EEA Technical report | No 13/2010

Mapping the impacts of natural hazards and technological accidents in Europe

An overview of the last decade

ISSN 1725-2237

European Environment Agency

Cover design: EEA
Layout: Rosendahl-Schultz Grafisk/EEA

Luxembourg: Publications Office of the European Union, 2010

ISBN 978-92-9213-168-5
ISSN 1725-2237
doi:10.2800/62638

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Acknowledgements

This report was coordinated by André Wehrli under the support of Josef Herkendell and André Jol. Assistance and feedback from EEA colleagues was appreciated (Robert Collins, Trine Christiansen, Hans-Martin Füssel, Eva Goossens, Hans Vos, Carlos Romao and Gerald Vollmer).

Main sources of information and data were from the EM-DAT database maintained by the Centre for Research on the Epidemiology of Disasters CRED, from the NatCatSERVICE maintained by MunichRE, DG JRC (IES and IPSC) and the European Maritime Safety Agency EMSA.

The EEA is grateful for the comments received from the following persons during the consultation processes:

Experts

Anders Solheim (NGI, Norway), Henny A.J. van Lanen (Wageningen University, the Netherlands), Laurens Bouwer (VU Amsterdam, the Netherlands), Petra Löw (MunichRe), Philipp Schmidt-Thomé (GTK, Finland), Regina Below (CRED, Catholic University of Louvain, Belgium), Thomas Voigt (ETC ACC/UBA, Germany).

Countries

Finland (Tapani Säynätkari, NFP Eionet), Poland (Lucyna Dygas Ciolkowska, NFP Eionet; Institute of Meteorology and Water Management; Institute of Environmental Protection), Slovak Republic (Slávka Štroffeková, NFP Eionet), Switzerland (Federal Office for the Environment: Arthur Sandri; Bernard Gay; Blaise Duvernay; Carolin Schaerpf; Gian Reto Bezzola; Hugo Raetzo; Luuk Dorren; Michael Reinhard; Roberto Loat).

European Commission

Marina Koussathana (DG Sanco), Peter Part (DG JRC), Javier Hervas (DG JRC/IES), Elisabeth Krausmann, Michalis Christou and Gerald Vollmer (DG JRC/IPSC).

UNISDR

Demetrio Innocenti, Paola Albrito, Michiko Hama, Rosa Abruzzese.

English editing

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Executive summary

Introduction

Europe is experiencing an increasing number and impact of disasters due to natural hazards and technological accidents caused by a combination of changes in its physical, technological and human/social systems. This report discusses the occurrence and impacts of disasters and the underlying hazards in Europe for the period 1998–2009. It is an update on and extension of the 2004 EEA report 'Mapping the impacts of recent natural disasters and technological accidents in Europe' (EEA, 2004) that covered the period 1998–2002. The information and data used in this report are, to a large extent, derived from global or European databases or sources (natural hazards: EM-DAT maintained by CRED (EM-DAT, 2010) and NatCatSERVICE maintained by Munich Re (NatCatSERVICE, 2010), the European Forest Fires Information System EFFIS (2010); technological hazards: European Maritime Safety Agency EMSA (2010) and the Major Accident Reporting System MARS (2010)). However, to provide a more comprehensive overview, additional national sources of information were used where available.

The potential for a hazard to cause a disaster mainly depends on how vulnerable an exposed community is to such hazards. Actions and measures, if well implemented, can reduce the human health and economic impact of a hazardous event. However, they can also (unintentionally) increase the exposure to risks and exacerbate the impacts of a hazardous event to the point of becoming a disaster. At the same time there are no internationally agreed minimum criteria for an event to be classified as a disaster. Furthermore, even events which do not reach a certain 'disaster-threshold' and, thus, do not appear in global disaster databases may account for a considerable proportion of losses (e.g. if there are many of these events, as is for example the case with landslides). This report includes events 'below international thresholds' for which other (national) data are available, without aiming to provide a comprehensive definition of a disaster.

There is some evidence that climate change is contributing to increasing the frequency and intensity of weather related natural hazards. It is projected that these effects of climate change could intensify in the future. However, an assessment of how climate change affects the intensity and frequency of disasters in Europe is considered beyond the scope of this report and is therefore not included.

Impacts of natural hazards and technological accidents in Europe in 1998–2009

Between 1998 and 2009, natural hazards and technological accidents caused nearly 100 000 fatalities and affected more than 11 million people. Events with the highest human losses were the heat wave of 2003 over western and southern Europe, with more than 70 000 fatalities, and the Izmit (Turkey) earthquake of 1999, with more than 17 000 fatalities. The largest disasters due to natural hazards caused, overall, a loss of about EUR 150 billion in the 32 EEA member countries ([1]), and if some other smaller hazardous events were included this amount would increase to an overall impact of about EUR 200 billion. Among the events resulting in the largest overall losses were the floods in Central Europe (2002, over EUR 20 billion), in Italy, France and the Swiss Alps (2000, about EUR 12 billion) and in the United Kingdom (2007, over EUR 4 billion); the earthquakes in Izmit (Turkey, 1999, over EUR 11 billion) and L'Aquila (Italy, 2009, more than EUR 2 billion) as well as winter storms over Central Europe in December 1999 (more than EUR 18 billion) and January 2007 (almost EUR 8 billion).

It was technological hazards, however, that produced particularly large impacts on ecosystems.

([1]) The thirty-two EEA member countries comprise the EU-27, Iceland, Liechtenstein, Norway, Switzerland and Turkey.

Table ES1 Overview of the major events in Europe 1998–2009

Hazard type	Recorded events	Number of fatalities	Overall losses (EUR billion)
Storm	155	729	44.338
Extreme temperature events	101	77 551	9.962
Forest fires	35	191	6.917
Drought	8	0	4.940
Flood	213	1 126	52.173
Snow avalanche	8	130	0.742
Landslide	9	212	0.551
Earthquake	46	18 864	29.205
Volcano	1	0	0.004
Oil spills	9	n/a	No comprehensive data available (a)
Industrial accidents	339	169	No comprehensive data available (b)
Toxic spills	4	n/a	No comprehensive data available (c)
Total	**928**	**98 972**	**148.831**

Note: (a) Estimation is between EUR 500 and EUR 500 000 per tonne of oil spilled.
(b) Costs for major events reported in Table 12.1 aggregately amount to more than EUR 3.7 billion.
(c) Costs for one particular toxic spill amount to EUR 377 million, see Chapter 13.

Source: EM-DAT, 2010; EMSA, 2010; MARS, 2010.

Accidents such as the oil spills of tankers Erika (1999) and Prestige (2002), and the toxic waste spills in Aznacollar, Spain (1999) and Baia Mare, Romania (2000) greatly altered the fluvial and coastal ecosystems and resulted in high costs of remediation (e.g. about EUR 377 million in the case of Aznacollar). During the period 2003–2009, the number of oil and toxic spills as well as their adverse effects across Europe decreased significantly, partly because of stricter legislation and controls.

Storms

Between 1998 and 2009, the costliest natural hazard in Europe in terms of insured losses were storms. As regards fatalities, storms rank fourth after heat waves, earthquakes and floods, with 729 fatalities in the period under review. The most significant events were the storms *Lothar* and *Martin* in late December 1999 and *Kyrill* in January 2007. The former two storms affected about 3.5 million people in France, Switzerland, Germany, Denmark, Sweden, Poland, Lithuania, Austria and Spain, caused 151 fatalities and insured losses of EUR 8.4 billion (overall losses amounted to EUR 15.5 billion). The latter caused 46 fatalities and insured losses of around EUR 4.5 billion (EUR 7.7 billion of overall losses) in Germany, Austria, the Czech Republic, the United Kingdom, France, Belgium, Poland, the Netherlands, Denmark, Switzerland and Slovenia.

Ever since the late 1950s, storms have shown strong variability that makes it difficult to discern long-term trends. However, the scope of storm-related losses in recent years has been on the rise. This increase is mainly driven by increases in population and assets with increasing economic value in exposed areas.

The quality of information on storm impacts has improved in recent years. However, it is possible to improve both information and analysis even further, particularly concerning local public infrastructure, economic losses suffered by the forestry sector and monetisation of forest ecosystem services affected by storms.

So far, there is no specific policy at the EU level that would aim to reduce the impacts of storms but certain actions might be implemented in the context of adaptation to climate change. Future efforts to manage storm risk should place a particular focus on preventive measures, improvement of early warning systems and raising public awareness.

Extreme temperature events

During the period analysed in this report, heat waves were the most prominent hazard causing human fatalities. In total, more than 70 000 excess deaths were reported in Europe during the hot summer of 2003. Heat waves in the summers of 2006 and 2007, combined, brought about an increase in excess deaths of about 3 000. Cold spells that occurred in Europe in the period from 1998 to 2009 claimed the lives of almost 1 900 people.

Extreme temperatures are integral part of normal interannual temperature variability, but frequency and intensity of such occurrences have increased.

High-temperature extremes have become more frequent, while low-temperature extremes have become less. Climate change is projected to continue pushing up the frequency and intensity of heat waves, which could lead to significant consequences for human health, as mortality has been estimated to increase by 1–4 % for every 1 °C of temperature exceeding a location-specific temperature threshold.

There is a need for several types of information related to extreme temperature events. For instance, more precise forecasts of effects on human health are needed. Uncertainties in linking such forecasts to age distribution, the incidence rate and population data should be reduced. Coherent scenarios that would incorporate projections of climate change combined with socio-economic factors relevant for human health are needed. Additionally, it is necessary to facilitate the exchange of data and the sharing of good practices in management related to extreme temperature events (e.g. heat-health action plans).

Following the events of 2003, the health sector has initiated several actions (such as Heat Action Plans). Management options to reduce the direct impact of such extreme temperature events should focus on preparedness. However, equally important are early warning and the ability to intervene immediately before and during the event, since fatalities caused by such events are thought to be largely preventable. In the long term, it is crucial to reduce the vulnerability of the population and the relevant infrastructure.

The most recent policy actions include the 2009 European Commission staff working document on climate change and human health (EC, 2009a) and a new European regional framework for action, entitled 'Protecting health in an environment challenged by climate change', which was agreed at the Fifth Ministerial Conference on Environment and Health in 2010 (WHO, 2010).

Forest fires
An average of 70 000 fires take place every year in Europe. They destroy more than half a million hectares of the forested areas in Europe, mainly in the Mediterranean region (it accounts for 70 % of fires and is responsible for 85 % of the total burnt area in Europe). Large fires that raged for several days occurred in Portugal (2003, 2005), Spain (2006) and Greece (2007), the latter causing 80 fatalities. In total and according to EFFIS (2010), during the period under consideration, forest fires were the cause of 307 deaths. The estimate for the European death toll in the EM-DAT data is somewhat lower (e.g. 191 fatalities recorded in EM-DAT for the period 1998–2009), which is mainly due to the threshold levels used in EM-DAT. The damage to the economy is estimated at EUR 1.5 billion a year. Forest fires are also responsible for significant adverse effects on natural areas and ecosystems, which, in turn, may lead to increased land degradation or desertification.

It does not seem possible to detect, during the period analysed in the report, any clear trends regarding the areas burnt by forest fires. However, fires did become more intense and their impacts more pronounced for several reasons. The impacts produced by fires largely vary from year to year, while most of the damage is normally caused by a few large events (e.g. in 2003 or 2007).

Following the establishment of EFFIS in 1998, large amounts of information on forest fires are now available but it is still possible to improve data even further, especially regarding the socio-economic and ecological impact of forest fires.

Specific forest fire policies exist in most EU member states but they have not yet been harmonised at the European level. Nevertheless, in 1992 forest fire prevention policies at EU level were created. Fire prevention is a very important component of integrated fire risk management and since most fires in Europe are caused by humans, it is imperative to strengthen policies that encompass education and training. Forest fire prevention is also addressed in the EC Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change (EC, 2010).

Water scarcity and droughts (WSD) (2)
Large areas of Europe are affected by WSD, and pressures on European water resources have increased. WSD is not an exclusive characteristic of drier areas, and in recent years, several regions in Europe have been affected by severe large-scale WSD events. For instance, the 2003 drought, one of the most prominent events in the period analysed in the report, affected the area extending from Portugal and Spain to the Czech Republic, Romania and Bulgaria.

WSD events often affect a large number of people, but in Europe no fatalities can be attributed directly to WSD. However, WSD has severe consequences for most sectors, particularly agriculture,

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(2) As the impacts of water scarcity and drought are highly interlinked and hard to differentiate, the term used in the rest of the report has been Water scarcity and drought (abbreviated WSD).

tourism, energy, and for drinking and industrial water providers. For instance, the exceptional drought in 2003 was estimated to have cost EUR 8.7 billion. WSD can have detrimental impacts on freshwater and related ecosystems. Dry periods frequently result in reduced river flows, lower lake and groundwater levels, and the drying of wetlands. Over-abstraction can also worsen the dry conditions. WSD also affects the quality of water because there is less water to dilute discharges of pollutants, and the over-abstraction of aquifers in coastal areas often results in the intrusions of salt water. It also affects the quality and the use of groundwater. A heavy aquifer drawdown may be also the cause of ground subsidence.

In recent years, there have been growing concerns regarding WSD events. Increasingly countries experience seasonal or longer-term drought and water scarcity. This is not limited anymore only to southern Europe. In many locations across Europe, the demand for water in dry periods often exceeds availability, and the need to ensure adequate water supplies to vulnerable ecosystems is often neglected. Climate change is projected to exacerbate these adverse impacts, with more frequent and severe droughts foreseen for many parts of Europe.

Currently, the European information base on WSD is characterised by many data gaps and uncertainties. There is no systematic and comprehensive record of WSD events in Europe (duration, impact or severity), with the exception of long time series on precipitation and precipitation anomalies. Additionally, there is a lack of long time series of updated, pan-European river flow data. Such information would help to discern between drought and water scarcity and better understand global change. There are also many gaps in information on water abstraction and water use. Thus our knowledge of water availability, water abstraction and water use is poor, while our knowledge of impacts due to WSD (e.g. cost of events) is even less. Information on use of water is largely incomplete – particularly as regards agriculture, the largest user. Also, for some countries information is either lacking altogether or is more than 10 years old.

Nevertheless, several activities have started that already help with improving the knowledge base (e.g. by monitoring) and managing WSD. The European Commission adopted in 2007 a communication on WSD (EC, 2007a). It specifies the measures needed if Europe is to move towards a water-efficient and water-saving economy. Drought management plans are seen as a key element in the future water resource policy and strategies.

Floods

Flooding is, along with storms, the most important natural hazard in Europe in terms of economic losses. The floods that caused the largest economic losses occurred in the Elbe Basin in 2002 (over EUR 20 billion), in Italy, France and the Swiss Alps in 2000 (around EUR 12 billion), and a series of those in the United Kingdom during the summer of 2007 (accumulated losses exceeded EUR 4 billion). The events causing the highest number of fatalities were the floods in Romania in 2005 (85 fatalities) and the 1998 disaster in Slovakia (54 fatalities).

The floods that took place in Europe over the recent decades have shown an increase in economic losses. This is the result of increased populations and wealth in the affected areas. Additionally, improvements in data collection in the recent decades has probably also contributed to an increase as over time more disasters and losses are recorded.

There appears to be no evident trend in the number of fatalities, partly because the number of deaths is very much dependent on the specific nature of each event. Furthermore, in the past few years early warning systems and prevention measures have led to improvements in evacuation procedures applied in the areas exposed to floods.

Much information on flood events is now available through global disaster databases, although these do not cover events below certain thresholds and also are not complete for all European countries. Thus, it would be desirable to develop a comprehensive database of past flood events and their impacts in Europe.

In recent decades, the concept of flood risk management has shifted from defence against floods to a more integrated approach. The full implementation of such integrated flood risk management will, however, take some time.

Specific flood prevention policies exist in many European countries, and the Floods Directive adopted by the European Commission in 2007 (EC, 2007b) is a good example of such concerted action at the EU level. The directive aims at reducing the risks and adverse consequences of floods and will be implemented in the Member States in three stages, starting with a preliminary flood risk assessment (due in 2011), followed by the development of flood hazard and risk maps for flood-prone zones (2013), and flood risk management plans (2015). Moreover, the Commission intends to reinforce the links with existing early warning systems, such as the European Flood Alert System launched by the Joint Research Centre.

Avalanches

The last time a catastrophic series of avalanches hit Europe was in the winter of 1998/99, when snowfall in the Alpine region, the heaviest in 50 years, triggered numerous fatal events. The worst affected were Austria, France, Switzerland, Italy and Germany where the death toll reached more than 60 fatalities in secured areas, i.e. on traffic routes or residential areas. The economic losses were huge. Since then, only one large accident in a secured area occurred (Lyngen, Norway, 2000, road, four fatalities). In contrast to that, avalanches cause many fatalities each year in 'non-secured areas'; most of them in connection with snow sports. Major events in recent years include an accident that occurred during military training at the Jungfrau (Switzerland, 2007) and caused six fatalities, and two events related to outdoor sport activities at Mont Blanc (France, 2008, eight fatalities) and Mount Zigana (Turkey, 2009, 10 fatalities), respectively. The average number of fatalities due to avalanche activity during the past decade has been stable and climate change is projected, in the short term, only to affect it at lower altitudes.

Systematic data sources outside the Alpine countries are still incomplete, and the quality of the information, covering both human health effects and economic losses due to snow avalanches, varies throughout Europe. Global disaster databases like EM-DAT give only a limited estimate of the overall impact of avalanches, since many smaller events are not recorded. This is illustrated by a much lower total of fatalities recorded in EM-DAT for the period 1998–2009 (130) as compared to the information provided by the International Committee for Alpine Rescue (ICAR, 2010): 1 500 for the same period. Therefore, it would be desirable to create a common European data base of events that would also include information below the EM-DAT threshold.

During the recent decades many areas have been putting in place an integrated system of avalanche risk management. Nevertheless, the risk of avalanches in secured areas, such as public roads, persists. Despite the intense efforts of the avalanche safety services, each winter some avalanches do reach public roads that had not been closed. There is a growing debate on the need to increase personal responsibility for avoiding snow sport accidents, although so far no generally accepted approach has been implemented. At the moment, there is no common 'avalanche policy' at the EU level but it could be advantageous to formulate at least its fundamental elements, e.g. to define the avalanche safety services in the new Member States.

Landslides

For the period under review, various databases in Europe have records of almost 70 major landslides that claimed a total of 312 lives and damaged or destroyed an extensive amount of infrastructure, including roads and houses. Due to the thresholds used, the global EM-DAT database gives a limited estimate of the overall impact of landslides.

The largest events in terms of fatalities and destruction caused were the debris flows in Sarno (Italy, 1998) — sweeping away hundreds of buildings and claiming 160 lives —, and the mudslides in Messina (Italy, 2009), killing 31 people. Regarding economic losses and impact on ecosystems, the lack of information made no comprehensive overview possible. There seems to be no obvious pattern in terms of impact produced by landslides, and the effects of climate change on frequency and intensity of landslides are not clear either. It is, however, evident that the potential damage caused by landslides is often aggravated as a result of land use management that involves uncontrolled urbanization.

At present there is no comprehensive overview that would describe how landslides occur and how they affect Europe. Such an overview could be desirable, because it could help further improve landslide safety standards at the European level by providing essential background information for integrated risk management. However, there is a lot discrepancy between national landslide inventories as the resolution and level of detail of included information vary greatly. In addition, they are seldom accessible to the general public.

There has been a shift from a defensive mitigation approach to integrated risk management (IRM) which is thought to have reduced the impact of landslides successfully. As landslides are generally local phenomena, it is particularly important to gather knowledge on the hazard and the related risks at a local level, fully involving local stakeholders in the process. The focus should be on preventive measures, including land-use planning and technical or biological countermeasures (e.g. protection forests or green engineering).

To date, there is no specific policy implemented at the EU level that would aim at reducing the impact of landslides, and existing national policies are not harmonized. Nevertheless, some EU policies and activities, including the Soil Thematic Strategy and the proposed Soil Framework Directive (EC, 2006a), have an objective of protecting soils across the EU.

Earthquakes and volcanoes
According to EM-DAT, for the period 1998–2009, earthquakes in Europe rank second in terms of fatalities and third in terms of overall losses. The event that caused the largest number of fatalities took place in Izmit (Turkey) in August 1999, with more than 17 000 people killed and overall losses exceeding EUR 11 billion. Other significant events include the Düzce earthquake (Turkey) in the same year, resulting in about 845 fatalities, and the earthquake in L'Aquila (Italy, 2009), with 302 fatalities and the overall losses of at least EUR 2 billion. In contrast to the period 1998–2002, there were no events with a magnitude of more than 6.4 on the Richter scale recorded during the period 2003 and 2009.

As regards volcanoes, no highly-explosive eruptions occurred in Europe during the period 1998–2009, and the eruptions that did occur caused only limited impacts. However, a very prominent event took place in 2010, i.e. after the period covered by this report, when the eruption of the Eyjafjallajökull volcano in Iceland generated a large ash cloud, thus causing enormous problems for air traffic, especially in western and northern Europe. The most critical period lasted from 15 until 20 April 2010, when the effects caused by the closure of the most of the central-northern Europe airspace were even felt at a global level.

Even if the information base on earthquakes, volcanoes and their impacts is rather sound and well reflected in the global disaster databases, it still could benefit from some improvements. These could include a standardized and systematic approach to evaluation of the overall costs of earthquakes. It is also necessary to improve our knowledge of the impacts of earthquakes on the natural environment and ecosystems. As for volcanic eruptions, the most critical issue is the lack of any assessment of their indirect effects. After the 2010 event, with its huge impacts on air traffic in Europe, it has become possible to identify existing needs more specifically. These include a better understanding of critical dust concentration levels for air traffic (so as to define a critical dust concentration threshold better) as well as better monitoring of actual levels of volcanic dust concentration at airline flying heights. Such information will help to calibrate mitigation measures at the supranational level better.

As of now, there is no specific EU earthquake policy, since specific mitigation measures aimed at reducing seismic risks are generally undertaken at the national level. This is due to the fact that levels of seismic hazard faced by each country vary vastly. However, common design criteria and methods for anti-seismic civil engineering works are available at the EU level from Eurocode 8 — Design of structures for earthquake resistance (Eurocode 8, 2004).

As for volcanoes, the most useful measures to limit direct impacts of volcanic eruptions are understood to be land use planning and effective preparedness (emergency plans). While such measures are commonly taken at a national level, it is necessary to implement measures against indirect impacts of volcanic eruptions (e.g. on air traffic, human health, global temperature) at a supranational level.

Oil spills
In 1998–2009, there occurred nine major oil spills (more than 700 tonnes) originating by ships in European coastal areas and one major oil spill caused by an oil pipeline. The most important events were the oil spills from the tankers Erika (1999; Atlantic coast of France) and Prestige (2002; Atlantic coast of Spain). Those caused 20 000 tonnes and 63 000 tonnes of oil spilled, respectively. After these events, there have been no other extreme spills.

Economic costs of oil spills are very difficult to assess, and the cost per tonne of oil spilled ranges between EUR 500 and 500 000 (applicable only to offshore events). The two major events mentioned above caused some of the worst ecological disasters in European waters. In recent years, however, the ecological impacts of marine oil spills were rather minor, mostly as a result of favourable weather conditions.

Generally, the records reveal that number of accidents tends to go down, and the number of incidents where oil spills into the marine environment, as well as the impacts they produce, is expected to decrease even further. This is mainly due to the implementation of legislative measures (e.g. regulation requiring that about 90 % of the tanker fleet should be either equipped with features ensuring full protection or removed from service by 2010). Nevertheless, transportation of crude oil or oil products by ship, in particular, still poses an enormous potential hazard.

The activities of EMSA have been instrumental in improving the data and reporting on maritime accidents. However, access to data for specific cases depends very much on the willingness of individual companies and authorities. Pipelines are not yet subject to European legislation on accidents (with the exception of pipe networks within an establishment) and, therefore, there are no mandatory reporting obligations.

The decrease in the number of spill incidents over the past few years might be seen as a consequence of the relevant EU legislation. It imposes obligations that include a requirement to build tankers as double-hull vessels and implement the common system for vessel traffic monitoring (Directive 2002/59/CE on Maritime Safety (EC, 2002a) and the 'Third Maritime Safety Package' (EC, 2009b)). As regards pipeline safety, European operators must implement measures to ensure efficient protection. However, the regulatory framework for pipelines is less developed. With the aim to reduce spillage, there seem to be some possible improvements, notably undertaking a comprehensive and integrated risk analysis of every facility or procedure (e.g. loading operations 'platform–ship', third party interference, etc.).

Industrial accidents
For the period 1998–2009, 339 major accidents were reported under the Major Accident Reporting System MARS scheme (MARS, 2010) launched by the European Commission and managed by the Major Accident Hazards Bureau at the Joint Research Center. Additionally, there were also some transport–related accidents with severe consequences. The events with the highest number of fatalities for the transport sector occurred in Viareggio (Italy, 2009) and Ghislenghien (Belgium, 2004), resulting in 32 and 24 fatalities, respectively. At the same time the accidents in Toulouse (France, 2001) and Enschede (the Netherlands, 2000) were the worst in terms of involving fixed industrial installations. Those caused 30 and 22 fatalities, respectively. In total, industrial accidents claimed almost 170 lives, most of them being site staff or firefighting personnel.

No comprehensive picture of economic costs on the European level is available because cost estimates are very rarely undertaken after events. However, costs of some major events have been estimated and can be high, such as in the case of the Buncefield fire in 2005 (about EUR 1 billion). Major accidents with ecological impacts have been comparatively few in recent years. The MARS database reports 22 events associated with 'ecological harm' for the period 2003–2009. Apparently none of those caused widespread environmental consequences.

Also, of great importance are industrial accidents triggered by natural events, such as earthquakes, floods, landslides or forest fires. Referred to as NATECH (natural hazards triggering technological disasters), these accidents are likely to become of increased relevance in the future due to an increased frequency and severity of extreme natural phenomena and an increased complexity and interdependencies of industrial technological systems.

Since the number of installations falling under the Seveso Directive changes continuously and the Directive itself entered into force in the different EU-27 Member States on different dates, it is not possible to identify a clear trend. However, taking into account these limitations, it appears that the number of industrial accidents is rather stable over time and shows no significant trend to go down. Nevertheless, the severity in terms of the number of fatalities seems to be diminishing.

In comparison with information on disasters caused by natural events, information on technological disasters is less comprehensive. In Europe, the MARS database provides some useful information on major accidents. Nevertheless, the database could benefit from some improvements, since it currently does not allow a comprehensive overview of industrial accidents. This is due to the fact that MARS does not include all types of industrial accidents and does not systematically include near-accidents.

Spatial planning, i.e. the appropriate separation of establishments, infrastructures and residential settlements in industrial areas, offers an effective mechanism for risk mitigation and, as a key prevention factor, should be taken into account within an integrated risk management approach. A number of legislative instruments are in place to prevent and mitigate accidents and their consequences (in particular the Seveso II Directive 96/82/EC (EC, 1996) and its amendment 2003/105/EC (EC, 2003a) on the prevention and mitigation of major industrial accidents).

Toxic spills
In 1998–2009, only a few toxic spill events were recorded. Two events related to mining activities, namely, the collapse of dams servicing tailing ponds in Aznacollar, Spain (1998; Guadiamar River) and in Baia Mare, Romania (2000), seriously affected the environment. In 2004 and 2005, two more events of a considerable scope were reported in Aude (France) and Borsa (Romania). However, one of the worst toxic spill accidents in Europe in recent years occurred near the city of Ajka in Veszprem

County, Hungary in October 2010, i.e. after the period covered in this report. The failure of the tailing dam of an aluminium production plant's depository reservoir caused at least 800 000 m^3 of alkaline sludge to flood an area of 1 017 ha. The flood affected three villages with 7 000 inhabitants and caused at least nine fatalities (as per 14 October 2010) as well as considerable other impacts, including considerable damage to watercourses nearby; long-term consequences of this event are not yet assessable.

Economic costs of toxic spills are not very well documented. Nevertheless, estimates for the Aznacollar event indicate that the overall remediation costs were about EUR 377 million. Even more relevant than the economic aspect are the ecological impacts of toxic spills. In the case of Baia Mare, the spill of 100 000 m^3 of contaminated water led to a heavy pollution in a river system, resulting, inter alia, in the temporary closure of various water supply systems and more than one thousand tonnes of fish being killed.

In 2003–2009, the numbers and impacts of the reported accidents were comparatively low; this is, probably, in consequence of measures taken after the large accidents during the first half of the reporting period. Nevertheless, many tailing dams exist in EU Member States and they are considered to have a major potential to cause accidents, as evidenced by the event in 2010.

As mentioned above, information on the impact of toxic spills is still fragmentary. The main problem with gathering information is associated with the cross-cutting character of the topic that involves various authorities and their mandates. Disasters of this kind may fall into the category of natural hazards, or technological disasters, or mining (usually representing a separate legal entity) and water protection, and thereby relate to very different spheres of competence. This may cause reporting obstacles and make it difficult to identify aggregated data.

For toxic spills, prevention of accidents is key. This is very much related to the issue of NATECH, since the most frequent cause of accidents is the underestimation of the risks of extreme natural events. The Institute for the Protection and Security of the Citizen at the Joint Research Centre of the European Commission manages a project related to NATECH accidents. This project aims to enhance awareness of these types of industrial accidents and to reduce the NATECH risk. As the incidents in 1998 and 2000 raised concern about the hazardous potential inherent in toxic spills from mining activities, the European Union initiated legislation on the matter. Therefore, the scope of the amendment 2003/105/EC (EC, 2003a) to the Seveso II Directive 96/82/EC (EC, 1996) was extended by adding a section on toxic spills, and later, the Directive 2006/21/EC (EC, 2006b) introduced a chapter on major accident prevention and provided information similar to the requirements of the Seveso Directive. The overall framework was completed by the Reference Document on Best Available Technologies for the Management of Tailing and Waste-Rock in Mining Activities (EC, 2009c).

Disaster risk reduction and management

Disaster risk reduction and management in Europe has shifted from a response-oriented approach towards an Integrated Risk Management (IRM) approach that includes prevention, preparedness, response and recovery. Measures addressing the reduction of risks have ensured a better safety of the population, infrastructure and the environment, for example, in the case of avalanches, where IRM has already reached an advanced level and incorporates technical measures developed and implemented during the last five decades. Nevertheless, more effort is needed to implement such an integrated risk management approach throughout Europe that would address all hazards. It is imperative to enhance early warning systems, campaigns to raise public awareness, implementation of evacuation procedures or decision support tools. There is a need to improve technical and biological measures (such as protection forests) and spatial planning (including, e.g. the appropriate separation of establishments, infrastructures and residential settlements in industrial areas). Spatial planning can be a very powerful tool for reducing, effectively and efficiently, the potential impact of natural or technological hazards. Nevertheless, correcting or improving the 'legacy of the past' (i.e. deficient spatial planning in former times) still presents a challenge. Additionally, the robustness of (critical) infrastructure should be increased for example by enforcing a better implementation of building codes.

The vulnerability of people and territories affected throughout Europe shows great diversity as was highlighted by the disasters occurring during 1998–2009. When the heat waves were scorching France and other countries in the summer of 2003, most of the fatalities were elderly people. Many of them lived alone in flats not fitted out to cope with the heat. The UK floods of 2007 affected a disproportionate number of the poorer people living in flood-prone areas. A lot of the deaths from flooding in Romania and other eastern European countries occurred in rural areas where flood control and defenses were insufficient. Thus, measures within IRM should focus on the vulnerable parts of the population. This may mean a greater role played in the decision-making process by the local communities and households potentially affected. For example, pluvial flooding can be better managed through relatively simple and inexpensive measures that facilitate natural drainage and should be applied at the level of households and municipalities. Likewise, some of the worst effects of winter storms, such as the collapse of tree covers, could be reduced by implementing better forest management practices at the level of forest stands. Impacts of heat waves could be ameliorated by a better adaptation of households and hospitals and by making monitoring, prevention and preparation (including the raising of awareness) more efficient.

Risk reduction policies exist in many European countries. They aim at numerous hazards (e.g. forest fires, floods, earthquakes). However, these policies across Europe have not yet been harmonised (e.g. avalanches, forest fires) or the process has only started recently (e.g. floods). Concerted and coordinated actions at the European level, like those implemented under the Floods Directive (EC, 2007b), can bring a considerable added value and are likely to strengthen protection of population, infrastructure and ecosystems throughout Europe. Development of some EU-level policies for different hazards has started through the Commission Communication of 2009 (EC, 2009d) and the Council Conclusions of November 2009 (EC, 2009e).

As regards technological hazards, the fact that their impact has been declining since 2003 is probably mainly due to implementation of European legislation. For instance, the introduction of Regulation 417/2002/EC (EC, 2002b), as amended by Regulation 1726/2003/EC (EC, 2003b), which requires that oil and similar products must be transported in double-hull vessels only, as well as the setting up, in 2002, of the European Maritime Safety Agency EMSA were key initiatives at the EU level that aimed at reducing oil spills and their impacts. The EU extended the scope of the amendment to the Seveso II — Directive (96/82/EC (EC, 1996), Directive 2003/105/EC (EC, 2003a)) by adding a section on operational tailings disposal facilities. Nonetheless, in some sectors (e.g. pipelines) the regulatory framework is less developed.

As is evident from the experience of various hazards, a good cooperation at the European level could be beneficial for reducing the risk of disasters. Thereby, good cooperation at a technical level, such as the reinforcement of links between existing (early) warning systems (see e.g. sections on floods or avalanches) or the development of common guidelines or methods (e.g. Eurocode 8 for earthquakes (Eurocode 8, 2004)) can also be of a significant value for improving IRM throughout Europe. Moreover, as indicated in the Hyogo Framework for Action 2005–2015 (UNISDR, 2005), there is a need to apply a multi-risk approach in addressing vulnerability to hazards and disasters.

Information gaps and data needs

Successful disaster risk reduction and a policy for disaster prevention rely on good evidence. Even though the information and the data bases on different hazards have been substantially improved during the past decades, to assess the overall impacts of natural hazards and technological accidents in Europe is still difficult. Global disaster databases like EM-DAT or NatCatSERVICE provide a good overview of the impacts produced by major events throughout Europe. These databases were established to answer specific questions at a global level, for example comparing impacts across countries. Over the recent years those global databases have been harmonised, although some differences remain in respect of certain characteristics (e.g. threshold levels, specific methodologies for data recording, etc.). However, these databases are less suitable for analysing the impacts of smaller events or for analyses at the sub-national level.

Thus, from a European perspective, it may be desirable to establish more comprehensive information systems which would allow analysing and assessing the overall impact of different hazard types in Europe with a view of providing a more comprehensive and sound base for disaster risk reduction. Such databases already exist for certain hazard types, e.g. for forest fires (EFFIS, 2010) or, to some extent, for industrial accidents (MARS, 2010), but even these two good examples can be further improved.

While tackling the challenge of establishing a European information system for hazards not yet addressed at a European level, of great importance are systematic recording and evaluation of socio-economic and ecological vulnerabilities and impacts of different hazards based on standardised methodologies (including issues of terminology and classification). There is a need for clearly defined procedures regarding the maintenance and regular updates of such databases or information systems.

In addition to improving the information base on past events, there is a need for further improvement and harmonisation of the information base in support of other phases of the cycle of Integrated Risk Management. A particular focus should, therefore, be on the development of comparable approaches to vulnerability and risk assessment across Europe in respect of the hazards addressed in this report. For some hazard types, such as floods, such an approach has been already introduced, to a certain extent, with the implementation of the Floods Directive (EC, 2007b), which, inter alia, requires that flood risk maps should to be compiled by 2013. For other hazard types, however, there is currently a lack of common approach and, thus, further action will be needed. A first step in this direction has recently been taken by the European Commission, which intends to develop EU guidelines on risk assessment and mapping for civil protection by the end of 2010.

1 Introduction

1.1 Setting the scene

In this report, we assess the occurrence and impacts of natural hazards (3) and technological accidents in Europe for the period 1998–2009. Currently, Europe is experiencing an increasing number of 'natural (4) and technological disasters (5) that are caused by a combination of changes in its physical, technological and human/social systems. Hazards and disasters can result in human victims, economic losses as well as environmental degradation (Smith, 2004). They change continuously in terms of their impacts because nature, technology and society are all very dynamic and continuously changing too (Hewitt, 1997). Generally speaking, disasters normally occur when hazards meet vulnerability (Wisner et al., 2004), and the potential for a hazard to become a disaster mainly depends on a society's capacity to address the underlying risk factors, reduce the vulnerability of a community and to be ready to respond in case of emergency. It is important to note, however, that there are no internationally agreed minimum criteria for an event to be classified as a disaster (DFID, 2006). This is due to the variable manner in which hazardous events impact on population, economies or ecosystems. Thereby, even events which do not reach a certain 'disaster-threshold' and thus do not appear in global disaster databases (see below), may in fact account for a considerable proportion of losses or of the impact in general (e.g. if there are many of these events). Therefore, this report does not only focus on the impacts of disasters but tries to give a more comprehensive overview of the overall impact of natural hazards and technological accidents, as far as data on these impacts are available.

Box 1.1 Vulnerability

Many definitions of the term *vulnerability* exist, and these definitions vary according to the specific context. The United Nations International Strategy for Disaster Reduction UNISDR (2010a, 2010b) defines vulnerability as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. 'For more general socio-economic purposes and macro-level analysis, vulnerability is a less strictly defined concept. Scientists working on climate change and global environmental change often define the vulnerability of a region by integrating characteristics of the vulnerable system or community with its exposure to a wide range of hazards. The Intergovernmental Panel on Climate Change (IPCC, 2010) defines vulnerability to climate change as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). More generally, one could define vulnerability as *a measure of possible future harm* (Ionescu et al., 2009). While being aware of the different definitions and concepts of vulnerability, we do not use a specific definition or concept in this report but rather use the term in a more generic way.

1.1.1 Scope of the report

The report is an update and extension of the 2004 EEA Report 'Mapping the impacts of recent natural disasters and technological accidents in Europe' (EEA, 2004) that covers the period 1998–2002. It therefore mainly analyses the impacts of natural hazards and

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(3) UNISDR defines a hazard as 'a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage'. See further UNISDR, 2010b.

(4) The term 'natural disaster' is not entirely correct. Disasters happen only from a human and not from a natural perspective. As opposed to technological hazards, natural hazards do usually not lead to any harm to the nature as they are natural processes. If humans are affected the term disaster is used. Therefore, it is the natural hazard that causes the human disaster.

(5) A disaster is defined by UNISDR as 'a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses that exceed the ability of the affected community or society to cope using its own resources'. It must be noted, however, that the term disaster is often used in a less strict sense for events that cause great damage, destruction and human suffering. See also explanation in the text.

technological accidents on humans, the economy and ecosystems in the period 2003–2009, but also provides an overview of hazards and disasters in the 32 EEA member countries (6) for the entire period 1998–2009. Moreover, the report focuses on data gaps and lack of information on past events and their impacts, and possible ways to improve the knowledge base. The report does not, however, provide an analysis of existing vulnerability and risk assessments or assessment methods, nor does it specify the various needs for information and data for the entire disaster cycle. These issues, even if undoubtedly important, go beyond the scope of this report.

The report is divided into twelve chapters (see also Table 1.1). After this introductory chapter, Chapter 2 presents an overview of impacts of the major disasters in Europe during the period 1998–2009, based on the data from several generic databases (see below). The subsequent chapters present a more detailed description of the impact that various hazards had on human health (in terms of fatalities (7)), on the economy (in terms of overall and insured losses (8)) and on ecosystems (see Box 1.2). Chapters 3 to 7 deal with hydrometeorological hazards, namely storms, extreme temperature events, forest fires, water scarcity and droughts as well as floods. The subsequent three chapters focus on geophysical hazards, i.e. snow avalanches, landslides and earthquakes/volcanoes. Chapters 11 to 13 cover technological hazards, namely oil spills, industrial accidents and toxic spills from mining activities. To provide a more detailed analysis of important individual disaster episodes, each chapter includes one or two case studies.

1.1.2 Main sources of information

The information and data on natural hazards used in this report is, to a large extent, derived from two global disaster databases, namely the *EM-DAT* database maintained by CRED (EM-DAT, 2010) that places a particular focus on human fatalities, and displaced and affected people; and also the *NatCatSERVICE* database maintained by Munich Re (NatCatSERVICE, 2010) that provides reliable data on insured and overall losses (see Annex 1 for more detailed information on these two databases). The 'disaster thresholds' for an event to be included in these global databases are as follows:

- EM-DAT: (1) 10 or more people killed and/or (2) 100 or more people affected and/or (3) Declaration of a state of emergency and/or (4) Call for international assistance;
- NatCatSERVICE: Small-scale property damage and/or one fatality (9).

During the past decades both databases have improved their reporting. This means that caution is needed in formulating conclusions about trends based on data from EM-DAT (2010) and the NatCatSERVICE (2010), since such trends may at least partially reflect an evolution in the accuracy and comprehensiveness of the underlying data.

The data sets and information provided by these two generic databases serve as a good starting point for getting an overview of the impact of disasters throughout the world and in Europe. However,

Table 1.1 Typification of hazards and their major impacts

Chapter	Hazard	Hazard type	Major impacts
3	Storms	Hydrometeorological	Economic losses, human fatalities
4	Extreme temperature events	Hydrometeorological	Human fatalities
5	Forest fires	Hydrometeorological	Human fatalities, ecosystem degradation
6	Water scarcity and droughts	Hydrometeorological	Economic losses, ecosystem degradation
7	Floods	Hydrometeorological	Economic losses, human fatalities
8	Snow avalanches	Geophysical	Human fatalities, economic losses
9	Landslides (incl. debris flow)	Geophysical	Human fatalities, economic losses
10	Earthquakes/volcanoes	Geophysical	Human fatalities, economic losses
11	Oil spills	Technological	Pollution of ecosystems
12	Industrial accidents	Technological	Pollution of ecosystems
13	Toxic spills	Technological	Pollution of ecosystems

Source: EEA.

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(6) The 32 member countries include the 27 EU Member States together with Iceland, Liechtenstein, Norway, Switzerland and Turkey

(7) Due to a lack of data on how hazards affect human health, e.g. how they cause outbreaks of infectious diseases or lead to injuries after an event, the report focuses on fatalities.

(8) Analysis of the economical impacts presented here is similarly impeded by the poor data availability. Therefore, some interesting aspects (e.g. how the collapse of infrastructure during or after an event creates indirect costs, or calculations of total costs of an event) are only covered sporadically.

(9) Additionally, Munich Re uses different classes to classify the events (see Annex 1).

since both databases have been established to address particular questions that might differ from the ones discussed in this report, additional sources of information were used for each natural hazard (if available) to provide a more comprehensive overview of the overall impacts.

The main sources of information for the technological accidents include reports published by the European Maritime Safety Agency (EMSA, 2010), as well as the 'Major Accident Reporting System' (MARS, 2010) for industrial accidents of the European Union. Additionally, as in the case of natural hazards, we also used supplementary sources of information to provide a more comprehensive overview of technological accidents.

1.2 Natural hazards and climate change

According to the IPCC (2007), one of the most important consequences of climate change will be the increase in the frequency and magnitude of extreme events such as floods, droughts, windstorms and heat waves. Climate change may also trigger other hazards in which climate or weather conditions play a fundamental role, such as snow avalanches, landslides and forest fires. This report will not provide a detailed analysis of such events. They are more comprehensively explored in other assessments, in particular, the IPCC Fourth Assessment Report (IPCC, 2007), the EEA/JRC/WHO report on climate change impacts (EEA-JRC-WHO, 2008), and the forthcoming joint report by IPCC and UNISDR 'Managing the risks of extreme events and disasters to advance climate change adaptation' (to be published in 2011). Nevertheless, the relationships between occurrence and impacts of natural hazards and climate change are summarized briefly in this introductory chapter.

According to the NatCatSERVICE (2010, see Figure 1.1), of the disasters due to natural hazards that occurred in Europe since 1980, about 90 % of the events and 80 % of the economic losses were caused by hydrometeorological or climatological hazards.

In part, this conclusion may be related to the general absence of major geophysical hazards, such as large earthquakes or volcanic eruptions in Europe, with some exceptions in the north (Iceland), south (Italy, Greece) and east (Turkey). Compared with other continents, most of Europe has a relatively stable geology, which makes the occurrence of large earthquakes less likely. Furthermore, the fact that geophysical hazards are concentrated in the southern and eastern areas of Europe also affects the (potential) overall loss as the concentration of assets at risk in these areas is usually lower than in western or central Europe. Nevertheless, large earthquakes can still occur in specific areas in central Europe, albeit relatively rarely, and such events could generate huge losses, since the assets at risk are of considerable value.

The number and impacts of weather and climate-related events increased significantly

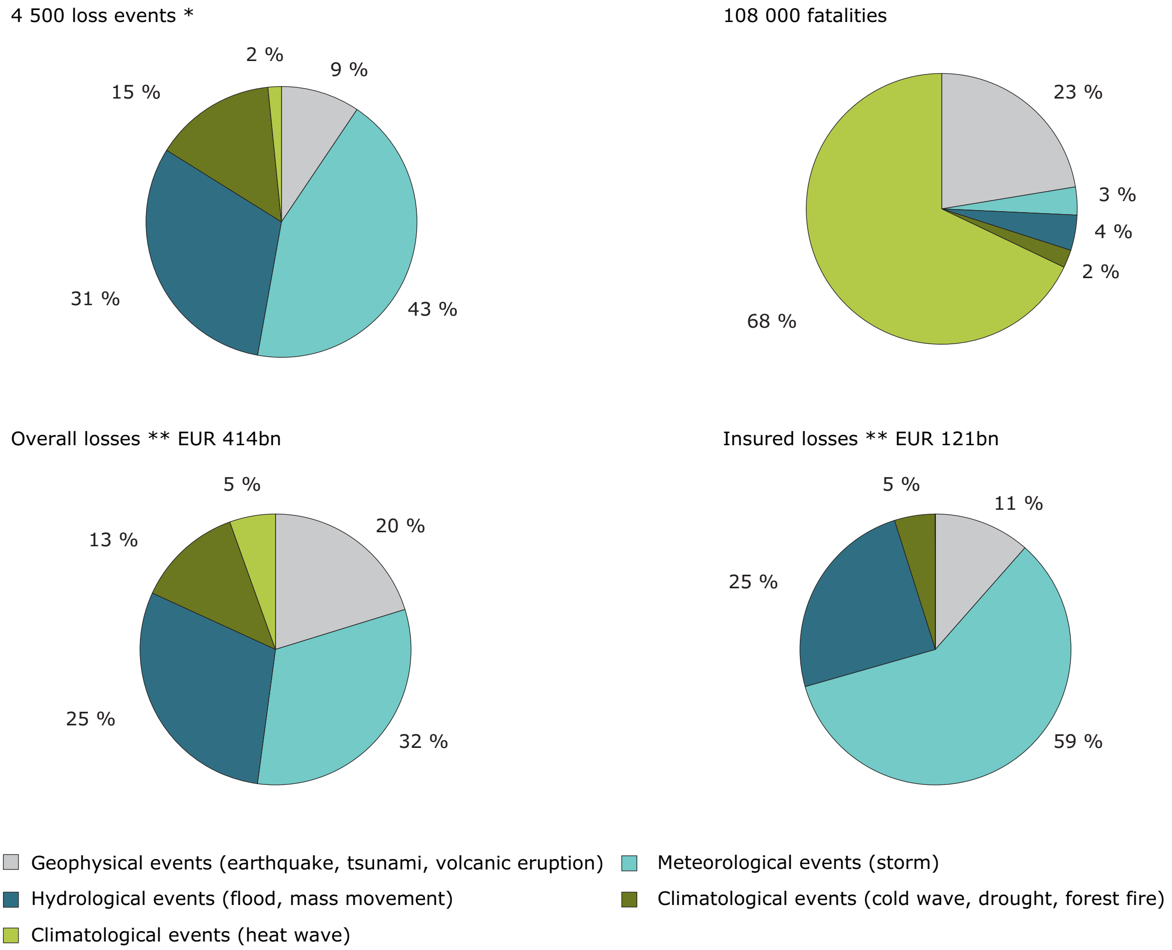
Box 1.2 Ecosystem goods and services

Ecosystems provide many goods and services that are vital for human wellbeing. In the case of forests, for examples, these goods and services range from socio-economic functions (provision of jobs, income, raw material for industry and renewable energy; protection of settlements and infrastructure; improvement of the quality of life) to environmental functions (soil protection; regulation of freshwater supply; conservation of biodiversity), and even climate regulation functions (forests are effective sinks and sources of carbon and they regulate regional and local weather). However, placing an economic value on an ecosystem good or service is still a complex challenge, even if much research has been and is still being undertaken on the topic (see e.g. the ongoing Economics of Ecosystems and Biodiversity project (TEEB, 2010)).

Hazardous events, in particularly technological accidents, can seriously influence the functioning of ecosystems and, thus, challenge their ability to provide further goods and services for humans and their socio-economic development. On the other hand, many natural hazards often do not have a large effect on ecosystems and could, thus, be rather considered a natural disturbance — one of many in the dynamics of the ecosystem.

This report does not address the topic of ecosystem valuation in depth. Rather, it provides a short overview of each main hazard's past and possible future impacts on ecosystems. In the future, it will be possible to perform further types of analysis regarding impacts on ecosystems, for example in the context of thematic assessments undertaken by the EEA and other organisations.

Figure 1.1 Disasters caused by natural hazards in EEA member countries, 1980–2009



Note: * Definition loss events: events can occur in several countries; events are counted countrywise; ** in 2009 values.

Source: NatCatSERVICE, 2010; © 2010 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE — as at August 2010.

between 1998 and 2009, while geophysical hazards appeared to have remained more stable (Chapter 2). One important question concerns the extent to which the increase in overall losses is due to (changing) climate conditions, or to other factors. In this respect, studies show that the observed increase in losses during the last decade and the projected losses for the future are, to a large extent, caused by changes in population and economic wealth, particularly by the increase of human activities in hazard-prone areas (see e.g. chapter on floods). Upward trends in losses can also be explained, to some extent, by better reporting. While it is currently impossible to determine accurately the proportion of losses attributable to climate change (EEA-JRC-WHO, 2008), the contribution of the climate change factor could increase in future, since climate change is projected to continue.

1.3 Advances in disaster risk reduction and management

In recent years, policies for disaster risk reduction and management have shifted from defense against hazards (mostly by structural measures) to a more comprehensive, integrated risk approach (see Figure 1.2). Within integrated risk management (IRM), the full disaster cycle — prevention, preparedness, response and recovery – should be taken into consideration when dealing with any type of hazard, be it natural or technological. The implementation of IRM is currently taking place at both international and national levels and is promoted by several initiatives.

At the global level, the Hyogo Framework for Action (HFA; cf. UNISDR, 2010a) adopted by

Box 1.3 Emerging and evolving risks

UNISDR defines risk as the combination of the probability of an event and its negative consequences (UNISDR, 2010b). An event can be induced by a wide variety of causes, like natural hazards, industrial accidents or biological agents (e.g. invasive alien species). In recent years, increasingly complex risks seem to be emerging throughout the world. These evolving and emerging risks show the increasing vulnerability of our society, economy and ecosystems. This socio-economic-ecological vulnerability to hazardous events is going, most likely, to increase in the coming years, mainly due to the ongoing socio-economic developments that include globalization, poverty, population growth, urbanization, environmental degradation and other factors, such as climate change.

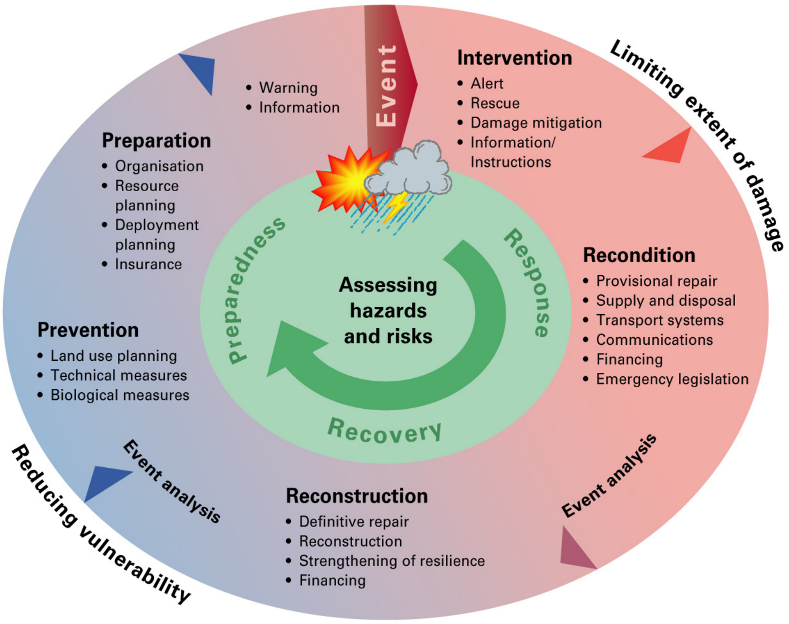
This report does not provide a comprehensive assessment of all emerging and evolving risks in Europe. It intends, however, to outline the recent impacts of several natural hazards and technological accidents — those thought to be relevant at the European level. Thus, the report serves as a potential starting point for future analysis and a basis for further risk assessment in relation to the hazards covered in the report. Such assessments could be performed by various organisations (including EEA), both at the EU and national levels.

The EEA's European environment state and outlook report 2010 (EEA, 2010) provides a comprehensive assessment of the European environment's status, trends and outlook and an evaluation of progress towards policy objectives. EEA will in the coming years develop and publish various other thematic assessments, e.g. on biodiversity, freshwater, and marine and coastal ecosystems, which will address the issue of increasing risks to society, the economy and ecosystems.

168 governments in 2005 sets out a global plan for efforts to reduce the risk of disasters during the next decade. Its goal is to reduce losses from disasters substantially by 2015, in terms of lives and the social, economic and environmental assets of communities and countries.

The European Union has already developed a set of instruments to address various aspects of disaster preparedness, response and recovery. These include the Community mechanism for civil protection (EC, 2001) or the European Union Solidarity Fund (EUSF; EC, 2002). Created in the wake of the severe

Figure 1.2 Cycle of integrated risk management



Source: Swiss Federal Office for Civil Protection FOCP, 2010.

floods that hit central Europe in the summer of 2002, the EUSF is designed to respond to major disasters caused by natural hazards and express European solidarity with disaster-stricken regions of Europe. Moreover, a number of sector-specific legislative activities have commenced or been extended in recent years, as shown in the list below.

