large set of data on the internet, through the "Portal of Geohazards" (Tomas and Moravcova 2008). The data is available through http://www.geology.cz/geohazardy (only in Czech). After selecting a certain area, the user obtains a report containing a map and information about six categories of geohazards, being some of them ground instability, sensitivity to landslides and rock falls.

References:

Klimeš, J., 2008: Analysis of preparatory factors of landslides, Vsetínské Vrchy highland, Czech Republic. ***Acta Research Reports***, 17, 47-53

Klimeš, J., I. Baroň, T. Pánek, T. Kosačik, J. Burda, F. Kresta, and J. Hradecký, 2009: Investigation of recent catastrophic landslides in the flysch belt of Outer Western Carpathians (Czech Republic): progress towards better hazard assessment. ***Natural Hazards and Earth System Sciences***, 9, 119-128, http://www.nat-hazards-earth-syst-sci.net/9/119/2009/.

Krejči, O., I. Baroň, M. Bíl, F. Hubatka, Z. Jurová, and K. Kirchner, 2002: Slope movements in the Flysch Carpathians of Eastern Czech Republic triggered by extreme rainfalls in 1997: a case study. ***Physics and Chemistry of the Earth***, 27, 1567-1576.

Tomas, R. and O. Moravcova, 2008: Portal of geohazards in the Czech Republic – information services for disaster prevention. http://www.geology.cz/geohazardy