- The Floods Directive (EC, 2007a) aims at reducing and managing the risks that floods pose to human health, the environment, cultural heritage and economic activity. The directive requires Member States first to carry out a preliminary flood risk assessment by 2011 and subsequently to prepare flood hazard and risk maps for flood prone zones by 2013. Finally, flood risk management plans with a focus on prevention, protection and preparedness need to be established for these zones by 2015. The directive applies to inland waters as well as all coastal waters across the whole territory of the EU.
- The Communication on Water Scarcity and Droughts (EC, 2007b) aims at preventing and mitigating water scarcity and drought situations. It specifies the measures needed if Europe is to move towards a water-efficient and water-saving economy. The communication was followed by two follow-up reports in 2008 (EC, 2008) and 2009 (EC, 2010a), respectively. These reports point out, inter alia, a number of areas to be tackled (e.g. land-use planning, water pricing, water metering, etc.).
- Forest fire prevention policies, which were established at European level as early as 1992 and continued until 2006, when the last EU regulation on forest fires, the so-called 'Forest Focus' Regulation (EC, 2003a), expired. Nevertheless, forest fire management activities still continue on a European level, mainly through the European Forest Fire Information System (EFFIS, 2010). This system aims, inter alia, at providing assessments of situations before and after fires conducted at the EU level, and supporting fire prevention through risk mapping. The Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change (EC, 2010b) acknowledges the efforts made by the EU and Member States to address the issue of forest fire prevention and highlights the need to step up these efforts, in view of climate change.
- The Seveso II Directive on the prevention and mitigation of major industrial accidents (EC, 1996) and the correspondent amendment (EC, 2003b). The directive and its amendment cover stationary establishments that store or process certain dangerous substances in volumes exceeding a defined quantity threshold; currently about 10 000 establishments in the EU have to comply with these requirements.
- Finally, in a wider sense the list should also include the EU Council conclusions on biodiversity post-2010 (EC, 2010c). It emphasises, inter alia, the need to protect biodiversity and the ecosystem services it provides, so that catastrophic changes caused by the loss of biodiversity could be avoided.

Additionally, the European Commission recently released the Communication on 'A Community approach to the prevention of natural and technological disasters' (EC, 2009a). This communication proposes that EU-level actions should focus on three areas: (1) developing knowledge-based prevention policies; (2) linking actors and policies throughout the disaster management cycle; (3) improving the effectiveness of existing financial and legislative instruments. As a consequence of this communication, the Council of the European Union adopted in November 2009 'Conclusions on a community framework in disaster prevention within the EU' (EC, 2009c). The Conclusions list the initial actions that should be taken by the European Commission in the following years. Based on the Conclusions, several activities have already been started, including efforts to develop EU guidelines on risk assessment and mapping for disaster management.

At a national level, one major activity has been the establishment of national strategies and national platforms for disaster risk reduction. National Platforms are multi-stakeholder national mechanisms that serve as an advocate for disaster risk reduction at different levels: from communities to the national institutions. So far, 16 European countries have established such a platform, and many more countries have established official Hyogo Framework Focal Points (see Table 1.2).

In Europe, representatives of National Platforms and HFA Focal Points regularly meet at the regional level at least once a year. The meetings are hosted by a European country and are supported by UNISDR and the Council of Europe European and Mediterranean Major Hazards Agreement (EUR-OPA) (CoE, 2010). In November 2009, European HFA Focal Points and National Platform coordinators agreed to establish a European Forum for Disaster Risk Reduction (EFDRR). The Forum will act as European regional platform for disaster risk reduction. The first meeting of the EFDRR was held in Sweden in October 2010.

The vulnerability of our society constantly grows as a result of growing population density, enormous

Table 1.2 National platforms and HFA focal points for disaster risk reduction in Europe

National platforms	HFA focal points	
Bulgaria	Albania	Moldova
Croatia	Austria	Monaco
Czech Republic	Bosnia and Herzegovina	Montenegro
Finland	Bulgaria	Norway
France	Croatia	Poland
Germany	Cyprus	Portugal
Hungary	Czech Republic	Romania
Italy	Denmark	Russian Federation
Former Yugoslav Republic of Macedonia	Finland	Serbia
Monaco	France	Slovak Republic
Poland	Germany	Slovenia
Russian Federation	Greece	Spain
Spain	Hungary	Sweden
Sweden	Iceland	Switzerland
Switzerland	Italy	Turkey
United Kingdom	Former Yugoslav Republic of Macedonia	Ukraine
	Malta	United Kingdom

Source: UNISDR, 2010c.

increase in economic assets in risk zones and the increased mobility of the population. Moreover, changing environmental conditions (such as climate change and degradation of ecosystems) may aggravate the risk related to particular natural hazards. For these reasons, disaster management cannot be disentangled from other initiatives. Such related initiatives include sustainable resource planning (in particular, land-use planning), the development of adaptation and mitigations strategies to address climate change and its consequences, and more generally, policies and research initiatives to increase the resilience of citizens and communities.

In particular, there is an increasing need to identify synergies between disaster risk reduction measures and actions to adapt to climate change, as described in the White Paper on Adaptation to Climate Change issued by the European Commission (EC, 2009b). This paper highlights the need to mainstream climate change impact and vulnerability assessments and adaptation actions into other key policy areas. The role of the EU will be to support and complement national and regional actions through an integrated and coordinated approach, particularly in cross-border issues and policies relevant at the EU level. As many weather-related hazards are projected to increase in intensity and frequency due to climate change, there are opportunities to better connect and integrate disaster risk reduction and climate change adaptation. A number of countries have developed national climate change adaptation strategies, which are already linked and coordinated with national strategies and platforms for disaster risk reduction, although these ties could be further enhanced.

It is essential to consider all phases (e.g. prevention, preparation and intervention) and to take into account and consequently maintain all measures (e.g. spatial planning; technical measures, such as rockfall nets; structural measures, such as dams, and biological measures, such as protection forests) within the cycle of integrated risk management (Figure 1.2). Furthermore, effective IRM relies on the involvement of all potential stakeholders, from national, regional and local administrations to the scientific community, the private sector (e.g. insurance companies) and citizens. Every stakeholder should contribute to measures and activities according to their own capacities and skills, and should be empowered to do so (e.g. by education, awareness raising and so on). For example, pluvial flooding could be better tackled at the household and municipal level by relatively simple and inexpensive measures designed to improve natural drainage locally. Similarly, the impacts of storms on forests could be reduced with more sustainable forest management practices at the level of forest stands.

2 Disasters in Europe in 1998–2009

2.1 Overview

2.1.1 Disasters caused by natural hazards

For the period 1998–2009, EM-DAT reports 576 disasters due to natural hazards causing near to 100 000 fatalities, and close to EUR 150 billion in overall losses. During this period, more than 11 million people (out of a population of 590 million, approximately, in the EEA member countries) were somehow affected by disasters caused by natural hazards (see Table 2.1).

Between 1998 and 2009, Europe suffered some of the world's costliest disasters including the earthquakes in Izmit (Turkey), the storms *Lothar* and *Kyrill* (western, central, and parts of eastern Europe), and widespread flooding episodes in the central areas of the continent and in the United Kingdom. Other important episodes were the floods and landslides of 2005 in the Alpine region; the forest fires in Greece and other parts of eastern Europe in 2007 and 2009, and drought events affecting the Iberian Peninsula in 2005, 2006 and 2008. As can be seen from Figure 2.1, the distribution of disasters in the reporting period is far from being uniform, with Turkey (64 recorded events), Romania (58) and France (56) being affected most frequently. Most of the disasters are thereby caused by either floods or storms (Figure 2.2).

According to NatCatSERVICE (NatCatSERVICE, 2010), which provides reliable long-term data series adjusted for inflation, the number of disasters in Europe has been showing an upward trend since 1980, largely due to the continuous increase of meteorological and hydrological events (Figure 2.3 and Section 1.2).

2.1.2 Disasters caused by technological accidents

During the reporting period, more than 350 major technological disasters were registered in the different databases (excluding mining accidents), causing almost 170 fatalities and leading to

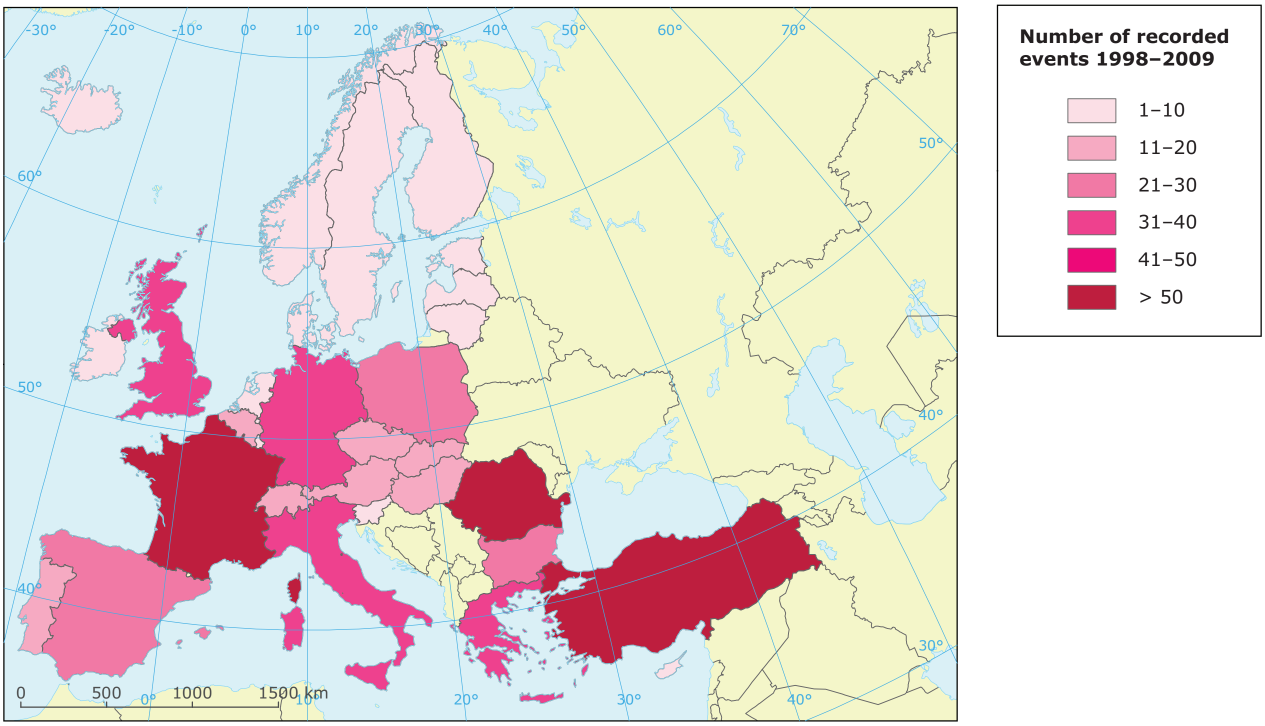
Table 2.1 Disasters caused by natural hazards in Europe in 1998–2009 as recorded in EM-DAT

Hazard type	Recorded events	Number of fatalities	Number of people affected (million people)	Overall losses (billion EUR ([a]))	Insured losses (billion EUR)
Storm	155	729	3.803	44.338	20.532
Extreme temperature events	101	77 551	0.005	9.962	0.186
Forest fires	35	191	0.163	6.917	0.097
Drought	8	0	0	4.940	0.000
Flood	213	1 126	3.145	52.173	12.331
Snow avalanche	8	130	0.01	0.742	0.198
Landslide	9	212	0.007	0.551	0.206
Earthquake	46	18 864	3.978	29.205	2.189
Volcano	1	0	0	0.004	0.000
Total	576	98 803	11.112	148.831	35.739

Note: ([a]) Loss values in US Dollars in EM-DAT are converted to euro per year using the respective exchange rates at the end of the corresponding year (EUR 1 = USD x; x: 1.18 (1998); 1.01 (1999);0.93 (2000); 0.88 (2001); 1.05 (2002); 1.26 (2003); 1.36 (2004); 1.18 (2005); 1.33 (2006); 1.47 (2007); 1.39 (2008); 1.44 (2009); cf. www.ecb.int/stats/exchange/eurofxref/html/eurofxref-graph-usd.en.html.

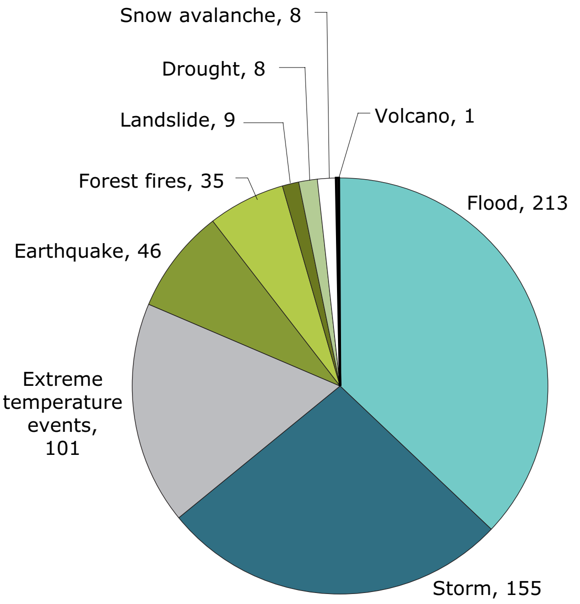
Source: EM-DAT, 2010.

Figure 2.1 Number of disastrous events recorded in EM-DAT by country in 1998–2009



Source: ETC-LUSI based on EM-DAT, 2010.

Figure 2.2 Disastrous events recorded in EM-DAT by hazard type in 1998–2009



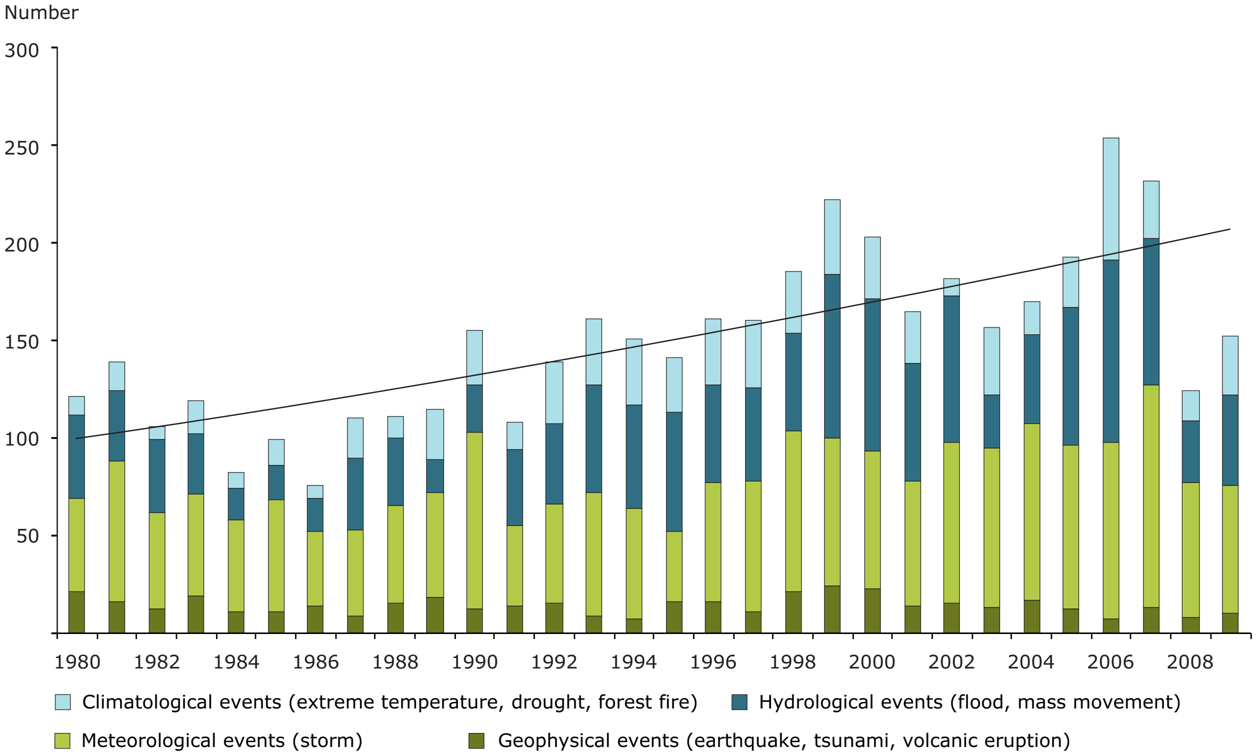
Source: ETC-LUSI based on EM-DAT, 2010.

important economic losses as well as ecological impacts. However, no reliable estimates are available for the total scope of overall costs or the overall impact on ecology (for further information, see Chapters 11–13).

Figure 2.4 presents an overview of the major technological disasters during the reporting period. As for natural hazards, the distribution of disasters caused by technological accidents in the reporting period is not uniform. According to the MARS database, for instance, during the reporting period France and Germany reported by far the highest number of incidents, followed by the United Kingdom and the Netherlands. It is unclear, however, whether the MARS database is capable of providing a comprehensive overview of all major events throughout Europe, since for many countries not a single event has been recorded.

In contrast to disasters caused by natural hazards, the records on technological accidents show a somewhat decreasing trend in the number of oil spills and a stable number of industrial accidents. In both cases, the consequences of these events during the last couple of years have been diminishing in severity, which is at least partly due to new legislation introduced on the European level (Chapters 11–13).

Figure 2.3 Disasters due to natural hazards in EEA member countries, 1980–2009



Note: Definition loss events, events can occur in several countries, events are counted countrywise.

Source: NatCatSERVICE, 2010; © 2010 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE — as at August 2010.

Table 2.2 Major technological disasters in Europe, 1998–2009

Hazard type	Events	Fatalities	Overall costs	Other impacts
Oil spills	9	n/a	No comprehensive data available. Estimation is between EUR 500–500 000 per spilled tonne of oil	Approximately 70 000 t oil spilled
Industrial accidents	339	169	No comprehensive data available (ᵃ)	
Toxic spills	4	n/a	No comprehensive data available (ᵇ)	Approximately 5 million m^3 toxic/contaminated substances spilled
Total	**352**	**169**	**n/a**	**n/a**

Note: (ᵃ) Costs for the major events mentioned in Table 12.1 amount to more than EUR 3.7 billion.
(ᵇ) Costs for one particular toxic spill amount to EUR 377 million, see Chapter 13.

Source: MARS, 2010; EMSA, 2010 and EM-DAT, 2010.

Figure 2.4 Major technological disasters in 1998–2009

Source: ETC-LUSI based on data from BARPI, 2010; CEDRE, 2010; EM-DAT, 2010; EMSA, 2010; MARS, 2010; Rainforest Information Center, 2010; and WISE, 2010.

2.2 Impact caused by natural hazards and technological accidents in Europe

2.2.1 *Human fatalities*

For the period under review, the most prominent natural hazard with regard to human fatalities has been heat waves. The heat wave of the summer 2003 claimed lives of a tremendous number of people on the continent, with over 70 000 excess deaths being reported in 12 western and central European countries (EEA-JRC-WHO, 2008). Heat waves were also responsible for numerous fatalities in the summers of 2006 in western Europe and the summer of 2007 in eastern Europe. After the 2003 heat wave, the 1999 Izmit (Turkey) earthquake ranks second in terms of destruction, with more than 17 000 fatalities. These two disasters accounted for more than 95 % of all human deaths between 1998 and 2009. As for other fatalities, a significant proportion of those can be attributed to several events. These include two earthquakes: Düzce in Turkey in November 1999, which caused over 850 fatalities, and L'Aquila in Italy in April 2009 with more than 300 fatalities. They also include cold spells, floods and storms. It should be noted, however, that except for the two earthquakes mentioned and the Romania floods of 2005 (85 fatalities), these events did not generally cause a large number of deaths.

The impact of natural hazards in terms of fatalities is not uniform throughout Europe, with France and Italy mourning more than 20 000 fatalities each, followed by Turkey (over 18 000 fatalities) and Spain (more than 15 000 fatalities). Obviously, these figures are so high largely because they incorporate the 2003 heat wave and the three large earthquake disasters mentioned above. Altogether, with the exception of heat waves, human fatalities tend to concentrate mostly in eastern and southern Europe (Figure 2.5).

Finally, it is important to realise that the numbers of fatalities presented in Table 2.1 and included in Figure 2.5 provide a conservative estimate of the overall impact of natural hazards. The reason is that some hazards, such as snow avalanches, landslides or forest fires, consist of smaller events that do not appear in EM-DAT due to its threshold values (see Chapters 5, 8 and 9).

The number of fatalities attributable to technological hazards in Europe is considerably smaller than that of natural hazards, and is usually associated with industrial accidents. For instance, between 2003 and 2009, the MARS database (MARS, 2010) reported 27 industrial accidents in Europe with human fatalities and an additional 34 accidents resulting in injuries to people. Most of the victims were workers of chemical plants. The most serious accident took place in Viareggio (Italy) in June 2009, with the explosion of two tankers of a freight train that left 32 people dead. Overall, a total of 169 fatalities due to industrial accidents were reported for the reporting period (Figure 2.6).

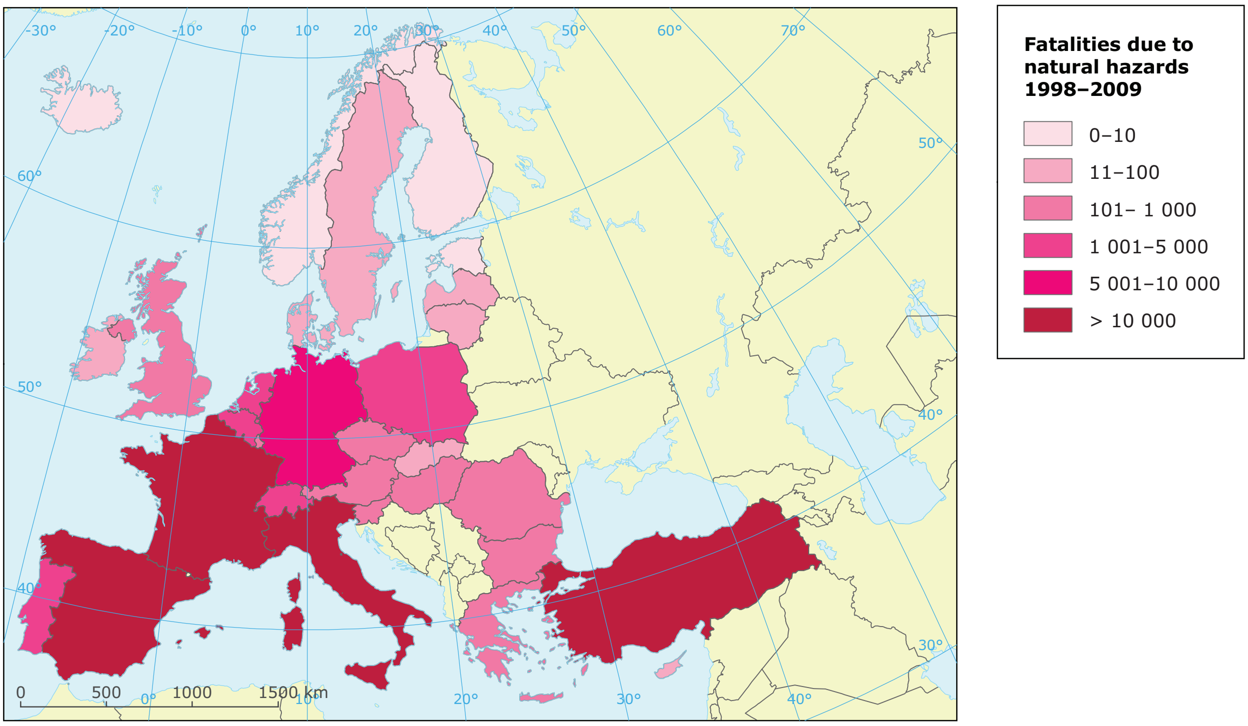
2.2.2 *Economic losses*

As mentioned above, according to EM-DAT (2010) estimates, the economic toll of natural hazards in Europe between 1998 and 2009 amounted to approximately EUR 150 billion (insured losses — approximately EUR 36 billion). Still, due to the thresholds used in EM-DAT, these figures must be seen as a lower estimate of the overall impact of natural hazards in Europe. NatCatSERVICE (2010), which includes events below the threshold used in EM-DAT, shows overall losses of more than EUR 195 billion, and insured losses of more than EUR 60 billion.

About half of all losses can be attributed to a few large events such as the earthquake in Izmit (1999), the winter storms Lothar (1999) and Kyrill (2007), and the floods of Central Europe in 2002 and in the United Kingdom in 2007. Two thirds of economic losses from natural hazards between 1998 and 2009 were caused by floods and storms (Figure 2.7). Both hazards tend to affect large areas of the continent. Hence, although per capita losses may be comparatively small, aggregate effects escalate to very important figures.

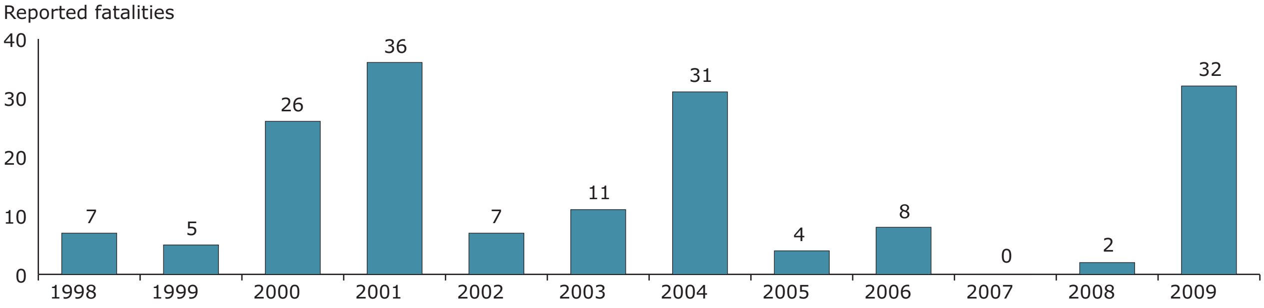
In general terms and in contrast to human fatalities, overall economic losses from natural hazards during the period 1998-2009 tend to be higher in western and central Europe than in southern and eastern Europe (see Figure 2.8), probably reflecting differences in the accumulation of infrastructure, wealth and in living standards in these different parts of the continent. This trend parallels to, a certain extent, global trends in the unequal distribution of human fatalities and economic losses from natural hazards

Figure 2.5 Number of human fatalities caused by natural hazards in Europe in 1998–2009 as shown in EM-DAT



Source: ETC-LUSI based on EM-DAT, 2010.

Figure 2.6 Reported fatalities caused by major technological accidents in 1998–2009

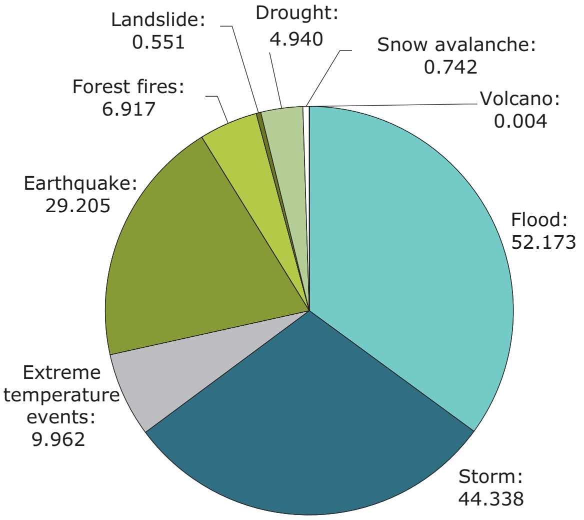


Source: BARPI, 2010 and MARS, 2010.

between developed and developing countries. The number of human fatalities in developed countries is usually small but economic losses may reach high levels, while the contrary would be the case for developing countries (Rodriguez et al, 2008). However, in relative terms (i.e. economic loss in relation to GDP), natural hazards may be costlier for developing countries than for developed countries (Rodriguez et al, 2008).

Whilst it is difficult to establish trends regarding human fatalities due to the presence of relatively rare but highly lethal hazards (i.e. the heat wave of 2003), NatCatSERVICE (2010) reports that overall average losses incurred as a result of weather events from 1980 (above EUR 5 billion) to 2008 (above EUR 10 billion) practically doubled (see Figure 2.9). Whether losses from natural hazards increase faster or slower than economic growth is unclear. Some sources indicate that losses may be increasing faster than economic growth (Kundzewicz, 2005) because urbanisation is concentrating populations and wealth, such that when disasters occur the losses are potentially far greater (Bouwer et al., 2007).

Figure 2.7 Overall losses by hazard type 1998–2009 according to EM-DAT (billion EUR)

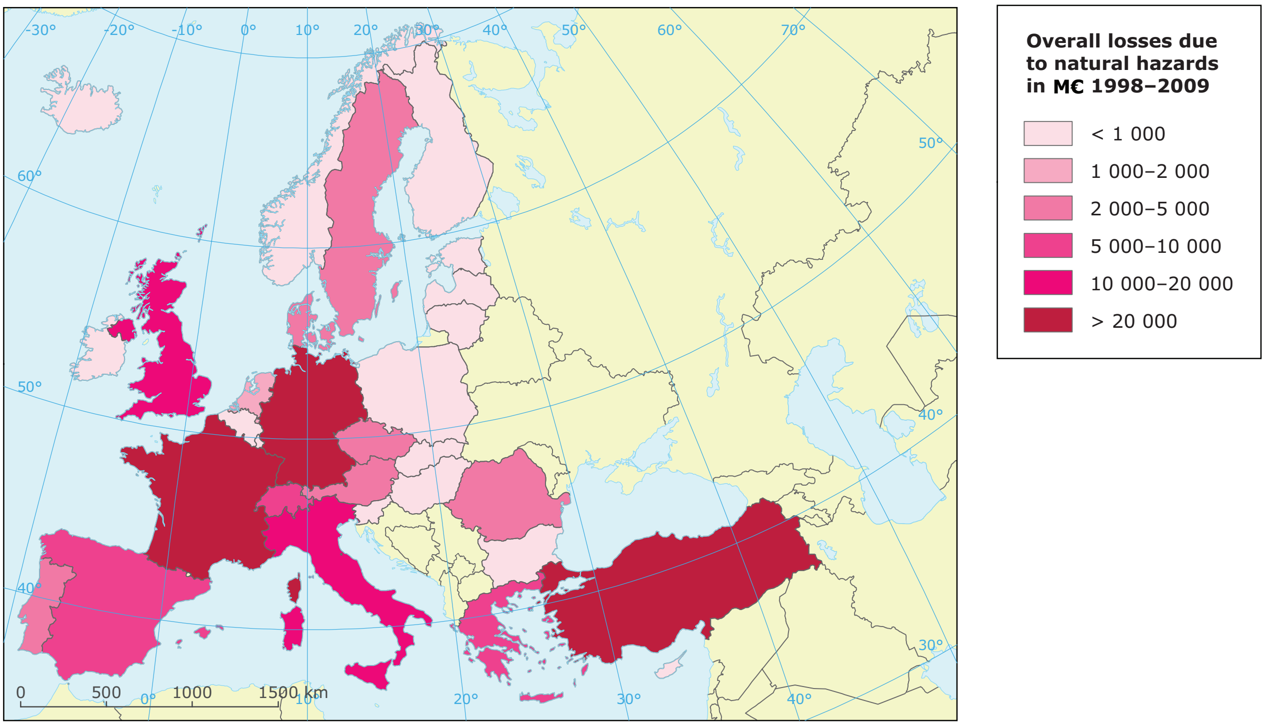


Source: ETC-LUSI based on EM-DAT, 2010.

2.2.4 *Impacts on ecosystems*

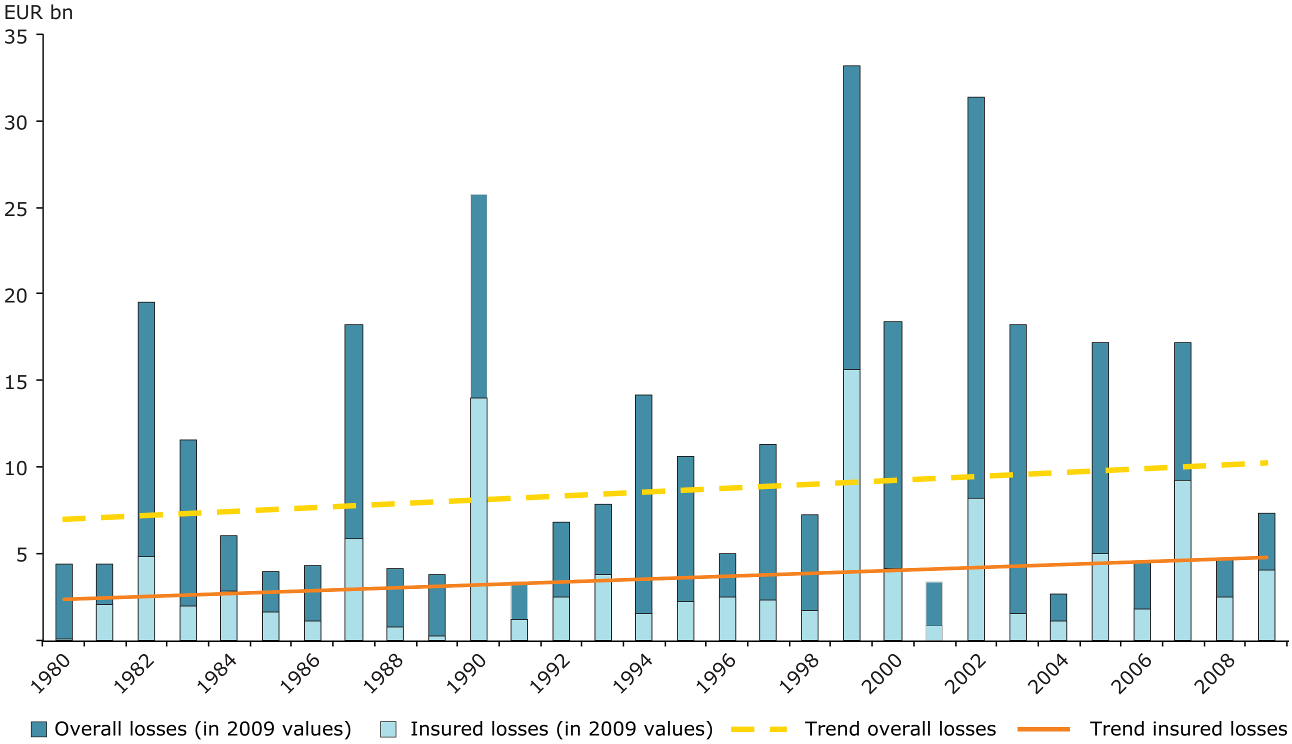
In contrast to impacts of natural hazards on human beings and economic assets, impacts on ecosystems are more difficult to assess. Natural events may have negative and positive effects on ecosystems, depending on the extent of a hazard and the specific spatial and temporal scales (EEA, 2004). For example, a severe storm can uproot many trees and thus cause serious damage to a forest (including forest services, such as timber production). On the other hand, the same event can also be beneficial from an ecosystems perspective if it creates a mosaic of small-scale patches of forest at different stages. This would create forests with trees of varying ages, which are generally richer in biodiversity and more resilient than forests with trees of uniform age. Additionally, storms can enhance the supply of dead wood, which in turn can lead to species enrichment (see e.g. Duelli et al., 2002). In this way, this same event would be considered a natural disturbance, one of many in the dynamics of the ecosystem. This ambiguity is probably one major reason why information on the impacts of natural hazards on ecosystems lacks specific databases and is, therefore, piecemeal and difficult to obtain and assess (see Chapters 3–10 for details on each hazard).

Figure 2.8 Overall losses by country in 1998–2009 according to EM-DAT



Source: ETC-LUSI based on EM-DAT, 2010.

Figure 2.9 Overall and insured weather-related losses in Europe with trend, 1980–2009



Source: NatCatSERVICE, 2010. Included are events from catastrophe class 1 up to 6 (Appendix A1). The main drivers due to the increasing of losses are social-economical factors.

Technological hazards usually have an unambiguously negative impact on ecosystems. After the oil spill disasters of *Erika* (December 1999) and Prestige (November 2002) and their tremendous impact on the environment (see EEA, 2004), legislation in Europe has been significantly expanded, including the Directive 2002/59/CE on Maritime Safety (EC, 2002) and the 'Third Maritime Safety Package' (EC, 2009). This is one reason why only relatively small incidents were reported between 2003 and 2009 (see Chapter 11).

Likewise, impacts related to releases of toxic waste from mining activities into sensitive ecosystems, such as the Baia Mare area in Romania or the wetlands of Doñana in Spain (EEA, 2004), were relatively small in the period 2003–2009. Again, this is partly due to new legislation, such as the European Directive on Environmental Liability (2004), the reformed European Directive on Major Accidents (2003), and the European Directive on the Management of Waste by Extractive Industries (2006). Nevertheless, tailing dams, which are numerous in EU Member States, are still considered to have a major potential to cause accidents. This was apparent in 2010, when the failure of a tailing dam released a considerable amount of alkaline sludge, flooding an area of 1 017 ha and causing at least nine fatalities (as of 14 October 2010).

As for industrial accidents, for the period 2003–2009 the MARS database reports 22 events associated with 'ecological harm', although apparently none causing widespread environmental consequences.

Part A — Hydrometeorological hazards
3 Storms

Key messages

- Between 1998 and 2009, storms were the costliest natural hazard in Europe in terms of insured losses. Regarding human losses, storms rank fourth after heat waves, earthquakes and floods.
- Storm occurrence has shown a strong variability with no discernible long-term trends since the late 1950s, but storm-related losses have been increasing in recent years. This increase is mainly driven by socio-economic factors and increasing exposure, i.e. increases in population and economic assets in the exposed areas.
- Information on storm impacts has improved in the past decades. Even so, a more comprehensive database as well as better evaluation methods are needed to obtain an improved estimate of the overall costs of storms, particularly with regard to local public infrastructure, losses in the forestry sector and monetisation of forest ecosystem services affected by storms.
- So far, there exists no specific policy at the EU level aiming at reducing the impacts of storms, but actions might be implemented in the context of the climate change adaptation. Storm management in the future should rely on integrated risk management, and place a particular focus on preventive measures: increasing the robustness of (critical) infrastructure, improvement of early warning systems and raising public awareness, especially concerning behaviour.

3.1 Introduction

3.1.1 Definition

Storms are natural events characterised by strong winds, often in combination with heavy precipitation (e.g. heavy rainfall, hail, etc.). In Europe, storms usually develop from extra-tropical cyclones that capture their energy through the contrast between subtropical air and polar air over the Atlantic Ocean. Since temperature differences between these warm and cold air masses attain a maximum in winter, the most intense storm events over Europe tend to occur during this season (Barredo, 2010).

The formation of extra-tropical cyclones depends on a number of factors including differences in North-South temperatures, strong jet stream currents, and anomalously warm and humid air. All these factors appear to be related to the so-called North Atlantic Oscillation (NAO). The NAO measures the variation in position and strength of the two dominant pressure systems existing over the Atlantic: the low pressure system over Iceland and the high pressure system over the Azores Islands. Large differences in pressure between the two systems (known as NAO positive) tend to activate the factors leading towards the formation of storms in western and central Europe which usually follow West-East tracks across the North Sea. Occasionally, storms may follow a more southerly track and affect southern and south-eastern Europe. Storms affecting Europe range from relatively small and localized events to large episodes spreading over a substantial part of the continent (see Table 3.1).

3.1.2 Sources of information

The main sources of information used for this chapter are the EM-DAT data base (EM-DAT, 2010), and the report by Munich Re on weather risks in Central Europe (Munich Re, 2008b). Additionally, the NatCatSERVICE of Munich Re has provided data on losses as well (NatCatSERVICE, 2010).

3.1.3 Storms in Europe 1998–2009

According to the EM-DAT database, storms were responsible for the death of 729 people throughout Europe between 1998 and 2009 (see Table 2.1 in Chapter 2). This is the highest number of human fatalities from natural hazards, after heat waves, earthquakes and floods. Moreover, storms, often accompanied by heavy precipitation, e.g. in the form of hail, were the most costly natural hazard for Europeans in the period identified in terms of insured losses. In Germany, for instance, between 1970 and 2004, storms caused more than 27 % of the economic damage created by disasters due to natural hazards and 45 % of insured damage (Heneka et al., 2006). In December 1999, a succession of three storm events *(Anatol, Lothar and Martin)* over the continent produced insured losses of almost EUR 11 billion (more than EUR 18 billion in overall losses). Insured losses from the storm *Kyrill* in 2007 reached the level of EUR 4.5 billion (an estimated EUR 2.4 billion in Germany alone), more than the cost of flooding in the United Kingdom in the same year. Storm *Klaus* (January 2009) caused estimated insured losses of EUR 2.4 billion in France, Spain and Italy. More localized storms may also be very costly. The series of storms known as *Hilal* (some depositing large quantities of hail that damaged many cars) affected the German states of Rhineland Palatinate and North-Rhine Westphalia in the spring of 2008 and produced overall losses of more than EUR 1 billion. Prospects for the future do not look very optimistic. According to Munich Re, annual losses from winter storms in Germany will probably increase in the coming years (Munich Re, 2008b). Table 3.1 presents some of the major storm events occurring between 1998 and 2009.

3.1.4 Storms and climate change

The occurrence of storms in Europe has been examined in the scientific literature on climate change with varying findings. Some studies suggest that storm intensity in terms of maximum gust wind speeds has locally increased during recent decades (e.g. Usbeck et al., 2009 and 2010) while other studies reporting evidence of a decrease in cyclone frequency since the late 1950s (see Ulbrich et al., 2009 for an updated review). Generally, it can be stated that storm occurrence has shown a strong variability with no discernible long-term trends ever since the late 1950s (EEA-JRC-WHO, 2008).

In respect of possible links between climate change and increasing storm activity over Europe, one common finding from the scientific literature concerns the anticipated reduction in the total number of cyclones but an increase in the number of the more active cyclones (i.e. less than 970 hPa; Fink et al., 2009). Therefore, many climatic models predict an increase in severe storms by the end of the 21st century — despite an overall decreased intensity of winter low-pressure systems over the North Atlantic (Ulbrich et al., 2009). Another important conclusion from such models is the shift of mid-latitude storm tracks towards higher latitudes (Trigo, 2006). In the Mediterranean, some studies predict an important reduction of winter storms but an increase in summer cyclones, and a general reduction in the more extreme events (Pinto et al., 2007). Overall, at this point, evidence regarding increases in future storm activity due to climate change appears inconclusive.

3.2 Storm events 2003–2009: Spatial analysis and trends

3.2.1 Spatial overview

In Europe, large storms tend to occur from October to April and, as indicated above, are associated with extra-tropical cyclones. These storms may cover an area extending from Scotland to the southern Alps and from the Atlantic to the Russian plain. Eventually, they may also affect lower latitudes, as they sweep from the Atlantic through southern France and the northern Iberian Peninsula. Recent examples of such large events include *Kyrill* (January 2007) and *Klaus* (January 2009), see Figure 3.1. According to data presented in the annual reports of insurance companies Swiss Re and Munich Re, winter storms over Europe are second only to hurricanes over the Caribbean and the southern United States in the ranking of world climatological events causing the largest insured losses.

3.2.2 Analysis of storm impact: human fatalities

Fatal events associated with storms are spatially rather diffuse (e.g. many are caused by trees falling on humans), although they naturally tend to concentrate in the areas where storm activity is more intense, especially in western and central European countries. During the period 2003–2009, according to the EM-DAT database, storms caused 292 deaths in Europe, half of them in the central part of the continent. Most of the deaths, for example during the storm Kyrill in the United Kingdom and in Germany, were traffic-related (e.g. overturning vehicles, collisions with fallen trees; Grundy, 2006) and individual accidents (being blown over, or struck by flying debris/masonry: cf. Baker and Lee, 2008; Baxter, 2005). A study of the wind-induced accidents involving road vehicles confirmed their

Table 3.1 Major storms in Europe, 1998–2009

Name of event	Date	Location	Impact
Cilly, Desirée and Fanny	January 1998	France, the United Kingdom - esp. Wales, Germany, Spain, Belgium, the Netherlands, Switzerland, Portugal, Austria and Poland	21 fatalities, EUR 600 million overall losses (EUR 460 million insured losses). Britanny and Loire (France) especially affected.
Anatol	December 1999	Germany, Denmark, Sweden, Lithuania, Poland, Estonia and Latvia	27 fatalities, EUR 3 billion overall losses (EUR 2.4 billion insured losses). More than 160 000 homes without power, considerable damage to Scandinavian and Baltic forests.
Lothar, Martin	December 1999	France, Switzerland, Germany, Denmark, Sweden, Poland, Lithuania, Austria and Spain	151 fatalities, about 3.5 million people affected, EUR 15.5 billion overall losses (EUR 8.4 billion insured losses). Generalised damages to housing and transportation systems, and the forestry sector,, especially in France, Switzerland and Germany.
Jeanett	October 2002	Austria, Belgium, Denmark, France, Germany, the Netherlands, Poland, Sweden and the United Kingdom	38 fatalities, over 60 000 affected. EUR 2.6 billion overall losses (EUR 1.7 billion insured losses). Thousands of trees uprooted and general disruption in power lines, roads, and railways.
Gudrun and Erwin	January 2005	Ireland, the United Kingdom, Denmark, Sweden, Norway, Finland, Germany, Estonia, Lithuania, Latvia, the Netherlands and Poland	16 fatalities. EUR 4.5 billion overall losses (EUR 2 billion insured losses). Most important event in southern Sweden in 100 years with heavy losses in the forestry sector.
Kyrill	January 2007	Germany, Austria Czech Republic, the United Kingdom France, Belgium Poland, the Netherlands, Denmark, Switzerland, and Slovenia	46 fatalities, EUR 7.7 billion overall losses (EUR 4.5 billion insured losses). Hundred of thousand of households in half a dozen countries affected by power cuts; forests heavily affected.
--	August 2007	Poland and Masurian Lakes	Heavy local storm with wind gust speed up to 130 km/h, causing 12 fatalities and more than 40 sailing boats to sink.
Emma	February 2008	Germany, Austria Czech Republic, Poland, Slovakia, Switzerland, and the United Kingdom	13 fatalities, EUR 1.3 billion overall losses (EUR 950 million insured losses).
Hilal	May-June 2008	Germany	Succession of hail storms in Western Germany; 3 fatalities, EUR 1.1 billion overall losses (EUR 800 million insured losses).
Klaus	January 2009	France, Spain and Italy	28 fatalities; EUR 4 billion overall losses (EUR 2.4 billion insured losses) > 1 million households with power cuts.
Wolfgang	July 2009	Switzerland, Austria, Poland, Czech Republic, Slovakia and Germany	Hailstorm with winds up to 130 km/h. 11 fatalities; EUR 1 billion overall losses (EUR 700 million insured losses). Damage to buildings, cars and some crops.

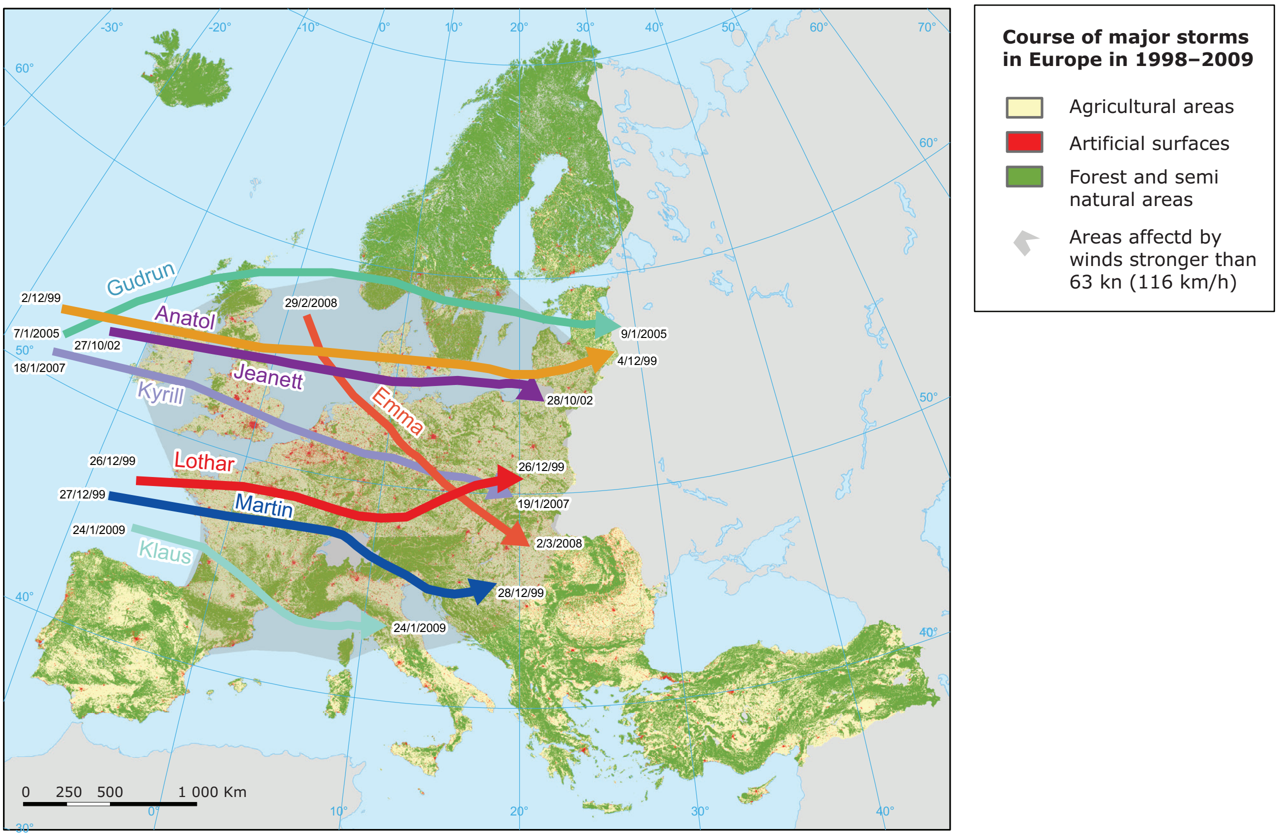
Source: EM-DAT, 2010 (fatalities); NatCatSERVICE, 2010 (overall and insured losses); EEA, 2004; EEA, 2008 and SwissRe, 2010.

vulnerability when being driven in wind gusts exceeding 20 m/s. Building failure represents a less significant, but still important, impact on human life (falling chimneys, collapse of structures), as evident from the collapse of a sports facility near Barcelona in January 2009 caused by the storm Klaus, in which five children were killed. Accidents that occur during the harvesting of fallen timber constitute yet another important cause of deaths following storms, as the harvesting risks are much higher during these periods than under normal conditions.

3.2.3 Analysis of storm impacts: economic losses

Storm events recorded between 2003 and 2009 caused an estimated overall loss of about EUR 20 billion. With the exception of the storm *Kyrill,* most of these events were of a rather local

Figure 3.1 Course of major storms in Europe in 1998–2009



Sources: ETC-LUSI based on EEA, 2004 and data and information from EM-DAT, 2010 and Fink et al., 2009.

importance, but nonetheless, still very damaging. Examples include the so-called *Hilal* series of storms over western Germany in the spring of 2008, and the storm *Gudrun* in southern Sweden in early 2005.

Direct economic damage (i.e. the tangible economic losses resulting from a storm, as determined after the event) normally result from the wind loading of structures such as property, vehicles, boats, scaffolding, cranes and overhead power networks (Barredo, 2010). The geographical scale of a large storm event is typically great, which explains the fairly high insurance market penetration for storm and hail damage in central Europe (between 75 and 80 % in German households, for instance), and also why insured losses are so significant — running into billions of euro.

Significant economic losses due to storm damage also occur in the forestry sector, as yet another major consequence of storms is uprooting trees. In the case of large events, the impacts may reach astonishing levels. Even in the case of relatively small and isolated storms, impacts on forests can escalate rapidly. For example, the *Gudrun* storm sweeping southern Sweden in January 2005, with winds in excess of 125 km/hour (the highest in the country since measurements began), produced 66 million cubic meters of storm-damaged wood. This figure is roughly equivalent to the annual timber harvest in Sweden. The storm *Kyrill* (see case study below) affected about 45 million m^3 of standing timber, which, overall, may seem a rather minor figure compared to the effects of previous storms, such as *Lothar* and *Martin* in 1999 — those caused the highest damage ever reported in Europe, amounting to nearly 200 million m^3 of merchantable timber (MCPFE, 2003). Nonetheless, the consequences in some countries, such as the Czech Republic, were overwhelming. Furthermore, storm events can also increase the number of dead trees by weakening the condition of trees still standing — they cause unknown damage to tree roots and increase susceptibility to attacks from fungi and insects, such as bark beetles.

According to the data provided by Schelhaas et al. (2003), the impact of storms on forests seems to have increased since the mid-19th century, although this trend may just reflect better reporting. At any rate, the main causes of any increased impacts are changes in forest composition and structure (e.g. the increase of coniferous forests and growing stock) as well as in an increase of forested area in certain regions (e.g. the United Kingdom), rather than an increase in storm frequency and severity (Lindner et al., 2008; Barredo, 2010). With regard to trends in economic losses, Barredo (2010) recently demonstrated that there is no trend in normalised losses caused by storm in Europe for the period 1970–2008. This confirms the view that the increasing storm-related losses of recent years are driven primarily by socioeconomic factors and increasing exposure (Barredo, 2010).

3.2.4 Impacts of storms on ecosystems

As indicated above, storms can affect forest ecosystems substantially. The ability to resist strong wind gusts depends on the tree and stand characteristics: height, diameter, crown area, depth of the root, species composition, tree density, site conditions such as soil properties, moisture and frost duration (see Lindner et al., 2008, p. 131; Mayer et al., 2005; UNECE, 2004). However, as is true for many other natural hazards, storms should be viewed as a disturbance in the natural dynamics of these ecosystems, and therefore, their impacts, from an ecosystems perspective, can, in many cases, be positive. Storms can increase the biodiversity of a forest ecosystem by creating a mosaic of small-scale forest patches at different stages, which results in forests with trees of varying ages. Such mixed-age forests are, in general, richer in biodiversity and more resilient than forests where the age of trees is uniform. Additionally, storms can enhance the provision of dead wood, which, in turn, can lead to species enrichment (see e.g. Duelli et al., 2002 on the positive effects of the storm *Vivian* on biodiversity in Swiss mountain forests).

Furthermore, and particularly in relation to large-scale events, storms can influence forest ecosystem services, such as the protection against natural hazards (e.g. rockfall), the availability and quality of drinking water or carbon sinks. For the latter, forests can even become a source of CO_2 generated by the rotting of unharvested timber, and the additional CO_2 released from the organic layer of the soil after removal of the canopy (Knohl et al., 2002; Kramer et al., 2004; Rusch et al., 2009). Another important impact of storms on ecosystems is the potential release of nitrate into the ground water (UNECE, 2004). While from the human perspective, most of the storm effects on ecosystem services are probably negative, the extent of the overall impact is, however, very difficult to assess.

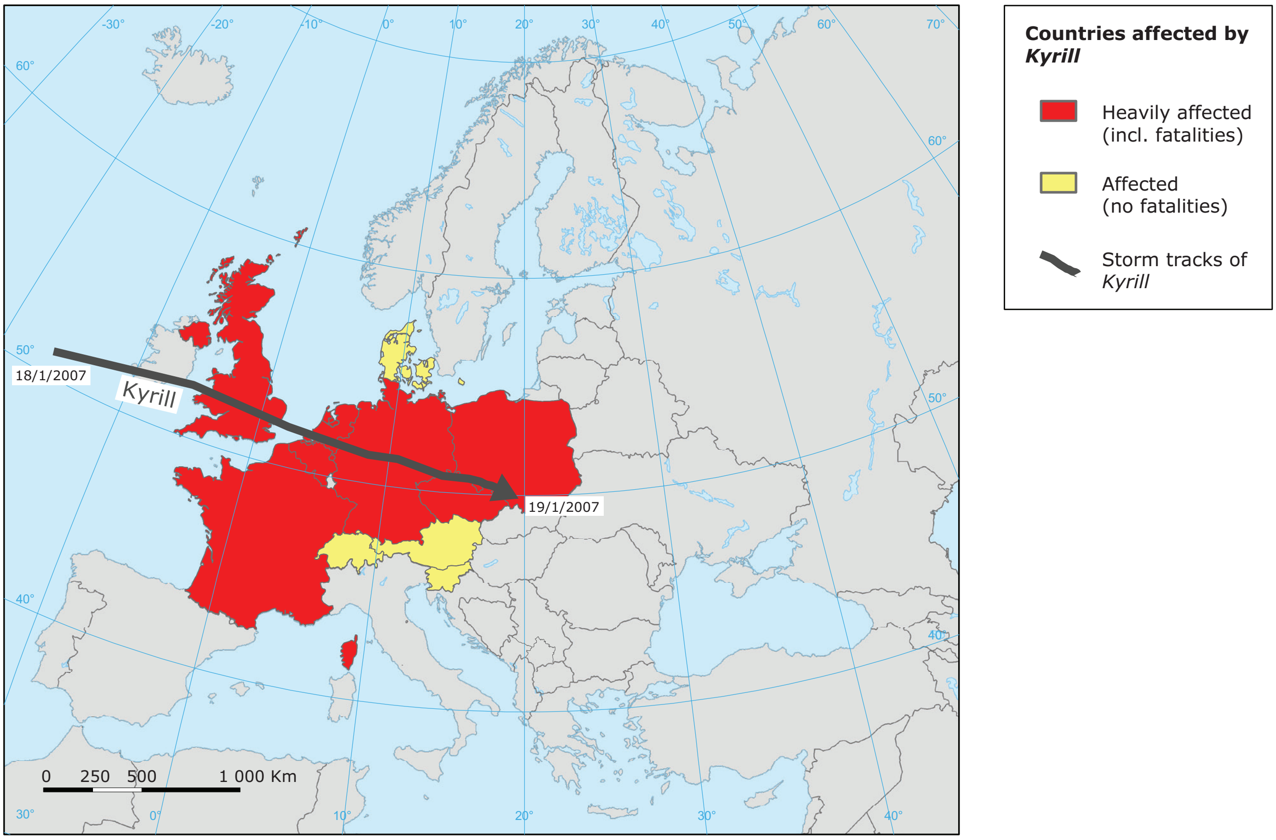
3.3 Case study: the storm *Kyrill* in central Europe (January 2007)

The winter of 2006–2007 had already witnessed above average storm activity in Europe when on the 17 January 2007 a new and unusually active low-pressure system formed over the north Atlantic and began its journey through the continent. It first swept across the United Kingdom, with maximum gusts of around 135 km/hour. Then it moved towards southern Denmark and Germany, from there to Poland and the Czech Republic, and finally reduced in intensity over the Russian plain. On the afternoon and evening of 18 January, peak gusts of 100 km/hour were widespread in Germany, the Netherlands, Belgium and other nearby countries. On the night of 18 January the storm shifted east and when in eastern Germany and Austria gained speed, with winds approaching 140 km/hour. Maximum wind speeds of 212 km/hour were recorded in the Krkonose Mountains on the border between the Czech Republic and Poland.

Kyrill is ranked among the most damaging extreme weather episodes ever recorded in Europe (see Figure 3.2). The storm caused 46 deaths and overall losses of almost EUR 8 billion (about EUR 4.5 billion insured losses); it was the most costly storm event since *Lothar* in 1999 (Munich Re, 2008a). *Kyrill* caused severe disruptions to infrastructures and communication networks in countries including Germany, Austria, Poland and the Czech Republic where more than 2 million households were left without electricity. Furthermore, *Kyrill* threatened several important economic sectors of eastern European countries, especially forestry in the Czech Republic.

Kyrill had a major impact on the central European forestry sector. It is estimated that about 62 million trees in central Europe, particularly Norway spruce in central Germany, were uprooted (see Figure 3.3). Timber left in the ground amounted to 25 million m^3 in Germany, 10 million m^3 in the Czech Republic, and 2.5 million m^3 in Poland. Overall losses were smaller than those caused by *Lothar* ten years before, but the concentration of major damage in certain countries made this event particularly catastrophic for some localities. The Czech Republic, for example, lost 65 % of its annual allowable timber cut, whereas some other countries with large absolute losses were much less severely affected as a proportion of their annual cut.

Figure 3.2 Countries affected by the storm *Kyrill*



Source: ETC-LUSI based on EM-DAT, 2010.

A state of emergency was declared for most of the south-west of the Czech Republic where state forests were particularly seriously affected. The Šumava National Park, located on the border adjacent to Germany and Austria and managed by the Czech Ministry of the Environment, lost about 700 000 m^3 of timber. The destruction of forest stands also had, initially, noticeable impacts on the local tourist economy as the number of visitors to the National park decreased in the ensuing months.

In Germany, the costs of *Kyrill* to forest owners were estimated at EUR 1 billion, although losses varied from region to region. The western German state of North Rhine-Westphalia suffered most and lost about 25 million trees. Many different types of stands were affected, including old stands with mainly Norway spruce and younger broadleaved stands, all dependent upon the exposure of the stand and the speed of gusts.

Figure 3.3 Effects of storm *Kyrill* in Germany

Source: NUA NRW, 2010.

Nevertheless, these figures are much smaller than those associated with storm *Lothar* (in 1999) and storms *Daria*, *Vivian*, and *Wiebke* (all in 1990). Moreover, economic conditions and a strong demand for timber and fuel wood eased the management of uprooted trees which were successfully marketed.

3.4 Management options to reduce storm impacts

3.4.1 *Measures*

As regards the impact on humans and infrastructure, storm management has traditionally focused on the ability to adapt to these events — by means of prevention (more resistant infrastructure), emergency planning (alerting and, eventually, evacuating the affected population) and post-disaster relief, including insurance.

Prevention in the form of erecting infrastructure capable of withstanding strong gusts of wind represents, perhaps, one of the best management options to curb losses from storms. During recent decades, Europe has seen major increases in investments in infrastructure. However, this spending has not always resulted in increased wind resistance. Infrastructures continue to collapse during storm events, for example the major loss of electricity pylons and interruption of electricity supply for 1.5 million households in France alone during storm *Klaus* in January 2009.

With regard to forest ecosystems, measures of prevention largely depend on forest management practices (Lindner et al., 2008). However, since storms are disturbances in the natural dynamic of forest ecosystems, their impact cannot completely be avoided — only reduced by sustainable forest management. Consequently, it is still likely that a large number of trees would be uprooted during a storm.

Emergency planning and management is already well developed and can be extremely effective. To a large extent, success of emergency measures depends on whether a storm is accurately predicted, especially its likely path and the timing of occurrence. As was demonstrated during *Kyrill* and *Klaus*, storms can be successfully predicted and reliable information can be used to alert the population. *Kyrill* was predicted days in advance which, at least in central Europe, helped to prevent more losses. Likewise, Météo France successfully predicted the magnitude and timing of *Klaus* in January 2009. Early warning and increasing the awareness of the potentially affected population should, therefore, become an important component of storm risk management, since both measures can significantly reduce the extent of damage. Nonetheless, in many instance countries have launched systems of early warning against natural hazards and awareness raising campaigns among local populations. Since those measures have been introduced only recently, they can be further improved with experience (see e.g. project OWARNA in Switzerland, FOEN, 2008a).

Finally, perhaps the most widespread storm-related management actions are post-disaster aid and insurance because a large number of public and private assets have usually been damaged or destroyed. Despite this, information on the costs of non-insured rehabilitation and the reconstruction of public infrastructure and services is relatively scarce. Insurance costs may be substantial but, within the overall framework of integrated risk management, those remain a relatively sound way of compensating for storm losses.

3.4.2 *Specific policy to reduce storm impacts*

At the present time there is no specific policy at the EU level aiming at reducing the impacts of storms. However, for some sectors, like forestry and forest management, initiatives exist on a national level (e.g. Guidelines on storm damage management in Switzerland; FOEN, 2008b) or at the level of Europe (e.g. Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change (EC, 2010) or the Declaration of the 2005 FAO workshop in Zvolen regarding policy options for storm damage management (FAO, 2005)).

Additionally, policies or courses of action for storm risk management might emerge during the development of strategies for climate change adaptation, as has already happened in some regions. For instance, the climate change adaptation strategy for North Rhine-Westphalia maps out a course of action to reduce storm impacts in different sectors (MUWLV, 2009). Climate change seems to justify some actions at the European level because storm events are often devastating and can even severely strain national capacities. This recently proved to be the case (March 2010) when, as a result of storm *Xynthia*, France applied for EU Solidarity Fund aid.

3.5 Data gaps and information needs

Storms are probably the natural hazard that affects the everyday life of Europeans most, and the hazard that generates the greatest volume of insurance claims. In central and western Europe, at least, the data on private economic losses appear to be fairly reliable, since a mature insurance market for storm protection has been developed there. However, no comprehensive database on the overall impact of storms in Europe currently exists. Barredo (2010) therefore had to merge different sources of information in order to obtain a sound database on economic loss due to storms. Clearly, policymaking in the field of natural hazards and disasters must be based on a thorough understanding of disasters and be supported by accurate long-term data and assessments (EC, 2009). Therefore, monitoring of the impacts of hazards with a view to accumulating reliable, accurate and comprehensive data should become a priority.

Moreover, better valuation methods are needed to assess the overall costs of storm events in a more comprehensive way. This is particularly the case when it comes to losses in specific sectors (e.g. public or forestry sectors), the monetisation of forest ecosystem services affected by storms, or assessments of the indirect, secondary and tertiary costs of such storm events.

4 Extreme temperatures events

Key messages

- In the period under review, heat waves have been the most prominent hazard with regard to human fatalities. In total, more than 70 000 excess deaths were reported in Europe during the hot summer of 2003, and heat waves in the summers of 2006 and 2007 together showed an increase in excess deaths of almost 3 000 fatalities. As regards cold spells and extreme winter conditions, several events have caused about 1 900 fatalities in Europe from 1998 to 2009.
- The elderly and infirm are more at risk, and socio-economically deprived population groups are more vulnerable. In congested urban areas with high levels of soil sealing and heat absorbing surfaces, the effects of heat waves can be exacerbated as a result of insufficient nocturnal cooling and poor air exchange.
- Extreme temperature events are normal features of inter-annual temperature variability, but their frequency and intensity have increased. High-temperature extremes have become more frequent, while low-temperature extremes have become less frequent.
- Climate change is projected to increase the frequency and intensity of heat waves further, which could lead to significant consequences for human health, as mortality has been estimated to increase by 1–4 % for every 1 °C increase above a location-specific temperature threshold. In contrast, in view of ongoing climate change, cold-related deaths are projected to decrease but this is unlikely to compensate for the increase in fatalities from heat waves. Overall, it will be crucial to reduce the vulnerability of the population and the relevant infrastructure in the long term.
- Information needs related to extreme temperature events include: projections of impacts of future extreme temperature events on human health (an area where there are still large uncertainties); projections of age distribution, incidence rate and population data; and coherent scenarios combining projections of climate change with socio-economic scenarios relevant for human health. Additionally, sharing of data and experiences related to extreme temperature events (e.g. heat-health action plans) should be improved.
- In the follow-up of the 2003 events, the health sector has started several actions (such as Heat Action Plans). Those are aimed at reducing the impact of extreme temperature events. Management options to reduce the direct impact of extreme temperature events should focus on preparedness but also early warning and intervention right before and during the event, since fatalities due to extreme temperature events are thought to be largely preventable. In the long term, the reduction of the vulnerability of the population and relevant infrastructure is crucial.
- The most recent policy actions include the 2009 European Commission Staff Working Document on climate change and human health and a new European regional framework for action, entitled 'Protecting health in an environment challenged by climate change'. The latter was agreed at the Fifth pan-European Ministerial Conference on Environment and Health in 2010.

4.1 Introduction

4.1.1 *Definition (including main causes)*

Extreme temperature events are extremes in the inter-annual temperature variability and can become manifest at both ends of the temperature scale, resulting in high-temperatures extremes like hot/warm spells or tropical nights, or low-temperature extremes like cold spells or frost days.

According to EM-DAT (2010a), a hot/warm spell or *heat wave* is a prolonged period of excessively hot, and sometimes also humid, weather relative to normal climate patterns of a certain region. Due to the fact that the term is relative to the usual weather conditions in a given area, there is no universal definition of a heat wave e.g. in terms of a temperature threshold that has to be reached for a number of consecutive days. Nevertheless, suggestions for a generic definition do exist. For example, the European Climate Assessment and Dataset project (ECA&D, 2010a) defines a warm spell as a period of at least six consecutive days on which the mean daily temperature exceeds the 90th percentile of the baseline temperature (average daily temperature in the 1961–1990 period). The WHO EuroHEAT project proposed the qualitative definition of a heat wave as 'a period when maximum apparent temperature and minimum temperature are over the 90th percentile of the monthly distribution for at least two days' (WHO, 2009).

A *cold spell* can be both a prolonged period of excessively cold weather and the sudden invasion of very cold air over a large area (EM-DAT, 2010a). A cold spell can be defined as a period with more than six consecutive days with minimum temperature below the 10th percentile of daily minimum long-term temperature (e.g in the period from 1961 to 1990) (EEA-JRC-WHO, 2008). In Europe, low temperatures mainly cause damage to agriculture, infrastructure and property. Cold spells are often associated with extreme winter conditions defined as 'damage caused by snow and ice. Winter damage refers to damage to buildings, infrastructure, traffic (especially navigation) inflicted by snow and ice in the form of snow pressure, freezing rain, frozen waterways, etc.' (EM-DAT, 2010a).

4.1.2 Sources of information

This chapter is primarily based on the data from the EM-DAT database (EM-DAT 2010b), the joint EEA-JRC-WHO report on *Impacts of Europe's changing climate* (EEA-JRC-WHO, 2008) and some subsequent information sources.

4.1.3 Extreme temperatures events in Europe 1998–2009

European populations are exposed to climate change directly — through changing weather patterns, and indirectly — through changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods and infrastructure (Confalonieri et al., 2007). These direct and indirect exposures can result in a variety of health impacts (Menne et al., 2008). This sub-section focuses on the direct effects of extreme temperature events on human mortality rates.

For the period under review, heat waves have been the most prominent weather-related extreme temperature events in terms of causing human fatalities. In total, more than 70 000 excess deaths were reported in western and central Europe in the hot summer of 2003 (June to September, Robine et al. 2007 and 2008). Heat waves were also responsible for many fatalities in the summer of 2006 in western Europe and in the summer of 2007 — in (south-) eastern Europe (see Table 4.1).

Between 1998 and 2009, cold spells caused about 1 900 fatalities (see Table 4.1). The winters of 2001 and 2005 saw particularly significant impacts, with more than 430 and 440 fatalities respectively (see Table 4.1).

4.1.4 Extreme temperatures events and climate change

Climate change has already influenced the frequency and intensity of extreme temperature events. High-temperature extremes like hot days, tropical nights and heat waves have become more frequent, while low-temperature extremes (e.g. cold spells and frost days) have most likely become less frequent (ECA&D, 2010b; IPCC, 2007a). The average length of a summer heat wave over western Europe doubled over the period from 1880 to 2005 and the frequency of hot days almost tripled (Della-Marta et al., 2007). The number of warm extremes has been increasing twice as fast over the last 25 years. This is in line with the general trend in Europe, warming more than the global average. In 2009, the average European land temperature increased by 1.3 °C compared to the 1850–1899 average value (ECA&D, 2010b). The temperature changes have been most significant in south-western, central and north-eastern Europe, and in mountainous regions.

Along with the overall warming, extreme high-temperature events across Europe are projected to become more frequent, more intense and to last longer (Tebaldi et al., 2006; IPCC, 2007a and 2007b; Beniston et al., 2007; van der Linden et al., 2009). Geographically, the maximum temperatures during summer are projected to increase far more in southern and central Europe than in northern Europe, whereas the largest reduction in the occurrence of cold extremes is projected for northern Europe (Kjelström et al., 2007; Sillman and Roekner, 2008; van der Linden, 2009). For example, central Europe is projected to experience the same number of hot days as are currently experienced in Spain and Sicily by the end of the 21st century under the A2 scenario (Beniston et al., 2007). According to the ENSEMBLES RCM scenarios for 2071–2100 (van

Table 4.1 Major events of temperature extremes events in EEA-32 ([a]), 1998–2009

Date of the event	Country/region	Event type	Impacts
Jul/Aug 1998	Italy, Romania	Heat wave	30 fatalities
Nov 1998	Romania, Bulgaria, Poland	Cold spell	127 fatalities
Jun 1999	Lithuania	Heat wave	32 fatalities
Oct 1999	Poland	Cold spell	154 fatalities
Jun/Jul 2000	Bulgaria, Greece, Romania, Turkey, Cyprus	Heat wave	56 fatalities
Dec 2000	Poland	Cold spell	84 fatalities
Oct/Dec 2001	Poland, Latvia, Lithuania, Hungary, Romania, Turkey	Cold spell	431 fatalities
Oct 2002	Poland	Cold spell	183 fatalities
Dec 2002/Jan 2003	Romania, Latvia	Cold spell	25 fatalities
Jul/Aug 2003	Austria, Belgium, Czech Republic, France, Germany, Italy, Luxembourg, the Netherlands, Portugal, Slovakia, Slovenia, Spain, Switzerland, United Kingdom	Heat wave	> 70 000 fatalities
Jan 2004	Turkey	Cold spell	10 fatalities
Jul 2004	Romania, Spain	Heat wave	66 fatalities
Jul/Aug 2005	Romania	Heat wave	13 killed
Nov 2005/Feb 2006	Austria, Belgium, Bulgaria, Czech Republic, Estonia, France, Germany, Hungary, Italy, Latvia, the Netherlands, Poland, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom	Cold spell and extreme winter conditions	440 fatalities
Jun/Jul 2006	Belgium, France, Germany, the Netherlands, Portugal, Romania, Spain	Heat wave	More than 2 400 fatalities
Jun/Jul 2007	Austria, Bulgaria, Greece, Hungary, Italy, Romania, Slovakia, Turkey	Heat wave	567 fatalities Forest fires in Greece
Dec 2007/Jan 2008	Bulgaria, Hungary, Romania	Cold spell	65 fatalities
Nov 2008/Jan 2009	Belgium, France, Germany, Poland, Portugal, Romania	Cold spell	132 fatalities
Nov 2009/Jan 2010	Austria, France, Germany, Italy, Poland, Romania, the United Kingdom	Cold spell	244 fatalities

Note: ([a]) Thirty-two EEA member countries, i.e. the EU-27 Member States together with Iceland, Liechtenstein, Norway, Switzerland and Turkey.

Source: EM-DAT, 2010b.

der Linden et al., 2009), the number of days with apparent temperatures exceeding 40.7 °C (heat index) will double in most parts of southern Europe.

With heat waves projected to become more common, mortality has been estimated to increase by 1–4 % for every 1 °C increase above a location-specific temperature threshold (WHO, 2008). The elderly and the disabled are at greater risk, and socio-economically deprived population groups are more vulnerable (Kirch et al., 2005; EC, 2008). The PESETA project estimated that by the 2080s, heat-related mortality resulting from projected climate change would be between 50 000 and 160 000 cases per year, mainly in central and southern European regions (Watkiss et al., 2009). The PESETA project also estimated the decrease in cold-related mortality to be between 100 000 and 250 000 cases per year by the 2080s. Once acclimatisation factors are taken into account, these estimates can be substantially reduced, although the short-term and long-term role of acclimatisation is still being debated (WHO, 2004).

4.2 Extreme temperatures events in 2003–2009: spatial analysis and trends

4.2.1 *Spatial overview*

Between 2003 and 2009, 23 of the 32 EEA member countries were affected by extreme temperature events. In terms of number of events, Romania was affected the worst, followed by France and Germany.

Regarding heat waves, the most extreme events occurred in 2003, 2006 and 2007. The 2003 event is described in Section 3. The 2006 heat wave was a period of exceptionally hot weather that arrived at the end of June and in some countries persisted until the end of July. In terms of fatalities, Belgium, France and the Netherlands were most affected. Several temperature records were broken. In the Netherlands, Belgium, Germany, Ireland and the United Kingdom, July 2006 was the warmest month since official measurements began. The 2007, heat wave affected most of southern Europe and the Balkans as well as Turkey. During the end of June, temperatures in Greece exceeded 40 °C for seven straight days. From 21–25 July, most parts of Greece, Italy, Bulgaria, Romania and Serbia had soaring temperatures exceeding 45 °C. In the beginning of August, extreme temperatures reached Croatia as well.

Cold spells occur relatively frequently in Europe and took place every year during the period studied. The years of 2001, 2005–2006 and 2009–2010 stand out as particularly intense in terms of fatalities. Various episodes have affected most European countries, especially in the central and eastern parts of the continent. Poland, in particular, tends to register the most extreme temperatures events, with values dropping down, for instance, to – 35 °C in January 2006 (the coldest winter in 30 years) or – 32 °C in December 2008.

4.2.2 *Impacts of extreme temperature events on human health*

In the wake of the 2003 event in Europe there has been a wealth of research on how heat waves affect human health. Some people are less able to cope with heat stress than others. A wide range of chronic diseases (including being confined to bed) and medical treatments, social isolation and some types of occupation increase the risk of heat stress for individuals. Across Europe, the influence of heat on health varies in accordance with housing and socio-economic conditions. Public health authorities need to identify and target particularly vulnerable groups and individuals. Urban areas are particularly affected by heat waves due to higher population numbers and densities. Another important factor that increases the impact on urban areas is the urban heat island effect. An urban heat island is a metropolitan area that is significantly warmer than its surrounding rural areas, with air temperatures 1–5 °C higher than in a nearby rural area.

The timing, intensity and duration of heat waves have been shown to influence mortality figures, with long and intense heat waves (more than 4 days) producing a mortality of 1.5–5 times higher than during short heat-waves (Matthies et al., 2008). In the nine European cities analysed by EuroHEAT (Athens, Barcelona, Budapest, London, Milan, Munich, Paris, Rome and Valencia), the estimated increase in mortality during heat-wave episodes ranged from 7.6 % to 33.6 % (WHO, 2009).

Additionally, major heat waves are often associated with other health hazards such as air pollution, which can also have adverse health effects and, thus, implications for a public health action. For instance, the combined effect of heat waves and peaks of ozone or fine particulate matter (PM_{10}) (10) air pollution increases mortality (WHO, 2009). The effects of heat wave days on mortality are larger when levels of ozone or PM_{10} are high, particularly among the elderly (75–84 years). The total daily number of deaths in this age group increased by 16.2 % on heat wave days with high ozone levels, and by 14.3 % on days with high PM_{10} levels, respectively, compared to an increase of 10.6 % and 10.5 % on days with low levels of ozone and PM_{10}.

There is less information on the health effects of cold events in Europe. Prolonged exposure to cold, often associated with insufficient clothing or physical activity, may result in whole-body cooling, which, in turn, results in a decrease in core temperature. This type of cooling is enhanced by exposure to wind or cold water, which increases the convective heat loss from human to the environment (Hassi et al., in preparation).

Three health studies on impacts of cold spells show the following. The first is an episode study of the effect of cold spells on the Dutch population. The average excess mortality during the cold spells was 12.8 % or 46.6 deaths/day, which was mostly attributable to the increase in cardiovascular mortality and mortality among the elderly (Huynen et al., 2001). The second is an episode study of cold spells in the Czech Republic (defined as periods of days on which air temperature was less than – 3.5 °C). Surprisingly, the relative mortality effects were most pronounced and most direct in adult men (25–59 years) (Kysely et al., 2009). The third, and most recent, study is UK-based and suggests that increases in the risk of myocardial infarction at colder ambient temperatures may be one driver of cold-related increases in the overall mortality (Bashkaran et al., 2010).

Accidental cold exposure in temperate and cold climates occurs mainly outdoors and mostly affect the socially deprived (alcoholics, the homeless), outdoor workers and the elderly (Ranhoff, 2000). In countries with populations well adapted to cold conditions, cold waves can still cause increases in mortality if electricity or heating systems fail. Generally, most European countries have 5–30 % higher death rates in winter than in summer, although there is sizable

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(10) With a diameter under 10 µm.

variation. The United Kingdom, for example, appears to have a larger seasonal fluctuation in mortality than many other countries of continental Europe and Scandinavia, despite the fact that it has relatively mild winters. Other countries with high rates of 'excess' winter mortality in Europe are Portugal and Spain. Winter-related mortality in many European populations has declined since the 1950s. The increased warming explains only a small part of this reduction: improved home heating, better general health and improved prevention and treatment of winter infections have played a more significant role (Carson et al., 2006). As is the case with heat, the risk of cold-related death rises steeply with age. Although highest among the elderly, it is not confined to people over the age of 70 years.

In addition to the effects on human health, extreme temperature events have had serious impacts on economic sectors such as agriculture, forestry or tourism. The hot summer of 2003 in Europe, for example, has been estimated to have led to EUR 10 billion of economic losses to farming, livestock and forestry from the combined effects of drought, heat stress and fire (EEA-JRC-WHO, 2008).

4.3 Case study: summer of 2003

Much of Europe was affected by a heat wave during the summer of 2003 (June, July and August). It is estimated that this was the hottest summer since at least 1500 (Luterbacher et al., 2004). Seasonal temperatures were the highest on record in Germany, Switzerland, France and Spain. Average summer (June–August) temperatures were far above the long-term mean, by up to five standard deviations, implying that this was an extremely unlikely event under current climatic conditions (Schär and Jendritzky, 2004). Hot summers like 2003 may, however, become much more frequent during the second part of the 21st century (Beniston, 2007; Dankers and Hiederer, 2008; van der Linden et al., 2009).

The 2003 heat wave was associated with a particular pattern of air pressure field over Europe, leading to an advection of hot air from the south which reinforced the strength and persistence of the heat waves. Nearly all radiation from the sun was converted to heat because of the soil and vegetation dryness. At many locations, day-time temperatures rose to more than 40 °C. In the European Alps, the average thickness loss of glaciers reached about 3 m in water equivalent, nearly twice as much as during the previous record year of 1998 (WMO, 2004; see EEA-JRC-WHO, 2008). Annual precipitation deficits of up to 300 mm caused droughts in many areas which resulted in reduced agricultural production (see EEA-JRC-WHO, 2008), more extensive forest fires (Portugal, Chapter 5), and record low levels of many major rivers (e.g. Po, Rhine, Loire and Danube; see EEA-JRC-WHO, 2008). As shown comprehensively by the Canicule study, for summer 2003 twelve European countries reported more than 70 000 deaths in excess of the average for five preceding summers (Robine et al., 2008).

4.4 Management options for reducing impacts from extreme temperature events

4.4.1 Measures

Management options for reducing the direct impact of extreme temperature events should focus on preparedness, but also early warning and intervention right before and during the event, since fatalities due to extreme temperature events are thought to be largely preventable (EuroHEAT-project for heat waves; WHO, 2009). In the long term, it is crucial to ensure that the vulnerability of the population and relevant infrastructure are reduced. This can be achieved by improving urban planning and architecture (e.g. increasing the canopy cover in the urban area, which may reduce air temperature by 1–3 °C in case of heat waves) as well as energy and transport policies. Such improvements should start being implemented now, as the lead time for policy development is very long. Heat wave effects can be reduced by keeping indoor temperatures low, keeping out of the heat, keeping the body cool and hydrated, and helping others. Moreover, the mortality due to the combined effect of heat and air pollution can be reduced, to a certain extent, by decreasing exposure to ozone and PM_{10} on hot days. However, using up-to-date technologies, such as diesel particulate filters, provides a more sustainable solution for permanently reducing ozone and PM_{10}.

Extreme temperature events often result in excess demand for health services, which can trigger a health crisis due to a mismatch between demand and available resources. Integrating plans to ensure preparedness and response to extreme temperature events (such as heat-health action plans developed in many countries in the wake of the 2003 heat wave) into generic programmes of preparedness for all-hazard emergencies can help hospitals and health facilities prepare.

Timely activation of emergency mechanisms would help to minimise the public health impacts of extreme temperature events. Planning is therefore essential to ensure health care system preparedness. It should be achieved in collaboration with weather services, thus providing accurate, timely weather-related health alerts. Strategies are needed to reduce the heat exposure of individuals and communities (especially vulnerable populations), to plan health and social services and infrastructure, and to provide timely information to the population (Matthies et al., 2008).

4.4.2 Policy

The European Commission White Paper on adaptation to climate change (EC, 2009a) presented a framework for adaptation measures and policies to reduce the EU's vulnerability to the impacts of climate change. The paper emphasises the need to integrate measures to ensure adaptation to climate change into all EU policies. The Commission presented a separate paper (EC, 2009b) on climate change and human health, which also included animal and plant health. This paper describes the policy means currently in place, and the key steps that the EU will have to take to tackle the problem in the most effective way possible, given the tools and financing plans available.

The countries represented at the Fifth pan-European Ministerial Conference on Environment and Health in Parma, Italy, (10–12 March 2010) adopted a declaration committing to implement national programmes to provide equal opportunities for each child by 2020 by ensuring access to safe water and sanitation, opportunities for physical activity and a healthy diet, improved air quality and an environment free of toxic chemicals. Governments also agreed to tackle the adverse health impact of climate change and to reduce social and gender inequalities in exposure to risk. A new European regional framework for action was agreed under the title 'Protecting health in an environment challenged by climate change'. The document provides a comprehensive road map laying out steps and priorities for coordinated international and national action (WHO, 2010).

It includes five main objectives:

- to ensure that all current and future measures, policies and strategies for mitigation of and adaptation to climate change integrate health issues at all levels;
- to strengthen health care, social and environmental systems and services to improve their capacity to prevent, prepare for, and cope with climate change (including early-warning surveillance and preparedness systems for extreme weather events);
- to raise awareness to encourage healthy mitigation and adaptation policies in all sectors;
- to increase the health and environment sectors' contribution to reducing greenhouse gas emissions;
- to share best practices, research, data, information, technology and tools at all levels where it concerns climate change, environment and health.

EU Member States and the Commission said at the conference that they would ensure that synergies between EU level actions and those arising from the Parma Conference are fully exploited.

4.5 Data gaps and information needs

Projections of impacts of future extreme temperature events on human health still contain large uncertainties. Acclimatisation, i.e. the physiological adaptation to changes in climate or environment (e.g. temperature), might partly decrease the projected adverse effects (excess numbers of deaths); however its role is still being debated. There are also many uncertainties in projections of age distribution, incidence rate and population data. More effort could be undertaken to develop coherent scenarios that combine projections of climate change with socio-economic scenarios relevant for human health.

Given the seriousness of the impacts of extreme temperatures events as evidenced by the events in recent years, there is a need to implement measures in all parts of the disaster risk management cycle, but particularly the preparedness part.

There is also a need to improve the exchange of experiences in implementing measures, such as heat-health action plans, in countries and regions across Europe. The EU Clearing House on Adaptation, due to be in place by 2011 (as mentioned in the White Paper), is expected to include information on impacts, vulnerability and adaptation actions regarding health and climate change, including heat waves. It could thus support better sharing of data and experiences. WHO Europe, in collaboration with partners, such as the European Commission, the EEA and the European Centre for Disease Prevention and Control, is expected to develop an information platform on climate change and health. There is a need to improve synergies between the planned WHO information system and the EU Clearinghouse.

5 Forest fires

Key messages

- An average of 70 000 fires take place every year burning more than half a million hectares of the forested areas in Europe. Large fire episodes that lasted several days occurred recently in Portugal (2003, 2005), Spain (2006) and Greece (2007), the latter causing 80 fatalities.
- In the period 1998–2009, no clear trend regarding the areas burnt by forest fires could be detected, even if a small decreasing trend in the number of fires was observed. However, fire events show increased intensity and impacts in the last years with a high number of fatalities (1998–2009: 307) and large economic damages (approximately EUR 1.5 billion per year). The impacts of the fires largely vary from year to year and most of the damages are normally caused by a few large fires (e.g. in 2003 or 2007).
- Since its establishment in 1998, the European Forest Fire Information System (EFFIS) has evolved into a comprehensive information source for forest fires in Europe. When contrasted to data from EM-DAT, substantial differences are apparent in terms of the number of fire events included in the databases as well as the overall impact of fires reported.
- Further developments in the context of EFFIS include a more profound understanding of the socio-economic impact of forest fires, harmonisation of the nomenclature of forest fire causation at the European level and better estimates of forest fire emissions and resulting impacts on populations.
- Specific forest fire policies exist in most EU Member States, but a harmonisation of these policies at the European level has not yet been achieved. Nevertheless, forest fire prevention policies were established at the EU level in 1992.
- To address the increasing intensity and possible impacts of forest fires, it is imperative that forest fire management were improved in an integrated way. Thereby, a particular focus should be on forest fire prevention measures.

5.1 Introduction

5.1.1 Definition (including main causes)

Forest fires are a recurrent phenomenon in Europe and on other continents. Fires are a natural disturbance, which are essential for the regeneration of certain tree species and ecosystem dynamics. In addition, fire has been used in the environmental context for many purposes, including shrub removal in the forest and straw burning in agriculture. However, fire events show increased intensity and produce more serious impacts. The reasons for this change are manifold, such as fundamental changes in land-use and demography. In the Mediterranean Region, for instance, the abandonment of traditional forest management practices and the suppression of fires for decades led to an accumulation of fuels in the forests, leading to more intense fires. Once these fires are ignited under high fire danger conditions that facilitate fire spread, they cannot be stopped. Despite the significant number of fire fighting resources used to extinguish them, large fire episodes that lasted several days occurred recently in Portugal (2003, 2005), Spain (2006) and Greece (2007). Although fires also take place in central and northern Europe, the conditions of fire spread in these areas are often mild, allowing for fire control and extinction without major damages.

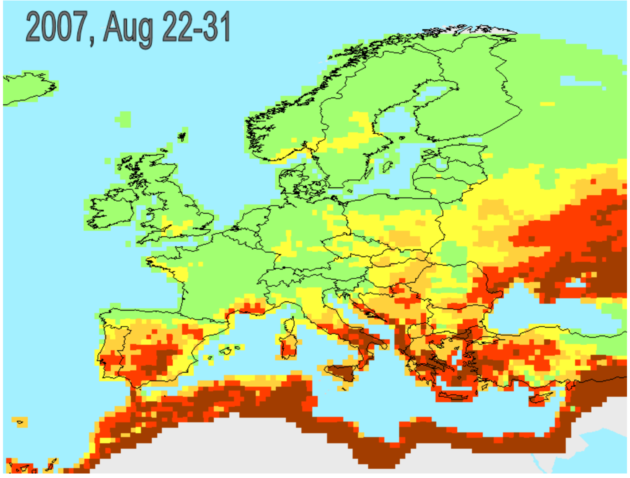
Over 95 % of the fires are caused by humans, either deliberately (e.g. malicious arson) or by negligence/accident. Important causes of this latter category include escaped fires associated with agricultural practices, such as straw or shrub burning, forest debris burning or pasture renewals, engine sparks, careless use of recreational fires, electric power lines, railways and cigarettes.

Despite the human causality, fire ignition and the subsequent spread are mainly driven by the presence of fuels, and the meteorological conditions that determine the dryness of the fuels. Fire ignition and spread are both enhanced by cumulated drought, high temperature, low relative humidity and the presence of wind. These factors are the essential components for the computation of what is known as fire danger indices, used to predict the degree of danger of fire occurrence and spread (Camia et al., 2008). Figure 5.1 shows a fire danger map of Europe as estimated by the Canadian Fire Weather Index for the European Forest Fire Information System (EFFIS, 2010). Work at the European Commission Joint Research Centre has shown a very high correlation between fire danger and monthly burnt areas in the European Mediterranean region (Camia and Amatulli, 2009).

5.1.2 *Sources of information*

This chapter is based on data from EFFIS (2010) that provides detailed analysis of fire events for the European region. The EFFIS data include statistical data reported by the European Member States and constitute the official data source on forest fires. In respect of the most damaging fires involving human casualties, the EFFIS data show substantial differences with the number of fire events included in EM-DAT (2010). The same is true in respect of the overall impact of fires reported in EM-DAT. These substantial differences are very likely to occur due to the fact that EM-DAT only includes major events that fulfil its specific entry thresholds (see Chapter 1), whereas EFFIS records all data reported by the Member States. Thus, in consequence and in order to provide a comprehensive overview on the impact of forest fires, EFFIS data have been adopted for the present report.

Figure 5.1 Fire danger map based on the Canadian Fire Weather Index during the large fire episodes in Italy and Greece, 2007



Source: EFFIS, 2010.

5.1.3 *Forest fires in Europe 1998–2009*

An average of 70 000 fires take place every year burning more than half a million hectares of the forested areas in Europe; in critical years, e.g. 2007, this figure can increase to 1 million hectares. However, systematic data collection about forest fires at the national level does not always take place outside the European Union Member States, which prevents a more detailed analysis of fires in a wider European context.

Fire activity and fire effects are concentrated in the European Mediterranean Region. About 70 % of fires occur in this region, and they are responsible for 85 % of the total burnt area of Europe. Although fire frequency shows three peaks during the year, i.e. winter fires in the mountain regions, spring fires related to agricultural practices, and summer fires closely related to high temperatures and summer drought, most fire damage occurs in the summer period, that is, during July, August and September.

Table 5.1 shows the number of fatalities in the EU Member States during the reporting period. These official figures were extracted from the EFFIS reports produced by the relevant fire services in the member states.

Figure 5.2 illustrates the trend of forest fires in 1998–2008 for the European Mediterranean Region. This graph does not show a clear pattern in the trends of burnt areas during the decade, although a slight decreasing trend is observed concerning the number of fires. Among various member states, large differences also exist from year to year (EC, 2008). It should be noted that most fires in Europe are small. Most of the damage caused by forest fires is due to large fires. This explains the reason why the number of fires in 2003 or 2007 was not very high, while the overall damage caused by them was extremely large.

Table 5.1 Number of fatalities caused by forest fires in EU Member States

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Portugal	3	1	4	21	2	18	11	6	3	7
Spain	6	0		9	5	17		1		12
France	9	4		10	2	6			0	0
Italy	2	3	5	7	2	3	1	23	3	4
Greece	10	4	0	1	2	0		80		0
Total	**30**	**12**	**9**	**48**	**13**	**44**	**12**	**110**	**6**	**23**

Source: EFFIS, 2010.

5.1.4 Forest fires and climate change

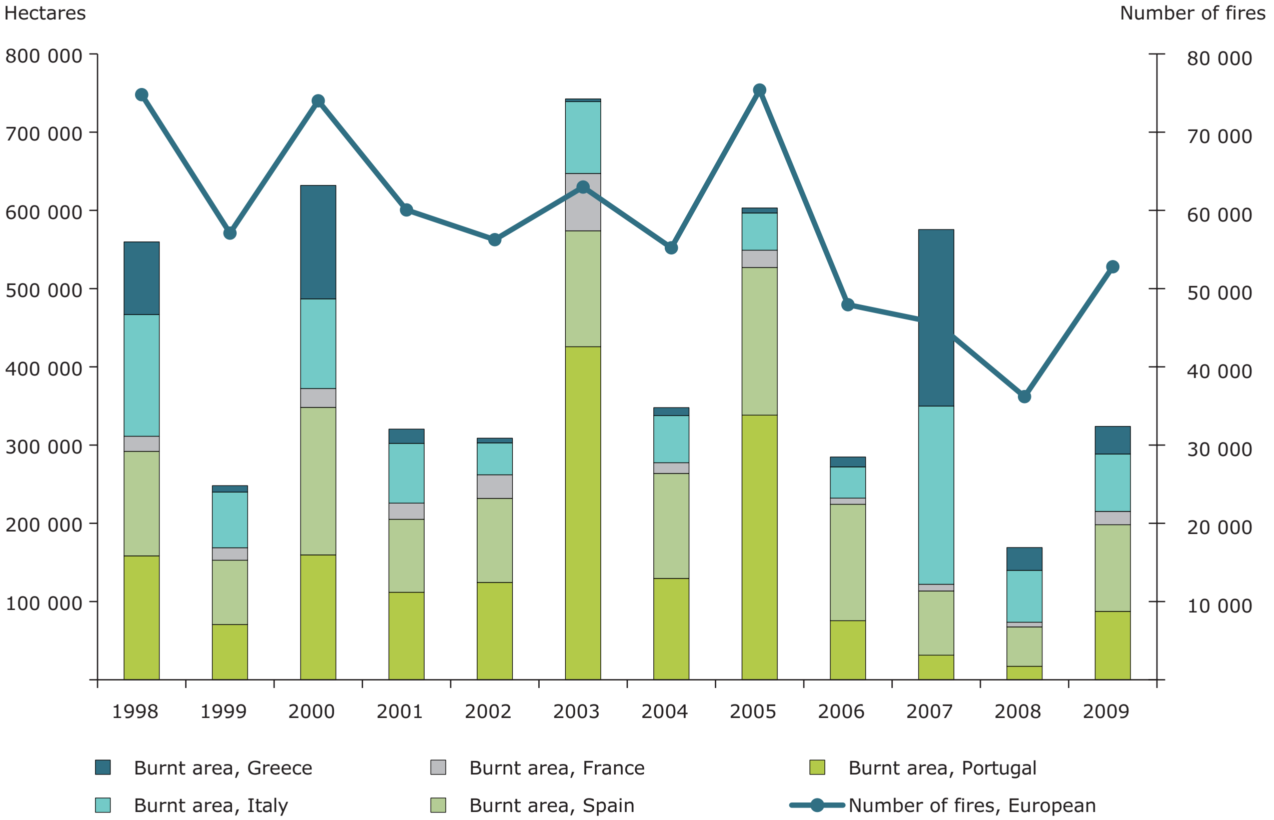
In Europe, climate change is thought to enhance the frequency of favourable conditions for forest fires and to extend the fire season in both time and space (Camia et al., 2008; Lavalle et al., 2009). Fire seasons will start earlier and will finish later in the year. Additionally, higher temperatures in central and northern latitudes could enhance fire probability in these areas, thus expanding the areas subject to forest fires. For instance, some large fire episodes occurred in Sweden and Norway in 2008 (EC, 2009) in the wake of unusually dry and warm weather conditions in late spring. Fires in Sweden spread quickly under strong wind conditions with spotting of firebrands of 50 to 100 m. In the case of Norway, a single fire burnt approximately 2 000 ha, creating the largest fire recorded in the country in the last half century.

5.2 Forest fire occurrence in Europe: spatial analysis and trends in 2003–2009

5.2.1 Spatial overview

Detailed mapping of fires larger than approximately 40 ha is undertaken on the basis of satellite imagery

Figure 5.2 Number of fires and burned area in southern Europe



Source: EFFIS, 2010.

(San-Miguel-Ayanz et al., 2009a). However, this cartography of forest fire impact extends back only to the year 2000. The EFFIS map of the fires between 2003 and 2009 is provided in Figure 5.3.

Although the analysis of forest fires in Europe shows a clear concentration of fires and burnt areas in the Mediterranean Region, the variability is very high within this region (San-Miguel-Ayanz and Camia, 2009b). For the period under examination, the most significant episodes of concentrations of burnt areas in a single country took place in Portugal in 2003, and in Greece in the year 2007. There is a very high correlation between fire danger, as derived from meteorological variables, and burnt areas. Fire episodes have occurred under critical weather conditions that favoured fire ignition and spread (Camia and Amatulli, 2009).

5.2.2 *Analysis of forest fire impacts: Fatalities and economic losses*

The major damage caused by forest fires is the loss of human life. As presented in the preceding chapters, recent years have shown a marked increase in human casualties. This was the result of fires with very high intensity that occurred under critical weather conditions leading to extreme fire danger levels. The analysis of human casualties and fire accidents is very complex. However, recently a study of major fire accidents has been published under the umbrella of EFFIS (Viegas et al., 2009). According to its authors, fire entrapment is the major threat posed by a forest fire, and this usually is a result of interaction between human behavior and fire behavior, both of which require detailed attention and understanding.

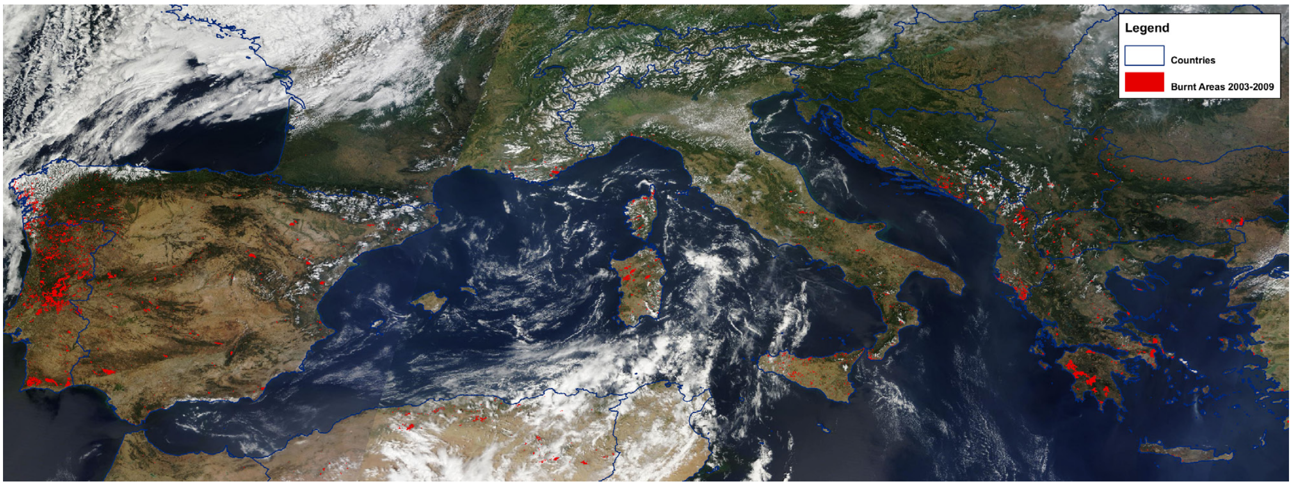
Economic losses due to forest fires are difficult to quantify in a harmonised manner for the entire European territory. If we use a value of EUR 3 000 per ha, derived through extensive consultation with stakeholders in the field (FUEGO, 2000), to estimate the economic loss due to forest fires, the average loss is about EUR 1.5 billion every year. Considering the fact that additional indirect damage to local economies and the loss of human lives and property are not taken into account, this is a conservative estimate.

In addition to the impacts referred to above, extreme fire events produce substantial emissions (Barbosa et al., 2008) that have harmful effects on populations in nearby cities and villages. In the case of large fire events, such as the ones in Portugal in 2003 and Greece 2007, these emissions constituted a significant percentage of the total CO_2 emissions in these countries.

5.2.3 *Forest fire impacts on ecosystems*

Over 3.5 million ha of forest areas were burnt by forest fires in Europe in the period of 2003 to 2009, affecting natural areas and ecosystems. These fires that occurred mainly in the Mediterranean Region, led to land degradation and desertification processes. Impacts on ecosystems, such as the Natura 2000 areas, are reported and evaluated yearly by EFFIS (EFFIS 2010b; San-Miguel-Ayanz et al., 2009c). Over half a million ha of these protected ecosystems were burnt in the reporting period. The highest impacts were recorded in Portugal in 2003 and 2005, with nearly 150 000 ha burnt, and in 2007, with over 100 000 ha burnt in Greece, Italy

Figure 5.3 Cumulative impact of forest fires mapped by EFFIS in southern Europe in 2003–2009



Source: EFFIS, 2010.

and Spain. Impacts of forest fires on ecosystems are widespread. High intensity fires remove the existing vegetation cover and leave bare ground exposed to further processes of soil erosion, or even landslides. In areas where the fire return period is short (i.e. fires occur frequently on the same site) or vegetation regeneration is hampered by the lack of precipitation, fires may lead to desertification processes.

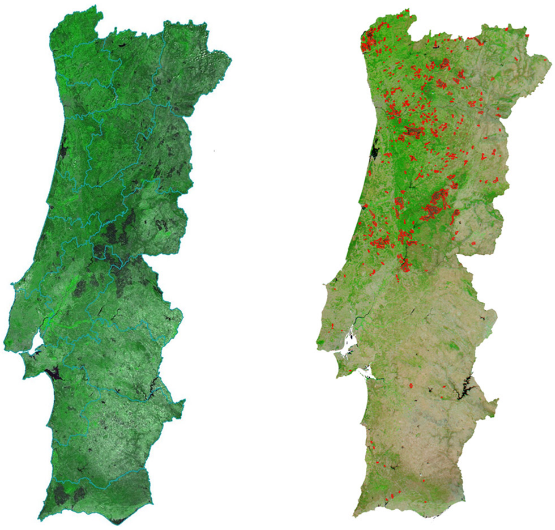
5.3 Case studies: the large fire episodes in Portugal 2003 and Greece 2007

The 2003 fire season in Portugal during the summer followed a drought period during the previous winter and spring and led to low moisture conditions in ignitable vegetation. Temperatures were already very high in July, with continuous periods of temperatures above 40 °C, especially in central Portugal. This intensive heat coincided with peculiar meteorological conditions that lead to dry storms accompanied by lightening. This caused simultaneous fires in large areas of the country that burnt out of control, killing 21 people.

Figure 5.4 shows the burnt scars produced by forest fires as mapped by EFFIS from MODIS satellite imagery at ground spatial resolution of 250 m. By 15 September 2003, a total of 379 038 ha of burnt areas was mapped. This corresponds to an estimated total burnt area of 425 726 ha (EC, 2008). Similar conditions occurred again in 2005, leading to an estimated total burnt area of 338 262 ha and the deaths of 18 people.

As in each of the preceding years since 2002, the meteorological conditions in Greece during 2007 were mild. While the year 2003 generally exhibited high temperatures and low precipitation in central and western Mediterranean areas, it was fairly humid in the eastern Mediterranean. In Greece, these conditions led to a small number of forest fires with low impacts in terms of burnt areas. Within the period 2002–2006, the year with the greatest amount of burnt areas was 2006. In this year approximately 12 000 ha were burnt in the entire country. However, 2007 showed similar conditions to that of Portugal in 2003. Accumulated drought periods in winter and spring were followed by hot and windy periods in the summer. These extreme meteorological fire danger conditions facilitated fire ignition and propagation. Similar fire conditions were also observed in Italy and the Balkans where the result was unprecedented fire damage. Fires caused the deaths of 15 people in Italy and 12 people in Croatia. The total area burnt in Greece at the end of the 2007 season was estimated by the Greek authorities as 225 734 ha. Moreover, in addition to the environmental damage, the fires in Greece caused a high number of fatalities; 80 people died in the country due to the forest fires of 2007. Although less dramatic in terms of loss of life, the fire season in Italy established a negative record for the country: with over 227 000 ha burnt and 23 fatalities. Figure 5.5 shows the burnt scars produced by forest fires in Greece during the 2007 fire season.

Figure 5.4 Burnt scars caused by fires in Portugal — 2003 (left) and 2005 (right) mapped from MODIS satellite imagery



Source: EFFIS, 2010.

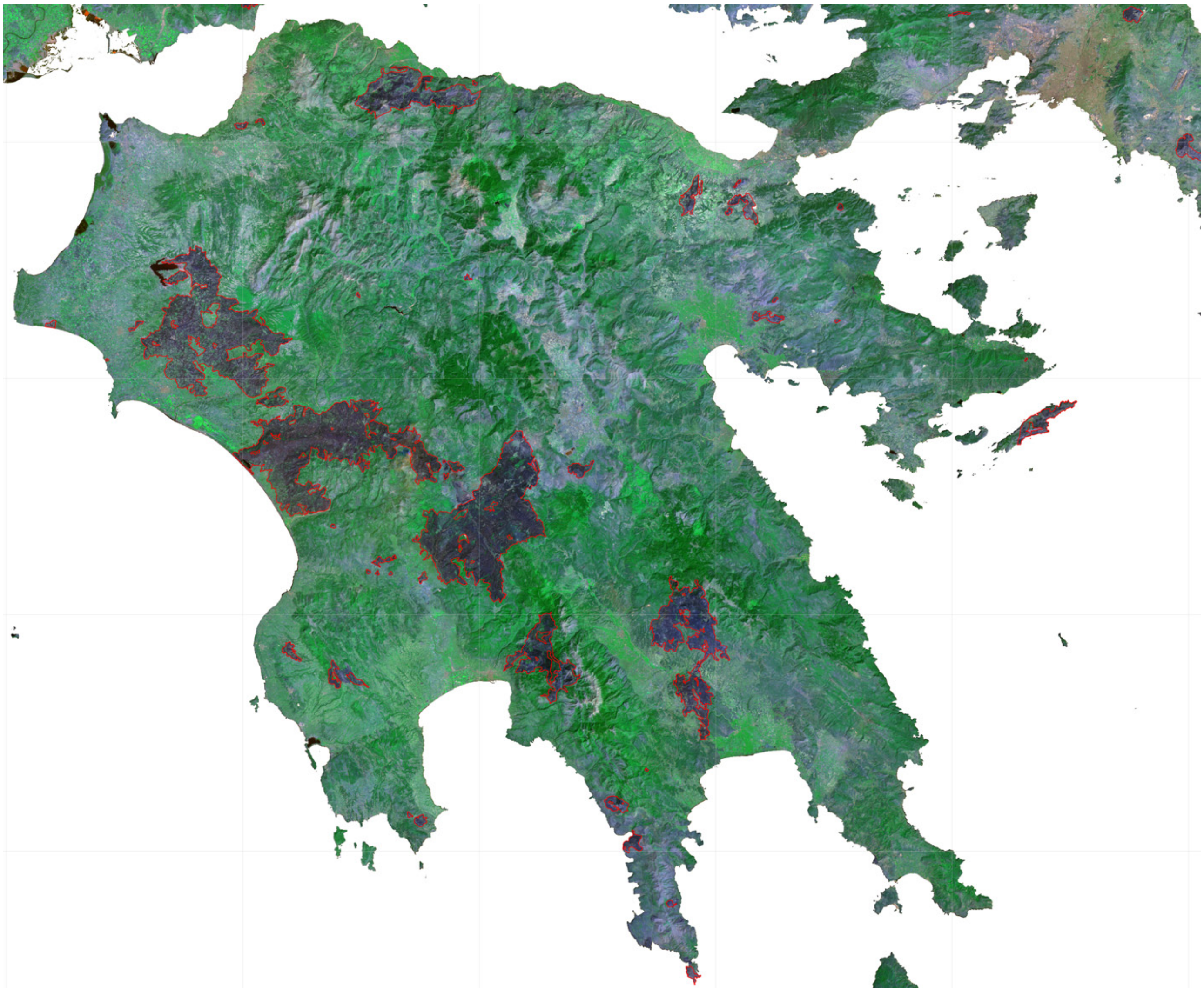
5.4 Management options to reduce forest fire impacts

5.4.1 Measures

Weather conditions are the main driver of forest fire occurrence and impacts. As the climate cannot be controlled, management options to reduce the impact of forest fires must deal with the causes of these fires, and the proper management of forest fuels.

Identified factors that influence forest fires are the human causality of fire ignitions and the driving forces of forest fire spread, that is, weather conditions and fuel distribution. Demographic shifts of population from rural areas to cities during the

Figure 5.5 Burnt scars caused by fires in Greece in 2007 mapped from MODIS satellite imagery



Source: EFFIS, 2010.

past decades have led to the abandonment of forest areas whose exploitation was not profitable, and to the accumulation of fire fuels in these areas. Forests were not managed, thus creating a high risk of forest fires. In some cases, similar consequences resulted from forest protection policies that prevented the implementation of traditional practices and the management of forest areas. Therefore, fire prevention measures must address the education of the population, especially in rural areas, and the implementation of forest management practices. The majority of forest fires are started intentionally or by accidents related to agricultural practices (shrub and straw burning). Educational programmes can therefore lead to a reduction in fire ignitions. Additionally, there should be measures put in place to reduce the amount of fuels in the forests, so that fire spread and fire intensity are reduced. These may include the use of silvicultural practices, such as thinning and pruning, and the use of forest fire fuels for energy production and household consumption.

Recent trends in the number and impacts of forest fires in Europe clearly indicate the need for stronger forest fire prevention and preparedness. In the past few years, the increased forest fire fighting capability in the EU Member States has failed to bring down the number of casualties or the damage caused by forest fires. Therefore, it is particularly important to include all possible measures and all stakeholders in any initiatives aimed at the development and improvement of forest fire management. It is particularly important to address the issues that may affect the risk of forest fires, such as land-use change, demographic change (e.g. less people living and using the countryside), inappropriate forest plantations with extensive monocultures, and fragmented ownership of land. Moreover, since fire entrapment is the major threat to humans posed by a forest fire, there is a need for better and faster warnings, and for awareness-raising and training (for example on how to react in case of a forest fire).

5.4.2 Specific policy on forest fires

Specific policies regarding forest fires exist in most EU Member States. They are often incorporated into forest management plans or exist under the umbrella of the civil protection authorities in these countries. However, harmonisation of these policies at the European level has not yet been achieved. At the level of the European Union, forest fire prevention policies were first established in 1992. These policies were in force until 2006 when the last EU regulation on forest fires, otherwise known as 'Forest Focus' Regulation, expired. At the heart of forest fire policies is fire prevention. Given the fact that most fires in Europe are caused by humans, fire prevention policies that encompass education and training are necessary for proper forest fire management in Europe (Montiel and San-Miguel-Ayanz, 2009).

5.5 Data gaps and information needs

The cycle of forest fires is complex and involves a great number of stakeholders. Proper fire management must include prevention and preparedness, response (e.g. fire fighting), post-fire management and restoration of the burnt areas. Of key importance is the collection of forest fire information enabling the analysis of forest fires, understanding of their causes and impacts at the European level. Following the establishment of the EFFIS by the European Commission in 1998, a large quantity of fire information has been collected and analysed. The EFFIS European Fire Database (EFFIS, 2010) contains nearly 2 million records of individual fires provided by the respective countries (currently, 26 countries constitute the EFFIS network). However, the weakest part of this database is the information on fire causation, which, as mentioned above, is essential for the development of adequate fire prevention policies. European countries are working closely with the EC to enhance fire information and to establish common policies that promote cooperation in respect of fire prevention and fire fighting among the countries. Following the European Parliament resolution of 2006 on fire and floods (EC, 2006), other important aspects that are being developed in the context of EFFIS include the analysis of the socio-economic impact of forest fires, the harmonisation of nomenclature of forest fire causation at the European level, and the improvement of estimates of forest fire emissions and the impact of these emissions on the population.

6 Water scarcity and droughts (WSD)

Key messages

- Large areas of Europe are affected by drought and water scarcity and pressures on European water resources have increased. WSD is not exclusive to drier areas and in recent years, several regions in Europe have been affected by severe and extensive events. For instance, the 2003 drought, which was one of the most prominent events in the period analysed, affected an area extending from Portugal and Spain to the Czech Republic, Romania and Bulgaria.
- In recent years, a growing concern has been expressed throughout Europe regarding drought and water scarcity. Seasonal or longer term drought and water scarcity has become a reality in an increasing number of countries. This is not longer limited to southern Europe. Water demand often exceeds availability in many locations and the need for adequate water supplies to service vulnerable ecosystems is often neglected. Climate change is projected to exacerbate these adverse impacts, with more frequent and severe droughts being projected for many parts of Europe.
- Currently, there are many data gaps and uncertainties in the European information base on WSD. No systematic and comprehensive record of the duration, impact and severity of WSD events in Europe exists, with the exception of climate data where there are long time series for precipitation and precipitation anomalies. In addition, there is no long time-series of updated, pan-European river flow data to learn from historic drought and to discern between drought and water scarcity and to investigate global change, incl. attribution to causes. Last but not least, there are many gaps in the information on water abstraction and water use. Our knowledge of water availability, water abstraction and water use is poor and our knowledge of the impact of WSD (e.g. cost of events) and water management (e.g. water pricing and water saving) is even poorer. Information is largely incomplete, particularly for agriculture, the largest user of water, and is lacking altogether for some countries. Furthermore in some cases the latest available data are more than 10 years old.
- Several activities have started to improve the knowledge base (e.g. by monitoring) and to manage WSD. The European Commission adopted a communication on WSD in 2007, which specifies the measures needed if Europe is to move towards a water-efficient and water saving economy. Drought management plans are seen as a key element in future water resource policy and strategies.

6.1 Introduction

6.1.1 Definition (including main causes)

Drought is a natural phenomenon, which is defined as sustained and extensive occurrence of below-average water availability, caused by climate variability. Drought should not be confused with aridity, which is a long-term average feature of a dry climate. Likewise, drought should not be confused with water scarcity, which reflects conditions of long-term imbalances between water availability and demands (Tallaksen and van Lanen, 2004; EC, 2007a; van Lanen et al., 2007a).

Droughts can affect both high and low rainfall areas of Europe and can develop over short periods of weeks and months or much longer periods of several seasons, years and even decades. In many cases drought develops gradually, making it difficult to identify and predict. Drought affects all components of the water cycle, resulting in low soil moisture and reduced groundwater levels, drying up of wetlands and reductions in river flow. Drought may refer to meteorological drought (precipitation well below average), hydrological drought (low river flows, lake and groundwater levels), agricultural drought (soil moisture deficit), and socio-economic drought (impact on economic goods and services) (Wilhite, 2000; Tallaksen and van Lanen, 2004; EEA-JRC-WHO, 2008).

Water scarcity arises due to an imbalance between abstraction and availability. The effects of over-abstraction upon water resources vary considerably depending upon the volume and seasonality of the abstraction, the volume and location of returned water, the sensitivity of the ecosystem and specific local and regional conditions. Peak abstraction for both agriculture and tourism typically occurs in the summer months when water availability is generally at a minimum. Water scarcity usually enhances the impact of droughts.

Imbalance between demand and water availability becomes most acute when abstraction occurs during prolonged dry periods or drought. Under these circumstances, a negative feedback can occur, particularly with agricultural water use, whereby the lack of rainfall drives greater abstraction in order to provide the water required for crops.

The balance between water abstraction and availability has now reached a critical level in many areas of Europe caused mainly by a combination of drought and over-abstraction for activities such as agriculture or tourism.

As the impact of water scarcity and drought are interlinked and hard to distinguish one from the other the term Water Scarcity and Drought abbreviated WSD has been used in the rest of the report.

6.1.2 Sources of information

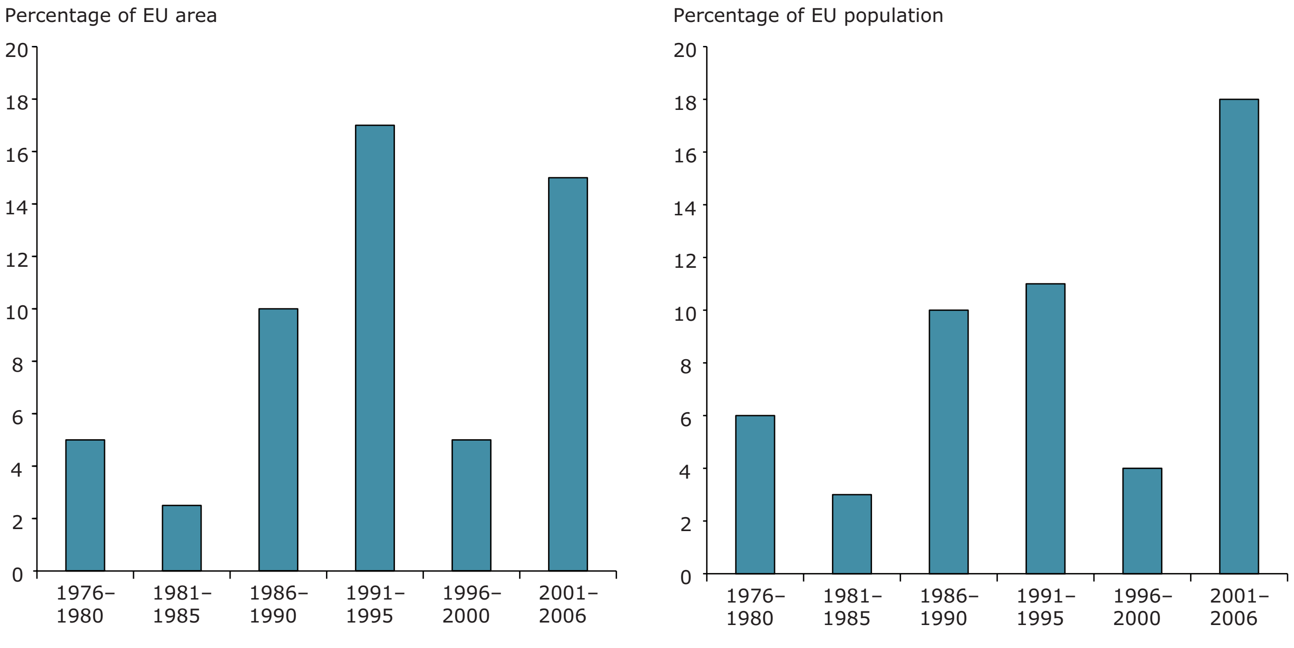
The main sources of information used in this chapter were European Commission assessments of WSD in 2006 and early 2007 (EC 2006; 2007b); EEA's reports on Impacts of Climate change (EEA-JRC-WHO, 2008) and Water resources across Europe (EEA 2009a) as well as a compilation of information available from national and international sources (scientific papers, reports and web-sites). The EM-DAT database (EM-DAT, 2010) has only registered eight European drought events over the last ten years due to the thresholds used in the database (see Chapter 1). A comparison of these events with the events described by national sources reveals that EM-DAT gives a very limited picture of WSD events in Europe.

6.1.3 WSD events in Europe

In Europe, over the past 30 years many countries were hit hard by WSD, particularly the European Mediterranean countries. The total area and population affected by WSD doubled from 6 to 13 % from 1976–1990 to 1991–2006 (Figure 6.1). In terms of population and area affected by WSD, peaks were observed in 1976, 1989-1991, 2003 and 2005 (EC, 2007b).

The duration of each event, and the area and population affected varied throughout this period. In Mediterranean countries droughts may last one or

Figure 6.1 EU area (left) and population (right) affected by WSD in the last 30 years



Source: Member States data, EC, 2006. Note that the diagrams present the average area and population being affected in the periods. In dry years a higher percentage is affected.

several years, while in central and northern countries droughts last some months, such as a dry winter season with low recharge of groundwater or a dry summer affecting crop yield. Droughts affect a large part of the territory of some countries, whereas in others they often only affect specific regions but with higher frequency.

The European problem is easier to manage than in many regions of the world that face serious water shortages, both because of the greater financial resources and the greater water availability. In general, water is relatively abundant in Europe, with only 13 % of the available resource abstracted each year (EEA, 2009a) but water availability and population are unevenly distributed. Except in some northern and sparsely-populated countries with abundant water resources, water scarcity occurs in many areas of Europe confronted severe water shortage and high demand, particularly in the south and lowlands.

One relatively straightforward indicator of the pressure or stress on freshwater resources is the water exploitation index (WEI), the ratio of annual total freshwater abstraction to the total renewable resource. A WEI above 20 % implies that a water resource is under stress, and above 40 % indicates severe stress and clearly unsustainable use of the water resource (Raskin et al., 1997). WEI refers to average conditions, while during droughts it is likely that abstraction will be higher and availability lower.

National estimates show that Cyprus (64 %), Belgium (32 %) and Spain (30 %) have the highest WEIs in Europe, with high values also for Italy, Malta and Turkey (EEA, 2010). Over the last 10–17 years WEI decreased in 24 countries, representing a 15 % decrease in total water abstraction. Most of the decrease occurred in the eastern EU Member States as a result of the decline in abstraction for most economic sectors. However, five countries (The Netherlands, Greece, Finland, Slovenia and Turkey) increased their total water abstraction during the period 1990 to 2007.

National estimates of the water exploitation index do not, however, reflect the extent and severity of water scarcity in sub-national regions. While Spain's WEI is 30 %, it is more than 100 % in the south-eastern river basins of Andalusia and Segura where demand can only be met by transfers from other river basins, additional supplies from water reuse and desalination.

In particular the following areas and sectors can be considered as water stress:

- Irrigated agricultural production in many southern European regions has grown markedly over the past 60 years. As a consequence, water resources are under severe pressure, with an increasing gap between water demand and available resources.
- Europe's larger cities generally rely on the surrounding region for water. Athens, Paris and Istanbul, for example, have all developed wide water networks for transporting water, often over more than 100–200 km, to their water-hungry densely-populated cities. Growing urban populations, improving lifestyles, reduced water availability due to climate change and drinking water quality standards that prohibit using water around large cities for drinking because it is often polluted, are all factors making large cities potential vulnerable to WSD.
- The Mediterranean islands including Cyprus; Malta; Crete; the Balearic Islands and Sicily are generally heavily water-stressed. They are totally dependent on precipitation, which is quite low, have large annual and inter-annual variations, and are geographically isolated so they cannot draw on more distant water sources. In addition, near-shore aquifers are threatened by seawater intrusion. The situation is worse in summer when average precipitation is very low and water demand for agriculture and tourism is high.
- The Mediterranean is the world's top tourist destination. Tourism peaks in summer, when natural water availability is at its lowest. Tourism generally overuses water resources for hotels, swimming pools, golf courses and personal use. This can result in water shortages.

Projections of population, economic development and agricultural production, predict that demand for water in most of Europe will be stable or decrease in the coming decades; however, many river basins will continue to face high water stress due to high demand relative to availability (EEA, 2005; PlanBleu, 2005; OECD, 2008). The decrease in demand is expected to be driven by more efficient use of water by all sectors together with generally stable populations and the projected limited change in the area of irrigated land.

6.1.4 Impact of climate change

There is growing evidence of changes in the global hydrological cycle over the last 50 years that may be linked with changes in climate, such as increasing continental run-off, a wetter northern Europe and a drier Mediterranean. Long-term trends in hydrological variables, however, are often masked by significant inter-annual to decadal variability (e.g. Bates et al., 2008; van Lanen et al., 2007b).

Annual precipitation trends in the 20th century showed an increase in northern Europe (10–40 %) and a decrease in some parts of southern Europe (up to 20 %) (EEA-JRC-WHO, 2008). The proportion of Europe that has experienced extreme and/or moderate meteorological drought conditions did not change significantly during the 20th century (EEA-JRC-WHO, 2008; Lloyd-Hughes and Saunders, 2002). To date, there is no evidence that river flow droughts have generally become more severe or frequent in Europe during recent decades (Hisdal et al., 2001; Stahl et al., 2008).

Climate projections indicate that droughts may become longer-lasting and more severe in warmer conditions in current drought-prone regions because of decreased rainfall and increased evaporation (e.g. Bates et al., 2008).

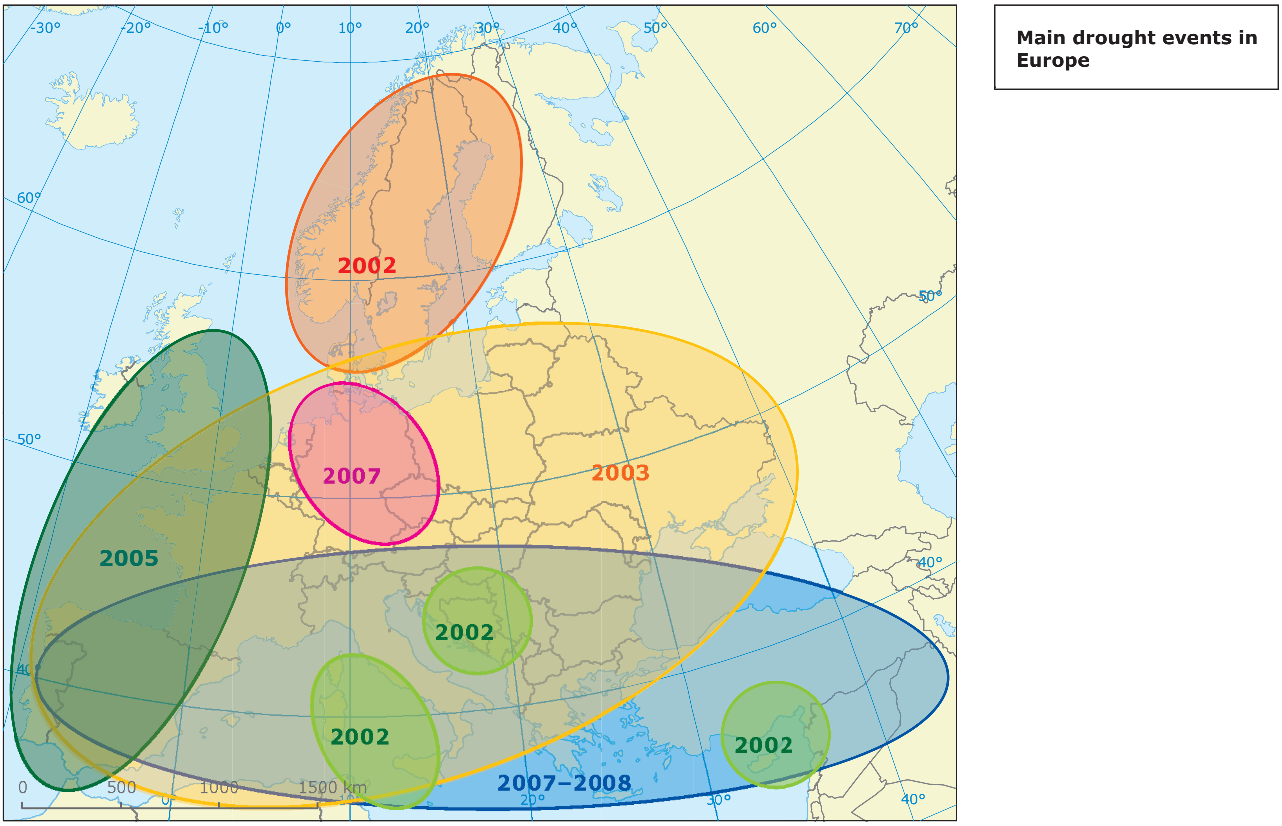
Climate change impact on water availability
It is projected that climate change will lead to strong changes in annual and seasonal water availability across Europe (EEA-JRC-WHO, 2008). Water availability will generally increase in northern parts of Europe, although summer flows may decrease. Southern and south-eastern regions, which already suffer most from water stress, will be particularly exposed to reductions in water availability and see an increase in the frequency and intensity of droughts.

Seasonal changes in river flows are also projected. For example, higher temperatures will push the snow line upwards in northern Europe and in mountainous regions and reduce precipitation from snow. This would result in a marked drop in winter retention and higher winter run-off in northern European and Alpine rivers such as the Rhine, Rhône and Danube. As a result of the declining snow reservoir, earlier snow melt and a general decrease in summer precipitation, longer periods of low river flow may be observed in late summer and early autumn in many parts of Europe (EEA-JRC-WHO, 2008).

Climate change impact on sectoral water demands
Climate change will certainly have an effect on agriculture and in many regions there may be an increase in irrigated area and water abstraction for irrigation. Agro-climatic zones are likely to move northwards as a result of climate change.

Water demand from households and tourism is likely to increase with climate change, with more water being used for gardens and personal hygiene, in particular for activities sensitive to climate

Figure 6.2 WSD in Europe



Source: ETC-LUSI, adapted from Tallaksen, 2007.

change (showering, gardening, lawn sprinkling, and pool filling). The general increase in wealth and generally hotter and longer summers may also increase the number of golf courses, swimming pools and aqua-parks, further increasing water demand. Problems of water supply in tourist resorts are becoming increasingly common; in some cases tankers now have to transport water to tourist islands, and water deficits may be further increased by climate change and increasing demand from other sectors.

6.2 Impacts of the latest WSD events in Europe

6.2.1 Spatial overview

WSD is not exclusive to drier areas and in recent years Europe has been affected by several severe WSD events (Figure 6.2). An area affected by WSD may range from hundreds to thousands of square kilometres; for example the 2003 drought in southern and central Europe affected an area which extends from Portugal and Spain to the Czech Republic, Romania and Bulgaria.

- South-eastern Europe is increasingly facing long periods of drought, creating economic problems. Romania and Bulgaria faced drought in 2007. Poor winter snow and little spring rain left more than half of Romania in drought.
- During the 2003 heat wave and drought, much of southern and central Europe experienced a substantial drop in crop yields — the largest negative deviation from the long-term trend in Europe in the past 43 years.
- In 2004–2006 severe droughts hit the south-western part of Europe including the Iberian Peninsula, France and the southern part of the United Kingdom.
- In 2008, Cyprus suffered a fourth consecutive year of low rainfall and the drought situation reached a critical level in the summer. To ease the water crisis, 30 tankers delivered water from Greece and households were supplied with water for around twelve hours only three times a week.

Hannaford et al. (2010) examined drought occurrence and spatial coherence in 23 European regions using over 500 gauging stations for the period 1961–2005. Their analysis of drought indicators across all regions has shown 'drought rich' and 'drought poor' periods which occur contemporaneously across European regions. Some droughts are spatially coherent over a large area. These periods broadly agree with major European droughts identified by others. There is, however, limited evidence of 'signature' patterns of spatial coherence that occur repeatedly in historical droughts, which would be useful for early warning.

6.2.2 Analysis of WSD impacts: fatalities and human health

The impacts of WSD on people and the environment result from a combination of the intensity and duration of WSD events and the vulnerability of the sectors, including water management policies, the characteristics of regional and local water infrastructure, and social responses to WSD.

WSD have a direct impact on people. Although WSD in Europe have affected a large number of people, no fatalities can be attributed directly to WSD.

6.2.3 Analysis of WSD impacts: economic losses

WSD has severe consequences for most sectors, particularly agriculture, tourism, energy, and drinking water providers. Activities that depend on high water abstraction and use, such as irrigated agriculture, tourism, and the use of cooling water, are affected by changed flow regimes and reduced water availability.

The overall economic impacts of WSD events in the past 30 years are estimated at EUR 100 billion at EU level (EC, 2007). The annual average impact doubled from 1976–1990 and the following 1991–2006 periods, rising to EUR 6.2 billion/year in the most recent years. The exceptional drought in 2003 was estimated to have costed EUR 8.7 billion (Figure 6.3).

There are many economic impacts on agriculture, in particular reduced crop yields and production. Low rainfall during the growing season can have serious consequences for rain-fed crops and water scarcity may affect irrigated agriculture over subsequent years as a result of low levels of water in reservoirs and groundwater aquifers.

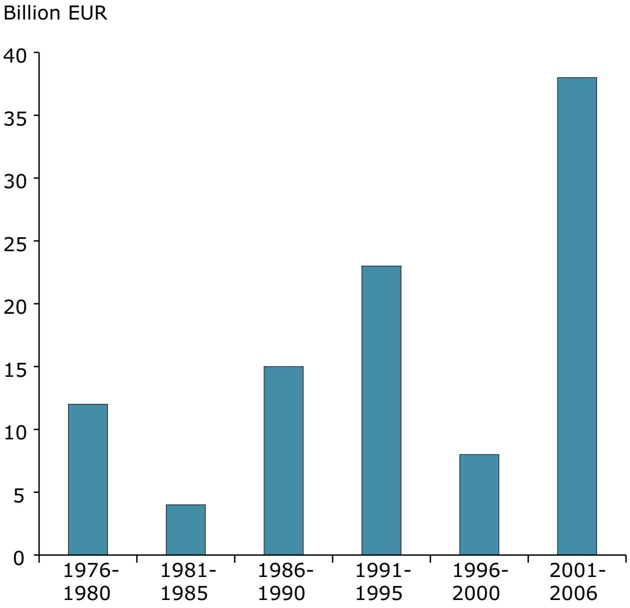
- The 2004/05 hydrological year was characterised by an intense drought throughout the Iberian Peninsula and cereals production decreased by 40 % on average (García-Herrera, 2007).
- During summer 2006, rainfall in Lithuania was only half of the long-term average and agricultural production fell by 30 % with an estimated loss around EUR 200 million (EC, 2007d).
- In 2003, the Slovenian Ministry of Agriculture, Forestry and Food estimated direct annual losses attributable to WSD of around EUR 100 millions. State aid was provided to the agricultural community (Sušnik and Kurnik, 2005).

The incidence of forest fires increases substantially during extended droughts. During the summer 2010 a series of Mediterranean wildfires broke out across France, Greece, Italy, Portugal, Spain, and Turkey. The most severe fires have been associated with strong winds that spread the fire during hot, dry periods (see Chapter 5).

The water demand of the energy sector is high, with hydropower and thermal power being the most water-intensive energy sources. The production of hydropower can be seriously affected by dry periods:

- A drought/dry period hit Norway, Sweden and Finland in 2002–03 with a considerable reduction in hydropower production and a considerable increase in the price of electricity (Kuusisto 2004; Silander et al. 2006; NVE 2003).
- The 2004/05 hydrological year was characterised by one of the worst droughts ever recorded in the Iberian Peninsula, with only half of the average precipitation. River flow dropped considerably throughout Iberia and hydroelectric power production was reduced by 40 % and had to be replaced by electricity from thermoelectric power plants (García-Herrera 2007). In 2005, Portugal had to compensate for the low hydro-electrical production by using fossil fuel worth EUR 182 million with an additional expense of EUR 28 million to purchase CO_2 emissions licenses. The total cost was finally estimated at EUR 883 million, which is equivalent to 0.6 % of GNP (Demuth, 2009).
- Dry periods have negative impact on the electricity generation sector where rivers provide the cooling water. Power stations have to be shut down when water temperatures exceed certain thresholds. Electricity production has already been reduced in various locations in Europe during very warm summers (e.g. 2003, 2005 and 2006) (BMU, 2007; Lehner et al., 2005). During 2003 the cooling capacity of several power stations in the Netherlands and France was threatened as a result of the high water temperatures and low river level. The requirement that cooling water discharge be no warmer than 30 °C meant that several companies needed to reduce their production capacity. The three hydroelectric power stations on the Meuse, Nederijn and Vecht also had to run on a very limited capacity for several weeks (10–25 % of normal).

Figure 6.3 Economic impact of WSD events in Europe



Sources: Member States data (EC, 2006).

Box 6.1 EU Solidarity Fund aids Cyprus following severe drought

Cyprus had suffered four consecutive years of low rainfall and the drought situation reached a critical level by the summer 2008. The government applied for financial assistance from the EU Solidarity Fund to help respond to the crisis, which had associated costs equivalent to an estimated 1.25 % of the country's gross national income (GNI). The European Commission agreed to grant EUR 7.6 million in aid from the EU Solidarity Fund. This will mainly help reimburse the costs of emergency measures, such as the transport of water from Greece. This is the first time the Solidarity Fund has been used to provide financial aid for emergency measures in response to drought.

During droughts, public water supplies often have priority over other uses. However, during severe droughts, different restrictions are implemented on different water uses:

- During the 2008 drought, Barcelona's authorities turned off civic fountains and beachside showers, brought in hosepipe bans, and banned the filling of swimming pools.
- In 2008 the Cypriot government was forced to apply emergency measures that included cutting water supply by 30 %. Households were supplied with water for around 12 hours a day, three times a week.
- In dry years there have been problems supplying sufficient water to the 12 million people living in Istanbul and the 4 million in Ankara, and water supplies have been rationed (EEA, 2009a).

- During the period 2004 to 2006, a drought developed in southern Britain and by summer 2006 13 million consumers were subject to minor restrictions on the use of hosepipe for some non-essential uses (Defra, 2010).

The effects of WSD may be more severe in rural areas. During the 2002 drought it was necessary to transport water to thousands of Finnish households and farms in rural areas. In addition, the low groundwater level caused problems with the foundations of many buildings and sewage pipe leakages (Silander et al., 2006).

During low flow periods, navigation on the large European rivers are affected.

Water scarcity and droughts can also seriously affect tourism: Portugal, for instance, had to take action during the drought of 2004–2005 in order to mitigate the impacts on tourism (EC, 2007b), whereas France reported losses of EUR 144 million during the winter 2006–2007 in the Alps-Savoie.

6.2.4 Impacts of WSD on ecosystems

Where water resources have diminished there may be detrimental impacts on freshwater and related ecosystems. Over-abstraction and dry periods frequently result in reduced river flows, lower lake and groundwater levels, and the drying of wetlands. Excessive abstraction from any of these types of water body can impact on one or more of the others. For example, rivers, lakes and wetlands can all be strongly dependent on groundwater, especially in the summer when it typically provides critical base-flow.

Over-abstraction can worsen water quality because there is less water to dilute discharges of pollutants, while over-abstraction of aquifers in coastal areas often results in salt-water intrusion, diminishing the quality and use of groundwater. Heavy drawdown of aquifers can also lead to ground subsidence sometimes producing sink holes.

In parts of southern Europe, groundwater levels have fallen significantly as a result of abstraction for irrigation and around large cities due to droughts. In intensive agricultural areas in southern Europe there are several examples of groundwater levels being lowered by several tens of metres (EEA, 2009a; Custodio, 2002; Dogdu and Sagnak, 2008). The results of sinking water tables are empty wells, higher pumping costs, dried up rivers, endangered wetlands and the intrusion of saltwater which degrades the quality of groundwater.

Drought also has an impact on terrestrial ecosystems leading to water stress, which can have a direct impact on forests, weakening trees and making them more vulnerable to diseases and insect attacks. In 2003, vegetation growth across Europe was reduced by an unprecedented 30 % during the dry and hot summer. Moreover, the extremely dry conditions increased the risk of fire by decreasing air humidity and increasing plant flammability (see Chapter 5).

6.3 Case study: WSD in Barcelona 2006–2008

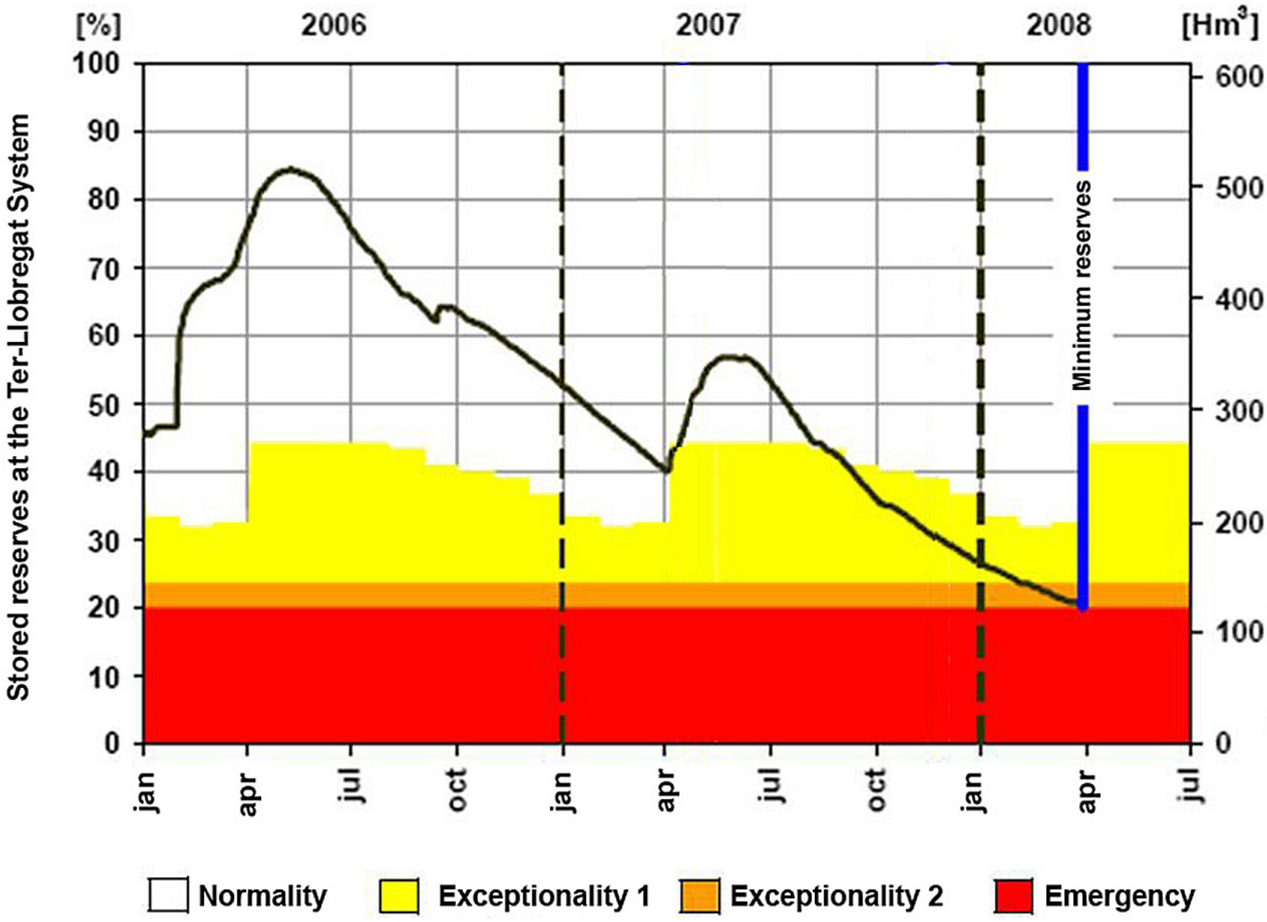
During the first half of 2008, the metropolitan area of Barcelona (4.6 million people) was on the verge of suffering domestic water cuts. The precipitation deficit was considered to be the largest in 60 years but lack of rain also revealed the precariousness of the water supply system serving this urban agglomeration.

Low water inputs following two years of abnormally high precipitation deficits in the springs of 2006 and 2008 meant that the basins supplying Barcelona with freshwater registered almost half the average values (Figure 6.4). In April 2008 the situation began to change and during the rest of the spring and the summer of 2008 precipitation returned so that the drought alert order issued by the Catalan Government was lifted by the end of 2008.

In the case of Barcelona, a major impact of the event was the images reproduced by the international media of tankers bringing water to the city. This had potentially important economic consequences as the negative images could have damaged tourism, one of the main sources of income for the city. Other, more tangible impacts of the event were the economic costs of water shipments (some 18 million euro) and the costs of emergency measures to increase supply (some EUR 450 million). Paradoxically, WSD events may have positive impacts, such as the increase in the collective awareness of the need for water conservation. After several public awareness campaigns in 2007 and 2008, the citizens of Barcelona were able to reduce per capita water consumption from 130 l/person per day to 110 l/person per day.

The Catalan Water Agency put a Drought Management Plan into practice. It was structured in three stages (see Figure 6.4) to be implemented as the event became more acute. The first stage

Figure 6.4 Evolution of water stored between January 2006 and April 2008 in the Llobregat-Ter reservoir systems supplying Barcelona and the related drought warning scenarios (exceptionality 1, 2 and emergency)



Source: Adapted from Catalan Water Agency.

applied to agricultural uses (exceptionality I), followed by non-essential urban users such as garden irrigation and swimming pools (exceptionality II) and finally essential urban uses (domestic cuts). Drought warnings related to these stages are issued when stored water falls to a certain level. At the same time, new resources have to be mobilised as the situation worsens, including bringing water by sea and recovering polluted wells. A connection to the Ebro catchment was even envisaged, although this was highly contested and abandoned after the rains returned after the 2008 event. The citizens of Barcelona did not see their water supply curtailed during the event, except for a few small towns which had to be supplied by water trucks. Many proposals were made to avoid this situation, including the possibility of using treated waste water for domestic purposes. Finally desalinisation was chosen as the (supposedly) definitive cure for all future WSD events.

6.4 Management options to reduce WSD impacts

6.4.1 Measures

First it is important to reduce the vulnerability to WSD by identifying and avoiding practices that increase vulnerability. Growing water intensive crops in drought prone areas and concentrating tourism in dry regions and periods are examples of practices that make sectors vulnerable to WSD.

In the past European water management largely focused on increasing supply by drilling new wells, constructing dams and reservoirs, desalination, large-scale water-transfer infrastructures, etc. However, Europe cannot endlessly increase water supply to its citizen, it must reduce demand. Management policies must be encouraged that increase the efficiency of water use, rather than supply-side approaches. Measures to reduce demand could include economic instruments, water loss control, water-reuse and recycling, increased efficiency of domestic, agricultural and industrial water use, and water-saving campaigns supported by public education programmes. Water savings will bring additional benefits, for example by reducing pollution discharges and energy consumption.

Water reuse can have two important benefits. It effectively increases the water resource available and it minimises waste water outflow. Treated waste water is currently reused in some southern European countries, primarily for irrigation (crop cultivation, public gardens, parks and golf courses), followed by industrial use. Some countries aim to increase the harvesting of rainwater and reuse of 'grey water' from baths, showers, washbasins and the kitchen, both of which can be used for non-potable purposes such as watering gardens and flushing toilets. Waste water reuse could supply 2 % of irrigation needs in the EU25 by 2025 and 3.5 % in the EU Mediterranean countries (Angelakis and Durham, 2008) and should be one of the water conservation measures.

Desalination has become a fast-growing alternative to reservoirs and inter-basin transfers, particularly in Mediterranean coastal areas. Many desalination plants are either being built or are planned in Europe, including one that will supply freshwater to London (EEA, 2009a). Energy consumption and the generation of brine are major environmental drawbacks. Decisions on the suitability of desalination plants need to be made on a case-by-case basis, taking into account all environmental aspects and long-term economic and technological investments.

Land management and land-use planning are essential to the management of water resources in water-scarce areas. Important wetlands that help to store water have been drained throughout Europe. One priority should be to retain rainwater where it falls, enabling water infiltration through the re-establishment of wetlands and increased recharge of aquifers. Spending on maintaining and increasing soil organic matter would enable soils to absorb more water, as would planning and regulating the crops grown within a river basin, including changing to crops more adapted to dry conditions or growing crops that require water at different times of the year.

6.4.2 Policy

In recent years, a growing concern has been expressed throughout the EU regarding WSD events. In 2007 the European Commission adopted a Communication on WSD (EC, 2007a), which specifies the measures needed if Europe is to move towards a water-efficient and water-saving economy. These include full implementation of the Water Framework Directive (WFD), water pricing, moving towards sustainable land-use planning, giving priority to water savings and water efficiency measures over any other alternatives and further integrating water issues into all sectoral policies. Adaptation to climate change will add a further challenge.

Drought management is an essential element of water resource policy and strategies. Drought Management Plans (DMP) (EC, 2007c), based on characterisation of possible droughts in a basin, their effect and possible mitigation measures, should be prepared on a river basin scale and before they are needed. By promoting sustainable water use, DMPs are closely linked with the WFD objectives. Measures to prevent and alleviate the consequences of WSD should aim to establish a drought-resilient society with a focus on lowering the demand for water so that negative impacts of droughts on the status of water bodies are avoided. Criteria should be established for minimum ecological flows and assuring good quantitative status for groundwater.

Additional water supply infrastructures (such as water storage, water transfers or use of alternative sources) should only be considered as an option when other demand options have been exhausted.

6.5 Data gaps and information needs

Reliable information on the extent and impacts of WSD is indispensable for decision-making at all levels. Several activities to monitor and manage WSD and desertification risk are currently ongoing in Europe both at national and European level. Several countries have activities for improving information on WSD and developing regional or national Drought Management Plans (DMP) (e.g. Spain, Portugal and the United Kingdom).

The European Commission DG Environment, European Parliament, EEA and JRC have all put more focus on improving the information basis of WSD. The Commission has strengthened its activities through the 2007 Communication on WSD and several studies. The EEA report 'Water resources across Europe — confronting water scarcity and drought' (EEA, 2009a) includes an overview of water availability, water abstraction and water scarcity in Europe and discusses management options. The EU Joint Research Centre, JRC's is developing a European Drought Observatory (EDO) for drought forecasting, assessment and monitoring. Several EU research projects have focused on WSD and the virtual European Drought Centre (EDC, www.geo.uio.no/edc/) is a start of getting an overview research activities.

The recently finished EU-FP7 XEROCHORE project (www.feem-project.net/xerochore/) produced Guidance Documents and Science Policy Briefs giving comprehensive information on the impacts of drought and management together with policy options to adapt to and to mitigate drought.

However despite the above activities, there are currently many gaps and uncertainties in the data in the European information basin on WSD.

- There is no systematic comprehensive record of WSD events in Europe (duration, impact, severity), with the exception of climate data where long time series for precipitation and precipitation anomalies exist.
- There is a lack of long-time series of updated, pan-European river flow data (Hannah et al., 2010) to learn from historic drought and to discern between drought and water scarcity and to investigate global change, incl. attribution to causes.
- There are many gaps in information on water abstraction and water use.

Our knowledge of water availability, water abstraction and water use is poor and our knowledge of the impact of WSD (e.g. cost of events) and water management (e.g. water pricing and water saving) is even poorer. Information is largely incomplete, particularly for agriculture, the largest user of water, and is lacking altogether for some countries. Furthermore in some cases the latest available data are more than 10 years old.

7 Floods

Key messages

- Several major flood disasters occurred in Europe in the last few years. The most destructive events in terms of economic losses were: the floods in the Elbe basin in 2002 that produced losses of over EUR 20 billion; floods in Italy, France and the Swiss Alps in 2000 causing around EUR 12 billion and a series of events in the United Kingdom during summer 2007 accumulating losses of more than EUR 4 billion (as of 2009).
- Overall losses as a consequence of floods have increased over the last few decades in Europe. Evidence suggests that increases in population and wealth in the affected areas are the main factors contributing to the increase in losses. Additionally, improvements in data collection in recent decades could bias trends over time.
- It seems that there is no evident trend over time in respect of the number of fatalities. This is because the number of deaths is very much dependent on single events. Furthermore, in the past few years early warning systems and prevention measures have improved evacuation procedures in the areas exposed to floods.
- Flash floods are particularly dangerous in mountainous areas where the steep slopes may increase their destructive potential. Flash flood forecasting is one of the most difficult problems facing the hydrological and meteorological forecasters at present. The improvement of forecasting and early warning systems is seen as the most effective way to mitigate the effects of flash floods.
- Much information on flood events is available through global disaster databases. Nevertheless, the development of a comprehensive publicly available database of flood events and their impacts in Europe is desirable in order to strengthen disaster prevention at European level.
- In recent decades, flood risk management has shifted from defence against floods to integrated flood risk management. The full implementation of integrated flood risk management will, however, take some time.
- Specific flood prevention policies exist in many European countries and the European Commission's Flood Directive adopted in 2007 is a good example of concerted action at EU level. The directive aims at reducing the risks and adverse consequences of floods and will be implemented in the Member States in three stages, starting with a preliminary flood risk assessment (due in 2011), followed by the development of flood hazard and risk maps for flood prone zones (2013) and flood risk management plans (2015). Moreover, the Commission intends to reinforce the links with existing early warning systems, such as the Joint Research Centre's European Flood Alert System.

7.1 Introduction

7.1.1 Definition

Flooding, along with wind related storms, is the most important natural hazard in Europe in terms of economic loss (CRED, 2009). Floods are complex processes that involve physical and socio-economic factors. Accordingly, flood disasters are the result of both societal and hydro-meteorological factors. It is important to make a distinction between hydrologic and damaging floods. The difference is that a hydrologic flood, occurring in an unpopulated area, may cause no damage and therefore, flood disasters are the result of the interaction between hydrologic floods and societal systems. The latter include many subsystems that determine the level of interaction, such as flood mitigation policies and the numbers of people and properties exposed to the risk (Barredo, 2009). A better understanding of flood disasters

Box 7.1 Flash flooding — a dangerous and sudden flood

Flash flooding is a type of flood caused by excessive rainfall in a short period of time, generally less than 6 hours. Flash floods are usually characterised by violent torrents after heavy rains that rip through river beds, urban streets, or mountain valleys sweeping everything before them. Flash floods are very dangerous because they can occur within several seconds to several hours, with little warning. The main characteristic of flash floods is their extremely sudden onset. The factors that contribute to this type of floods are rainfall intensity, rainfall duration, surface conditions and the topography and slope of the receiving basin (Perry, 2000).

Flash floods occur in mountainous or hilly areas because of their steep topography. However, they can also occur in flat areas where the slope is too shallow to allow for immediate run-off of water; instead water may accumulate in lower lying areas such as streets underpasses or basements. Urban areas are susceptible to flash floods because the imperviousness of the surface facilitates high run-off velocity. Dramatic examples of flash floods are the event occurred in Biescas (Spain) in 1996, when 160 mm of rain fell in 1 hour producing a flash flood that killed 87 people in a campsite. More recently, on 15 June 2010, 25 people were killed by a flash flood in the Var Department in France where more than 300 mm of rain fell in 12 hours.

Flash flood forecasting is one of the most difficult problems facing hydrological and meteorological forecasters at present. The improvement of forecasting and early warning systems is seen as the most effective way to mitigate the effects of flash floods.

is a prerequisite for developing efficient disaster prevention policies (EC, 2009). Relevant, accurate and up-to-date data is critical to underpin resource distribution, mitigation programmes, disaster monitoring and assessment.

7.1.2 *Sources of information*

This chapter is based on data from the EM-DAT database maintained by CRED (EM-DAT, 2010). EM-DAT data sets were complemented by and improved with information from NatCatSERVICE maintained by Munich Re (NatCatSERVICE, 2010) and the Dartmouth Flood Observatory (DFO, 2010) on several aspects, such as the amount of loss, geographical features affected (e.g. regions, cities, rivers) and the description of the events.

7.1.3 *Flood disasters in Europe 1998–2009*

Several severe flooding events have occurred in Europe over the last decade, causing loss of life, displacement of people and heavy economic losses (see Table 7.1). According to EM-DAT (2010) (see Table 2.1 in Chapter 2), floods have produced more than 1 100 fatalities and affected more than 3 million people in the period from 1998 to 2009. Direct economic losses in the period 1998–2009 were more than EUR 60 billion (based on 2009 values). For example, major disasters occurred in the Elbe basin in 2002 causing losses exceeding EUR 20 billion, and in Italy, France and the Swiss Alps in 2000 costing around EUR 12 billion.

7.1.4 *Hydrologic floods and climate change*

Although there is robust evidence of anthropogenic changes in the European climate (Alcamo et al., 2007; Rosenzweig et al., 2007; Trenberth et al., 2007) there is no conclusive evidence for any climate-related trend for hydrologic floods at the continental scale in Europe (Glaser and Stangl, 2003; Mudelsee et al., 2003; Lindström and Bergström, 2004; Kundzewicz et al., 2005; Kundzewicz et al., 2007; Macklin and Rumsby, 2007; Schmocker-Fackel and Naef, 2010).

7.2 Flood disasters 2003–2009: spatial analysis and trends

7.2.1 *Spatial overview*

Twenty-six major flood disasters were recorded between 2003 and 2009 (see Figure 7.1). The most affected countries in terms of number of disasters were Romania with six, United Kingdom with five and Italy with four events.

7.2.2 *Analysis of flood impacts: human fatalities*

Flood events in the reporting period produced around 320 human fatalities. The most fatal events occurred in Romania with 85 people killed in 2005,

Table 7.1 Significant flood disasters in Europe 1998–2009

Date of the event	Location	Impact (a)
9–13 April 1998	England (South Midlands: Warwickshire, Northamptonshire, Oxfordshire, Worcestershire, Cambridgeshire, Bedfordshire, Buckinghamshire, Gloucestershire, Leicestershire)	Rainfall totals exceeded 50 mm for a three-day period. The heaviest reported daily rainfall total came from Pershore in Worcestershire where 80 mm fell in 24 hours. Five people killed. Economic losses of EUR 450 million.
May 1998	Turkey (North western Anatolia, inner Black Sea Region)	Thousands of homeless. 2 200 houses damaged. Affected 25 000 ha of agricultural land. 27 people killed. High economic losses of EUR 2.5 billion.
8–24 June 1998	Romania (north-east and Central Romania)	Floods affected more than 1 000 km^2 of land. More than 1 800 houses destroyed. 31 people killed. Economic losses of EUR 240 million.
20–24 July 1998	Slovakia (Presov and Sabinov districts)	Brief torrential rain triggered floods killing 54 people and producing economic losses of EUR 50 million.
14–15 September 1998	Belgium (Provinces of Brabant Wallon, Liege, Antwerp and Leuven); The Netherlands (Haringvliet River and lowlands)	143 mm rain in 12 hours in Belgium. Highest precipitation in 130 years. Economic losses of EUR 600 million.
22 May 1999	Germany (Bavaria) and Switzerland. Minor damage in Liechtenstein and Austria	Excessive regional rain combined with snow melt. Five people killed. Economic losses of EUR 370 and 435 million respectively in Germany and Switzerland.
June 1999	Romania	Week of heavy rain prior to floods. 19 people killed, more than 1 500 houses destroyed.
12 November 1999	France (Aude and Tarn Rivers)	Heavy rainfall. Over 600 mm rain in 48 hours recorded in parts of the Aude Department with a maximum rainfall intensity of 112 mm in one hour. 33 people killed. Economic losses of EUR 570 million.
5–25 April 2000	Romania: 16 counties in central and western Romania (other affected countries: Hungary, Serbia and Ukraine)	Rain and snow melting in Romanian and Ukrainian highlands (Carpathian and Transylvanian Mountains). Nine people killed. Economic losses of EUR 400 million.
11 October to 6 November 2000	Large areas of England and Wales	Wettest autumn since records began in 1773. Heavy rain with maximum daily precipitation of 150 mm. 10 people killed. Economic losses of EUR 1.4 billion.
13–16 October 2000 (*)	Italy (Piedmont, Valle d'Aosta and Liguria Regions). France, Swiss and Italian Alps	Excessive regional rain. At some locations up to 740 mm rain in four days. 29 people killed. Very high economic losses of EUR 11.7 billion.
19–22 June 2001	Romania (Central and South Transylvania)	Three days of heavy rain caused floods that forced evacuation of hundreds of people and killed seven. 50 000 hectares of farmland flooded. Economic losses of EUR 220 million.
25 July 2001	Poland (Wisla River in several Regions)	Torrential rains and dyke failure. 25 people killed. Economic losses of about EUR 810 million.
1–18 August 2002	Germany (Elbe River, State of Saxony, Dresden); Czech Republic (Moldau, Vltava and Elbe –Labe- Rivers, Prague); Austria (Salzburg and other areas)	Intense long-lasting rain over large areas. Flooding the result of two periods of intense rainfall. > 125 mm rain on August 6–7, and > 320 mm on 11–13. Flood heights with return periods of up to 500-years in Germany and Czech Republic. Excessive regional rain in Austria. Daily precipitation amounts of 100–160 mm. 47 people killed. Very high economic losses of EUR 20.9 billion (Germany 13.7 billion, Czech Republic 3.5 billion, Austria 3.7 billion).
8–9 September 2002	France (Rhone River, Gard Department)	Heavy rainfall, 650 mm rain in 24 hours. 23 people killed: Economic losses of EUR 1.5 billion.
22 November to 3 December 2002	Italy (Northern Italy. Regions: Liguria, Emilia Romagna, Lombardy and Trentino)	Overflowing rivers and lakes flooded several towns and cities and caused landslides across northern Italy. Economic losses of EUR 440 million.
25–27 January 2003	Italy (southern Italy. Regions: Apulia, Abruzzi and Molise)	Widespread damage across southern Italy from floods and landslides. Economic losses of EUR 150 million (Map 7.1 n. 1).
2 February 2003	Greece (Regions: Athens and Peloponnese)	Severe storm and floods. Economic losses of EUR 650 million (Map 7.1 n. 2).
28 August 2003 (*)	Italy (Udine Province)	Heavy rainfall. 400 mm rain in four hours. Three people killed: economic losses of about EUR 510 million (Map 7.1 n. 3).
1–3 December 2003	South-East of France (Rhone River, 20 departments affected)	Wind storm (148 Km/h) and more than 500 mm rain in three days. Seven people killed: economic losses of EUR 1.6 billion (Map 7.1 n. 4).
16–17 August 2004	England (Boscastle, Tintagel and Camelford)	Storms on 16th August saw more than 60 mm rain fall in two hours. Economic losses of EUR 700 million (Map 7.1 n. 5).

Note: (a) Economic losses adjusted to values of 2009.

Table 7.1 Significant flood disasters in Europe 1998–2009 (cont.)

Date of the event	Location	Impact (a)
April–May 2005	Romania (south-western. Counties: Timis, Caras-Severin, Hunedoara. River Timis), Serbia.	Heavy rain caused the worst floods of the last 50 years in Timisoara. EUR Economic losses of 565 million (Map 7.1 n. 6).
May–August 2005 (*)	Bulgaria (north-east, Sofia region and southern), the most affected municipalities were Sofia, Lovech, Targovishte, Veliko Tarnovo, Vratza, Pleven, Rousse, Pernik, and Sofia District Regions Basins: Yantra, Vit, Osam, Baniska, Jantra, Suhata, Iantra, Kamchia	Heavy rains in late May and early June caused extensive flooding in the north-west and northern regions of Bulgaria. Heaviest rainfall in Bulgaria for the last 50 years. While still recovering from flooding in May and June, continuous rain fell from beginning of July leading to a second period of flooding. 24 people killed. Economic losses of EUR 285 million and 335 million respectively in May and August (Map 7.1 n. 7).
July–August 2005	Romania (Affected counties: Harghita, Bacau, Vrancea, Galati and Braila, where the situation was still critical after the spring floods. Rivers: Siret and Trotus)	Torrential rainfall. 85 people killed. Economic losses of EUR 1.2 billion (Map 7.1 n. 8).
21–26 August 2005 (*)	Switzerland, Austria (Voralberg, Tyrol, Styria, Carinthia); Germany (Bavaria State)	Heavy regional rains. In places over 300 mm in 72 hours. 11 people killed (it is likely that this number includes casualties by landslides): economic losses of EUR 2.8 billion (Germany 190 million, Austria: 620 million, Switzerland 2 billion) (Map 7.1 n. 9).
13 March 2006	Greece (Evros river)	Worst flooding over the last 50 years. Economic losses of EUR 410 million (Map 7.1 n. 10).
28 March – 9 May 2006	Hungary (Danube and Tisza rivers), Slovakia, Romania, Serbia, Czech Republic, Austria, Germany.	Large quantities of melting snow and heavy rainfall. 12 people killed; economic losses of 590 million euro in Hungary and EUR 210 million in Czech Republic (Map n. 11).
20 June 2006	Romania (Northeastern. Counties: Bistrita, Maramures, Hunedoara, Alba. Rivers: Tibes, Valea and Ilisua).	Heavy rain. 14 people killed (Map 7.1 n. 12).
30 June 2006	Romania (Counties: Bistrita, Maramures, Arad, Suceava)	Heavy rain. 30 people killed (Map 7.1 n. 13).
27 October -7 November 2006	Turkey. Provinces of Sanliurfa (town: Harran), Diyarbakir (Cinar, Bismil), Batman (Batman), Mersin (Mersin), Istambul (Beykoz, Sariyer).	Heavy rain and flash floods. Worst floods in the region since 1937. 47 people killed. Economic losses of EUR 265 million (Map 7.1 n. 14).
23–26 May 2007	Spain (Central Spain: Madrid area, Castile-Leon, Castile-La Mancha, Extremadura)	Several days of heavy widespread rain. Economic losses of EUR 310 million (Map n. 15).
15–21 June 2007	England (Yorkshire, North Yorkshire and Midlands. Severn, Avon and Wye valleys)	More than a month's rainfall in 24 hours in some areas. River Ouse bursts banks in York. River Tame overflows in Water Orton in Warwickshire. River Dearne burst its banks in the Darfield area of Barnsley. Economic losses of EUR 270 million (Map 7.1 n. 16).
25 June 2007	Northern England (counties: Yorkshire, Lincolnshire, Worcestershire, South Yorkshire, Gloucestershire and Shropshire) and Wales	May, June, and July in England and Wales were the wettest for over 200 years. Estimates give the return period as ranging from 150 years to 200 years. Six people killed. High economic losses of EUR 1.9 billion (Map 7.1 n. 17).
23–25 July 2007	England (counties: Gloucestershire, Worcestershire, Oxfordshire, Berkshire, Bedfordshire, Herefordshire, Warwickshire, Lincolnshire. Rivers: Thames, Severn, Avon, Ock, Ouse, Evenlode, Windrush and Wye) and Wales	An almost static depression produced major rainfall over the British Isles. 143 mm in 24 hours in Pershore (Worcestershire) and 126 mm in 24 hours in Brize Norton (Oxforshire). Seven people killed. High economic losses of EUR 1.9 billion (Map 7.1 n. 18).
8–9 August 2007	Switzerland (large parts of northwestern Switzerland and the central plateau)	Record downpours in Canton Jura 150 mm in 72 hours. 100 mm in 24 hours in Zurich. Economic losses of EUR 290 million (Map 7.1 n. 19).
18 September 2007	Slovenia (Severnoprimorska, Gorenjska, Zahodnostajerska, Vzhodnostajerska, Ljubliana and Posavska regions)	Heavy regional rainfall. More than 100 mm rain in six hours. Flash floods and landslides. Economic losses of EUR 245 million (Map 7.1 n. 20).
22–31 July 2008 (*)	Romania (North-East region: Suceava, Neamt, Botosanim Iasi and Maramures counties)	Extensive regional rain. Five people killed: economic losses of EUR 440 million (Map 7.1 n. 21).
11–15 December 2008	Italy (several regions in North, Centre and South)	Widespread torrential rain. State of emergency in Rome after two weeks of heavy rain. Three people killed. Economic losses of EUR 290 million (Map 7.1 n. 22).

Note: (a) Economic losses adjusted to values of 2009.

Table 7.1 Significant flood disasters in Europe 1998–2009 (cont.)

Date of the event	Location	Impact (^{a})
21–28 June 2009	Czech Republic (Silesia, Olomouc and South Bohemia regions) and Poland (south-eastern)	In Czech Republic heavy rainstorms affected Silesia, Olomouc and South Bohemia regions. 13 people killed: estimated economic losses of 200 m euro In the South-eastern part of Poland floods occurred in the mountain and sub mountain areas. Local storms and heavy short-lasting rain triggered floods in small rivers and streams. 1 killed, estimated losses of around EUR 250 million (Map 7.1 n. 23).
7–10 September 2009	Turkey (Istanbul)	Flash flooding triggered by record rainfall in Istanbul. 31 people killed, estimated economic losses of about EUR 100 million (Map 7.1 n. 24)
1–2 October 2009	Italy (Sicily)	Some 250 mm rain fell in the space of a few hours. Flash floods and mudflows hit the southern town of Messina leaving at least 35 people dead and 10 missing (Map 7.1 n. 25).
November 2009	England (Cumbria county) and southern Scotland	Rainfall in Cumbria reached record levels of 314 mm in 24 hours. Hundred of homes and businesses were affected. Economic losses still being estimated but thought to amount to around EUR 230 million (Map 7.1 n. 26)

Note: (^{a}) Economic losses adjusted to values of 2009.
Flood events are often associated with landslide events. Therefore, some events included in Table 7.1 also appear in the landslide chapter in Table 9.1. These events are marked with an asterisk (*).

Source: JRC — updated from Barredo (2007) (data from: EM-DAT, Dartmouth Flood Observatory and NatCatSERVICE).

in Turkey with 47 killed in 2006 and in Italy with 35 killed in 2009, as can be seen from Table 7.1.

Figure 7.2 shows the number of fatalities caused by floods in the period 1970–2008. It seems that there is no evident trend in fatalities. The number of deaths is very much dependent on single events, as it is the case for Romania and Hungary in 1970, Spain in 1973, and Romania in 2005. Furthermore, in the past few years early warning systems and prevention measures have improved evacuation mechanisms in the areas exposed to floods.

7.2.3 *Analysis of flood impacts: economic losses*

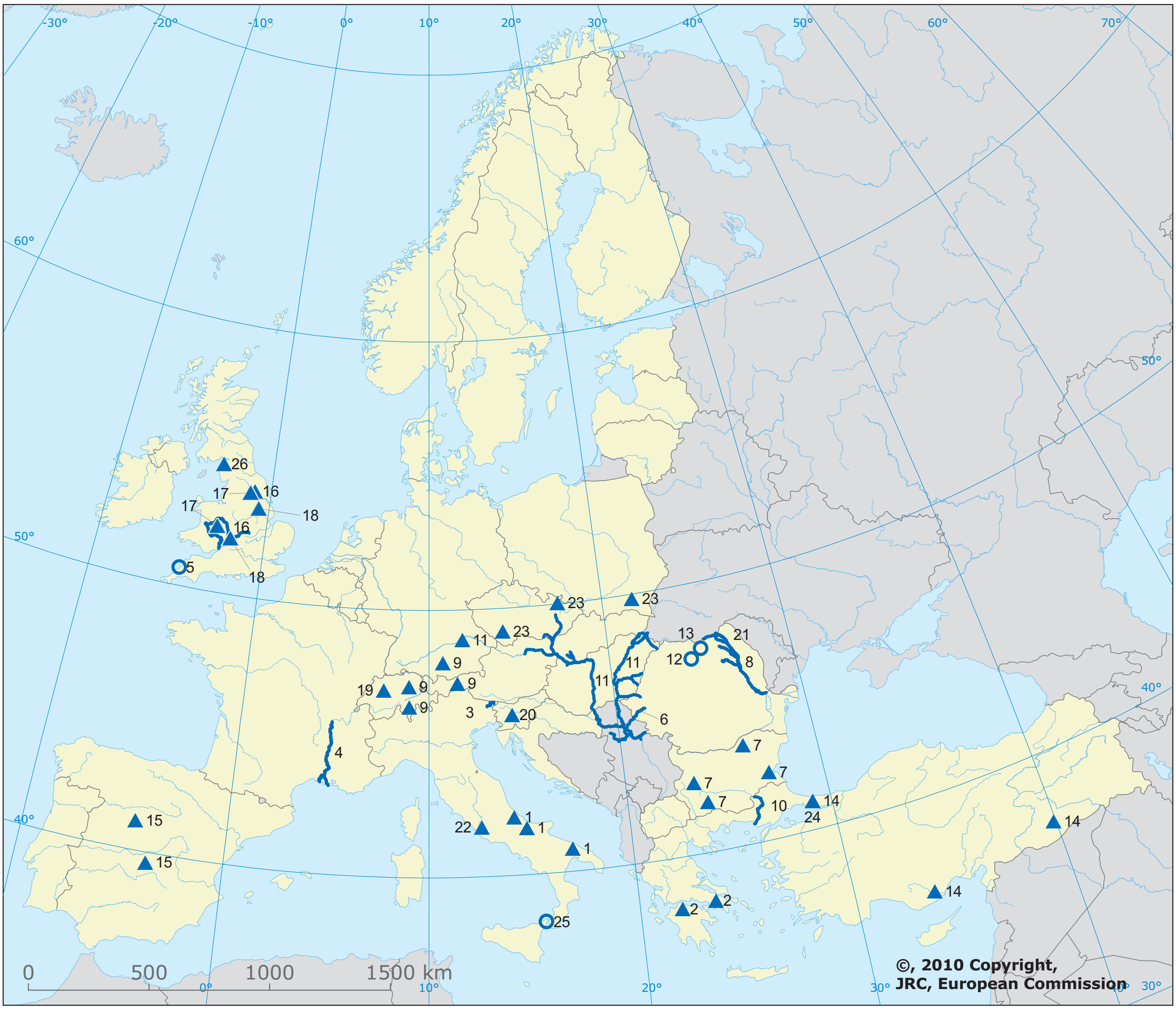
The direct economic losses from the major events between 2003 and 2009 were about EUR 17 billion. Exceptional flooding produced significant impacts included the floods of summer 2007 in the United Kingdom, which accounted for overall economic losses of more than EUR 4 billion: the flooding of 2005 in Switzerland, Austria and Germany accounted for EUR 2.8 billion and the winter storm and flooding affecting France on December 2003 caused EUR 1.6 billion in losses. Several areas were affected several times in the relatively short period of time between 2003 and 2009. This is the case for Worcestershire and Gloucestershire in England where two major events were reported (Figure 7.1). Also north-east Romania and Bulgaria experienced repeated flooding. Two particularly large floods hit both countries within just a few weeks of each other during the summer of 2005.

The countries registering the highest economic losses were United Kingdom (EUR 5 billion), Switzerland (EUR 2.3 billion), Romania (EUR 2.2 billion), and France (over EUR 1.6 billion). The flooding of summer 2007 in the United Kingdom and the event of 2005 in Switzerland have been selected as case studies for this chapter to illustrate the processes behind such disasters.

Trends in flood losses

Losses as a consequence of floods have increased over the past decades in Europe (Figure 7.3). Nevertheless, there is evidence suggesting that increases in population and assets in exposed areas are the main factors contributing to the increase of flood losses. Additionally, when assessing data from global disaster databases, it should be noted that improvements in data collection in recent decades may introduce some bias by suggesting a trend for increased losses over time. After filtering out the influence of socio-economic factors and the effect of improved data collection there is no evidence to suggest any influence of anthropogenic climate change on the trend of flood losses in Europe (Figures 7.4 and 7.5) (Barredo, 2009). Since the 1970s Europe has enjoyed an increasing standard

Figure 7.1 Significant flood disasters in Europe 2003–2009



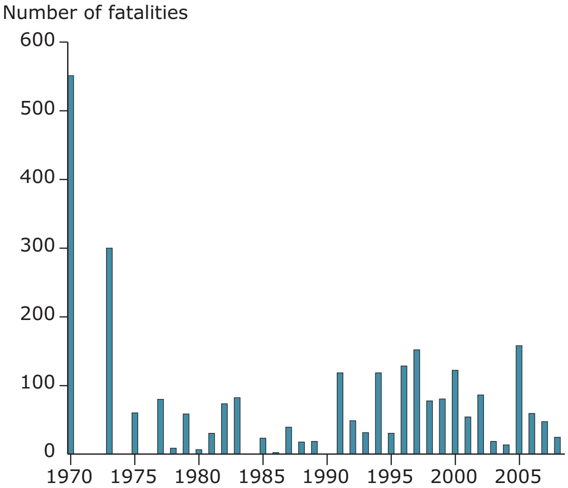
Note: Numbers on the map link each event with records in Table 7.1. Triangles represent large regional events and circles local events (large regional events are those usually affecting several river basins. The flooded area may extend over regions of more than one country. Widespread flooding occurs in this type of event).

Source: JRC — updated from Barredo, 2007.

of living, real per capita wealth and population. As a consequence, exposure of people and assets in flood-prone areas has been growing.

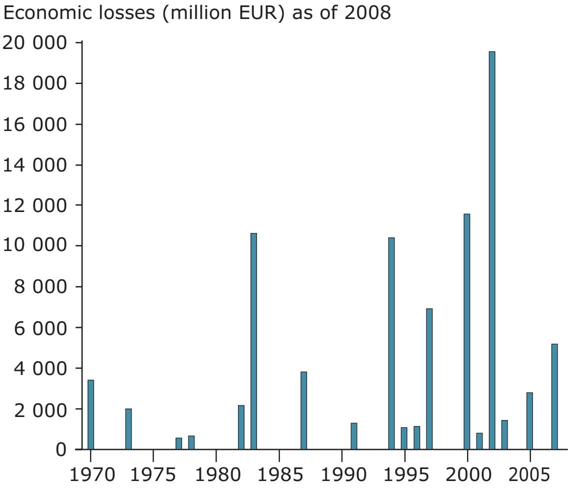
Figure 7.4 shows the normalised annual distribution of direct flood losses between 1970 and 2008. Normalisation is a method used for eliminating the socio-economic influence on disaster records. The purpose of normalising historical loss records is to produce values that are more representative in today's context (Barredo, 2009). The year of maximum normalised losses is 1983, followed by 2002 and 1997. The time series of normalised flood losses in Figure 7.4 show no evident trend over time. Hence the increase of flood related losses at continental level in recent decades is most likely due to socio-economic factors. This is also evident in studies at national and sub-national levels in Switzerland (Hilker et al., 2009), Italy (ISPRA, 2009) and Catalonia in NE Spain (Barnolas and Llasat, 2007). However, the absence of a clear signal of anthropogenic climate change in the normalised losses from floods should not be used as a justification for inaction. Evidence using state-of-art climate scenarios suggests that anthropogenic climate change most likely will result in a further increase of hydrologic flooding in many European regions (Dankers and

Figure 7.2 Number of fatalities caused by flood disasters in Europe, 1970–2008



Source: JRC — EM-DAT updated from Barredo, 2007.

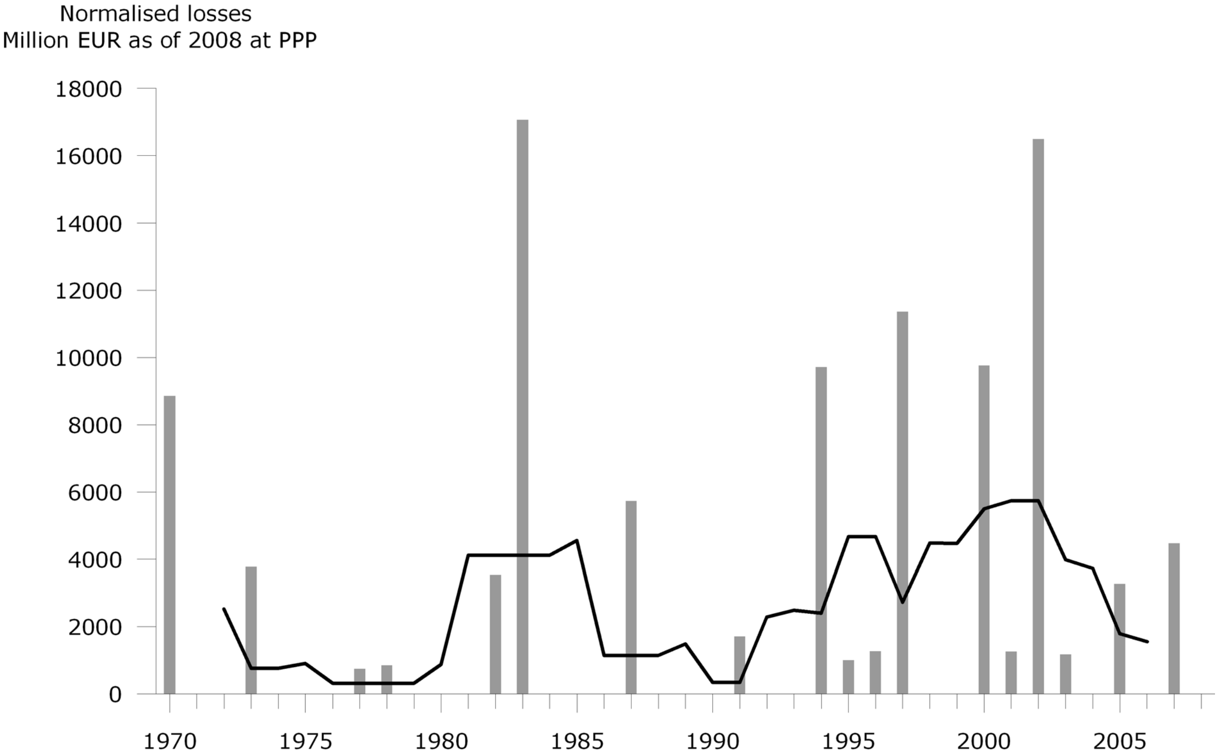
Figure 7.3 Annual flood losses in Europe from major flood disasters, 1970–2008



Note: Figures adjusted for inflation.

Source: JRC — updated from Barredo, 2009.

Figure 7.4 Normalised flood losses per year in Europe from major flood disasters, 1970–2008



Note: In black 5-year moving average.

Source: JRC — updated from Barredo, 2009.

Feyen, 2009), which, in turn, could result in even greater impacts. However, questions concerning the linkage between flood disaster losses and the role of anthropogenic climate change will remain an important area of research for years to come (Höppe and Pielke Jr, 2006).

7.2.4 *Analysis of flood impacts: ecosystems*

It is difficult to account for the impacts of floods on ecosystems and no databases are available in Europe to form the basis for such an analysis. Floods often have mixed impacts on the riverine environment.

One single event may produce benefits and losses to different parts of the riverine ecosystem. These impacts are extremely difficult to quantify or monetise e.g. by quantifying ecosystem services before and after an event or accounting for the number of fish killed or trees damaged.

Regular annual floods provide water resources for domestic supply, irrigation or industrial use. Some of the most important benefits of floods are linked to the maintenance of biological diversity in the flood plain ecology (Smith and Ward, 1998). Furthermore, many rivers carry minerals and nutrients which support agricultural production on the flood plains. Another aspect that makes it difficult to quantify the ecological consequences of floods is that some of the benefits from floods tend to become evident months or years after the event, or are often not apparent at all (e.g. recharging of groundwater stocks). This suggests that any immediate ecological accounting is prone to error (NRC, 1999). To conclude, flooding in river ecosystems should be regarded as a natural process not as a disturbance.

7.3 Case studies

7.3.1 UK floods 2007

May, June and July 2007 were the wettest months on record in England for the last 200 years. Heavy rainfall had already affected parts of Yorkshire and Central England in June with limited damage. Towards the end of June a new series of precipitation events flooded Hull, Sheffield and Doncaster, whereas in July new depressions brought heavy rains and flooding to the Avon, Severn and Thames basins. Residential areas in Gloucestershire, Oxfordshire, Berkshire and some areas in Lincolnshire, already flooded in June, were again under water. All together, this succession of flood events caused one of the world's largest disasters caused by natural hazards in 2007, especially in terms of economic losses, and was responsible for the biggest civil emergency in the history of Great Britain since World War Two.

One important characteristic of these events was the high proportion of overland flooding trapped in areas of poor drainage. According to the UK Environment Agency five times as many homes and business were inundated by surface flow as by river floods.

The 2007 summer floods caused a major social and economic upheaval in the United Kingdom. Although the number of deaths was low (13 people), economic damage and the disruption of essential services reached major proportions. More than 7 000 people had to be rescued by emergency services and tens of thousands had to abandon their homes. Half a million people lost access to water supply and electricity, and in Gloucestershire 350 000 people did not have their water supply restored until 17 days after the event. With 55 000 properties flooded, insured costs soared to EUR 2.4 billion, making this event one of the costliest disasters in UK history.

The UK 2007 floods also showed the relationships between disasters cause by natural hazards and social deprivation. According to a report by the UK Environment Agency, a high proportion of deprived people in the United Kingdom (poor, old, unemployed, ill etc.) tend to live in flood risk areas (Walker et al 2006). For instance, over half the population of the city of Hull, which was heavily damaged by the 25 June flood, lived in areas that were amongst the 20 per cent most deprived in England, many of which suffered from flooding. Some 180 000 insurance claims were made and the response by the insurance industry worked reasonably well. However, there were also important problems during the recovery process due to the lack of information, the sluggish responses by some local councils, hidden flood damages not accounted for (rising damp, mouldy carpets and the deformation of walls and floors due to the presence of undetected water) and the general resistance of the insurance industry to payments for repair to households, as normally reimbursements are made for what is actually lost. One important lesson from the Hull episode, for instance, was that many of the factors that make people vulnerable to flooding remained unaffected in the process of getting back to normal.

Finally, the UK 2007 floods also demonstrated the need for new modes of flood management. Pluvial flooding is likely to become a major problem in many European urban areas, especially those experiencing significant expansions of the urban environment. The most effective management measures may come from individual households and local authorities, rather than from national governmental agencies. The reason is that the most effective action may lie in protecting properties so that natural drainage can be retained. This implies avoiding paved and impermeable surfaces, maintaining back gardens, using flood resilient construction materials, etc. On a local scale, authorities should attempt to protect farmland to hold water and create wetlands and other natural water retention schemes.

7.3.2 Alpine floods, Switzerland 2005

Between 22 and 27 August 2005, the northern part of the Alpine region was affected by severe floods caused by tributaries of the Rhine in Switzerland and Austria, and by several tributaries of the Danube in Germany, Austria, and Hungary, as well as in the German part of the Danube itself. Floods also extended into Serbia and Romania where they caused the largest human toll associated with this event.

Floods followed heavy precipitation triggered by a low pressure system bringing warm and moist air from the Mediterranean to the northern parts of the Alps. As in England two years later, the most surprising aspect was the large amounts of rain recorded (up to 200 mm) over a very wide area that, in Switzerland for instance, stretched from the Alpine region to the Alpine foothills and into the Swiss Central Plateau where several lakes flooded their shorelines. Furthermore, precipitation fell on very saturated soils due to previous rainfall, and consequently quickly produced overland flow. Landslides and debris flows followed and, together with inundation, caused extensive damage to households, commercial and industrial buildings, infrastructure, and agricultural land. Several valleys remained cut-off from external communication for days.

In Switzerland, floods produced 6 fatalities and some EUR 2 billion in losses (as of 2009), making the precipitation episode the costliest disaster during the past 100 years. More than 900 municipalities (one out of three) suffered damage from floods, landslides and debris flows. The economic losses were highest in the cantons of Berne, Lucerne, Uri and Obwalden with damage exceeding EUR 200 million in each canton. One important characteristic of the August 2005 floods in Switzerland was that about three quarters of the damage was concentrated on private buildings and other assets. Damage in the private sector with insurance cover rose to more than CHF 2 billion; that is, four to five times as much as in any event since 1972. Contrary to other episodes such as the 1987 event, only 25 per cent of the total cost was attributed to public infrastructures.

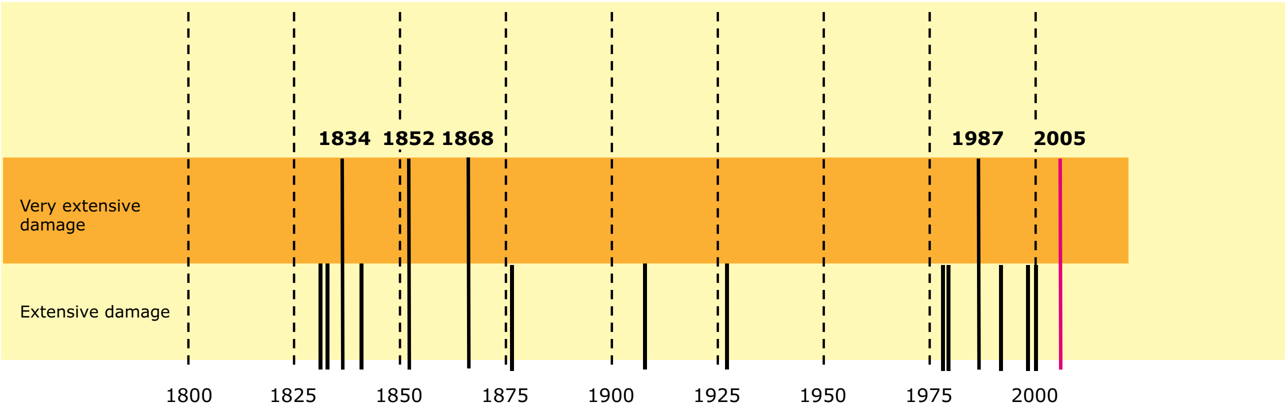
The 2005 floods also put the well organised Swiss Civil Protection Service to a severe test. Nonetheless, despite difficulties in providing an early forecast of these events, the emergency services worked reasonably well. Evacuation of tourists, as in the case of Engelberg, took place without major difficulties, as did the evacuation of the Matte neighbourhood in Bern, despite the dramatic images of people being lifted from the waters by helicopters. However, one major concern is the low level of awareness to flood and other hazards shown by the local population. The 2005 floods cannot be considered a unique event despite the magnitude of damage reported. In fact, several floods occurring in the 19th century (see Figure 7.5) caused damage that matched or exceeded the 2005 event.

7.4 Management options to reduce flood impacts

7.4.1 Measures

In recent decades, flood risk management has shifted from defence against floods to a more comprehensive approach. Many European countries are already practising integrated flood risk management, an

Figure 7.5 Historical comparison of flood damage in Switzerland



Source: DETEC, 2008.

approach that considers the full disaster cycle — prevention, protection, preparedness, response and recovery – in the management and prevention of flood disasters. However, the full implementation of integrated flood risk management, will, take some time, so it will be essential to further reduce vulnerability to floods in order to reduce the risks associated with them. Avoiding development in flood-prone areas, adapting future development to the risk of flooding, improving protection measures and promoting appropriate land-use, agricultural and forestry practices are all necessary in the short term.

7.4.2 *Specific policy on floods*

Specific flood prevention policies exist in many European countries. However concerted and coordinated action at the level of the EU would considerably add value and improve the overall level of flood protection.

The 2007 Commission Directive *On the assessment and management of flood risks* (EC, 2007) is a good example of such an action. It aims at reducing the risks and adverse consequences of floods. The directive applies to all types of floods and will be implemented in the Member States in three stages, beginning with a preliminary assessment of the river basin's flood risk, as well as associated coastal zones to be carried out by 2011. This is to be followed by the development of flood hazard maps and flood risk maps by 2013. During the last stage Member States are required to produce Flood Risk Management Plans (FRMP) by 2015.

Moreover, the Commission intends to reinforce the links with existing early warning systems, such as the Joint Research Centre's European Flood Alert System (EFAS, 2010). FRMP are to include measures to reduce the risk of flooding in an integrated framework. FRMP consider the interrelationships between all risk management measures and their analysis, including costs and effectiveness. FRMP should follow a long-term strategic approach, taking into account changes that might be expected in the long term in many domains such as socio-economic, land use and anthropogenic climate change.

7.5 Data gaps and information needs

Available information from global disaster databases is limited and suffers from a number of weaknesses (Bouwer et al., 2007). One important consideration concerns increases in the reporting of events during the past few decades as a result of improvements in data collection and flows of information. On this basis, an analysis of the number of flood disasters over time may reveal an increase that is due mostly to improvements in data collection. Furthermore, records are usually sourced from different institutions and often collected using a wide range of different assessment methods and rationales. This may further increase uncertainty regarding the attributes associated with each event (i.e. losses, casualties, etc.). Hence caution is needed in assessing any time-series of flood disasters from global databases.

The classification of events in hazard sub-types and more general the applied methodology provides another difficulty in disaster databases. This is particularly difficult for complex flooding events, for example how to classify an initial flash flood that derives in a large regional flood or a storm surge resulting from the combination of a storm and high water levels? The recent example of the storm Xynthia (February 2010) perfectly illustrates the dilemma: in EM-DAT (2010), which records events based on the triggering event, Xynthia is classified as a storm (Type: Storm. Sub Type: Extratropical cyclone –winter storm), but losses were due to extreme winds (in Spain, France and parts of central Europe) as well as coastal flooding (western coast of France; in EM-DAT, this is recorded as associated disaster type). Thus, proper classification is a critical aspect in a disaster base and the first steps for a common approach have recently been taken for global disaster databases (see e.g. Below et al., 2009).

Last but not least, cooperation between European countries should be further strengthened and comprehensive, publicly available inventories of flood events should be initiated in Europe at different levels of government. At the national/regional level, such an inventory would be particularly useful to provide accurate data and assessments which would serve as a basis for disaster prevention. At the European level, these inventories could assist in tracking the trends in flood-disaster losses, and in mitigation programmes monitoring and obtaining a clearer picture of the linkages between climate change and flood losses.

Part B — Geophysical hazards
8 Avalanches

Key messages

- The last winter in Europe with catastrophic avalanches was in 1998/1999 but snow avalanches still cause many fatalities each year, most of them occuring in relation to snow sports. Major events 2003–2009 include: 12 July 2007 Jungfrau/Switzerland (6 fatalities); 25 August 2008, Mt. Blanc/France (8 fatalities); 25 January 2009 Mt. Zigana/Turkey (10 fatalities).
- Average avalanche activity has not changed during the last decade and climate change will only affect it at lower altitudes, in short term. Integral Risk Management for avalanches is already advanced, with technical measures developed during the last five decades. These measures were further developed and supplemented after the last catastrophic events of 1999 in Europe, e.g. by decision support tools.
- Systematic data sources outside the Alpine countries are still incomplete and the quality of information concerning both human and economic losses due to snow avalanches is variable throughout Europe. Global disaster databases like EM-DAT give a limited estimate of the overall impact of avalanches, since many smaller events are not recorded. This is shown by the much lower total recorded fatalities in EM-DAT for the period 1998–2009 (130) compared to ICAR (1 500) for the same period. Therefore, a common European data base of events including information below the EM-DAT threshold would be desirable.
- High safety standards have been attained in Europe due to good cooperation at the European level. The key challenge is to maintain high safety standards by (1) maintaining technical countermeasures and (2) improving early warning systems.
- So far, no common avalanche policy exists at the EU level and the formulation of at least the basic elements of such an EU level policy would be desirable to support such activities as the avalanche safety services in the new member states.
- A growing debate is taking place on the degree of personal responsibility for snow sport accidents, although no generally accepted approach has been implemented.

8.1 Introduction

8.1.1 Avalanches — definitions and main causes

According to the multi-language glossary developed by the Group of European Avalanche Warning Services (EAWS, 2010) an avalanche is 'a snow mass with typically a volume greater than 100 m^3 and a minimum length of 50 meters that slides rapidly downhill'. Avalanches range from small slides barely harming skiers, up to catastrophic events endangering mountain settlements or traffic routes. Avalanche formation is the result of a complex interaction between terrain, snow pack and meteorological conditions. Avalanches are generally natural events and the majority occur without causing damage or even being noticed. Alpine avalanches kill around 100 people every winter (average for the past 30 years). However, it should be emphasised that in the past few years the great majority of fatalities in Europe have occurred in connection with snow sports, and not in relation to large catastrophic avalanches.

8.1.2 Sources of Information

The sources of information used by this chapter include the official avalanche warning services in the different European countries and regions, organised by the European Avalanche Warning Services (EAWS, 2010), and the International Committee for Alpine Rescue (ICAR, 2010). When compared to EM-DAT (CRED, University of Louvain; EM-DAT, 2010), these sources provide a much more comprehensive overview on the overall impacts of avalanches in

Europe, since they also include smaller accidents with less than 10 fatalities (see below).

8.1.3 Avalanches in Europe 1998–2009

The last catastrophic winter in Europe with a large number of fatalities in secured areas (i.e. settlements and traffic routes) was 1998/1999. The heaviest snowfall in the Alpine region for 50 years triggered numerous fatal avalanches, in particular in Austria, France, Switzerland, Italy and Germany. Table 8.1 shows the major avalanche accidents (events with at least 5 fatalities) from 1998 to 2009 in EEA member countries. With the exception of the winter of 1999, almost all fatalities occurred in relation to snow sports. Despite the significance of avalanches in the countries affected, data gathering is difficult as there is no generally agreed and standardised way to collect data on fatalities, damage and economic losses across Europe.

To our knowledge, no avalanches caused casualties or large damage to roads or settlements, in the Alps, Scandinavia and Turkey in the period 2003–2009. Unfortunately, systematic data sources outside the Alpine countries are still incomplete and the quality of the information concerning both human and economic losses due to snow avalanches is variable throughout Europe. Still, the available data by ICAR (2010) report about 1 500 fatalities in the period from winter 1998/1999 until 2009/2010 in Austria, Italy, France, Switzerland, Bulgaria, Germany, Great Britain, Liechtenstein, Norway, Poland, Romania, Slovakia, Slovenia, Spain, Sweden and the Czech Republic. This clearly demonstrates the impact of snow avalanches and also illustrates that EM-DAT, which only reported 130 fatalities for the period 1998–2009, can only give a limited estimate of the overall impact, since most of the fatalities recorded by ICAR occurred in smaller events with impacts below the thresholds used in EM-DAT (2010).

8.1.4 Avalanches and climate change

An analysis of the avalanche records in the Swiss Alps shows that natural avalanche activity has not changed over the last 70 years (Laternser et al., 1997). Climate change is, however, having a more and more pronounced effect at altitudes below 1 000 m a.s.l., where a significant temporal as well as spatial reduction of snow coverage is already taking place. In contrast, no trend is visible at higher altitudes. Further increases of temperature obviously reduce the period during which large avalanches can occur. However, the occurrence of large avalanches is not governed by general climatic trends but rather by short term weather events, such as particularly intense snow falls during a couple of days, possibly linked with strong winds or a rapid temperature increase with rainfall at high altitudes. Such marked weather periods will possibly become more frequent with climate change. The percentage of wet snow avalanches is expected to increase relative to dry snow avalanches. An increase or decrease in the size of the avalanches should not be expected, as avalanche size is governed by the release height and release area, which are hardly influenced by climatological developments but mainly by the topography and shear strength of the snowpack. From the conflicting tendencies described above — reduced snow coverage as against possibly more heavy precipitation events — it is currently still difficult make a clear forecast for the long term development of avalanche hazards under a changing climate.

Table 8.1 Major avalanche accidents, 1998–2009

Date of the event	Location (Country)	Number of fatalities	Area
28.01.1998	Les Orres (France)	11	Sports area
22.03.1998	Tuncely (Turkey)	12	Military
9.02.1999	Montroc (France)	12	Secured area
21.02.1999	Evolène (Switzerland)	12	Secured area
23.02.1999	Galtür (Austria)	31	Secured area
24.02.1999	Valzur (Austria)	7	Secured area
28.12.1999	Jamtal (Austria)	9	Sports area
28.03.2000	Kitzsteinhorn (Austria)	12	Sports area
12.07.2007	Jungfrau (Switzerland)	6	Military
25.08.2008	Mt. Blanc (France)	8	Sports area
25.01.2009	Mt. Zigana (Turkey)	10	Sports area

Source: EAWS, 2010 and ICAR, 2010.

8.2 Avalanche events 2003–2009: spatial analysis and trends

8.2.1 Analysis of avalanche impacts: Casualties

Since winter 1999, there have been practically no fatal avalanche accidents in residential areas or on traffic routes ('secured areas') throughout Europe. However, avalanche risk in these secured areas has not become negligible. Despite the intense efforts of the avalanche safety services, there are several cases each winter where avalanches reached public roads that had not been closed. With the precision of forecasting currently available such events could only be prevented by substantially increasing the closure of traffic routes.

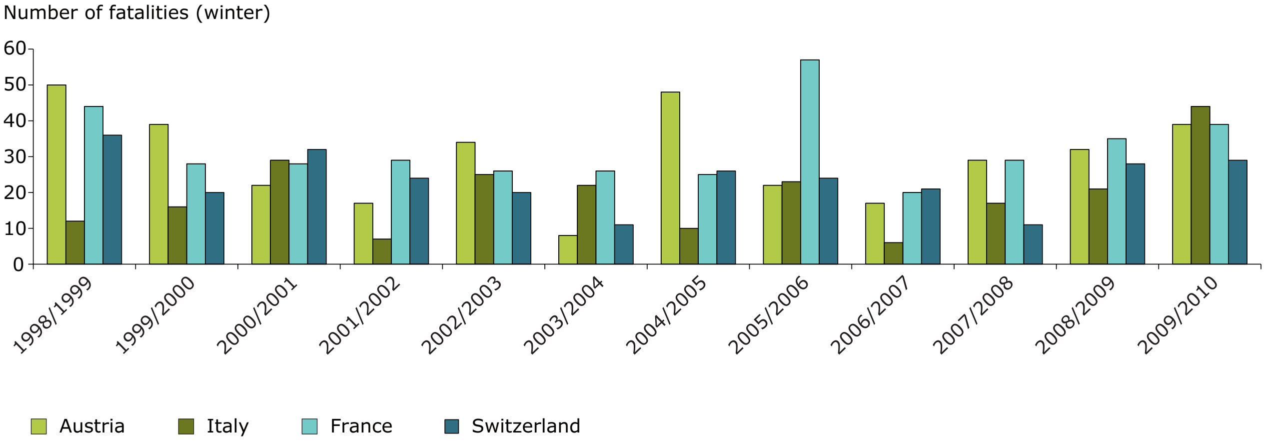
While catastrophic avalanches generally occur naturally, many of the smaller ones are triggered by skiers. The growth in winter sports over the recent decades is increasing the risk of avalanches caused by skiers and there are still a considerable number of fatal snow sports accidents. However, the number of fatalities has stayed at a constant level in all Alpine countries in spite of a steady increase of the number of snow sport avalanche accidents. Figure 8.1 shows the development of the total (including accidents with less than five fatalities) number of fatalities in the 'core' Alpine countries — France, Italy, Austria, and Switzerland — during the past 10 years: During this period, snow avalanches claimed around 100 lives per year in these four countries, amounting to a total of 1 257 fatalities. The main reason why the number of fatalities has not increased during recent years, apart from improved warning systems, is the widespread use of highly developed avalanche beacons, which facilitate fast search and rescue of people buried under the snow.

A growing debate is taking place as to the degree of personal responsibility for snow sport accidents; although no generally accepted answer has been found.

8.2.2 Analysis of avalanche impacts: economic losses

Generally, the direct economic losses due to the impacts of avalanches in Europe during the reporting period have been small. However, the tourist agencies are still concerned with the so-called indirect losses, even from avalanches that can not be called extreme. Tourism is a very important economic factor for the Alpine regions and in some areas the only source of income for the local population in winter. According to a study following the avalanche winter 1999 (Nöthiger et al., 2004) the short term reactions by tourists to avalanche events is substantial. Disastrous avalanches and the consequent, often slightly exaggerated media coverage are the main cause of loss of tourism revenues. Reductions in overnight stays in the alpine region are still noticeable one year after a disaster, though the number of day trippers recovers after a relatively short period. Deaths on roads or in residential areas lead to the biggest reduction in the numbers of visitors. Communication seems to be a crucial factor in reducing these indirect losses, suggesting the need for the engagement of professional public relations specialists during and after an event or crisis (Nöthiger et al., 2004).

Figure 8.1 Avalanche fatalities in the Alpine countries, 1998–2009



Source: SLF, 2010 based on ICAR, 2010.

8.2.3 Analysis of avalanche impacts: ecosystems

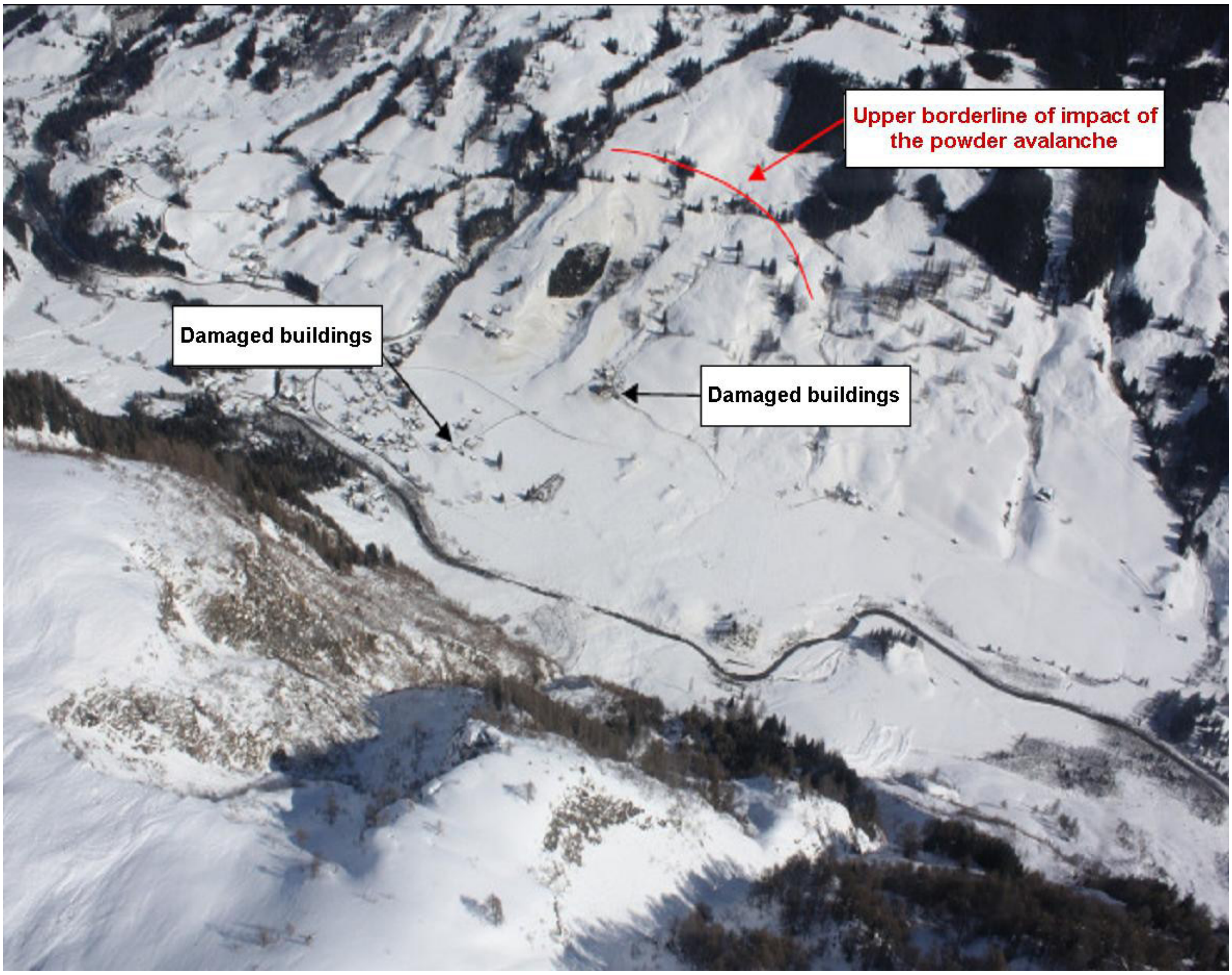
In environmental terms avalanches are a part of the dynamic regime of a mountain ecosystem and can cause soil erosion, break trees or even destroy whole forests. Therefore, despite their destructive force, avalanches should be viewed rather as a disturbance than a hazard from an ecological point of view. This disturbance can have a beneficial influence on several aspects of the ecosystem, as a recent study for the Swiss Federal Institute for Snow and Avalanche Research (SLF) shows (Brugger, 2004). When an avalanche starts above the forest, large trees can break off increasing the amount of light reaching the ground. Levels of nutrients and water also rise in the absence of the dominant trees that use these resources. These changes can create the conditions that many plant species need for growth, thereby allowing a different plant population to develop. The seedlings and saplings are sheltered by the snow cover or are flexible enough not to be destroyed by subsequent avalanches.

The biodiversity in avalanche tracks is often high, up to three times higher than in the surrounding forests (Rixen et al. 2004). The frequency of avalanches is highest in the centre of an avalanche track. Also, there are areas where the snow accumulates and others where it is eroded. Because of these factors, a variety of habitats develop within a small area.

8.3 Case study: the Avalanche Incident — Marchkar, Austria 2009

The avalanches which occurred in Austria in the past years have not been extraordinary with regard

Figure 8.2 Overview of area affected by powder avalanche in Marchkar



Source: Die.wildbach, 2009.

to damage to persons or material possessions. The winter 2008/09 however, was characterised by very heavy snowfalls, reaching up to more than 200 % of the monthly precipitation. This resulted in avalanches of exceptional size and form. For instance on 27 February 2009, around 07.00, a huge powder avalanche in the form of a snow slab was released from a cirque (Marchkar) at 2 450 m a.s.l. in the Austrian state of Salzburg. The 300 000 m³ of snow spread over the entire valley of Bucheben (Figure 8.2). The impacts of the powder avalanche reached far up the opposite slope of the valley. The main impact area was heavily damaged.

Early in 2009 up to 250 % more snow was precipitated as compared with the long-term average. The snow cover could barely settle because of the very low temperatures and strong north-westerly winds created a large volume of wind transported snow. During the days preceding the avalanche, the snowfall was particularly heavy. Furthermore, the composition of the snow layer was disadvantageous. The sliding surface of the avalanche was a hard snow crust which had formed during the previous few weeks. Additionally, strong winds led to snow slab conditions. The formation of a powder avalanche was also favoured by low temperatures and the substantial amount of snowfall.

In the main impact area the avalanche had a devastating effect. Farm buildings, hayricks and electricity poles were destroyed or damaged, mainly due to the shock wave of the avalanche. Also the forests protecting the slopes of the Marchkar valley were directly affected by the avalanche or by its shock wave (Figure 8.3). Most trees were bent over or uprooted. Due to the

Figure 8.3 Forest area damaged by the Marchkar avalanche

Source: Die.wildbach, 2009.

Figure 8.4 Building damaged by the Marchkar avalanche

Source: Die.wildbach, 2009.

inaccessibility of the steep terrain the damaged trees remained. This situation may lead to secondary effects such as lower stand stability, bark beetle infestation or erosion.

Immediate measures by the Austrian Torrent and Avalanche Control Department included the mapping and surveying of the avalanche and its damage (Figure 8.4) and the local population was supported in securing the damaged buildings. Furthermore, the potential for additional incidents was assessed via a Hazard Warning Map. As of October 2009, decisions on further mitigation measures are still pending.

8.4 Management options to reduce avalanches impacts

8.4.1 Measures

As a result of the massive avalanche protection programme (including avalanche barriers, afforestation, and early warning systems) together with intense efforts by the local avalanche safety services, high safety standards are achieved in the core Alpine countries. In normal winters, fatalities in secured areas, including roads and railways or settlements, are exceptional. The large majority of fatalities happen in connection with snow sports, away from secured traffic routes or secured ski slopes.

One positive view of the severe 1999 avalanche winter is that it is evident that the technical protection measures developed during the last five decades fulfilled their function to a great extent and prevented a large number of additional fatalities.

A detailed analysis of avalanche crisis management in Switzerland (11) during the 1999 avalanche period generally demonstrated very good performance by the local avalanche warning services (the so-called avalanche commissions) but also revealed several shortcomings, mainly in the areas of rapid communication, education and training, as well as the organisation of the avalanche safety services. Particularly at fault were those regions in which no action has to be taken in average winters, providing little opportunity for the local avalanche safety services to gain practical experience. The needs identified as a result of this experience were addressed by a comprehensive project, the Intercantonal Early Warning and Crisis Information System (IFKIS). In addition to an information platform for the avalanche safety services, the project developed comprehensive education and training programs, with a goal to achieve a common level of education and training throughout Switzerland (Bründl et al., 2004).

A particularly influential event was the avalanche catastrophe of Evolène on 22 February 1999, with 12 fatalities. This accident led to a lawsuit, lasting more than seven years, as a result of which the mayor of the community of Evolène and the head of the avalanche commission were sentenced to conditional prison by the Swiss Federal Court on 30 August 2006. Among other issues, the responsible agencies were accused of insufficient organisation of the avalanche safety service and insufficient management and documentation of the decision making procedure during the critical situation preceding the avalanche.

This sentence led to intense discussion among the safety services in Switzerland, as well as in neighbouring alpine countries, concerning the appropriate criteria for the work of the safety services, with respect to both the organisation and the decision-making process. As a result of these discussions, a new IFKIS module for a structured decision making and documentation procedure (IFKIS-EVAL) was developed as a support for the safety services. Information platforms and decision making schemes similar to IFKIS or IFKIS-EVAL, have been developed in other Alpine regions, for example in the Tyrol in Austria.

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(11) Due to the intense cooperation among the European countries, particularly in avalanche forecast and warning within EAWS, similar developments have taken place in other countries, particular in the central Alpine countries.

To maintain the highest safety standards the most important tasks identified for the near future include maintaining existing technical protection measures, which in many cases are reaching the end of their normal life span, and further developing early warning and crisis management systems.

8.4.2 *Specific policy to reduce avalanche impacts*

The Group of European Avalanche Warning Services (EAWS, 2010) forms an important basis for the advancement of avalanche security in Europe. EAWS is an informal but active effort by all European avalanche warning services to coordinate outputs and forecasting procedures. The most successful and important achievement is the generally accepted 5-level European Avalanche Danger Scale. Decisions are prepared by a permanent core working group and made at a biannual meeting (2001 Trento/Italy, 2003 Munich/Germany, 2005 Davos/Switzerland, 2007 Stary Smokovec/Slovakia, 2009 Innsbruck/Austria).

Despite this intense cooperation at the technical level, most evident in the success of EAWS, a minimal common 'avalanche policy' does not yet exist at EU level. The formulation of the basic elements of such an EU level policy would be highly desirable as a minimum requirement for the younger avalanche safety services in the new member states, which are often under pressure from growing tourism.

8.5 Data gaps and information needs

As indicated above, the quality of information concerning both human and economic losses is variable throughout Europe. A common European data base or register of events to collect such information would be highly desirable. It is clear that a detailed assessment of the metadata to be recorded should be undertaken at the start of the project. A different problem occurs in respect of data on injuries. Accidents with non-fatal injuries are not registered in a dedicated data base and minor injuries are often not registered at all. Therefore it will most probably continue to be impossible to establish high quality statistics on non-fatal accidents.

9 Landslides

Key messages

- For the period 1998-2009, almost 70 major landslides were recorded in different databases in Europe. These events, which often occured at multiple sites for the same triggering factor, claimed a total of 312 lives and damaged or destroyed an extensive amount of infrastructure including roads and houses.
- There seems to be no obvious trend in terms of landslide impacts. Potential impacts are often aggravated by land use management including uncontrolled urbanisation. The effects of climate change on the future frequency and intensity of landslides are not fully understood due to lack of information on the development of triggering factors of landslides at local levels. Thus, major research is required in this area.
- Currently, no comprehensive and up-to-date database of landslide occurrence and impacts exists in Europe. Inventories of landslides exist in most European countries but access is often restricted. There appears to be a need to work towards a European database on landslide occurrence and impacts, since this would benefit stakeholders and decision-makers. The information could also be used for awareness-raising.
- Land-use planning and management are key factors in landslide risk management. It is crucial to implement an Integrated Risk Management scheme, focusing on resilience and prevention policies without disregarding emergency and recovery. The reduction of vulnerability is a key factor that has to be addressed in risk assessment and prevention strategies. For the time being, methodologies and legislation regarding landslide risk management are still rather heterogenous throughout Europe or even absent in many countries. There is thus a need to enhance cooperation at European level in order to reduce the impact of landslides in Europe. The development of comparable guidelines for landslide risk assessment and a database on landslide occurence and impacts can be considered.

9.1 Introduction

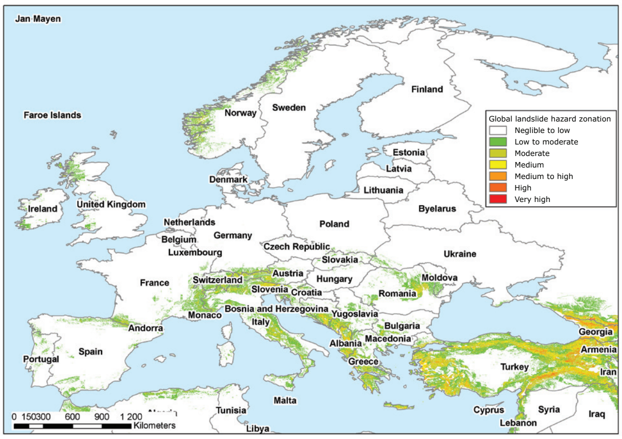
9.1.1 Definition

Landslides represent a major threat to human life, property, buildings, infrastructure and natural environments in most mountainous and hilly regions of the world (c.f. SAFELAND, 2010). Landslides are defined as the gravitational movement of a mass of rock, earth or debris down a slope (Cruden, 1991), which are basically described by two characteristics: (1) the material involved *(rock, rockdebris, earth)* and (2) the type of movement *(falls, topples, slides, spreads, flows)* (Cruden and Varnes, 1996). The above classification, e.g. rockfall, debris-flow, earth-slide, facilitates the understanding of the failure mechanism.

The occurrence and reactivation of landslides are conditioned by a number of contributing factors related to bedrock and soil properties including slope morphology, relief energy or land-use cover. In Europe, most catastrophic landslides are associated with heavy and/or prolonged rainfalls, coupled with soil erosion on mountain slopes. Other important triggering factors include earthquakes, snow melt and slope toe erosion by rivers or sea waves, thawing mountain permafrost, volcanic eruptions, and man-made activities such as slope excavation and loading, land use changes, blasting vibrations or water leakage from utilities (Hervás, 2003).

The distribution of landslide hazards over Europe is strongly linked to the initial geological and relief conditions of the continent. Therefore, mountainous areas, such as the Scandinavian Peninsula, the Alps and also the southern part of Europe are most prone to landslides (Figure 9.1). Central Europe is only marginally affected, as is eastern Europe with the

Figure 9.1 Landslide hazard zonation Europe, ranging from none (0-1) to very high (6) susceptibility



Source: NGI, 2009.

exception of Romania and Bulgaria (EEA, 2004; Jelínek et al., 2007; Schweigl and Hervás, 2009).

9.1.2 *Sources of information*

The major landslide phenomena that occurred in Europe during the period 2003–2009 were compiled from an analysis of global disaster databases, such as the EM-DAT (2010), NatCatSERVICE (2010), International Consortium on Landslide (ICL, 2010) ([12]) and the Geological Survey of Canada (GSC, 2010) ([13]) as well as by review of the scientific literature and the web. Last but not least, a special enquiry was carried out with the support of the Association of Geological Surveys of Europe (Eurogeosurveys, 2010) to get a more comprehensive picture of landslide events at regional to local scales. The different sources of information varied significantly in their representation of the problem. For example, EM-DAT (2010) reported only three events for the period 2003–2009, NatCatSERVICE (2010) reported no events but other sources recorded 61 major landslide events. Even the two case studies (cf. below) with high impacts in Austria and Italy, were not mentioned in either EM-DAT (2010) or NatCatSERVICE (2010). However, even these major events represent only a glimpse of the real impact of landslides, as the enquiry carried out with *Eurogeosurvey* yielded a total of 712 089 recognised mass movements (Figure 9.2) in Europe.

It is evident that national databases provide a much more comprehensive picture of the frequency, distribution and impact of landslides, as compared with global databases (see e.g. Trigila and Iadanz, 2008 or Trigila et al., 2008). This is not surprising, as most landslides are small and isolated events that produce, very few fatalities and/or slight economic damage per event. Therefore these events are likely to fall below the threshold values used in the global disaster data bases like EM-DAT.

9.1.3 *Major landslides in Europe 1998–2009*

Table 9.1 lists the major landslides in Europe during the period 1998–2009, in which 312 people were killed and infrastructure including roads and private house damaged or destroyed. Landslides are often associated with flood events. Therefore, some events included in Table 9.1 also appear in the floods chapter in Table 7.1. These events are marked with an asterisk (*).

9.1.4 *Landslides and climate change*

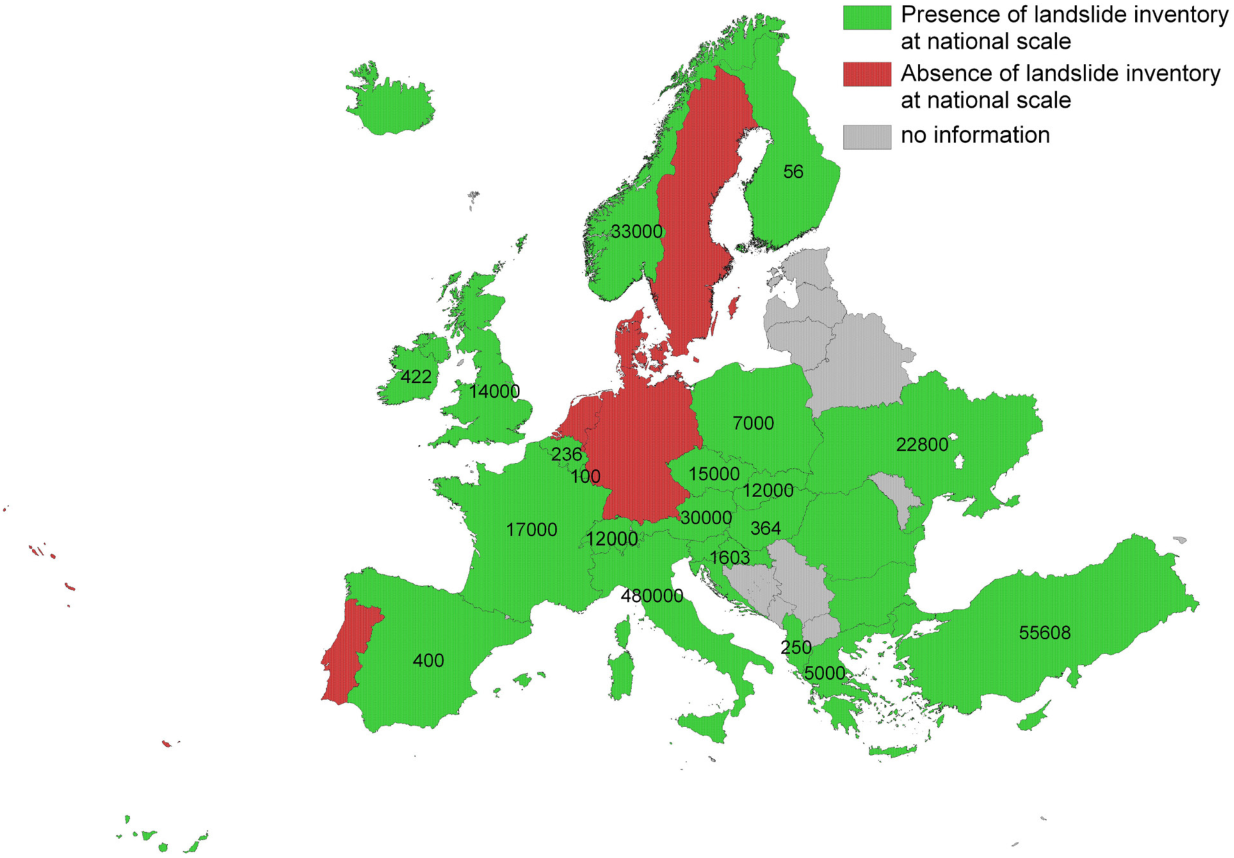
Anthropogenic climate change is expected to increase the mean temperature and to alter precipitation patterns in Europe in the future (IPCC, 2007, EEA-JRC-WHO, 2008). Precipitation patterns are expected to be more spatially variable, with decreasing precipitation in the Euro-Mediterranean area and increasing precipitation in central and northern Europe. Moreover, the intensity of precipitation extremes, which has already increased over the past 50 years, is projected to become more frequent (EEA-JRC-WHO, 2008). Since heavy rainfall events are frequent triggering factors for landslides, the following trends can be assumed (Margottini et al, 2007):

- Increase in the number of debris flows from high intensity rainfall, together with soil erosion and degradation phenomena, as a consequence of increases in temperatures and aridity;

([12]) The ICL catalogue of landslides provides information gathered from web searches engines ranging 2003-2007; the data base is clearly dominated by English language information.

([13]) GSC offers news reports based on the following search engines (www.google.com; www.google.fr; www.yahoo.com; http://ca.yahoo.com; http://ca.altavista.com). Results are checked for valid links and only those news items referring to actual landslides are retained in a database. The data based only covers the years 2005-2008 and is likely to be slightly biased since it is dominated by English language information.

Figure 9.2 Availability of a national landslide inventory in European Countries and related number of detected landslides



Source: ISPRA, 2010, based on an enquiry carried out with the support of the Association of Geological Surveys of Europe.

- Decline in activity for slow landslide phenomena due to the drop in the total average annual rainfall and the consequent decrease in the recharge capacity of the water tables;
- Increase in deformations of slopes (rock falls due to freeze thaw, debris flows, earth flows) in areas which are now covered by permafrost and therefore substantially stable, following progressive increases in temperature and the consequent reduction in permafrost and glacial areas.

For the time being however, it's difficult to make a clear long term forecast of the development of landslide hazards under a changing climate, partly because landslides are mainly triggered by meteorological events that are quite different from climate. The downscaling of climate modelling and future scenarios to predict shorter term meteorological events is still to be fully investigated and applied to different types of mass movements.

9.2 Major landslide events 2003–2009: spatial analysis and trends

9.2.1 Frequency and spatial distribution of landslides

As mentioned in Section 9.1.1, mountainous areas are most prone to landslides. This is also reflected in Figure 9.3, which presents an overview of the major landslide events reported in the period 2003–2009 by the different information sources. Figure 9.3 shows that the distribution of real 'landslide hotspots' is very close to the distribution of landslide prone regions showed in Figure 9.1.

Figure 9.4 identifies the temporal distribution of major landslides during the period 2003–2009. The limited number of events does not permit any detailed interpretation.

Table 9.1 Major landslide events, 1998–2009

Date of event	Location	Impact	Source
May 1998	Sarno (Na), Italy	Debris flows swept away hundreds of buildings and killed 160 people.	EEA, 2004
March 1999	Romania	About 12 landslides, more than 100 homes destroyed, railways and roads damaged.	EEA, 2004
13 October 2000 (*)	Switzerland	Landslides destroyed several buildings, causing 14 deaths.	EEA, 2004
November 2000	Slovenia	About 25 hectares of forest swept away.	EEA, 2004
November 2001	Turkey	Landslides triggered by torrential rains, nine people killed, about 600 evacuated.	EEA, 2004
01 September 2002	Lutzenberg, Switzerland	Landslide demolishes a house and kills 3 people.	www.planat.ch/index.php?userhash=122590720&navID=1384&l=e (accessed 11 November 2010)
01 January 2003	Surrey, England	Landslide derails a train carrying 105.	ICL, 2010
29 August 2003 (*)	Udine, Italy	Landslides triggered in Malborghetto-Valbruna municipality. 2 victims.	Case study in this report
08 September 2003	Kvasov, Slovakia	Landslide threatens 3 homes, a road and a funeral parlour.	ICL, 2010
12 September 2003	Albena, Bulgaria	Landslide kills 2 people.	ICL, 2010
19 September 2003	Mayo, Ireland	Landslide triggered by heavy rain damages bridges and a road, some 100 people stranded in their homes.	ICL, 2010
27 October 2003	Sheffield, the United Kingdom	About 25 people relocated from flats on Solly Street due to a landslide in Sheffield Hallam University.	ICL, 2010
06 February 2004	Athens, Greece	The Saketas military camp on the outskirts of Vyronas, eastern Athens was shut due to a landslide.	ICL, 2010
14 November 2004	Lecco, Italy	Landslide destroys house in Italy — two people killed.	ICL, 2010
17 March 2005	Sivas, Turkey	Landslide — 15 killed, 9 injured.	EM-DAT, 2010, ICL, 2010
09 March 2005	Cosenza, Italy	Landslide caused by severe winter storms, hundreds evacuated.	ICL, 2010
03 August 2005	Trazbon, Turkey	Landslide triggered by heavy rainfall brought down a house in northern Turkey killing three people.	ICL, 2010
07 August 2005 (*)	Balkan, Bulgaria	Bulgarian floods and landslide prompt mass evacuation, one old woman died under a landslide.	ICL, 2010
22 August 2005 (*)	Styria, Austria	Disasters 2005 — Communities of Gasen and Haslau — two people killed.	Case study in this report
22 August 2005 (*)	Several places Switzerland	Several landslides and mudflows, destroying several buildings and causing 6 deaths.	www.planat.ch/index.php?userhash=122590720&navID=1384&l=e (accessed 11 November 2010)
22 August 2005	Rize,Turkey	Landslide in Turkey's Black Sea province of Rize — , four people killed.	ICL, 2010
08 November 2005	Gwynedd, England	Landslide injured four workmen.	ICL, 2010
14 November 2005	Bergen, Norway	Heavy rainfall triggered landslides, seven people working on a house swept away and injured.	ICL, 2010
17 November 2005	Ebbw Vale, England	People living in eight houses evacuated after heavy rain caused hillside collapse.	ICL, 2010

Table 9.1 Major landslide events, 1998–2009 (cont.)

Date of event	Location	Impact	Source
27 November 2005	Edinburgh, Scotland	Landslide caused by winter freeze derails Inverness train — 9 people injured.	ICL, 2010
20 December 2005	Bilbao, Spain	Landslide injures two.	ICL, 2010
21 January 2006	Turkey	Landslide buries bus — eight killed and fifteen injured.	ICL, 2010
23 March 2006	Silven, Bulgaria	Landslide kills one man injures another.	ICL, 2010
01 May 2006	Naples, Italy	Man and three of his daughters killed when a landslide caused by heavy rain destroyed their house.	EM-DAT, 2010, ICL, 2010
18 May 2006	Turkey	Landslide triggered by heavy rains buries eight hillside homes.	ICL, 2010
31 May 2006	Gurtnellen, Switzerland	Rockfall kills two people on Gotthard highway.	ICL, 2010
22 June 2006	Romania	Mudslide kills seven.	ICL, 2010
01 November 2006	Algard, Norway	A 40-50 meter wide wall of earth slid onto E39 highway covering road to a depth of about 1.5 metres.	ICL, 2010
02 December 2006	Bulgaria	Landslide kills construction worker.	ICL, 2010
12 December 2006	Valencia, Spain	One man killed and another injured due to a landslide.	ICL, 2010
20 December 2006	several place, Sweden	Part of major road collapses in landslide.	ICL, 2010
25 December 2006	Azores Islands, Portugal	Landslide kills two.	ICL, 2010
02 January 2007	United Kingdom	Landslide on beach kills woman.	ICL, 2010
03 March 2007	Mont Blanc, France	Tunnel closed due to landslide.	ICL, 2010
22 March 2007	Kozjak, Macedonia	Landslide kills construction worker.	ICL, 2010
28 March 2007	Sofia, Bulgaria	Landslide buries 32-year-old worker.	ICL, 2010
09 April 2007	Alps, Austria	Six people injured due to landslide caused by collapse of part of hotel.	ICL, 2010
09 April 2007	Kerry, Ireland	Road closed after landslide.	ICL, 2010
13 April 2007	Zaragoza, Spain	Four people injured — buried by a landslide caused by heavy rain.	ICL, 2010
23 April 2007	Macael, Spain	Landslide of 150 000 cubic metres of earth destroyed part of the municipal sports stadium.	ICL, 2010
15 May2007	Varna, Bulgaria	Road to Bulgaria's Golden Sands Resort may be moved because of landslides.	ICL, 2010
20 May 2007	Sofia, Bulgaria	Landslide closed off Sofia-Pernik road in Vladaya area.	ICL, 2010
28 May 2007	Van, Turkey	Two-year-old child dies due to landslides triggered by heavy rain.	ICL, 2010
30 May 2008	Piemonte region, Italy	Landslide kills four people.	www.lastampa.it/Torino/cmsSezioni/cronaca/2008 05articoli/7112girata.asp (accessed 11 November 2010)
27 July 2008 (*)	Romania	Landslide kills one person.	http://afp.google.com/article/ ALeqM5ghGX8amKEwQnbSmKSN658PLRXCUQ (accessed 11 November 2010)
05 September 2008	Costwolds, the United Kingdom	Mudside buries geologist.	www.timesonline.co.uk/tol/news/weather/ article4699184.ece (accessed 24 November 2010)
10 September 2008	Turkey	Landslide due to heavy rain kills three village guards, injures two others with one missing in south east Turkey.	http://english.people.com. cn/90001/90777/90854/6497011.html (accessed 11 November 2010)

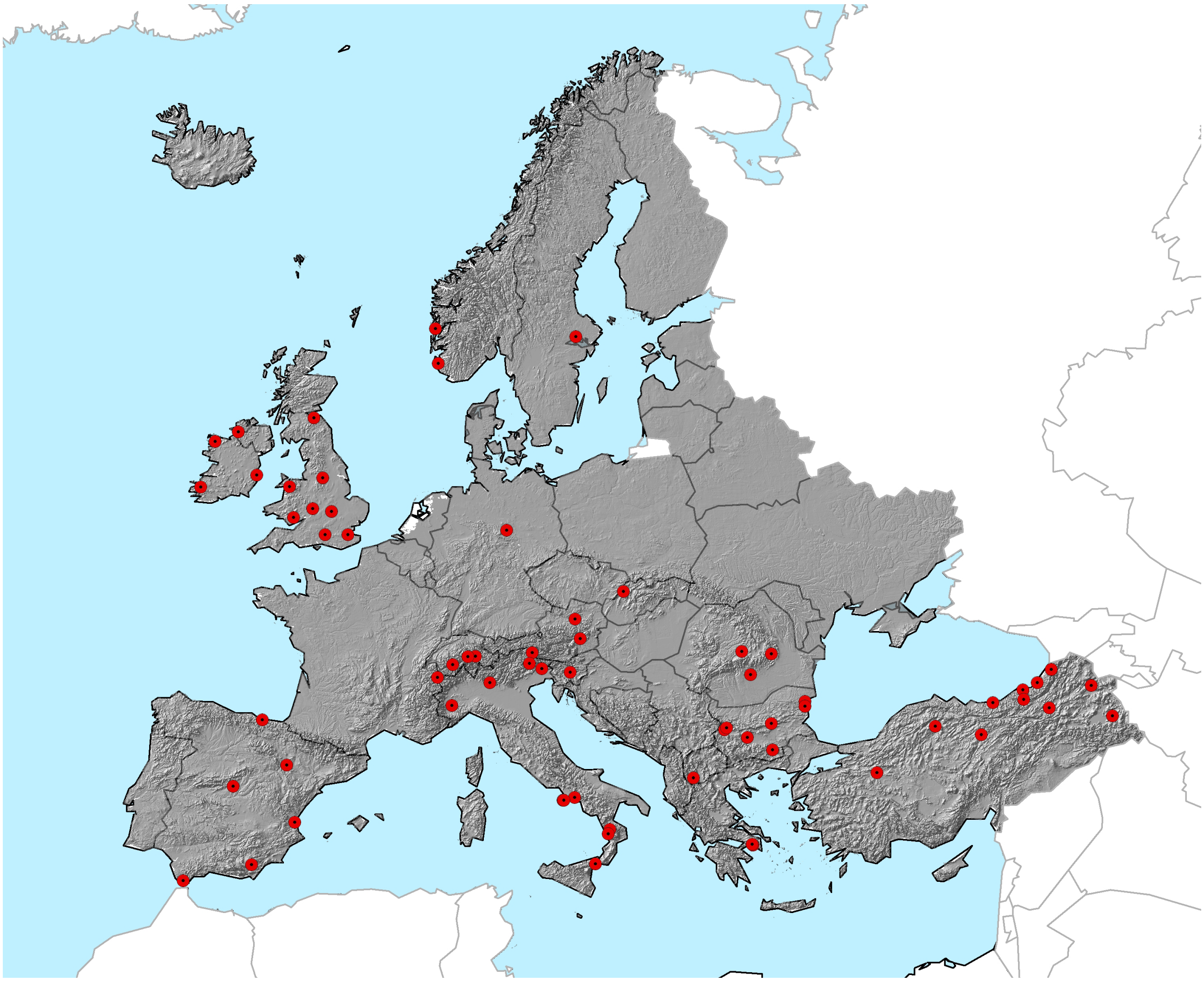
Table 9.1 Major landslide events, 1998–2009 (cont.)

Date of event	Location	Impact	Source
11 October 2008	Ceuta, Spain	Mudslide injures person.	www.independent.co.uk/news/world/europe/british-mother-and-daughter-killed-in-spanish-floods-957572.html (accessed 11 November 2010)
24 November 2008	Asturias, Spain	Mudslide kills man.	www.iol.co.za/news/world/stormy-weather-lashes-spain-1.426849 (accessed 24 November 2010)
25 January 2009	Salerno, Italy	Rain also triggered a mudslide onto the main highway south of Naples, killing at least two people and injuring five.	www.corriere.it/cronache/09_gennaio_26/frana_morti_autostrada_a3_200c86f4-eb6f-11dd-92cf-00144f02aabc.shtml (accessed 11 November 2010)
08 April 2009	Pöchlarn and Ybbs, Austria	Landslide causes closure of two lanes of A1.	http://austriantimes.at/index.php?id=12384 (accessed 11 November 2010)
14 July 2009 (*)	Ordu province, Turkey	Two people died in a landslide in northern Turkey caused by heavy rainfall.	www.reuters.com/article/idUSLF409377 (accessed 11 November 2010)
18 July 2009	Nachterstedt, Germany	A violent landslide tipped a house in Saxony-Anhalt into a lake early on Saturday morning. Three people are missing and feared dead.	www.thelocal.de/national/20090718-20679.html (accessed 11 November 2010)
18 July 2009	Veneto region, Italy	Borca di Cadore. Landslide kills mother and son.	http://corrieredelveneto.corriere.it/notizie/cronaca/2009/18-luglio-2009/borca-cadore-due-morti-una-frana-1601580304550.shtml (accessed 11 November 2010)
25 August 2009	Gaeltacht, Irleand	Donegal mudslide cuts off 20 families.	www.irishtimes.com/newspaper/ireland/2009/0825/1224253194759.html (accessed 11 November 2010)
24 September 2009 (*)	Artvin province, Turkey	Heavy rains in northeast Turkey have triggered floods and a landslide that killed people.	http://blog.taragana.com/n/4-killed-1-missing-in-floods-landslide-in-northeast-turkey-177289/ (accessed 11 November 2010)
01 October 2009	Sicily region, Italy	Mudslide in Messina, killed 31 people and forced hundreds from their homes. 75 injured.	www.corriere.it/cronache/09_ottobre_01/maltempo-temporali-sud_734326e6-ae99-11de-b62d-00144f02aabc.shtml (accessed 11 November 2010)
10 November 2009	Naples, Italy	Mudslide hits town, 20 injured and 1 killed.	www.upi.com/Top_News/International/2009/11/10/Mudslide-hits-town-on-Italian-island/UPI-52801257892260/ (accessed 11 November 2010)
17 November 2009	Dublin, Irleand	Landslide disrupts Rosslare rail line.	www.rte.ie/news/2009/1117/rail.html (accessed 11 November 2010)
22 November 2009	Giresun province, Turkey	A landslide killed two people, while another person survived the landslide with serious injuries.	www.worldbulletin.net/news_detail.php?id=50272 (accessed 11 November 2010)
30 November 2009	Dorset, the United Kingdom	A passenger train was derailed, after a landslide pushed a tree on to the track.	http://news.bbc.co.uk/2/hi/uk_news/england/dorset/8386354.stm (accessed 11 November 2010)
21 December 2009	Tempi Valley, Greece	Greece's main north-south highway remained closed on Friday, after a major landslide on Thursday killed a 62-year-old motorist.	www.ana.gr/anaweb/user/showplain?maindoc=8246559&maindocimg=8246495&service=102 (accessed 11 November 2010)

Note: Landslide events are often associated with flood events. Therefore, some events included in Table 9.1 also appear in the flood chapter in Table 7.1. These events are marked with an asterisk (*).

Source: ISPRA, 2010, based on the sources mentioned in Section 9.1.2.

Figure 9.3 Major landslide events in EEA countries, 2003–2009



Source: ISPRA, 2010, based on Table 9.1.

9.2.2 *Analysis of landslide impacts: fatalities*

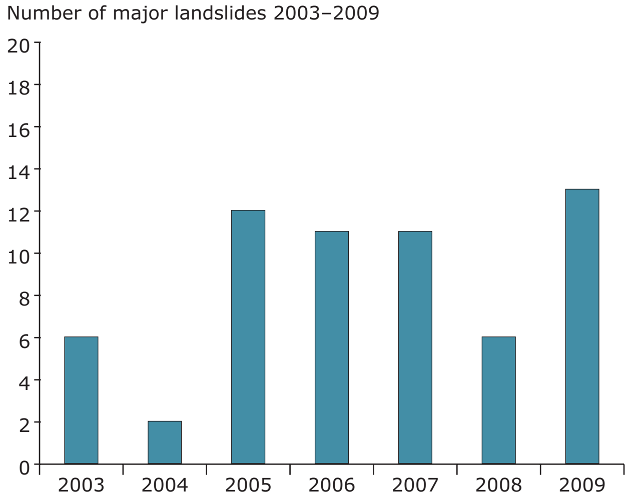
In general, fatalities due to landslides are a consequence of rapid and extremely rapid slope movements such as debris and earth flows, triggered by high intensity precipitation.

From 2003 to 2009, 125 fatalities were recorded in 61 events (Figure 9.5). This number is much higher than that stated in EM-DAT (2010) for the same period, and certainly provides a more comprehensive picture of the major events in Europe at that time. However, it still doesn't reflect the full number of landslides as is evident from the results of the enquiry carried out with *Eurogeosurvey* (2010; see Section 9.1.2).

9.2.3 *Analysis of landslide impacts: economic losses*

Currently, there is no comprehensive overview of the overall economic losses resulting from landslides in Europe. However, figures are available for several European member states, e.g. Spain (EUR 170 million/year), Sweden (EUR 8–15 million/year), and Norway (EUR 6.5 million/year) (Shuster, 1996). Italy spent approx. EUR 146 billion between 1957 and 2000 as a result of damage caused by landslides and floods (Cellerino, 2006), plus an estimate of approximately EUR 44 billion calculated by the River Basin Authorities to make the entire country safe.

Figure 9.4 Temporal distribution of major landslides in Europe, 2003–2009



Source: ISPRA, 2010, based on Table 9.1.

Figure 9.5 Fatalities and injured in Europe, 2003–2009

Source: ISPRA, 2010, based on Table 9.1.

It is not possible to calculate the exact economic cost of major landslides reported in Table 9.1. The main reasons for this is that a landslide is a local phenomenon, generally managed by different institutions at the local level including local municipalities, road authorities, railway authorities etc.

9.2.4 Analysis of landslide impacts: ecosystems

The impacts of landslides on natural ecosystems are normally ascribed to the loss of land due to degradation, erosion and the inaccessibility of areas affected by landslides. However, major landslides can lead to general modification of the landscape and associated ecosystems (e.g. by creating a dam resulting in an artificial lake). No clear information on ecosystem impacts was discovered in the different sources of information for 2003 to 2009 and it is assumed that there had been no major impact on ecosystems.

9.3 Case studies

Some of most destructive landslides during 2003–2009, in terms of victims and damage, have been the debris flows which affected the Alpine region, in particular Italy (2003), Austria and Switzerland (2005). These were extremely rapid and often newly formed landslides, triggered by short and intense rainfall over large areas. These complex geological and hydraulic phenomena are the subject of the following case studies.

9.3.1 Italy — Friuli Venezia Giulia Region, 29 August 2003

Description of the event
On 29 August 2003 an extreme meteorological event affected the north-eastern sector of the Friuli Venezia Giulia Region causing the many water courses to overflow flooding town centres and triggering more than 1 100 landslides, mainly of the mud flow and debris flow types (Borga et al., 2007; Manca et al., 2007). The main outcropping bedrocks in the area are Triassic Dolomite, limestone and marls. These events impacted on the population, buildings, hydraulic structures and communication infrastructures. There was significant interruption to normal economic and social activities for several days, resulting in the implementation of massive projects by the Civil Protection Agency in the Friuli Venezia Giulia Region. A team of experts was set up immediately after the event which, on the basis of site visits and ground surveys, aerial photo analyses and laser scan surveys, surveyed 1 108 landslides distributed over an area of approximately 17 km^2.

Type of movement and magnitude (volume and speed)
Most of the landslides were classified as extremely rapid debris flows and soil slips evolving into mud flows. The debris set in motion amounted to several hundred thousand cubic metres; single debris flow deposits consisted of between a few hundred to some ten thousand cubic metres, with peak values of 100 000 m^3 (Tropeano et al., 2004; Cavalli et al., 2007).

Triggering and causative factors
On 29 August 2003, at the end of a long period of drought, a major convective system affected the basin of the River Fella, in the upper basin of the River Tagliamento. Exceptionally high intensity rainfall was recorded, with peaks of 90 mm/h, and rainfall of more than 350 mm in 12 hours and almost 300 mm in just 4 hours. Due to the immediate saturation of highly

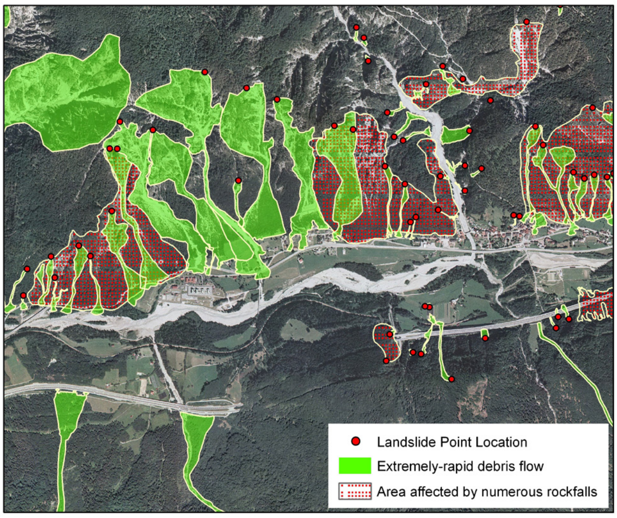
permeable talus detritus and in-channel deposits, the debris-release processes were easily triggered at the head of the catchments and along entire channel reaches. Soil slips occurred on soil-covered slopes, evolving, generally into mud debris flows.

Damage

The main communication routes were interrupted by large debris flows which invaded the highways (Highway A23, National Road 13 Pontebbana) and the Udine-Tarvisio railway line as well as rotational slides which, in some cases, completely destroyed roads. Three bridges were completely destroyed, 100 houses were buried, and entire villages were overrun by detritus and mud with sediment thicknesses of more than 2 metres. Direct impacts on the local population occurred primarily in the municipality of Malbroghetto-Valbruna and in the Municipality of Pontebba, with several injuries and 2 deaths. The direct reconstruction costs were EUR 364 million.

Mitigation measures taken after the event to reduce the landslide risk

The management of the emergency carried out by the Civil Protection Agency of the Friuli Venezia Giulia Region included the following phases: a) aid and assistance to the population and recovery of missing persons, b) study and analysis of the event with surveys of the landslides, estimate of the damage and the repair, reconstruction and restoration costs; c) construction of emergency remedial works to protect public health and safety. With regard to the analysis of the event, the following activities were carried out: acquisition of territorial data (helicopter high resolution digital orthophoto and laser scanning survey — ALTM acquired immediately after the event 31/08 and 1-2/09), identification and mapping of landslides and critical hydraulic situations, production of thematic maps (scale 1:5 000), study of the hydraulic safety of the River Fella. The emergency works included: restoration of the hydraulic cross-section of streams and rivers, removal of detritus (e.g. village of Cucco), reconstruction of roads and bridges, restoration of network services (lighting, sewerage system, water supply pipeline); remedial works on landslide slopes and hydraulic-forestry works (Garlatti et al., 2004; Massari and Potleca, 2004).



Landslides triggered on 29 August 2003 in Malborghetto-Valbruna municipality

Large debris flows in Cucco village

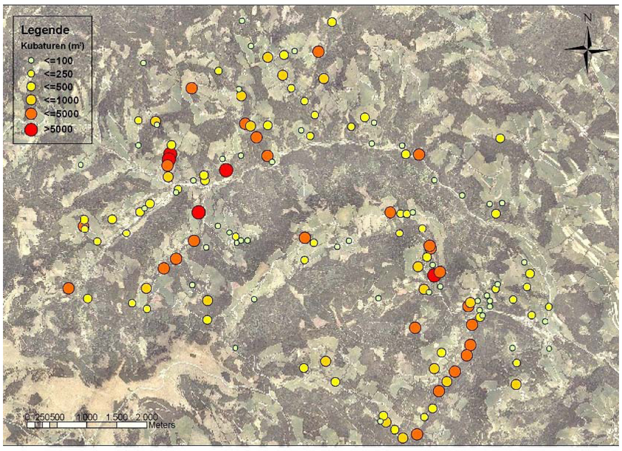
9.3.2 *Austria — Styria, 21 and 22 August 2005*

Description of the event

On 21 and 22 August 2005, heavy rainfall triggered 250 landslides in the two neighbouring municipalities of Gasen and Haslau in the Austrian state of Styria. The topography of both municipalities is characterised by narrow valleys and steep hillsides. The affected area covers more than 60 km² and is close to the western foothill of the Fischbacher Alps. On average, 4.3 landslides/km² occurred in Gasen and 6.6 landslides/km² in Haslau.

Type of movement and magnitude (volume and speed)

The majority of the 250 landslides were classified as translational slides. Most of them were spontaneous debris flows or earth slides on steep slopes. 21 % of the landslides had a volume of more than 1 000 m³. 3 % even had a volume of more than 5 000 m³. The largest landslide covered an area of 25 000 m². Altogether, the landslides delivered a volume of 148 000 m³ covering an area of 183 000 m². As the affected hillsides were rather steep, most landslides reached high velocities. In several cases cracks were visible in the surface soil some hours before the event or release.



Location and volume of the landslides which occurred in Austria on 21 and 22 August 2005. Volume ranges from < = 100 m³ (light yellow) up to > 5 000 m³ (red).
Source: Andrecs et al., 2007.

Triggering and causative factors
The region, which is rather densely forested (between 53 % and 80 % coverage), was hit by intensive precipitation (106 mm/24 h) caused by a low-pressure area rotating above the central Alps. The soils were already saturated with rain in the weeks before, reaching a total of 380 mm, 80 % above the long-standing mean average value. The rain infiltrated into a thick layer of unconsolidated rock which led to a significant increase in mass and a reduction of shearing strength. The strong pore pressures finally led to an efflux of soil in weak zones and triggered landslides and debris flows. Landslides occurred primarily in areas with an increased hydrogeological predisposition. However, triggering of slides was also related to human activities (e.g. reduced slope stabilisation due to road embankments, ground edges formed by agricultural activity, uncontrolled drainage, intensive grazing, large-scale harvesting activities and clear cuts in forests). Naturally occurring non-homogeneities in slopes also contributed to the triggering of landslides. The prevalent processes can be described as rotational slides in unconsolidated material which often developed into a subsequent debris flow (Rudolf-Miklau et al, 2006).

Destroyed house in which two people were killed
Source: Andrecs et al., 2007.

Damage
The landslides caused immense damage: Two people were killed, 40 properties and 2 180 m of roads were damaged. 13 properties as well as 810 m of roads were destroyed. Moreover, forest and agricultural areas were devastated. Closed roads affected the economy and private life for months. One of the two affected communities spent more than EUR 7 million in the reconstruction of the damaged traffic infrastructure. Overall, the calculated economic losses were about EUR 65 million.

Mitigation measures taken after the event to reduce the landslide risk
EUR 1.73 million were spent by the Austrian Torrent and Avalanche Control Department for immediate aid, including consolidation of the landslides or drainage of surface water.

Other measures taken:

a) Data compilation from the various Austrian institution and research organisations and creation of a new GIS database 'Incident Cadastre.shp' (where all landslide incidents are recorded).
b) Geo-risk Mapping and analysis of all slides in this area; revision of the Hazard Warning Map.
c) Funding of a research project and report: Assessment of the risk disposition of landslides using Gasen/Haslau as an example.
d) Construction of barriers in several creeks and torrents in the affected area. As far as possible, the sluices of the creeks or torrents were restored with natural materials (no concrete, no pipes).

9.4 Management options to reduce landslide impacts

9.4.1 Measures

Landslides result from complex interactions between geological and triggering factors of different origins. Some of these factors cannot be influenced: others such as land cover or slope excavation, however, provide important opportunities for preventative measures such as land use planning and management, or structural (rockfall nets, dams, rock clearance, etc.) and biological countermeasures (green engineering, protection forest). Generally speaking, landslide management should follow the principles of integrated risk management, thereby making use of all potential measures and integrating all stakeholders. Apart from the above major options to reduce landslide impacts, measures should include at least the following:

- restoration of rivers, slopes and coasts, recovering as much of their functionality as possible: this process should include proper land use management at the catchment scale;
- prioritisation of interventions with low environmental impact;
- development of emergency plans;
- establishment of monitoring networks for the activation of alert and alarm systems;
- relocation of very high risk settlements;
- definition of priority interventions and concentrating site consolidation funding on priority locations;
- development of inter-institutional cooperation, activating all possible synergies and respecting respective roles and missions.

9.4.2 Specific policy on landslides

To date no specific policy on landslides has been implemented at EU level. Some countries include landslide hazard/risk maps in spatial planning legislation (e.g. Finland, France, Germany, Italy, Poland, Spain, United Kingdom) but not in a consistent manner. Other countries only include such maps within the process of issuing building permits and developing Geological Suitability Studies (e.g. Greece) (Fleischhauer et al., 2006).

Certain EU policies, including the Soil Thematic Strategy (EC, 2006a) and the proposal for a Soil Framework Directive (EC, 2006b) include an objective to protect soils across the EU. In November 2009, the Council of European Union reaffirmed the importance of disaster prevention as a tool for adaptation to climate change (EC, 2009).

Finally, with respect to disasters due to natural hazards in general, some principles and guidelines can be recovered from international agreements and resolutions (e.g. Hyogo Framework for Action 2005-2015 (*Building the resilience of nations and communities to disasters*, UNISDR, 2005).

9.5 Data gaps and information needs

Landslides are complex phenomena based on the interaction of various factors including material type, bedrock, slope and triggers such as heavy rainfall. The influence of these factors varies from site to site and makes predicting the extent and intensity of a single event challenging. This is particularly true with respect to climate change, whose consequences for landslide hazards cannot be predicted with today's knowledge. Therefore, there is still a need for continuing research on different aspects of landslides, taking into account the various types of landslides considered here.

In spite of the complexity of landslide hazards, the shift from a defensive mitigation approach to a consistent application of integrated risk management (IRM) is thought to have successfully reduced the impact of landslides. As landslides are generally local phenomena, it is particularly important to gather knowledge on the hazard (records of past events, hazard maps showing the current situation, etc.) and the related risks at a local level, fully involving local stakeholders in the process.

A questionnaire developed with the support of *Eurogeosurvey,* has provided, for the first time at the European scale, an assessment of the limits and potentialities of national landslide inventories for the whole continent. The results of the questionnaire can help identifying future priorities and needs. The results reveal that landslide inventories exist in many European countries (cf. Table 9.2), but that they are highly variable with regard to the resolution and level of information. Many of these inventories are not available to the public (Figure 9.6). These shortcomings and the lack of a comprehensive database at the European level are two major impediments to a more comprehensive overview of landslide events and their impact at the European scale. As indicated above, an overview based on global databases is considered to be too coarse to provide an integral overview. Such an overview would, however, be highly desirable in further improving safety standards for landslides at the European level, as it could provide essential background information for different aspects of integrated risk management (e.g. simulation of future scenarios, distribution framework for European countermeasures subsidies, C/B analyses, etc.). Therefore, the need is evident for the development of a better knowledge base and a more comprehensive overview of landslide impacts at the European scale. The questionnaire mentioned above can be seen as a first step towards the improvement of this knowledge base.

Last but not least, European cooperation on landslide management and Disaster Risk Reduction in general should be further enhanced. An interesting example of large EU cooperation is given by the ongoing Safeland project, funded by EU, DG Research in 2009 (SAFELAND, 2010).

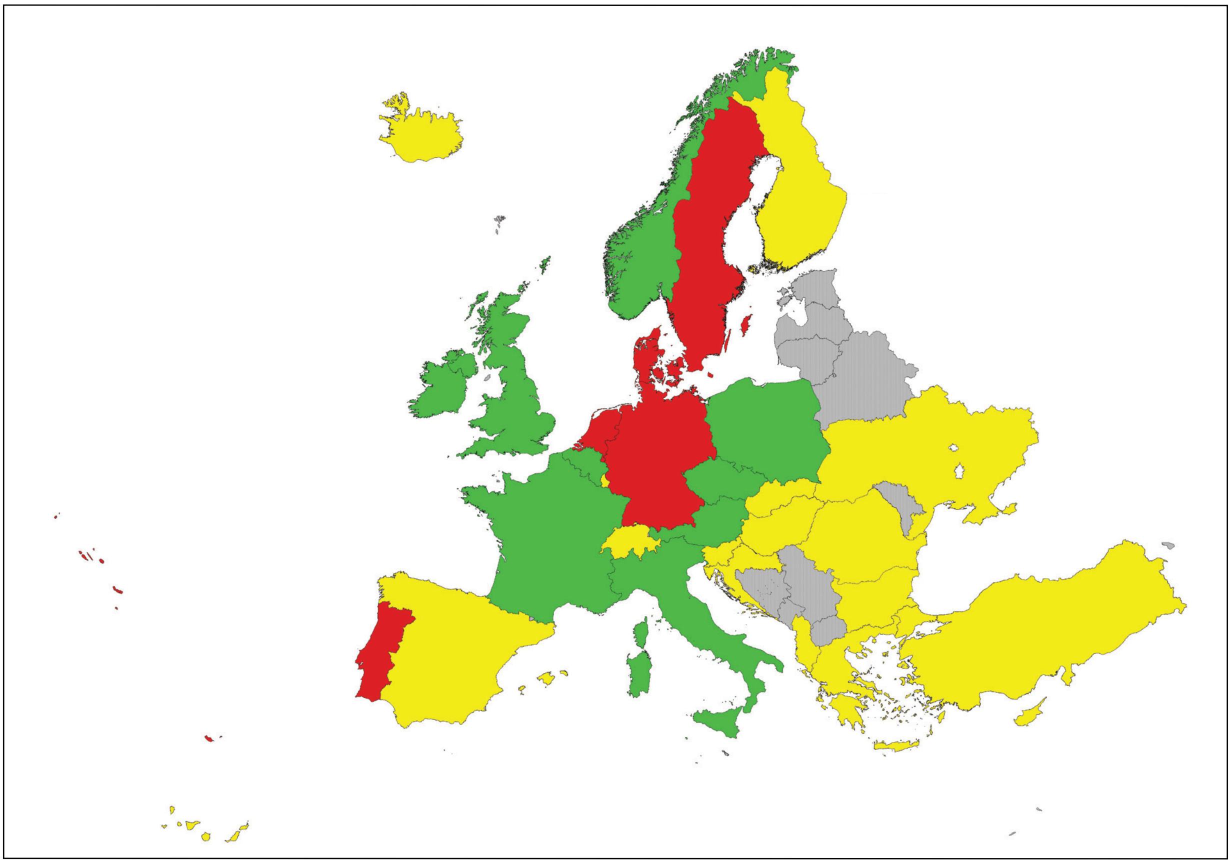
Table 9.2 Summary of landslide inventories available at European Geological Services

Countries	Presence of landslide inventory	Level of detail L=only location (e.g. point) C=complex inventory (classifi-cation, map, activity, etc.)	Number of Land-slides (L) Land-slide events (E)	Map Scale	Coverage (%)	Format: D=digital P=paper	Data of creation	Last Updates	Public Web services on landslide	Main Organization(s) in charge
Austria	Yes	-	30 000	25 000/50 000	National	P, some D	2002	-	http://geomap.geolba.ac.at/MASS/index.cfm	GBA
Albania	Yes	L	250	1:25 000	23%	D	2007	2009	not available	GSA
Belgium	Yes	C	236	all scale levels	5,30%	D	July 2007	July 2007	freely available on DOV (http://dov.vlaanderen.be)	GSB
Bulgaria	Yes,	-	-	500 000	National	D (Not geofeferenced) & P	1999	Not updated	not available	MOEW
Bosnia and Herzegovina	-	-	-	-	-	-	-	-	not available	-
Croatia	Yes	L=1258; C=201	1603	1:25000 = 1 258; 1:5 000=201	20%	D=1 088; P=371	2001–2008	1998–2008	not available	Coatian Geological Survey
Cyprus	Yes			5 000/10 000		P, some D	1986	Not specified	not available	GSD
Czech Republic	Yes	C	ca 15 000	1:50 000	100	D	1960-	2008	Yes	Czech Gelogical Survey and Geofond
Denmark	No	L	very few		< 1%				No	GEUS
Estonia	-	-	-	-	-	-	-	-	not available	EGK
Finland	Yes	L	56	no	100	D/P	1999	1999	not available	Finnish Environment Institute / Ministry of Agriculture and Forestry
France	Yes	C	> 17 000	1/25 000	96 %	D	1994	8/14/2009	www.bdmvt.net	BRGM, LCPC, RTM, MEEDDM
Germany	no countrywide inventory; only existing in some Federal States	no information	no information	no information	no assessment possible	D; P	no information	no information	not available	(State Geological Surveys of the Federal States)
Greece	Yes	C	1 850(D) - 5 000(P)	1:50 000	100	D	2007	2009	It will published in 2010	IGME
Hungary	Yes	L	364	1:100 000	100	D	*.dbf	Continuous	not available	Hungarian Office for Mining and Geology
Iceland	Yes					D	2002		not available	ISOR
Irland	Yes	L & C	156 (+ 266 Breifne)	1:2 250 000	80-90%	D	10/14/2005	9/21/2009	http://spatial.dcenr.gov.ie/imf/imf.jsp?site=GSI_Simple	GSI
Italy	Yes	C	480 000	10 000–25 000	National	D	1999	2006	www.sinanet.apat.it/progettoiffi	ISPRA
Latvia	-	-	-	-	-	-	-	-	not available	LEGMA
Liechtenstein	-	-	-	-	-	-	-	-	not available	
Lithuania	-	-	-	-	-	-	-	-	not available	LGT
Luxembourg	Yes	L and C	+-100	1:20 000	60	d	2003	2009	not available	SGL
Macedonia	-	-	-	-	-	-	-	-	not available	
Malta	-	-	-	-	-	-	-	-	not available	
Montenegro	-	-	-	-	-	-	-	-	not available	
Netherlands	No	-	-	-	-	-	-	-	not available	TNO
Norway	Yes	C	33 000	1:50 000	100	D	2001	2009 (continously)	www.ngu.no/kart/skrednett/?map=Skredhendelser - skredtype	NGU
Poland	Yes	C	7 000	1:10 000	5	D	2007	XII.2009	http://geoportal.pgi.gov.pl/portal/page/portal/SOPO/Wyszukaj	Ministry of the Environment. Polish Geological Institute-National Research Institute
Portugal	No	-	-	-	-	-	-	-	not available	INETI
Romania	Yes			25 000	National	P, some D	2001		not available	GIR
Serbia										
Slovakia	Yes	L	12 000	250 000	National	P, some D	1960	continual update	not available	
Slovenia	Yes	L	3 500	250 000	100	D	2005	2009	not available	Ministry for defence and Ministry for environment and spatial planning

Table 9.2 Summary of landslide inventories available at European Geological Services (cont.)

Countries	Presence of landslide inventory	Level of detail L=only location (e.g. point) C=complex inventory (classifi-cation, map, activity, etc.)	Number of Land-slides (L) Land-slide events (E)	Map Scale	Coverage (%)	Format: D=digital P=paper	Data of creation	Last Updates	Public Web services on landslide	Main Organization(s) in charge
Spain	Yes	C and L	aprox. 400	1/200.000	100%	D and P	2003		not available	IGME
Sweden	No	-	-	-	-	-	-	-	not available	SGU
Switzerland	Yes	C	12 000	-	National	D	1996	continual update	not available	Federal Office for the Environment FOEN
Turkey	Yes	C	55 608	25 000	National	D & P	1997	in progress	not available	MTA
United Kingdom	Yes	C	14 000	10 000/50 000	100% of Great Britian not the United Kingdom	D	1995	Ongoing	Web pages, case studies (www.bgs.ac.uk/ landslides)	BGS

Figure 9.6 Availability of landslide inventory and public access in European countries



Availability of landslide inventory and public access in European countries

🟩 National landslide inventory available with public access

🟥 National landslide inventory not available

🟨 National landslide inventory available with no public access

▨ No information

10 Earthquakes and volcanic eruptions

Key messages

- In Europe, the most catastrophic earthquake event in terms of human fatality took place in Izmit (Turkey) in August 1999, when more than 17 000 people died in an earthquake with magnitude Mw = 7.6. Since 2003, four M > 6 earthquakes (two in Greece, one in Turkey and one in Italy) and eight other events with magnitude M > 5 have occurred; the most disastrous in terms of loss of life and damage to buildings being those in 2003 in Diyarbakir (Turkey) and 2009 in L'Aquila (Italy). The other events were of moderate intensity, causing limited damage to buildings and few deaths.
- During the period 1998–2009, there were no destructive explosive volcanic eruptions in Europe, but some volcanoes exhibited persistent activity (for example Mount Etna and Stromboli) and caused limited economic damage and some injuries. However, in 2010, the eruption in Iceland of the Eyjafjallajökull volcano had a significant impact on air traffic in Europe.
- The 2003–2009 seismic events were not as severe as the potential worst case based on evidence spanning several centuries for the areas affected. The impact was remarkable only in cases where anti-seismic regulations in building codes were not proportional to the seismic hazard or not properly applied. Information about the economic cost of earthquakes is frequently lacking.
- Like seismic events, volcanic eruptions were much less intense than the potential maximum eruptions from active volcanoes in Europe.
- Despite the fact that information about earthquakes, volcanoes and their impacts is sound and well documented in global disaster databases, there is definitely room for improvement. For example, it would be beneficial to set up a standardised, systematic approach to evaluate the overall costs of earthquakes, and improve our knowledge of the impacts of earthquakes on the natural environment and ecosystems. For volcanic eruptions, a critical issue is the lack of any assessment of their indirect effects, as highlighted by the 2010 eruption. For example, there is a need for a better understanding of critical dust concentration levels for air traffic (in order to better define a critical dust concentration threshold) as well as better monitoring of actual volcanic dust concentration levels at airline flight altitudes.
- For earthquakes, there is a need for better implementation of building codes and further reduction of vulnerability, as well as for standardised risk-based assessment methods for existing buildings and infrastructures.
- Mitigation measures for impacts of volcanic eruptions should include prohibiting urbanisation in areas at risk and even the relocation of highly vulnerable settlements. Where relocation is not possible, early warning systems and sound evacuation plans should be implemented.

10.1 Introduction

10.1.1 Definition

Earthquakes

Earthquakes are caused by a sudden release of energy in the Earth's crust or upper mantle as a result of an abrupt shift of rock along a fracture. More than 90 % of earthquakes are related to plate tectonics and are caused at plate boundaries.

The seismic hazard in Europe is far from uniform (Figure 10.1): seismic hazard models clearly indicate that the major seismic areas, with expected earthquake magnitudes (14) even higher than 7, are in the Mediterranean area, particularly in:

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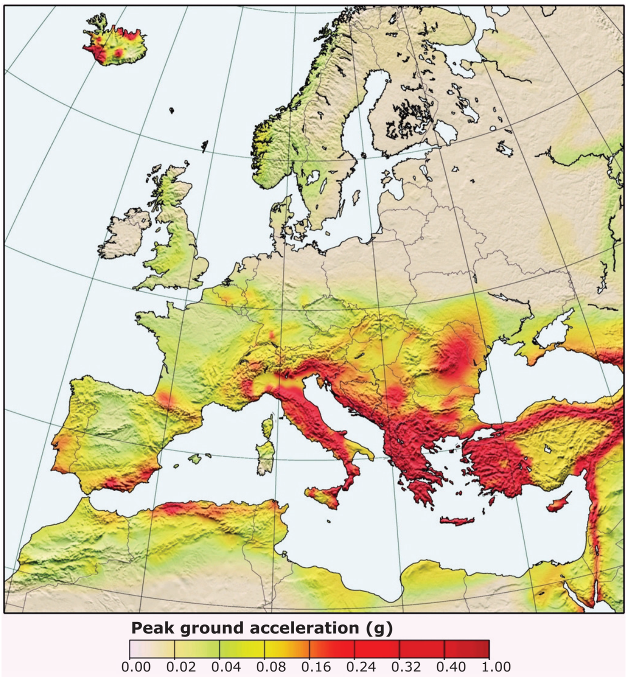
(14) Richter magnitude (or local magnitude, M_L) provides a measure of the seismic energy released by an earthquake. It is calculated on the basis of the shaking amplitude recorded in seismograms on a 10-logarithmic scale. In the last years, seismologists have favoured moment magnitude (M_W), which takes into account the average amount of slip on the fault and the size of the area that has slipped.

- Turkey, especially along the North Anatolian fault, which caused the largest event in the last decade (Izmit, 17 August 1999; M = 7.6);
- almost the entire territory of Greece, where the largest events in Europe occurred in historical time (M about 8.0);
- Italy, especially along central-southern Apennines and Sicily;
- some sectors of the Balkan region and southern Spain.

This seismicity is caused by geodynamic activity along a convergent margin where the African plate is subdued under the European plate. Central and northern Europe are characterised by very low seismicity, with the exception of the Rhine Valley and Iceland. In the latter case, seismicity is strictly linked to geodynamic activity along the Mid-Atlantic ridge.

Earthquakes not only lead to direct impacts and damage, but can also trigger additional hazardous events such as landslides and tsunamis. The latter are likely to be significant for Europe, as strong earthquakes caused by off-shore faults in the Mediterranean Sea may trigger tsunamis along the coasts of southern Europe, which in turn may cause casualties, damage to buildings and have impacts on ecosystems. Examples of relevant tsunamis in historical time include events i) in AD 365 causing widespread destruction in southern Greece and in several islands of the Aegean archipelagos; ii) in 1755 (Lisbon earthquake) which had a huge impact on the coastlines of Portugal and southern Spain; iii) in 1693, 1783 and 1908 along the coastlines of eastern Sicily and southern Calabria, causing major casualties and damage. However, since there have been no devastating tsunamis in Europe in recent decades, this chapter focuses on direct damage and impacts caused by earthquakes.

Figure 10.1 Seismic hazard model based on Peak Ground Acceleration probability for the European-Mediterranean region proposed by the ESC-SESAME project



Note: Based on this model, the following intensities are expected in the next centuries i) strong earthquakes (6.5 < M < 7.4) in the red zones; ii) medium earthquakes (5.5 < M < 6.5) in the yellow zones; iii) no damaging earthquakes in the green zones.

Source: Jiménez et al., 2003.

In general, the data source for any seismic hazard assessment is an instrumental record, frequently integrated with information from historical events which enable assessments dating back several hundreds of years. Thanks to paleoseismological investigations conducted in recent years, especially in Greece, Italy and Turkey, it is possible to extend the time window for seismic hazard evaluation to several tens of thousands of years.

Volcanoes

A volcano is an opening, or rupture, in the Earth's crust that allows hot magma, ash and gases to escape. Volcanic eruptions are basically of two types: effusive eruptions (for example Kilauea and Mount Etna) characterised by almost continuous lava emission, and explosive eruptions (for example Vesuvius, Santorini and Mount St Helens), which are more rare but very devastating due to the interaction between gas and magma.

Volcanoes are generally located along tectonic plate margins (for example the Mid-Atlantic Ridge and the Pacific Ring of Fire), but can also form in intra-plate areas characterised by rift processes (such as the East African Rift) as well as by mantle plumes (in hot spots such as Hawaii).

In Europe, there are active volcanoes (Figure 10.2) in Greece, Iceland, Italy and Spain (Canary Islands). Some active volcanoes (not mapped) located in the territory of European countries are a long way away from the European continent (for example Aqua de Pao, Azores, Portugal; Le Piton de la Fournaise, Reunion, France; Mount Pelee, Martinique, French Antilles).

The major eruptions in Europe recorded in historical time were probably the result of explosive volcanism in Santorini and Vesuvius-Campi Flegrei.

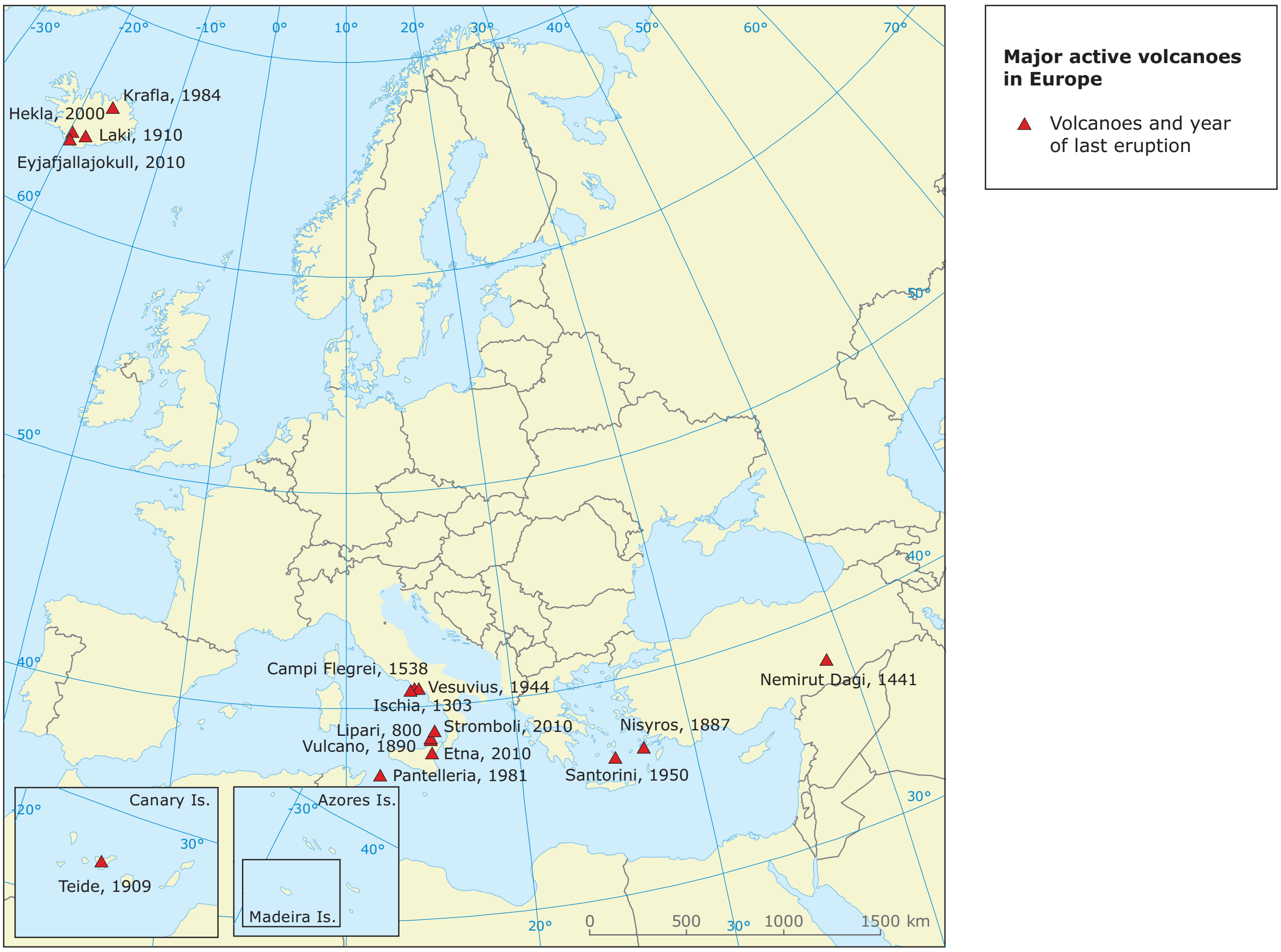
It is likely that the Santorini eruption in 1630 BC (Thera crater), and the associated tsunami, caused the end of the Minoan civilisation. The most recent devastating Santorini eruption, although less intense than the one in 1630 BC, occurred in 1649 (Kolumbo crater).

The Vesuvius eruption of AD 79, widely documented by contemporary eyewitnesses (for example Pliny the Younger), is probably the most famous worldwide. It destroyed a very large area, including the cities of Pompeii and Ercolano. The last eruption of Vesuvius, in 1944, was relatively minor.

However, in the Campi Flegrei volcanic districts there were other, even more intense eruptions in pre-historical time. In fact, there were two calderic collapses: one in about 39 000 BC (Ignimbrite Campana) and the second in 15 000 BC (Tufo Giallo Napoletano), which resulted in a 5 m thick layer of volcanic deposits over an area in excess of 30 000 km^2 — now the site of Naples and other largely urbanised areas.

When assessing the impact of volcanic eruptions, in addition to the local, direct physical effects on people and the environment, it is important to look at the wider picture. For example, the ash cloud emitted by the recent eruption of the Eyjafjallajökull volcano (spring 2010; see Box 10.1) caused the grounding of air traffic across northern and central Europe. This had implications at a global level and caused significant economic damage (see Box 10.1). In addition, volcanic gases particularly sulphur dioxide, fluorine, chlorine and radon, can harm human health and ecosystems. Sulphuric acid aerosols linger in the atmosphere for years after an eruption and can affect the weather by causing cooler temperatures at a global level — for example, the year without a summer in 1816 caused by the Mount Tambora,

Figure 10.2 Major active volcanoes in Europe



Note: The year of the last eruption in brackets.

Source: EEA, 2010, based on ETC-LUSI data.

Indonesia, eruption in 1815. Conversely, carbon dioxide emitted during volcanic eruptions is a greenhouse gas and contributes to global warming.

However, volcanic eruptions can have a positive effect on society and the environment: they enrich soils for farming and the hydrothermal activity associated with any active volcano is a potential alternative energy source (geothermal).

10.1.2 Sources of information

This chapter is based on data from the EM-DAT (2010) and NatCatSERVICE (2010) as well as information from the Euro-Med Bulletin (Euro-Med, 2010), historical seismic catalogues of several countries, and several published professional reports dealing with single seismic events. The EM-DAT and NatCatSERVICE datasets were compared with additional information from national catalogues. The latter are obviously more detailed and provide a many more events for the same time period. Nonetheless, with regard to the most damaging earthquakes, no substantial differences have been found in the information provided by these various sources.

Table 10.1 Major earthquakes in Europe, 1998–2009

Date	Location	Impact
August 1999	Izmit, Kocaeli, Yalova, Golcuk, Zonguldak, Sakarya, Tekirdag, Istanbul, Bursa, Eskisehir, Bolu (Turkey)	M_w = 7.6, 30 % of Turkey's area and 45 % of the population affected, more than 17 000 fatalities, about 600 000 homeless, more than EUR 11.4 bn in overall losses (EUR 570 m insured losses)
September 1999	Athens suburbs of Menidi, Metamorphosis and Thracomekedones (Greece)	M_w = 5.8 , more than 140 fatalities, more than 30 000 buildings partly or totally damaged, about 70 000 people homeless, high overall losses of about EUR 4 bn. (insured losses EUR 113 m)
November 1999	Düzce, Bolu, Kaynasli (Turkey)	M_w = 7.2, about 845 fatalities, more than 50 000 people homeless; overall losses about EUR 500 m (insured EUR 40 m)
February 2002	Bolvadin (Afyon province, Turkey)	M_w = 6.2, more than 40 fatalities and about 30 000 homeless, hundreds of buildings damaged
October 2002	San Giuliano di Puglia (Campobasso province, Italy)	M_w = 5.4, 30 fatalities(mostly children in a school that collapsed), more than 10 000 people homeless; overall losses about EUR 300 m
January 2003	Pulumur, Turkey	M_w = 6.2, one fatality
April 2003	Izmir, Turkey	M_w = 5.7, no fatalities
April 2003	Alessandria, Piemont, Italy	M_L = 4.6 M_L, VI–VII MCS (a) intensity, no fatalities, about 200 homeless; overall losses about EUR 60 m
May 2003	Diyarbakir, Bingöl, Turkey	M_w = 6.4 , VIII EMS (b) intensity, 177 fatalities, about 45 000 homeless, overall losses about EUR 42 m
July 2003	Buldan, Western Turkey	M_w = 5.4 M_w, no fatalities
August 2003	Lefkada, Greece	M_w = 6.2 M_w, VIII EMS intensity, no fatalities, about 50 injured
March 2004	Askale, Turkey,	M_w = 5.3 M_w, nine fatalities and about 36 000 affected
July 2004	Dogubeyazit, Turkey	M_w = 5.1 M_w, 18 people killed and about 400 affected
July 2004	Kobarid, Bovec area, Slovenia	M_L = 5.1, VII–VIII EMS intensity, one fatality and about 600 affected, overall economic losses about EUR 8 m
December 2004	Waldkirch, Emmerdingen; Germany	M_w = 4.6, VI EMS intensity, no fatalities, about 150 affected, overall losses about EUR 9 m (insured losses about EUR 6 m)
January 2005	Van, Hakkari, Turkey	M_w = 5.5, two fatalities
March 2005	Karliova, Bingol; Turkey	M_w = 5.7, about 2 300 affected
February 2006	Murgovo area, Bulgaria	M_w = 4.6, VI–VII EMS intensity, about 500 affected
June 2008	Achae, Elide, Leucade Islands, Greece	M_w = 6.4, VIII EMS intensity, two fatalities, 3 700 affected
April 2009	L'Aquila, Abruzzo, Italy	M_w = 6.3, IX EMS intensity, 302 fatalities, about 56 000 homeless, overall economic losses EUR 2 bn (insured losses EUR 200 m), estimated overall costs including rebuilding and other measures to support the local economy at least EUR 11 bn (c).

Note: (a) MCS = Mercalli Cancani Sieberg intensity scale.
(b) EMS = European Macro Seismic intensity scale.
(c) Author's estimate based on costs of previous, comparable events in Italy (Friuli, 1976; Umbria-Marche, 1997).

Source: EM-DAT, 2010 (fatalities); NatCatSERVICE, 2010 (economic and insured losses); Euro-Med, 2010.

10.1.3 Earthquakes in Europe, 1998–2009

In the last decade, there were several major earthquakes in Europe (Table 10.1), which caused extensive damage and killed many people. The most catastrophic in terms of human fatalities was in Izmit in August 1999, when more than 17 000 people died. In contrast to the period 1998–2002, there were no events with a magnitude > 6.4 on the Richter scale during the period 2003–2009. However, the lower magnitude events that did occur still had major impacts in terms of human and economic loss.

10.1.4 Volcanic eruptions in 1998–2009

In the period 1998–2009 there were no highly explosive eruptions in Europe. EM-DAT (2010) records just one eruption, Mount Etna in 2001, which caused economic damage of approximately EUR 3.5 million (USD 3.1 million). However Mount Etna's persistent activity throughout the period caused further disruption in 2001, 2007 and 2008–2009, covering surrounding villages with ash and disrupting air traffic to and from Catania airport.

The Stromboli volcano was also active throughout the period, which in 2002 resulted in the partial collapse of a mountain flank (Sciara del Fuoco). This caused an anomalous wave, clearly recorded even in the other islands of the Eolie archipelago, which injured three people.

The volcanic eruptions that occurred in the reporting period caused only limited economic losses. Therefore, no specific spatial assessment has been performed. However, Table 10.2 shows a risk assessment for major volcanoes in Europe.

10.2 Earthquake events, 2003–2009: spatial analysis and trends

10.2.1 Frequency and spatial distribution of seismic events

From 2003 to 2009, 15 major earthquakes occurred in the 32 EEA member countries (Figure 10.3).

10.2.2 Analysis of earthquake impacts: human fatalities

Eight of the 16 major earthquakes recorded between 2003 and 2009 claimed a total of 512 lives, in particular the 2003 Diyarbakir earthquake (117 fatalities) and the 2009 L'Aquila earthquake (302 fatalities).

However, the death toll in the same period was much higher in events outside Europe, where earthquake and related hazards resulted in hundreds of thousands of fatalities (for example the 2004 Sumatra earthquake/tsunami: $M_W = 9.0$, > 230 000 deaths; the 2005 Pakistan earthquake: $M_W = 7.6$, > 73 000 deaths and the 2008 Wenchuan, China earthquake: $M_W = 7.9$, > 70 000 deaths).

A reason for the relatively low human death toll in Europe is that many of the earthquakes were far less severe than expected ([15]). On the other hand, in the case of seismic events during the reporting

Table 10.2 Risk assessment for major European volcanoes in terms of direct impacts on exposed people and residential property

Volcano	People exposed (inhabitants)	Exposed residential property (billion USD)
Vesuvius, Italy	1 651 950	66.1
Campi Flegrei, Italy	144 144	7.8
Etna, Italy	70 819	2.8
Aqua de Pau, Portugal	34 307	1.4
Soufrière St Vincent, Saint Vincent	24 493	1.0
Furnas, Portugal	19 862	0.8
Sete Cidades, Portugal	17 899	0.7
Hekla, Iceland	10 024	0.4
Mt Pelèe, Martinique	10 002	0.4

Source: Spence et al., 2010.

([15]) The maximum expected earthquake is provided by seismic hazard maps for a pre-fixed time window (typically 500–1 000 years).

Box 10.1 The 2010 eruptions of Eyjafjallajökull (Iceland)

In Iceland, there are about 130 active volcanoes along the Mid-Atlantic Ridge. Among them, the Eyjafjallajökull volcano has erupted relatively frequently in the last millennia, most recently in the period 1821–1823 and in 2010.

The 2010 eruption was preceded by a gradual increase in seismic activity that began at the end of 2009 and by a small eruption on 20 March 2010. The most active phase started on 14 April, resulting in about 0.25 km^3 of ejected tephra (fragmental material ejected by the volcano) and an ash plume to a height of about 9 km. By the end of May, the volcano had stopped emitting lava and ash but was emitting sulphurous gases. Early in June a new crater opened, causing emission of small quantities of ash. Since then, seismic activity has been monitored and the volcano is now considered dormant.

This was a much smaller eruption than some recorded in Iceland, for example Eldgja in 934 and Laki in 1783. Nonetheless, the large ash cloud caused enormous problems for air traffic, particularly in western and northern Europe. From 15 to 20 April 2010 most of the airspace over central-northern Europe was closed, which had a global knock-on effect. The persisting eruption was still causing localised air traffic problems in May 2010.

This example illustrates that even when an eruption has little or no direct destructive impact, the overall impact may be enormous and have global implications. Hence, strategic measures to mitigate such impact should be taken at the global level.

period which were comparable to the maximum expected earthquakes in terms of released energy, the vulnerability of the buildings and their degree of compliance with building codes has been identified as the crucial factor determining the gravity of the impacts. Not surprisingly therefore, the effect on both humans and buildings was much more significant in areas where building codes have not been properly applied, leaving people in highly vulnerable buildings, despite being exposed to seismic risk.

10.2.3 Analysis of earthquake impacts: economic losses

In order to develop a policy to mitigate seismic risks, it is crucial first to evaluate the overall damage and the related economic cost of an earthquake. However, a correct evaluation is a very difficult. In fact, the economic impact of an earthquake should take into account not only the cost of repairing damaged buildings and infrastructures but also other costs related to business interruption and relocation, unemployment, and strategic measures to redevelop the local economy and restore the social structures.

Official information relating to reconstruction costs is only available for three events (2003 Diyarbakir: about EUR 90 million; 2004 Slovenia, about EUR 8 million; 2004 Germany, about EUR 9 million). Of the events in 2003–2009, the 2009 L'Aquila earthquake had the largest economic impact. More than 50 000 people lost their houses; a number of strategically important buildings, including hospitals and schools, were badly damaged; and the region's cultural heritage was severely affected. According to the Munich Re's NatCatSERVICE (2010) the overall losses totalled approximately EUR 2 billion. However, as the earthquake occurred only a few months before the compilation of this report, a reliable assessment of the overall economic cost is not yet possible. On the basis of assessments of the overall economic cost of similar events that have occurred in Italy over the past decades, however, it is expected that the L'Aquila earthquake will cost more than EUR 11 billion. Bearing in mind that the 2009 earthquake was less severe than the maximum expected earthquake for that area, and that some heavily populated cities in Italy and other earthquake-prone countries are exposed to similar levels of seismic risks, it is absolutely essential to develop a long-term strategy to reduce the economic loss due to earthquakes.

10.2.4 Analysis of earthquake impacts: ecosystems

In principle, the direct impact of earthquakes on ecosystems depends on two main factors: earthquake intensity and the vulnerability of the natural environment. Only the most severe earthquakes ($M > 7.0$; intensity > XI) (16) causing major landscape

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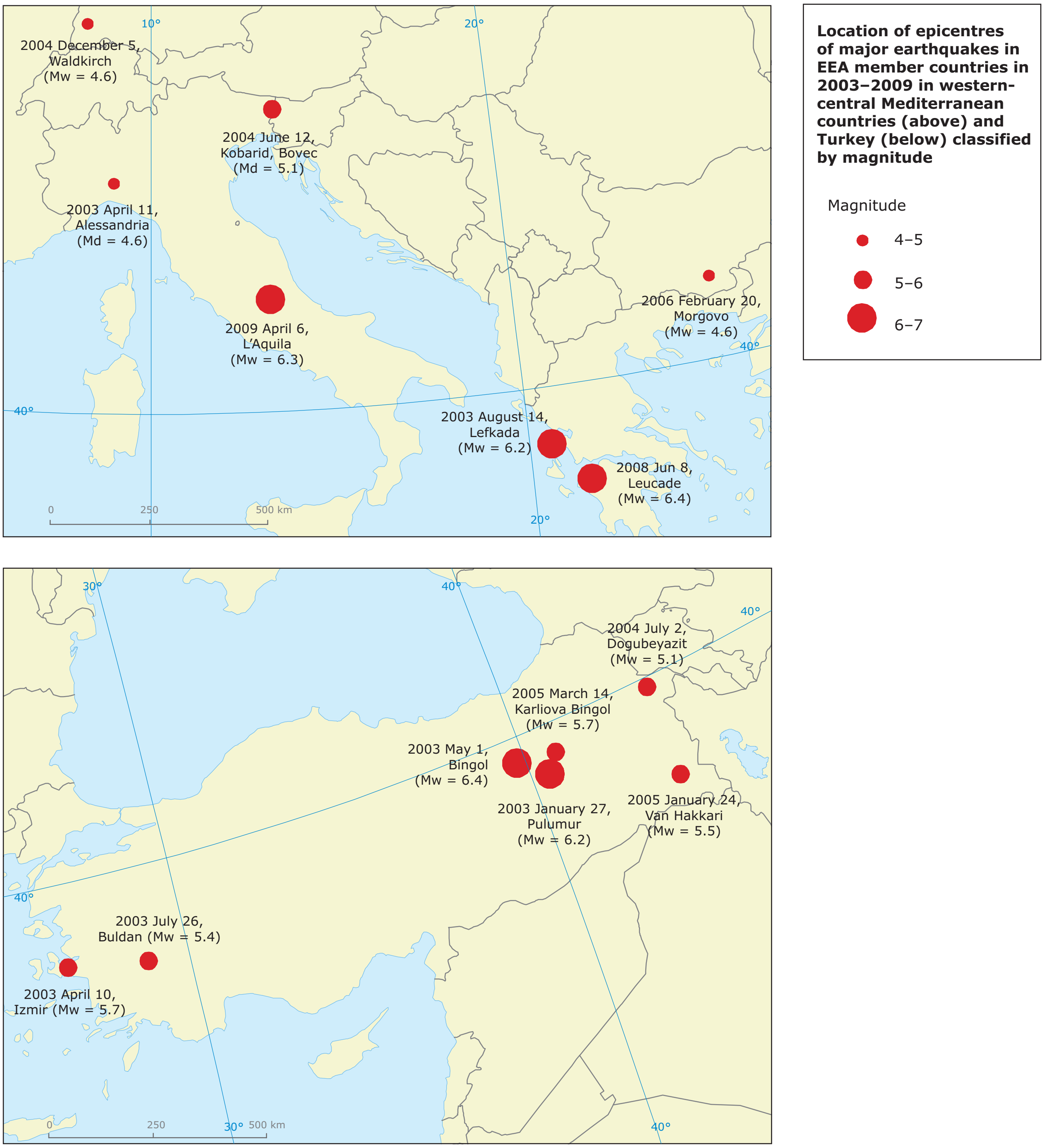
(16) Intensity scales classify earthquakes in 12 degrees based on the effects on humans, buildings and natural environment. Worldwide, the most used intensity scales are the MM (Mercalli Modified) and the MSK (Medvedev Sponheuer Karnik). The EMS (European Macroseismic Scale) (Grünthal et al., 1993) is the most used in European countries.

Figure 10.3 Location of epicentres of major earthquakes in EEA member countries in 2003–2009 in western-central Mediterranean countries (above) and Turkey (below) classified by magnitude



Note: Md = Duration Magnitude.

Source: EM-DAT, 2010.

transformations over a large area have significant impacts on ecosystems. Also, earthquake-induced tsunamis, such as the one in Sumatra in 2004, can have significant impacts on marine and coastal ecosystems.

Indirect impacts of earthquakes may even be more significant for ecosystems. For example, an earthquake could damage industrial plants or other critical facilities, which in turn leads to a spill of toxic and dangerous substances (see Chapter 12).

For the 2003–2009 events, i) the direct impact on ecosystems of these events may be considered negligible, as landscape modifications were very small (deformations no higher than a few centimetres) and/or occurred at a very local scale, ii) no information was found in available documentation regarding indirect impacts related to induced pollution.

10.3 Case study: the impact of earthquakes on natural environment: L'Aquila 2009

10.3.1 Introduction

Traditionally, the impact of earthquakes has been estimated in terms of its effect on humans and damage to buildings and infrastructure. Earthquake-related environmental effects are typically not taken into account or are underestimated, although they can cause additional hazards, especially at a local scale. Recent studies (Michetti et al., 2007) have demonstrated clearly that the occurrence, size and spatial distribution of environmental effects are tools for seismic intensity assessment. Furthermore, as mentioned in the previous section, in large earthquakes ($M > 7.0$; intensity > XI), the co-seismic effects on natural environments may have a significant impact on ecosystems.

Typically, environmental effects are classified as primary (for example, the surface expression of the seismogenic fault) and secondary (for example, effects induced by the seismic shaking — landslides, liquefactions, hydrological anomalies). The information on environmental effects of the 2009 L'Aquila earthquake collected during post-seismic field surveys is summarised below (Blumetti et al., 2009), with the aim of identifying the vulnerability of the natural environment to moderate earthquakes.

10.3.2 The 2009 L'Aquila earthquake

On 6 April 2009, the central Apennines were rocked by a moderate earthquake (M_L 5.8, M_W 6.3, depth around 9 km). Two $M_L > 5$ aftershocks followed on 7 April (M_L 5.3) and 9 April (M_L 5.1). The epicentre was near Roio village, a few kilometres south-west of the historic town of L'Aquila, which was severely damaged as were many villages in the surrounding area. The death toll was more than 300 and about 56 000 people were made homeless. The earthquake did not damage high-risk sites, for example underground tanks for oil and LPG. Nevertheless, it did cause significant damage to strategic sites, including a major hospital and some industrial plants. Economic losses were as described in Section 10.2.3.

The earthquake was caused by the reactivation of the Paganica fault, a normal fault documented in at least two historical events, in 1461 and 1703, suggesting a cycle of about three centuries. This 1703 earthquake was probably even stronger (Me ([17]) about 7) than the 2009 event.

10.3.3 Description of environmental effects

Environmental effects (see Figure 10.4) occurring over an area of about 1 000 km^2, can be categorised as listed below.

- Surface faulting. Along the Paganica fault there is clear evidence of surface faulting (length about 3 km; maximum offset about 10 cm). Surface ruptures are easy to see on paved/concrete and often dirt roads, and on other artificial surfaces, as well as on buildings and walls. The pipeline rupture of the Gran Sasso aqueduct is particularly prominent. There is evidence of other potential surface reactivations along other active faults located in the epicentral area.
- Slope movements. Rockfalls on calcareous slopes and artificial cuts were the most obvious indicators. Huge rockfalls severely damaged some buildings at Fossa and Stiffe. Landslides also occurred, in some cases threatening the viability of important roads.

([17]) Me = Magnitude equivalent evaluated for pre-instrumental events on the basis of macroseismic intensity distribution.

Figure 10.4 Impact of earthquake environmental effects

Note: A) The pipeline of the Gran Sasso aqueduct cut by the Paganica fault; B) Lake Sinizzo, a recreational area destroyed by ground failures. C) Fossa, a large rockfall blocked an asphalt road; D) Stiffe, a building was hit by a huge boulder.

Source: Blumetti et al., 2009.

- Ground cracks. These were particularly evident in loose unconsolidated sediments. Shaking caused fractures in paved roads and there were significant ground failures along the shoreline of Lake Sinizzo.
- Other effects. Temporary turbidity was recorded in Tempera, and there were significant changes in water discharge: springs disappeared or shifted hundreds of metres. There was evidence of liquefaction at Vittorito and in the Bazzano industrial area.

10.3.4. Remarks

Even for moderate earthquakes, the effects on the natural environment strongly influence the overall impact of an earthquake. For example, the surface reactivation of a seismogenic fault may cause the rupture of strategic infrastructure (as in the damage to the pipeline at Gran Sasso caused by the Paganica fault during the 2009 L'Aquila earthquake). Even local effects, like the rockfalls at Fossa and Stiffe, may have a serious impact not only in terms of damage but also on emergency management in the first weeks after the event.

Therefore, in a future perspective, it is clearly crucial to identify the areas most vulnerable (artificial as well as natural areas) to earthquake occurrence, where the adoption of mitigation measures is more urgent. To this end, post-seismic surveys of environmental effects induced by earthquakes are very useful.

10.4 Management options to reduce impacts

Earthquakes

Because countries have very different levels of seismic hazard, specific mitigation measures aimed at reducing seismic risks are generally instigated at the national level. At the EU level, Eurocode 8 (Eurocodes, 2004) provides common design criteria and methods for anti-seismic civil engineering works.

In the immediate future, priority actions for mitigation of earthquake impacts should focus on filling the existing gaps between research and legislation, and translation of these as soon as possible into up-to-date seismic zonation and building codes. In fact, recent scientific research in the fields of seismology and seismotectonics has led to a significant improvement in knowledge of seismic hazards in Europe.

In the areas of Europe most affected by seismic activity, it is important to reduce the vulnerability of buildings and infrastructure. Building codes are always applied to new constructions but there is no specific legislation in place to cover existing buildings. A possible measure could be the extensive application of seismic isolation and energy dissipation systems (18) to structures and buildings, which may significantly reinforce their stability even under dynamic (i.e. seismic) conditions. Unfortunately, the costs of such applications are very considerable and a prioritisation process is therefore necessary. Nevertheless, the application of such systems is less expensive than rebuilding (about three times according to an estimate for Italy, cf. Martelli and Forni, 2009). A first step in this direction will be to conduct an analysis of the vulnerability of strategic infrastructures and other primary elements (such as hospitals, schools, cultural and artistic heritage) located in the areas most affected by seismic activity.

Volcanic eruptions

With regard to volcanic eruptions, risk mitigation measures must focus primarily on prohibiting settlement within areas that are most at risk and, when necessary, considering even the option of relocating settlements. However, the latter is not a realistic option in densely populated areas like Vesuvius-Campi Flegrei. In such cases, it is critical to have in place effective emergency plans for the evacuation of people, based on real-time monitoring of the volcanic activity and forecasts of potential economic damage.

In contrast to the mitigation of direct impacts of volcanic eruptions, the reduction of indirect impacts, for example on air traffic, human health or global temperature, requires measures at a supra-national level (by countries, insurance companies and so on). However this is a more challenging issue because as yet there has not been a quantitative evaluation of these effects.

10.5 Data gaps and information needs

In order to further reduce the impact of earthquakes, it will also be crucial to fill the gaps between seismic zonation, building codes and seismotectonic research to secure improved safety for new buildings. There is also a need to improve knowledge of the earthquakes' potential effects on the natural environment, due to the resulting impacts at the local scale on buildings, infrastructures and, for larger earthquakes ($M > 7.0$), even on ecosystems.

In addition, a systematic evaluation of the economic costs of earthquakes, using a standardised approach, would be beneficial in order to provide a sounder basis for cost–benefit analyses. Such analyses are of major importance, as most of the countermeasures in earthquake prevention are rather costly.

With regard to volcanic eruptions, the most critical issue include the lack of any assessment of their indirect effects. More specific needs have been identified since the 2010 event with its huge impacts on air traffic in Europe. These needs include a better understanding of critical dust-concentration levels for air traffic (in order to achieve a better definition of a critical dust-concentration threshold) as well as better monitoring of actual concentration levels of volcanic dust at airline flight altitudes. Such information will help to improve the calibration of mitigation measures at supranational level.

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(18) These systems are designed to isolate foundations from seismic effects, thereby protecting the higher parts of buildings from seismic shaking.

Part C — Technological hazards

11 Oil spills

Key messages

- In 1998–2009, there were nine major oil spills (> 700 t) originating from ships in European coastal areas and one major oil spill from an oil pipeline. The most significant were oil spills from the tankers *Erika* (1999, Atlantic coast of France, 20 000 t oil spilled) and *Prestige* (2002, Atlantic coast of Spain, 63 000 t oil spilled). Since then there have been no oil spills of such extreme extents.
- The economic costs of oil spills are very difficult to assess; costs per ton of spilled oil range from EUR 500 to 500 000 (note that these figures apply to offshore events only).
- The two major events (as mentioned above) were amongst the worst ecological disasters to have occurred in European waters. In recent years, however, the ecological impacts of marine oil spills have been comparatively minor, largely because of favourable weather conditions.
- The decrease in the number of spill incidents over the past few years is probably due to new EU legislation, which imposes obligations, including the construction of tankers as double-hull vessels (Regulation 417/2002/EC, and Regulation 1726/2003/EC), and the common system for vessel traffic monitoring (Directive 2002/59/EC). The number of marine oil spills incidents and their impacts are expected to further decrease, mainly due to the implementation of legislative measures. Nevertheless, the transport of crude oil or oil products by ship, in particular, still poses an enormous hazard potential.
- Data and reporting on maritime accidents have improved since the European Maritime Safety Agency (EMSA) was set up in 2002. However, obtaining more details of specific cases depends very much on the willingness of individual companies and authorities to share information.
- For oil pipelines, awareness on the part of European operators to ensure efficient protection measures has increased. A few remaining options for further improvement are optimal selection of the pipeline route and the reduction of accidents caused by third-party interference. However, most pipelines are not yet subject to European legislation on accidents and therefore no mandatory reporting obligation exists.
- Overall there is still room for improvement, for example the implementation of comprehensive and integrated risk analysis of any facility or procedure — such as platform–ship loading operation and third-party interference.

11.1 Introduction

11.1.1 Definition (including main causes)

The term 'oil spill' relates to the release of crude oil, or a product derived from crude oil that shows persistency when released accidentally into the environment. Persistent oil is the most relevant and important case of oil spills, since it dissipates slowly when spilled onto surface water. Non-persistent oil products (for example gasoline and light diesel oil) evaporate from the water surface or dissolve quickly and thus pose a much smaller hazard.

Oil spills from ships are the most common. Typically ships spill part of the fuel (bunker oil etc.) after a storm, a collision or another event that causes damage to the vessel. However, there may also be spills of environmentally hazardous freight such as crude oil, mineral oil products and other chemicals. Increasing oil production, consumption and waste has resulted in an increase in marine transport and a corresponding increased risk of major oil spill accidents in European coastal areas (19).

The European network of oil and oil product pipelines (see Figure 11.1) is another potential source of oil spills.

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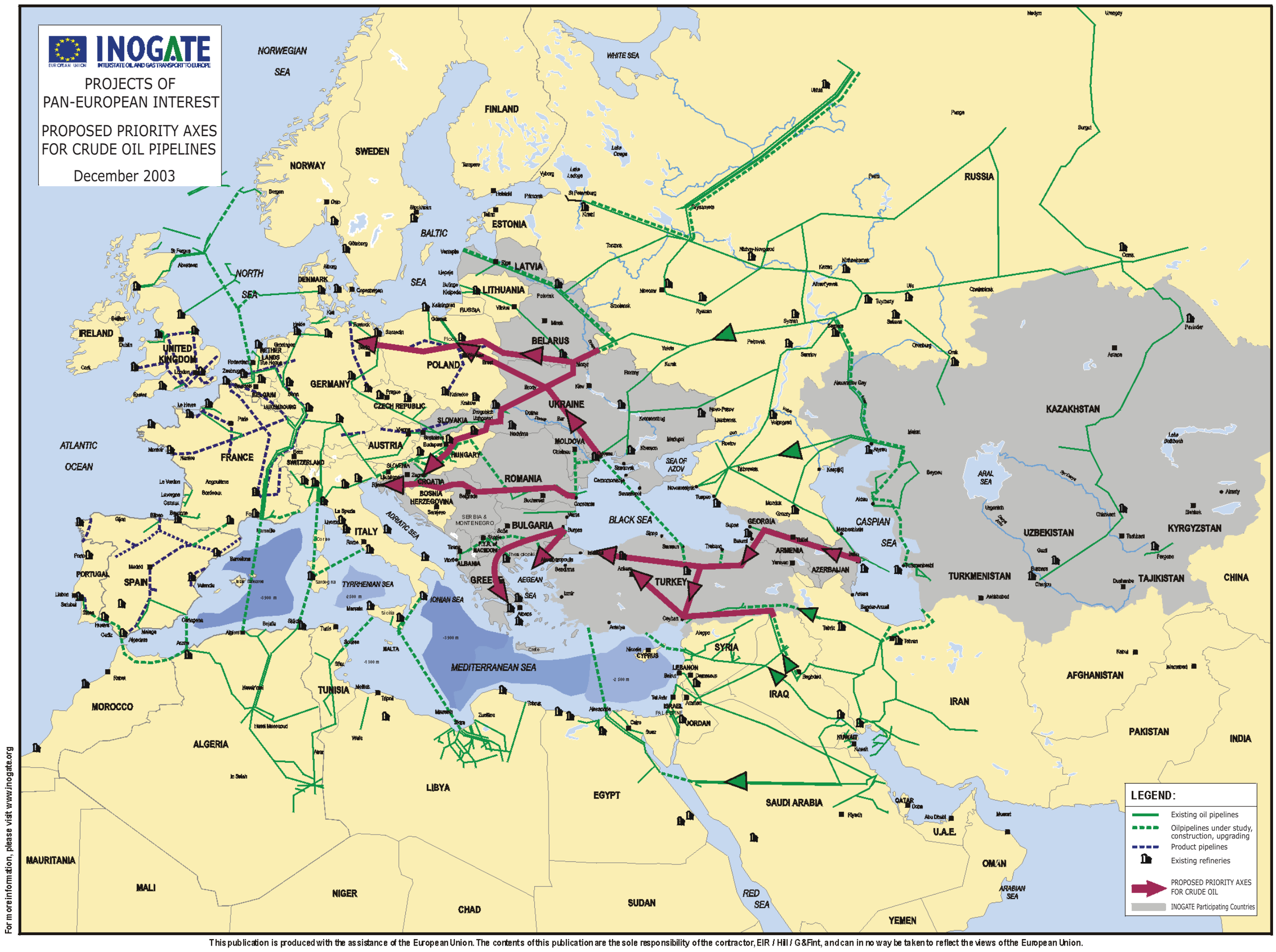
(19) The European coastal area comprises the Black Sea, the Mediterranean, the Atlantic coast of Spain, Portugal, France and the British Isles, the North Sea, the Atlantic coast of Norway and the Baltic Sea; in total an area of 6 062 400 km^2 with a coastline of about 85 600 km (Jorry, 2007).

Figure 11.1 European network of crude oil pipelines



Source: INOGATE, 2009.

Spills of crude oil or mineral oil products have major environmental consequences. The most noticeable consequence is wildlife mortality (birds, sea mammals, fish etc.), followed by contamination of the coastal zone and severe impacts on the sea bottom or ground water (in the case of spills from pipelines).

11.1.2 Sources of information

The main sources of data on oil spills, and maritime incidents in general, are the Centre of Documentation, Research and Experimentation of Accidental Water Pollution (CEDRE, 2010) in France and the European Maritime Safety Agency (EMSA, 2010) in Portugal. The best source of information about oil spills from pipelines is Conservation of Clean Air and Water in Europe (CONCAWE, 2010), the European oil companies' organisation for environment, health and safety. Additional, complementary information on some of the most significant events is available from EM-DAT maintained by CRED (EM-DAT, 2010).

11.1. 3 Oil spills in Europe, 1998–2009

Prior to 2003, two large oil spills affected European coastal waters. The first, in 1999, involved the tanker *Erika* and the second, in 2001, involved the tanker *Prestige*. There were other smaller spills in Greece (2000), Norway (2000, 2001), Sweden (2000) and Denmark (2001). After 2003, extreme spills such as these have not occurred. Table 11.1 lists the major oil spill events 1998–2009.

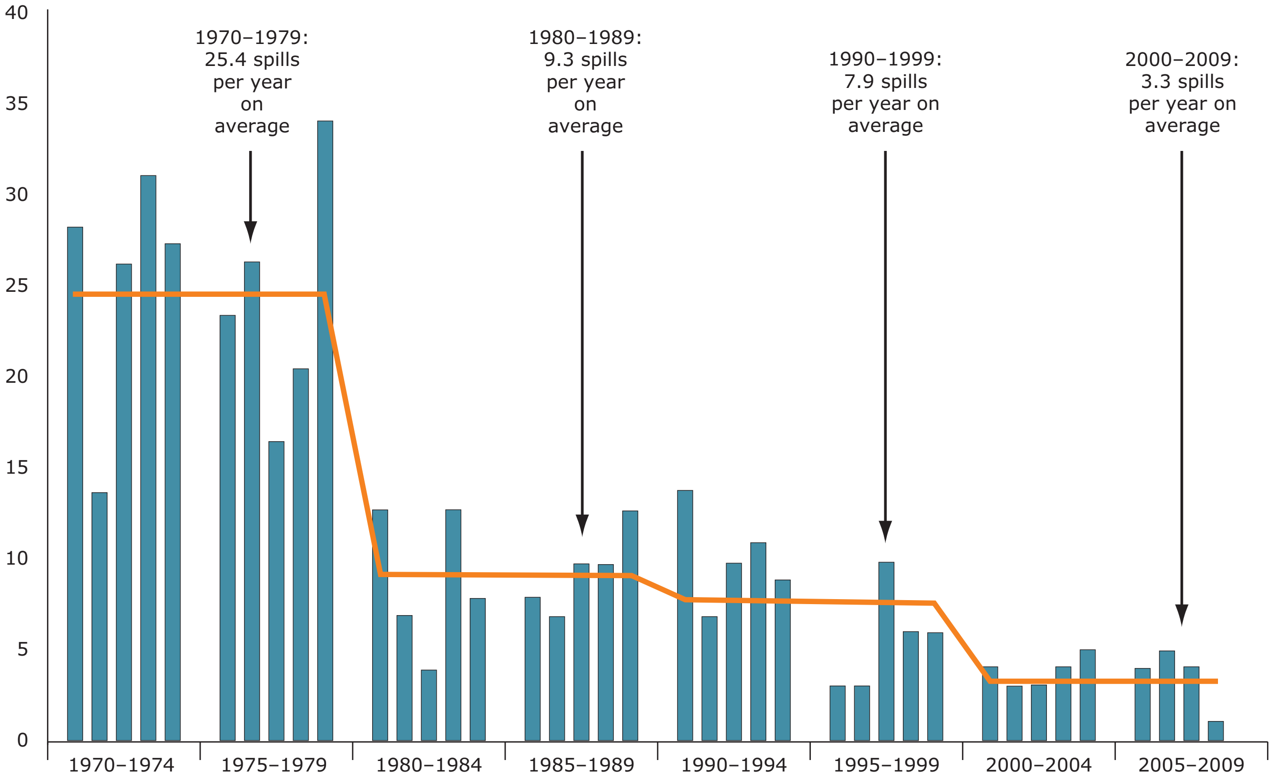
In general, the worldwide trend for large oil spills (> 700 t) indicates a decrease since the 1970s. Between 2000 and 2008, the average number of large spills was 3.4 per year, compared to 7.8 in the decade before (see Figure 11.2). Nevertheless, the transport of crude oil or oil products by ship, in particular, still poses an enormous hazard. EMSA reported 23 groundings and 23 collisions in 2007, and 20 groundings and 31 collisions in 2008, leading to estimated oil spills of 8 000 t (2007) and 3 000 t (2008). Whereas this is

Table 11.1 Major oil spill events, 1998–2009 (> 700 t)

Source	Date	Location	Size of spill (t)
Tanker *Erika*	December 1999	Atlantic coast of France	20 000
Tanker *Volgoneft 248*	December 1999	Black Sea (Marmara/Turkey)	4 000
Tanker *Baltic Carrier*	March 2001	Baltic Sea (Denmark)	2 700
Tanker *Prestige*	November 2002	Atlantic coast of Galicia (Spain)	63 000
Oil barge *Spabunker*	January 2003	Mediterranean coast of Spain	1 000
Freighter *Claudel*	January 2007	Port of Rotterdam	800
Carrier *New Flame*	August 2007	Atlantic coast of Gibraltar	1 000
River oil tanker *Volgoneft 139*	November 2007	Strait of Kerch (Russia/Ukraine)	1 300
Tanker *Navion Britannia*	December 2007	Atlantic coast of Norway	4 000
Pipeline	August 2009	St Martin-de-Crau	About 3 000

Sources: CEDRE, 2010; EMSA, 2010; France24, 2009.

Figure 11.2 Average oil spills, 1970–2008



Source: ITOPF, 2010.

certainly a significant improvement compared to the single spill amount of 63 000 t from the *Prestige*, there is still potential for severe pollution. The likelihood of oil spills from pipelines seems to be relatively low, as the available records demonstrate.

In the future, the situation will be determined largely by the commitment of national and European policymakers to reducing dependency on oil imports, replacing oil products with other sources of energy and the anticipated upgrading of transport infrastructure. In general the likelihood of accidents with really long-range impacts should decrease further, due to the factors identified above, as well as an expected decline in oil consumption in the long term (e.g. due to replacement by renewable energy sources).

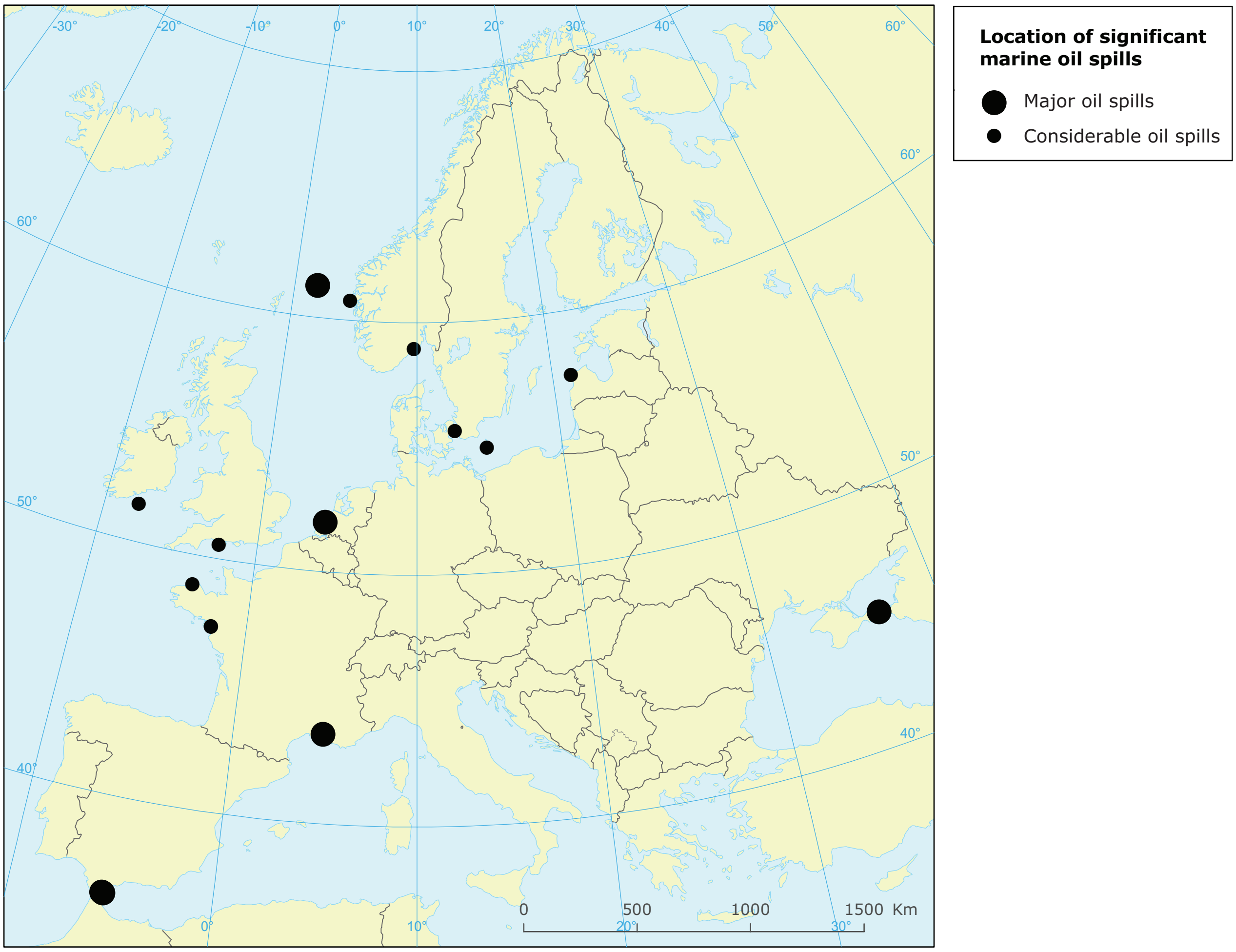
11.2 Oil spill events in Europe — spatial analysis and trends, 2003–2009

11.2.1 Spatial overview

For the period 2003–2009, altogether 19 spills of considerable scale (> 100 tonnes of accidental oil release) were identified from different sources (CEDRE, 2010; EMSA, 2010). According to the International Tanker Owners Pollution Federation (ITOPF, 2010), which maintains summary statistics, a spillage of more than 700 tonnes is considered a major spill; incidents exceeding this threshold are listed in Table 11.1. All considerable and major spills occurred in European ocean areas; there were no large spills recorded in European inland waterways.

Between 2003 and 2009 there were spills near most parts of the European coastline, but the majority occurred either near major ports (such as Algeciras and Rotterdam) or in areas of dense traffic, such as the English Channel. A comparison of the number of incidents with overall figures for maritime traffic in European ports shows no evidence of a spatial aggregation of events. In 2007 there were 1 659 110 vessel calls at European ports, with a corresponding number of trips around European coastal areas (Eurostat, 2009). The probability of an oil spill, based on the 19 cases reported, is therefore approximately 1.8 x 10-6 incidents per year which may be regarded as very low (20). Despite the low probability, the associated risk can be quite

Figure 11.3 Location of significant marine oil spills, 2003–2009



Sources: ETC-LUSI based on CEDRE, 2010 and EMSA, 2010.

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(20) See Section 12.1.2 for an indicative comparison of risk figures.

considerable as any oil spill can have a major impact on the environment.

Only one major spill from pipelines was recorded in the period. On 7 August 2009 in southern France, a pipeline leaked 2 400–3 200 t of crude oil over an area of approximately 2 ha within a nature reserve close to the town of St Martin-de-Crau (France24, 2009). The pipeline, which runs from the French coast to Germany, has a diameter of 1 m with a capacity of 23 million tonnes year, and is buried about 0.8 m below the surface.

There are more than 35 000 km of oil pipelines in Europe (as reported by CONCAWE at the end of 2006, see also Figure 11.1). All spills > 1 m^3 (approximately 0.8 t on average) are reported and appear in the CONCAWE database (CONCAWE, 2010). The long-term statistics show a spillage volume of approximately 1 600 t per year: an average of 40 t per 1 000 km of pipeline length and a spillage recovery of about 70 % of the released amount. The net loss of most of the single incidents is relatively small (around several tonnes). Over time, statistics from the CONCAWE database show a clearly declining trend, from around 1.05 spills per 1 000 km of pipeline length and year to 0.36 by 2007. It is not easy to compare this value with those in other areas, since reporting methods are not always comparable and refer to both under- and over-ground pipelines. The generic failure frequency value for small leakages of over-ground pipes (without taking into account actual spillage events and distinction between gases and liquids) are 1.75 incidents per 1 000 km annually and for full-bore ruptures around 0.1 incidents per 1 000 km annually, as defined in the Accidental Risk Assessment Methodology for Industries (ARAMIS, 2010)· Evidently the likelihood of damage above ground is much higher, as this might happen by external impacts or thermal loads, whereas for underground pipelines, third party interference is the most relevant impact.

11.2.2 Analysis of oil spill impacts: human fatalities and economic losses

There is no evidence for occurrence of human fatalities as a direct result of oil spills.

Estimates for response costs in terms of economic losses vary enormously and depend on a number of factors, including location, amount of oil spilled and the actual behaviour of the spill. For offshore events, the costs per ton spilled are estimated to be between EUR 500 and 500 000 (IMO, 2005). Costs are influenced mainly by the following:

- direct economic losses (fishery, tourism etc.);
- implicit economic consequences (business image, drink water supply in case of waterway pollution);
- non-economic losses (damage to environmental values);
- costs of response measures (cleaning, etc.).

A good example is the survey carried out after the spill from the tanker Volgoneft, which leaked 1 300 t of oil into the Black Sea after it was wrecked on 11 November 2007 (UNEP, 2008). According to the survey, the economic loss resulting from the spill was about EUR 19 million — equivalent to EUR 15 000 per tonne — of which 12 % was spent on the clean-up, 14 % was due to effects on fisheries, and 74 % was due to effects on tourism.

In respect of recent accidents, the data on economic losses are sparse, but figures reported for the Exxon Valdez spill of 1989 indicate that Exxon had to pay about USD 2 billion for clean-up works (Tomich, 2005) and USD 100 million for ecological recovery efforts.

11.2.3 Impacts of oil spills on ecosystems

Marine oil spills

The impacts of marine oil spills are numerous. Floating oil may contaminate animals in contact with the water surface (birds, mammals, turtles). Oil may affect the sea bed and also smother coastal habitats, affecting animal and plant life. In addition, long-term bioaccumulation can affect fish stocks (or similar aquatic species) and have knock-on effects in the food chain. The numerous studies on these issues (for example Neff, 2002) show an accumulation within animals of markers from oil spills, such as polycyclic aromatic hydrocarbons (PAHs), with the highest levels found in animals with very low mobility, for example oysters and mussels. Relevant thresholds, as defined, for example, by EU Regulation 208/2005 (EC, 2005) were significantly exceeded in these cases. The toxicity of these contaminants also influences the development of fish stocks in the longer term; as seen in the aftermath of the Exxon Valdez oil spill off the coast of Alaska in 1989, where PAHs affected the early life stages and subsequent development of herring and salmon (Heintz et al., 1999).

However, for nearly all the significant accidental oil spills during the analysed period, there were no reports of severe environmental damage. This is due largely to favourable weather conditions at the times of the accidents (for example, see Section 11.3). The only exception was the Volgoneft 139 accident. Rigorous investigations of the environmental effects indicated significant damage because of the local very shallow profile of the coast. The studies found residues of oil, tar and oil-contaminated material that will have a long-term impact on the environment.

Oil spills from pipelines

The oil spill from the pipeline in France (described in Section 11.2.1) may be used to highlight the differences between potential environmental impacts on land ecosystems and those on maritime ecosystems. The incident occurred far from water resources and residential areas, but in the middle of a nature reserve. Soil contaminants caused toxic effects on micro-organisms and vegetation; but the main concern was the potential contamination of groundwater resources. Groundwater aquifers can be contaminated either by direct contact with spilled oil, or oil parts washed out by precipitation. Even at low concentrations, oil can affect groundwater quality and may cause severe damage over long periods (as a rule, one litre of hydrocarbon, such as oil, may make 1 million litres of groundwater unfit for human consumption). So far, there have been no reports of severe environmental damage as a result of the accident. However, it was reported that 1 600 lorry loads of contaminated soil (36 000 t) had been removed as a precautionary measure (Viva, 2009).

11.3 Navion Britannia accident (based on Petroleumstilsynet, 2008)

On 12 December 2007, during loading operations at the Statfjord A oil platform about 200 km west of Bergen, Norway, 4 400 m^3 of crude oil spilled into the North Sea. The accident happened while the tanker ship *Navion Britannia* was taking on oil during heavy weather conditions with waves up to 7 m high during the early morning hours. Initially the spill affected 23 km^2 to the northeast of the platform. Poor weather conditions meant that response measures, including skimming, were impossible. The weather remained unchanged over the following days, and the size of the affected area increased to about 50 km^2. Three days after the release no visible traces were detected. It was assumed that about half the oil had evaporated or dissolved, and the rest had formed droplets. Samples of fish caught after the spill showed no oil components above the detection limits. Nevertheless, media reported the incident as the biggest oil spill in Norway in 30 years. There are no records of figures for claims for economic loss.

An investigation by the platform operating company identified the cause of the spillage as a rupture in the tanker's hydraulic system that led to over-rapid closure of the coupler valve between the ship and the platform, and thereby caused a pressure surge up to 115 bars in the loading hose of the platform; this hose ruptured and caused the spill which remained undetected until 4 400 m^3 had been released. The hose ruptured entirely, at a location 10 m under the water surface, and 35 m from the loading head (see Figure 11.4). Inaccuracies in the tanker measurement system prevented an immediate cessation of the loading operation and accordingly the spill remained undetected until the following day. An investigation attributed the main causes to 'inadequate system robustness', 'inadequate risk assessment' and 'inadequate responsibility description'.

The main lesson learnt from this experience is that risk analysis of any procedure, such as the platform–ship loading operation, needs to be more comprehensive. Either the compatibility of the tanker's subsystems and the loading equipment on the platform were not assessed or the analysis did not identify potential hazards sources. There should also have been a more robust break-away device in place.

11.4 Management options to reduce oil spills and their impacts

11.4.1 Measures

The decrease of spill incidents over the past few years is due in part to recent EU legislation (see Section 11.4.2).

Figure 11.4 Picture of the ruptured loading hose

Source: StatoilHydro, 2008.

For pipelines, there are well-developed technical safety measures (for example corrosion protection and leakage monitoring) and well-established safety management methods (inspection systems and dissemination of information to the public and third parties).There is limited scope for reducing the potential for spillage, apart from ensuring optimal selection of the pipeline route. This can reduce the possibility of third-party interference (unintentional damage from outside) and, mostly importantly, minimise risks associated with events such as landslides and earthquakes.

11.4.2 Specific policy to reduce oil spills

Council Directive 417/2002/EC (EC, 2002a), as amended by Regulation 1726/2003/EC (EC, 2003), requires that oil and similar products must be transported in double-hull vessels only, with transposition deadlines depending on the production date of the ship, but not later than 2010 (and in rare exemption cases 2015). This legislation is in line with an international agreement on the same matter (the marine pollution MARPOL-Convention; MARPOL, 1973/78). Accordingly, by 2010 about 90 % of the tanker fleet, representing the main accident potential, should either be equipped with full protection as required by the Regulation or removed from service. Furthermore, Directive 2002/59/EC (EC, 2002b) establishes vessel traffic and monitoring systems which, for example, require a notification for dangerous freight.

The effectiveness of the requirements on double-hull equipment is not easy to demonstrate. Available statistics generally apply to vessels of 10 000 deadweight tonnage (DWT), whereas the legislation covers ships from 5 000 DWT upwards. Thus, the development reflected in Table 11.2 can only be seen as an indicative reference for the increasing proportion of double-hull tankers worldwide, based on the number of tankers worldwide above 10 000 DWT, which has been relatively stable in the last years (1996: 3 130 tankers, 2008: 3 411).

Table 11.2 Percentage of double-hull tankers in relation to the overall number of tankers worldwide above 10 000 DWT

Year	1990	1996	2000	2004	2008
% double-hull tankers worldwide	4	14	20	51	79

Source: Stopford, 1996, 2009; Greenpeace, 2004; McQuilling Services, 2008; EC, 2000.

For pipelines, the regulatory framework is less developed. The most significant document to date is a guideline paper published by the UNECE in 2006 (UNECE, 2006). This document addresses, in particular, the relevance of spatial aspects (for example land-use planning, see Section 11.4.1).

11.5 Data gaps and information needs

Data and reports on maritime accidents have clearly been improved by the activities of EMSA. But obtaining more detail of specific cases depends very much on the willingness of individual companies and authorities to share information. The Norwegian case described above was an exception, as all specific details were provided openly on the internet. In general, there is a tendency to disclose only aggregated information.

Pipelines are not yet subject to European legislation on accidents (with the exception of pipe networks within an establishment) and therefore no mandatory reporting obligation exists. The CONCAWE database is the only source of information about accidents involving pipelines that carry hydrocarbons.

12 Industrial accidents

Key messages

- 339 major accidents were reported under the MARS (Major Accident Reporting System) scheme for the period 1998–2009 (MARS, 2010). Additionally, there were a number of serious transport-related accidents. The highest numbers of fatalities, 32 and 34 respectively, resulted from accidents in Viareggio (Italy, 2009) and Ghislenghien (Belgium, 2004). In total, technological accidents claimed about 169 lives during the period. In contrast, in the same period there were only 22 incidents that had impacts on the environment.
- After having increased steadily until 1998, the annual number of industrial accidents has been more or less stable since then (around 28 major accidents per year). Although the number of serious accidents has remained constant, overall they are tending to be less severe.
- The MARS database provides useful information on major accidents in Europe. Nevertheless, the database could benefit from some improvements, since it currently does not allow a comprehensive overview of industrial accidents. This is due to the fact that MARS does not include all types of industrial accidents, and does not systematically include near-accidents.
- There are a number of legislative instruments in place to prevent and mitigate accidents and their consequences. However, due to the complexity of certain installations or deficiencies in safety management systems, accidents still happen.
- Spatial planning including the appropriate separation of industry, infrastructures and residential settlements in industrial areas offers an effective mechanism for risk mitigation and is a key prevention factor to including in an integrated risk management approach.
- In recent years safety performance indicators have gained more significance in specifying targets for risk reduction and thereby reducing the likelihood of severe industrial accidents. Nevertheless absolute safety is not easily achievable and methods have therefore been developed to estimate the residual risk of industrial accidents and measure its acceptability or tolerability. A key element in all these methodologies is either an effect- or risk-threshold defining a security distance where land use is restricted.

12.1 Introduction

12.1.1 Definition

Industrial accidents are defined by European legislation, in particular by the Seveso II Directive 96/82/EC (EC, 1996a) as amended by 2003/105/EC (EC, 2003a) on the prevention and mitigation of major industrial accidents. The directive covers stationary establishments that store or process certain dangerous substances above a defined quantity threshold.

Transport and all transport-related accidents are excluded from this legislation if they are not directly related to the scope of the directive. The criteria for an accident to be regarded as a major industrial accident and reported under this obligation are defined by Annex VI of the Directive (21). Approximately 10 000 sites within the European Union fall under the requirements of this legislation.

NATECH accidents, industrial accidents triggered by natural events, such as earthquakes, floods and

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(21) Criteria for a reportable major accident: a) any fire, explosion or accidental discharge of a dangerous substance involving, a quantity of at least 5 % of the quantity established in the annex of the Directive, b) an accident involving a hazardous substance and producing one death, six persons injured inside the establishment or one outside the establishment, c) damaged and unusable dwellings outside the establishment, d) evacuation of at least 500 persons, e) interruption of vital infrastructure for at least 1 000 persons, f) permanent or long-term environmental damage to 0.5 ha protected habitat, 10 ha of other land, 10 km river, 1 ha lake, 2 ha delta or coastline or 1 ha of groundwater aquifer, g) property damage of at least EUR 2 million inside or EUR 0.5 million outside the establishment, h) any accident triggered by an activity falling under the Directive with transboundary effects.

forest fires, require special attention and analysis. Such accidents are occurring more often because of the increased frequency of extreme natural events and increased complexity and interdependencies of industrial systems.

In recent years, some accidents categorised as transport accidents (and thus not included in the scope of the Seveso Directive) involved hazardous substances that are regulated by the directive. Some examples include:

- May 2007, Montluel/Dagneux (France): Explosion of two parked road tankers transporting liquid petroleum gas (LPG), thermal effects to 70 m, harmful effects due to overpressure to 400 m, missile effects to 800 m distance (BARPI, 2010);
- June 2009, Viareggio (Italy): Derailment of a freight train, explosion of two tankers with LPG, 32 fatalities, 1 000 people evacuated (Brambilla and Manca, 2010).

Another area not covered by the Seveso Directive that poses a major industrial-related accident risk concerns pipelines outside establishments (22). There was a serious accident of this type in July 2004 in Ghislenghien (see Section 12.3).

12.1.2 Sources of information

The main source of information on industrial accidents is the MARS database (Major Accident Reporting System) (MARS, 2010), managed by the Major Accident Hazards Bureau (MAHB) at the Joint Research Centre of the European Commission. The MARS database contains information about major accidents reported by the Competent Authorities of EU Member States since 1980. According to the Seveso II Directive, reporting of major accidents fulfilling the criteria of Annex VI of this directive is obligatory for EU Member States. The directive also invites Member States to report other events and near-misses valuable for lesson-learning. However, only a small number of such events have been reported so far.

The MARS database is also used by OECD countries (23) on a voluntary basis. To date, the MARS database holds details of 699 incidents, of which 615 were major accidents. However, it does not provide a full overview. First, it does not cover all types of industrial accidents, for example only certain aspects of mining activities are covered (24). Second, reporting of events and updates of the database could probably benefit from more structured reporting procedures.

So far, the Member States that joined the EU since 2004 have contributed relatively few accident reports for various reasons (see Figure 12.1). First, the chemical industry in new Member States represents only 15 % of the EU total. Second, lack of familiarity with the legislation is likely to have made authorities uncertain about which accidents should be reported and delayed reporting. Thus, Figure 12.1 shows a rather stochastic variation in the number of accidents per year, presumably with a slowly declining trend, which needs to be confirmed in the future. The European Commission (DG ENV and JRC/MAHB) has been working with the new Member States to overcome these problems. A new reporting scheme was agreed in 2009 (Commission Decision 2009/10/EC; EC, 2009) and the JRC has developed a new online system for reporting and direct queries (MARS, 2010).

A major shortcoming of the MARS database is that it contains very little information about near-accidents, i.e. hazardous events that could have led to disaster but did not. This means that it does not give a complete picture of the hazard potential of a specific substance or process. Nonetheless, as an indicative value, a specific 'industrial accident risk figure' of 3x10-3 cases per site annually (ratio of average number of reports and estimated number of Seveso sites in the EU) can be estimated. This is still far higher than the figures for other technological risks (25), although the consequences in most of the reported cases were less serious (see Section 12.2.1).

In addition to the MARS database, this study draws on two more sources of information: the database of the French Bureau for Analysis of Industrial Risks and Pollution (BARPI, 2010) and the EM-DAT database (EM-DAT, 2010). The former contains information on approximately 30 000 accidents and incidents that have occurred since 1992, of

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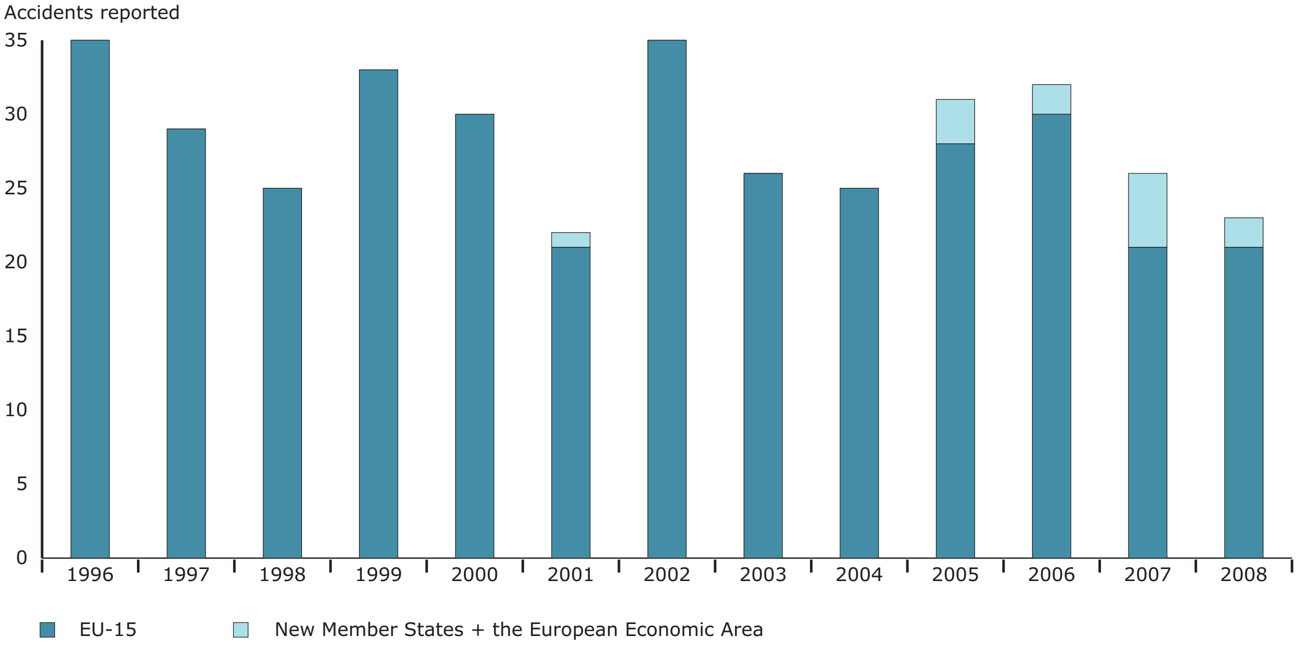
(22) Accidents involving oil pipelines are described in Chapter 11. Transport of natural gas in pipelines is also a potential hazard.

(23) All such additional entries (from USA and Japan) were discounted for this study.

(24) Before the amendment Directive 2003/105/EC came into force, mining activities and waste land-fill sites fell outside the scope of the MARS database. Since the directive, some mining process or storage operations and tailing ponds are included if the quantity of dangerous substances exceeds the thresholds set out in the directive.

(25) For comparison, the likelihood of a plane crash (civil aviation) per flight is 6.5×10^{-7}; (BFU, 2010), the ratio of fatalities in road traffic accidents in Europe per year and number of vehicles is 2×10^{-4} (Eurostat, 2010) and the risk of an oil spill is 1.8×10^{-6} incidents per year (see Section 11.2.1).

Figure 12.1 Major accidents reported in eMARS



Source: MAHB, 2010.

these some 25 000 occurred in France. EM-DAT is a global database maintained by CRED, which, due to the thresholds used (see Chapter 1) only holds information about major events.

12.1.3 Industrial accidents, 1998–2009

The MARS database holds records of 339 incidents that occurred in EEA member countries between 1998 and 2009. Of these, 262 were major accidents that fulfilled the criteria described in 12.1.1 (see also Table 12.1). Prior to 2003, a series of serious incidents, such as the explosion disasters in Toulouse (2001) and Enschede (2000) and the cyanide spill in Baia Mare (Romania, 2000 ([26])) were instrumental in securing the amendment of the Seveso II Directive.

Before 1998 the number of industrial accidents was increasing steadily every year, but this has now stabilised at about 28 major accidents per year (2003: 27, 2004: 22, 2005: 31, 2006: 30, the total figures for 2007–2009 were not available at the time of writing ([27])). There is, however, no sign of a tendency towards fewer major accidents. Analysis of accident reports over recent years indicates some significant causal factors underlying these trends:

- triggering events for major accidents increasingly included maintenance works (very often carried out by subcontractors);
- many major accidents involved loading/unloading operations or were initiated by intermediate storage where it may be assumed that limitations of on-site storage and therefore increased transportation requirements were contributory factors;
- some accidents had limited impacts in terms of consequences outside the installation, but caused human deaths on site, probably due to inadequate training.

12.2 Industrial accidents in Europe: spatial analysis and trends, 2003–2009

12.2.1 Spatial overview

For the period 2003–2009, the MARS database holds data on 125 major accidents that occurred in EEA

([26]) At the time, neither the accident nor the site of the accident was covered by the Seveso Directive. See Chapter 13 for more information on toxic spills from mining disasters.

([27]) The list is not exhaustive and comprises a selection of accidents; the individual cases either caused particular public concern or are significant because of their consequences.

Table 12.1 Significant industrial accidents in Europe, 1998–2009

Date	Location	Description of accident	Major impacts
24 September 1998	Bergkamen, Germany	Explosion of a transport container for organo-metallic compounds	One fatality, human injuries, material loss (> EUR 1.8 million)
24 October 1998	Porto, Portugal	Crude oil spill, followed by ignition	One fatality, human injuries, material loss (EUR 20 million), water contamination
23 November 1998	Thessaloniki, Greece	Gasoline spill during unloading, followed by a flash fire	Four fatalities, human injuries, material loss
2 April 1999	Bellmullet, Ireland	Fire at a rubber products plant	700 people evacuated because of toxic fumes
9 June 1999	Aetsa, Finland	Explosion in a reactor for production of chemicals	One fatality, material loss (> EUR 2.5 million)
13 May 2000	Enschede, Netherlands	Explosion at fireworks storage facility	22 fatalities, 2 000 people evacuated, 500 houses seriously damaged
8 September 2000	Gällivare, Sweden	Tailing dam failure	Material loss, ecological harm
8 December 2000	Haguenau, France	Large fire in a factory for glues and resins	Ecological harm, material loss (> EUR 15 million)
21 July 2000	Neratovice, Czech Republic	Release of a toxic liquid	10 people injured
21 May 2001	Ludwigshafen, Germany	Explosion in a chemical plant	130 people injured, including 50 children
13 August 2001	Guimaraes, Portugal	Explosion in a fireworks factory	Six fatalities, human injuries, widespread fire
21 September 2001	Toulouse, France	Large explosion of fertiliser	30 fatalities, 10 000 people injured, material loss/damage (about EUR 2.5 billion)
16 July 2001	Newport, United Kingdom	Release of toxic cloud during waste treatment process	One fatality, three people injured, community disruption
3 June 2002	Erkner, Germany	Release of a toxic substance from a chemical reactor	One fatality
22 October 2002	Liège, Belgium	Explosion of oven gas	Two fatalities, 13 people injured
1 April 2003	Sittard-Geleen, Netherlands	Explosion of a furnace	Three fatalities
14 August 2003	Puertollano, Spain	Explosion and fire in a storage tank	Seven fatalities, three people injured
19 September 2003	Tornio, Finland	Explosion and fire after a pipeline failure	Three fatalities, material loss
1 June 2004	Villeneuve-sur-Lot, France	Explosion in a fireworks factory	Two fatalities, material loss (14 storage buildings destroyed)
30 July 2004	Ghislenghien, Belgium	Explosion after gas leakage from a pipeline	24 fatalities, 132 people injured, overall losses about EUR 100 million
8 September 2004	Ancona, Italy	Explosion and fire in a storage facility during loading	One fatality, three people injured, material loss (EUR 6.5 million), costs for renovation and disrupted production EUR 56 million; ecological harm
3 November 2004	Kolding, Denmark	Explosion in a fireworks factory	One fatality, 70 people injured, damage of buildings up to 1 km distance
6 January 2005	Troisdorf, Germany	Explosion in an explosives factory	One fatality
25 October 2005	Kallo, Belgium	Major leak in a storage tank	Soil contamination
11 December 2005	Buncefield, United Kingdom	Explosion and fire in a tank farm	43 people injured, overall costs about EUR 1 billion, community disruption, ecological harm
30 April 2006	Priolo Gargallo, Italy	Leakage of a pipeline in a process plant, followed by a fire and explosion	10 people injured, EUR 28 million costs for clean-up and restoration, community disruption (road and rail closure)

Table 12.1 Significant industrial accidents in Europe, 1998–2009 (cont.)

Date	Location	Description of accident	Major impacts
26 June 2006	Stockbridge, United Kingdom	Explosion in a fireworks factory	One fatality, four people injured
12 September 2006	Arnsberg, Germany	Fire after a dust explosion	One fatality, two people injured
7 May 2007	Montluel/ Dagneux, France	Explosion of two parked road tankers transporting LPG	Five people injured, widespread damage
31 October 2007	Coryton, United Kingdom	Fire in a refinery	Repair costs approximately EUR 15 million, installation closed for two months
11 March 2008	St Lambrecht, Austria	Explosion in explosives factory	Two fatalities, three people injured
17 March 2008	Dormagen, Germany	Explosion and fire after a pipeline rupture	Material loss (direct costs approximately EUR 40 million), EUR 3.2 million costs for on-site and environmental damage
29 June 2009	Viareggio, Italy	Derailment of a freight train, explosion of two LPG tankers	32 fatalities, 1 000 evacuated

Note: Figures refer to EEA member countries. The MARS database lists eight accidents for 2007, six accidents for 2008, and two accidents for 2009; 15 of these occurred in the EU and Norway. Oral communications from the Major Accident Hazards Bureau indicate a number of other reports are yet to be included.

Source: BARPI, 2010; MARS, 2010 ([28]), EM-DAT, 2010.

member countries. Figure 12.2 shows the most significant of these.

Accidents since 2002 have been less serious than previously, with only five resulting in multiple fatalities. The explosion and fire in 2007 at Buncefield, the United Kingdom (see Section 12.3) generated most public attention, although fortunately caused no deaths.

12.2.2 Analysis of impacts of industrial accident: fatalities

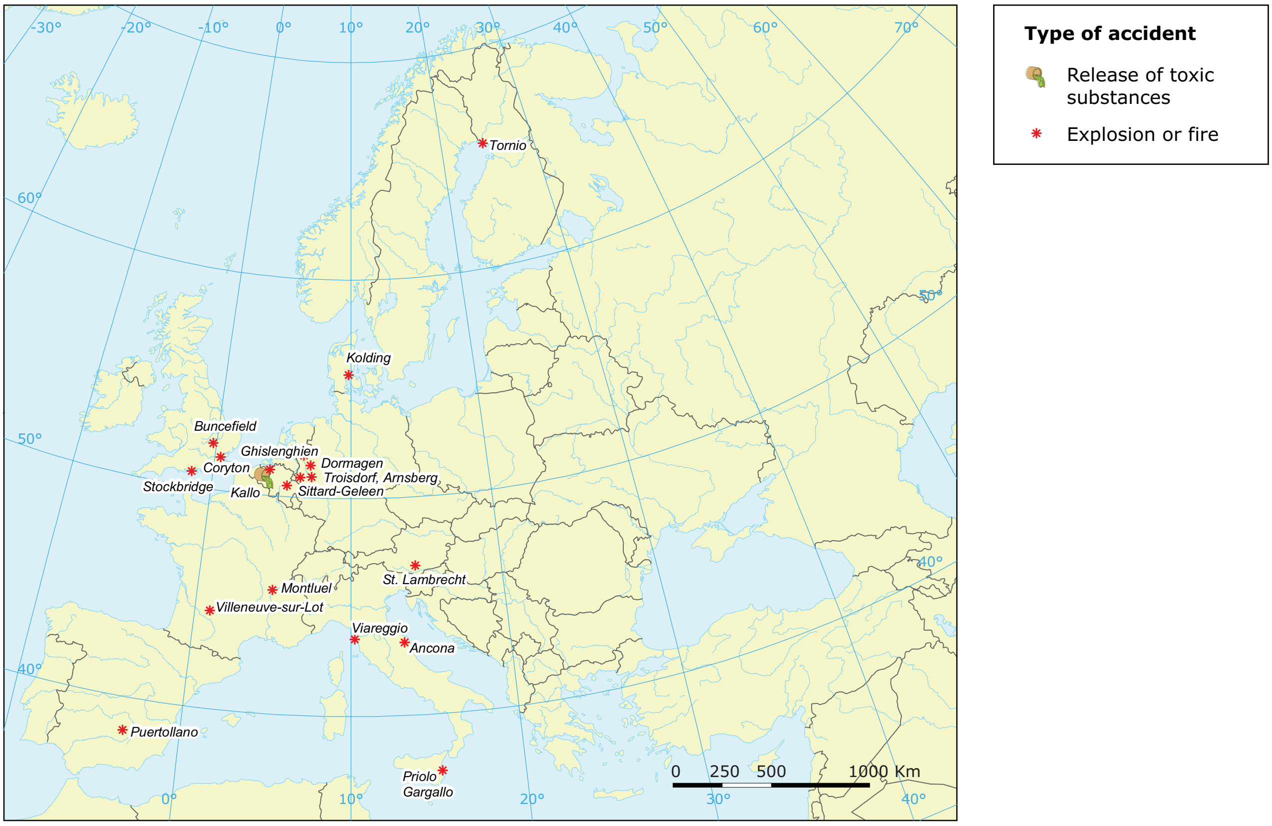
During the reporting period 38 accidents resulted in human injuries and 30 resulted in fatalities. In most cases the fatalities were on-site staff or fire-fighting personnel. The greatest loss of life occurred in two accidents that were not required to be reported under the Seveso Directive, i.e. the accidents at Viareggio and Ghislenghien, resulting in 32 and 24 fatalities, respectively.

12.2.3 Analysis of impacts of industrial accidents: economic losses

The data available in the MARS database do not permit a quantitative estimate of the material or economic loss for most events. The data simply indicate whether the underlying thresholds (see Section 12.1.1) were exceeded. Subsequent cost estimates are rare and the available information is limited in all but a few cases, as follows. The costs of damage caused by the 2006 Arnsberg accident are estimated at EUR 4 million (ZEMA, 2005). For the accident in Dormagen near Cologne in 2008, the company estimated the direct or expected costs at EUR 40 million (ksta, 2008). The costs of the accident at Buncefield in the United Kingdom are described in more detail in the case study below. The known costs associated with the events in the period 1998–2009, as listed in Table 12.1, total at least EUR 3.7 billion; but for the reasons given above, this is a conservative estimate.

([28]) MARS contains only accidents in industrial establishments covered by the Seveso II Directive, i.e. pipelines, mining activities and accidents in the transportation sector are not included. Also, information on the location of the accident is not available within MARS, yet certain accidents — such as the Buncefield accident — are recognisable.

Figure 12.2 Location of major industrial accidents in Europe, 2003–2009



Source: ETC-LUSI based on Table 12.1.

12.2.4 Impacts of industrial accidents on ecosystems

The record of major accidents shows that few have ecological impacts (22 in 2003–2009). In the past few years the majority of major accidents were explosions, which usually have limited impact on the environment. The plumes of smoke from large fires do create widespread attention, but again have only limited impact on ecosystems. The main threat to ecosystems (as was the case in the 2005 accident at Buncefield, the United Kingdom) is the wastewater from fire extinguishing activities, which may pollute surface water or groundwater if not captured effectively. In recent years there have been no reported incidents of large releases of toxic gas or widespread discharges into the water table of toxic liquids with long-term impacts.

12.3 Case studies

12.3.1 Buncefield — the United Kingdom, 2005

On Sunday 11 December 2005, in the early morning, an incident at the Buncefield depot, near Hemel Hempstead, about 45 km north of London, resulted in the biggest fire to have occurred in peace-time Europe. The fuel depot managed 8 % of the British supply of fuel products, serving as a petrol distribution point at the southern end of a pipeline system. At about 6.00 a.m. there were a series of explosions followed by a fire that involved 23 storage tanks. This fire caused a smoke plume several thousand meters high (Figure 12.3) that could be seen from most parts of south-east England. More than 2 000 people in an area of 0.8 km radius from the site had to be evacuated. Buildings up to 8 km from the site suffered minor damage, such as broken windows. The last remaining fires were extinguished in the early morning of 14 December.

The incident caused no fatalities but 43 people were injured. An industrial business estate nearby was badly disrupted. The emergency response forces also confirmed environmental pollution of over-ground water and soil by the outflow of oil products, as well as from contaminated fire-water and foam, but the effects on the groundwater were more severe, causing contamination 2 km downstream. The overall costs were estimated at about EUR 1 billion — 60 % for claims from the industrial estate, 25 % for the disruption of aviation subservices, and the remainder for emergency services (immediate response measures and subsequent cleaning up) and assessed costs of environmental damage. The accident caused widespread public concern.

The triggering event was the overfilling of a tank with unleaded petrol from the pipeline system. The tank was equipped with an automatic measuring device that should have detected when the tank was two-thirds full and shut off the supply. The device failed and the filling continued. When the tank capacity was exceeded by the continued inflow of petrol, the additional overfill safety alarm also failed. The fuel leaked through vents in the tank roof and the outflow continued for over 40 minutes. Most of the leaking petrol was retained in the bund around the tank, but a considerable amount was not contained and formed an explosive cloud. The formation of the cloud was assisted by a deflector plate and a wind gird attached to the tank, which permitted the leaking products to mix with air. Estimates indicate that the overfilling amounted to about 300 t of petrol, of which at least 10 % escaped as vapour cloud or spray mist to an area of about 80 000 m^2 before it finally ignited. As the area covered by the vapour cloud was so large, it was impossible to pinpoint the ignition source. (Source: HSE, 2008)

12.3.2 Ghislenghien — Belgium, 2004

On July 30 2004, Belgium experienced the biggest industrial disaster since 1956 (mining disaster in Marcinelle with 262 fatalities). In Ghislenghien, about 40 km south-west of Brussels, gas leaked from an underground transport pipeline and exploded, killing 24 people and injuring 132. The accident led to intense discussions on the safety of pipelines, as previously this form of transport had been considered safe.
The pipeline transported natural gas from Zeebrugge on the North Sea coast to the French border. It had a diameter of 1 m, operated under a pressure of 80 bars, was laid in 1992 and had a yearly transport capacity of 1.6 million m^3. It was one of two parallel pipelines; the other had a diameter of 0.9 m, a capacity of 1.0 million m^3 and was not affected by the accident.

In Ghislenghien the gas pipeline ran under an industrial park, and at the time of the accident building work was taking place. At about 6.30 a.m.,

Figure 12.3 Buncefield fire

Source: Thames Valley Police, 2008.

the pipeline operating company was informed of a suspected gas leak at the site. At 8.30 a.m. emergency services arrived, and although the gas flow had been shut off, there was an explosion that produced a huge jet of flames and a shock wave that was felt up to 10 km away.

Some of the fire-fighters and staff at the adjacent construction works suffered severe burns, and 24 of them died of their injuries. The number of victims was comparatively high because of problems with response measures and evacuation procedures before the explosion. The explosion crater was about 10 m wide and 4 m deep. Media reports claimed an 11 m-long section of pipe weighing more than 1 t was found about 200 m from the crater. The overall costs were estimated at EUR 100 million.

The official investigation began in mid-2009 and was continuing at the time of writing. Nevertheless, the main causes seem clear. According to available information, the pipeline was damaged by a power shovel during construction work for a diamond-cutting factory more than a month before the explosion. This accident is thus a typical example of third-party interference described in pipeline safety analyses. The incident was reported but no action was taken. Additionally, the severity of the accident was made worse by the lack of response coordination. Reports indicate that evacuation measures could have been initiated much sooner as approximately 2.5 hours elapsed between the first detection of a leak and the explosion. Furthermore access by fire-fighting teams to the endangered area could have been prevented when it became evident that the escaped gas could ignite at any moment. (Source: Hazards Intelligence, 2005.)

12.4 Management options to reduce the impacts of industrial accidents

12.4.1 Measures

Although the number of industrial accidents with major consequences in the reporting period was comparatively low, the risk of industrial accidents remains an issue. This is because many sites with major accident potential are in densely populated areas, with limited risk mitigation opportunities — such as relocation to safer neighbourhoods. Clearly, the main target is to reduce the number of accidents. But a major concern is the hazard potential posed by industrial sites where a high volume of dangerous substances is stored or processed. This justifies specific legislation to bring about adequate protection, which should be based on enhanced integrated risk assessment, taking into account not only the hazard potential from fixed sources but also the overall hazard of fixed installations and transport, in order to avoid any unnecessary shifting of hazard sources.

Safety is difficult to quantify, and responsibility for assessing and mitigating risk lies with the operators of establishments containing hazardous substances. In recent years safety performance indicators have become important in specifying targets for risk reduction, and thereby reducing the likelihood of severe industrial accidents (see for example OECD, 2005).

12.4.2 Specific policy on industrial accidents

For historical reasons most industrial centres are located in or near urban areas. The case studies described above illustrate the importance of land-use planning as a device to mitigate the consequences of accidents. This applies in particular to risks related to major accidents (such as those in 2000 in Enschede, Netherlands and 2001 in Toulouse, France). Spatial planning, i.e. the appropriate separation of establishments, infrastructures and residential settlements in industrial areas, offers an effective mechanism for such mitigation of risk, and as a key prevention factor, should be taken into account within an integrated risk management approach. European environmental regulation also has a role, in particular:

- the IPPC-Directive 96/61/EC (EC, 1996b; codified by Directive 2008/1/EC, EC, 2008), main objective integrated permitting and accident prevention;
- Directive 85/337/EEC on environmental impact assessment (EC, 1985; amended by 97/11/EC, EC, 1997; and 2003/35/EC, EC, 2003b);
- Directive 2001/42/EC on strategic environmental assessment (EC, 2001);
- the European Spatial Development Perspective (ESDP) (EC, 1999).

These legislative (or, in the case of the ESDP, generic political) commitments include objectives such as accident prevention, impact consideration, spatial extent of effects or risk evaluation. Therefore a framework for management of the risks posed by technological hazards is available either by means of prevention or mitigation.

The Seveso Directive 96/82/EC (EC, 1996a; amended by Directive 2003/105/EC, EC, 2003a) goes a step further. Article 12 of the Directive states: *Member States shall ensure that the objectives of preventing major accidents and limiting the consequences of such accidents are taken into account in their land-use policies and/or other relevant policies.*

The scope of the Seveso Directive (EC, 1996a) is defined by substance thresholds listed in its annex; currently, about 10 000 establishments in the EU have to comply with the requirements. Besides the land-use planning provisions, operators must establish a safety management system, and they also need to testify in a specific report that they adhere to the current state of the art.

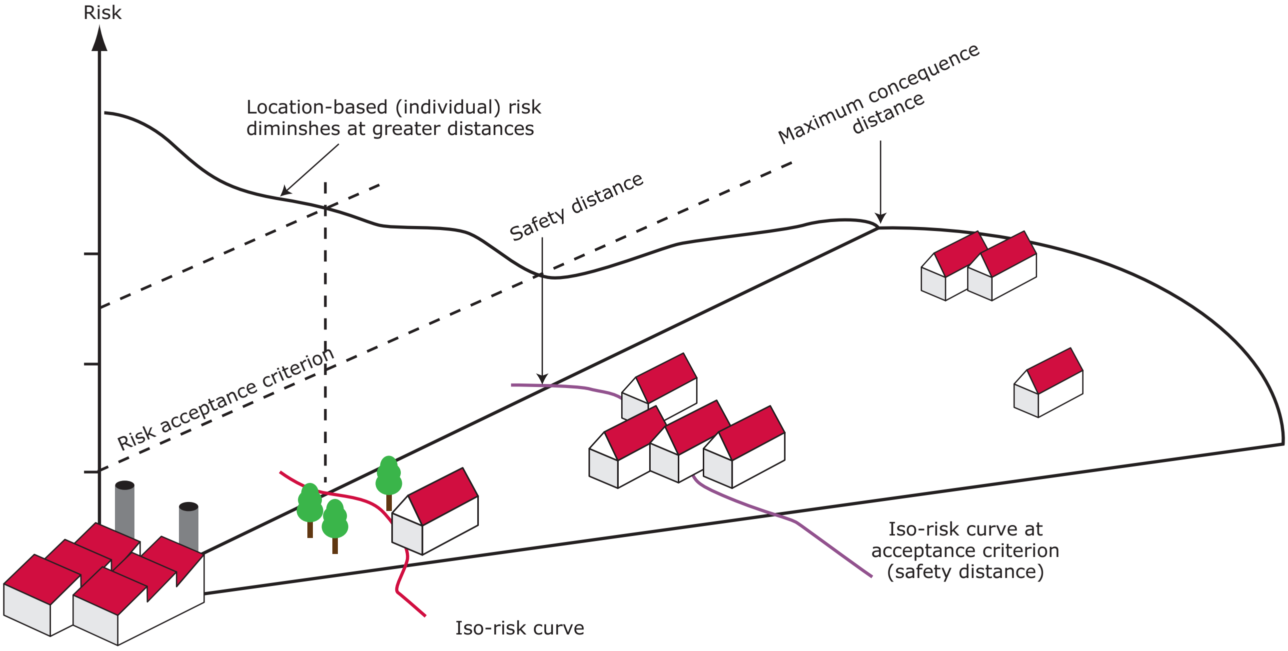
Nevertheless, absolute safety cannot be achieved by these means alone, and other methods have been developed to estimate the residual risk of industrial accidents and measure its acceptability or tolerability. A key element in all these methodologies is either an effect-threshold or risk-threshold, which define a security distance (42). Within this distance from any Seveso site, land use is restricted (Figure 12.4). It is, however, not a hazard zone in the strict sense, but rather a consultation area where the existence of the technical risk derived from the installation requires action — in the most common case, separation between the hazard source (the installation with major accident potential) and sensitive land-use forms (housing, spots with high-density public use etc.).

The principles described above are equally applicable to pipeline safety. In the Ghislenghien case study above (see 12.3), the reason for the incident was simply lack of knowledge of the existence of the pipeline. Third-party interference is by far the most common reason for pipeline failure. Some sources claim that 50 % of failures are due to this, 17 % are attributed to technical failures, 15 % to corrosion, 7 % to underground movement or similar, and 11 % for other or unknown causes (Konersmann et al., 2009). For pipelines, given the risks associated with third-party interference, it is particularly important to minimise these risks by effectively disseminating information on the location and surveillance of the route.

12.5 Data gaps and information needs

In comparison with disasters caused by natural events, technological disaster reporting is less comprehensive. One reason is that in order to avoid subsequent increased interest from local authorities, companies may be reluctant to disclose incidents that could have led to disaster but did

Figure 12.4 Criteria for land-use planning near hazardous facilities



Source: Miljöstyrelsen, 2010.

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(42) The approaches currently used can be grouped into two main types: consequence-oriented and risk-based. Both are based on reference scenarios of major accidents, which include assumptions for accident types (explosion, fire, toxic cloud) and calculations of effects. The consequence-oriented approach compares the result with given threshold values for impacts; the risk-based approach defines the acceptability with risk figures for individual or societal risk (Basta et al., 2008).

not. More frequent reporting of near-misses is essential for any proactive analysis. As described in the previous chapters, the only data source entirely dedicated to this issue is the EC MARS database, but this suffers from various problems, for example delays in updating the database as a consequence of legal actions associated with a particular incident. The EM-DAT database on the other hand mainly focuses on major events (due to its underlying thresholds) and additionally mixes incidents of different types of technological disasters (for example transport, industrial and miscellaneous). The lack of a clearly harmonised classification within industrial accidents therefore impedes statistical analysis of specific disaster categories.

13 Toxic spills from mining activities

Key messages

- Two recent major toxic spills related to mining were caused by the collapse of dams for tailing ponds in Aznacollar in Spain (1998 in the River Guadiamar) and in Baia Mare in Romania (2000). Both spills seriously affected the environment. In 2004 and 2005, there were two further significant spills in Aude (France) and Borsa (Romania).
- The limited information available about the economic costs of toxic spills shows that overall remediation costs can be very high (for example about EUR 377 million for the Aznacollar spill).
- Ecological impacts of toxic spills can be tremendous, as is evident from the Baia Mare event, where the spill of 100 000 m^3 of contaminated water led to heavy pollution of a river system, resulting in the temporary closure of various water supply systems and killing more than one thousand tonnes of fish.
- Reporting on the impact of toxic spills is often inadequate. The main problem is that these events have wide-ranging effects that can involve multiple organisations and authorities. This can be an obstacle to reporting and makes it difficult to compile aggregated data.
- For toxic spills, accident prevention is key and this is very much related to the issue of NATECH (natural hazards triggering technological disasters), since the most frequent accident cause is underestimating extreme natural events.
- After the 1998 and 2000 events, the European Union introduced legislation by including a section on toxic spills in amendment 2003/105/EC of the Seveso II Directive 96/82/EC. Subsequently, Directive 2006/21/EC included a section on major accident prevention and information similar to the requirements of the Seveso Directive. The reference document on best available technologies for the management of tailing and waste-rock in mining activities (EC, 2009) completed the legislation.

13.1 Introduction

13.1.1 Definition (including main causes)

Toxic spills from mining activity is a relatively new category of accident created in the wake of two events: the Guadiamar spill in Spain (1998) and the Baia Mare accident in Romania (2000), both caused by the collapse of dams for tailing ponds. Tailings are waste products and are usually stored in liquid form in ponds. Tailings may comprise highly toxic components, such as cyanide or heavy metals.

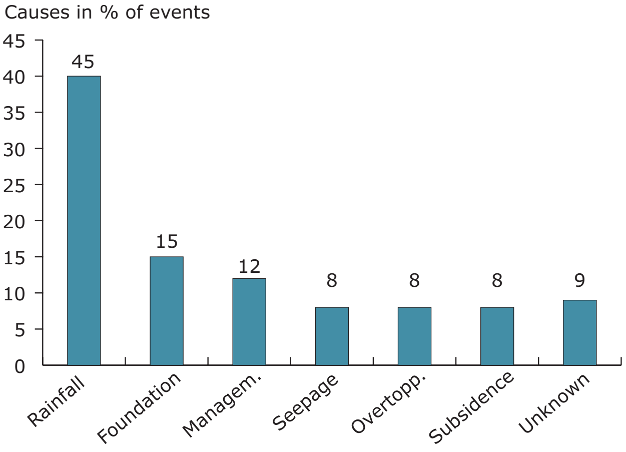
Although the number of reported accidents is comparatively low, the many tailing dams in the EU are considered to have the potential to cause significant accidents, as evidenced by the most recent event in Hungary in October 2010. Any accidents could have long-range effects and severe social and economic impacts. For example, tailing dam failure can cause serious environmental pollution by releasing heavy metals and toxic chemicals, like cyanide.

In 2004 the EU set up e-EcoRisk, a regional enterprise network information management and decision-support system to provide information on the potential and actual environmental and social risks of large-scale industrial spills (e-EcoRisk, 2010). By 2007, the e-EcoRisk database held records of 147 tailing dam incidents worldwide. Of these, 26 had occurred in Europe and nearly all were the result of heavy rainfall or similar natural events, such as snow melt (see Figure 13.1 and Section 13.4.1).

13.1.2 Sources of information

The main source of information was the database provided by the e-Eco-Risk studies (Rico et al., 2008), comprising an overview of the current safety

Figure 13.1 Causes of tailing dam failure



Source: Rico et al., 2008.

research. The few incidents listed in 13.1.3 were reported by individual sources (EM-DAT, 2010; WISE, 2006; Rainforest, 2010).

13.1.3 Toxic spills, 1998–2009

During the reporting period, there were four main incidents (Table 13.1).

13.2 Toxic spills from mining activities, 2003–2009

13.2.1 Spatial overview

Between 2003 and 2009 very few incidents with comparatively small effects were reported (see Figure 13.2). The low number of reported incidents does not permit any in-depth analysis but would seem to suggest that there is no need for further action. However, one of the worst toxic spill accidents in Europe in recent years occurred near the city of Ajka in Veszprem County, Hungary in October 2010, after the period covered in this report (see Box 13.1).

13.2.2 Analysis of the impacts of toxic spills: fatalities and economic losses

According to the available reports, neither of the incidents reported for 2003–2009 (Aude, France; Borsa Romania) resulted in fatalities. As concerns economic aspects, the two incidents are not very well documented and there is no information on the substantial economic losses attributed to these two cases. To gain some impression of the possible costs, the Aznacollar/Guadiamar case may serve as example: after a dam failure approximately 5 million m^3 of toxic sludge was discharged into a river basin where it polluted around 40 km of the river course. Furthermore, about 4 500 ha of a nature preserve was affected. Estimates indicate that overall costs for remediation (clean up, purchase of polluted land, river restoration and interruption of mining activity) amount to EUR 377 million (UNECE, 2007).

13.2.4 Impacts of toxic spills on ecosystems

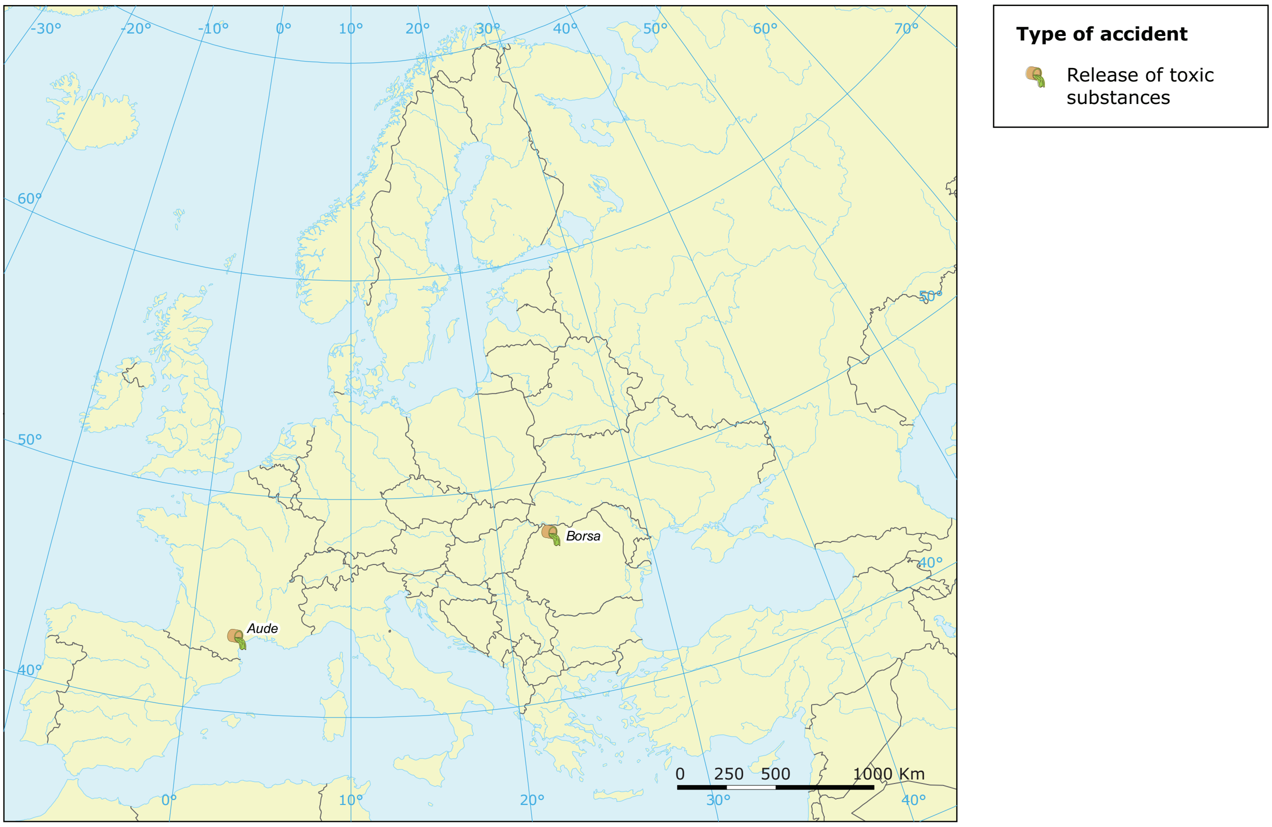
The Baia Mare accident (2000) illustrates the possible impacts on ecosystems of toxic spills from mining accidents. The spill was triggered by a failure of a tailing pond dam. Approximately 100 000 m^3 of toxic wastewater was released accidentally into a river system and caused severe pollution. Because aquatic organisms are often more sensitive than mammals to certain toxins, water pollution can cause enormous damage to aquatic environments. Another very serious effect is the possible impact on the water supply for the population in the downstream area (as water from the river may be taken directly and used after treatment, or the pollution influences the groundwater when there is hydraulic correspondence between the two systems). In the case of Baia Mare the accident led — among other consequences — to the temporary closure of various

Table 13.1 Toxic spills from mining activities, 1998–2009

Type of incident	Date	Location	Impact
Dam failure	April 1998	Aznacollar/ Guadiamar, Spain	5 000 000 m^3 of tailings and acid wastewater spilled; 3600 ha of cropland affected, 12 t of dead fish collected; overall cost of remediation about EUR 377 million
Dam failure	January 2000	Baia Mare, Romania	100 000 m^3 of contaminated water (cyanide, heavy metals) spilled
Dam failure	March 2004	Aude, France	30 000 m^3 of polluted liquid (nitrate, uranium) released
Accidental release	November 2005	Borsa, Romania	300 m^3 cyanide solution released into nearby river

Sources: EM-DAT, 2010; WISE, 2006; Rainforest Information Center, 2010.

Figure 13.2 Toxic spill events from mining activities in Europe, 2003–2009



Source: ETC-LUSI based on WISE, 2010 and Rainforest Information Center, 2010.

water supply systems and killed more than one thousand tonnes of fish (UNEP/OCHA, 2000).

13.3 Case study: Aude/Malvesi Dam Failure 2004

On 20 March 2004 the dam of a decantation and evaporation pond at a uranium conversion plant near Malvesi in southern France failed, releasing 30 000 m^3 of liquid and slurry (WISE, 2010). The dam failure was probably caused by 'abnormal presence of water' after heavy rain in the previous summer, so was a typical NATECH event. The uranium conversion process is typically carried out by an initial purification process using nitric acid, followed by various forms of filtration and dehydration, which generates liquid waste sludge. Typically, the next step in the conversion process is the production of uranium hexafluoride, involving fluorine in gaseous or liquid form. The uranium process tailings are therefore contaminated by fluorine components. As a consequence, the liquid flows following the Malvesi accident contained high concentrations of nitrate, resulting in high nitrate concentrations in the canal leading from the pond for several weeks afterwards, while uranium concentrations remained unchanged. The uranium concentration was monitored for several weeks afterwards but did not raise cause for concern. Apart from that, the release caused elevated concentrations of nitrates in a downstream canal. There were no estimates of the economic loss caused by this event.

13.4 Management options to reduce the impacts of toxic spills

13.4.1 Measures

The technological aspects of preventing toxic spills in mining are comparatively straightforward, as dam construction techniques are well defined. The main question is how to take the potential impacts of natural hazards into account properly. To this end, the Institute for the Protection and Security of the Citizen at the European Commission's Joint Research Centre has launched a project related to NATECH accidents in order to enhance the awareness of these types of accidents and to reduce

Box 13.1 Alkali sludge depository dyke breach in Veszprém County, Hungary (status as of 14 October 2010)

On 4 October 2010 one of the worst toxic spill accidents in Europe of recent years occurred near the city of Ajka in Veszprem County, Hungary, approximately 160 km south-west of Budapest. As a consequence of a failure of the tailing dam of a depository reservoir for an aluminium production plant at least 800 000 m^3 of alkaline sludge flooded an area of 1 017 ha. The sludge flood affected three villages with 7 000 inhabitants and 260 houses were heavily damaged. Nine persons are dead, 134 suffer from severe alkaline burns. According to Hungarian official sources, the accident has so far caused financial costs of some EUR 70 million. There is considerable damage to water courses nearby; long-term consequences are not yet assessable. The response measures focused on neutralising the waste water, using 15 000 tonnes of gypsum for that purpose.

The alkaline sludge is red due to the iron oxide compounds it contains. It is a remnant of the extraction of aluminium from bauxite. Besides residual amounts of caustic soda stemming from the extraction process, other toxic substances are also typical for this sludge. An analysis of samples taken at the accident spot revealed that the spilled amount must have contained 300 tonnes of chromium compounds, 500 kg of mercury and 50 tonnes of arsenic compounds.

The cause of the dam failure is still not clear; there are reports that the reservoir was not designed for the actual load. The available reports indicate that the disaster was not caused by a natural event such as extreme weather conditions or an earthquake. Furthermore it seems that there was evidence of the dam failure in advance. Consequently a lack of control, an underestimation of the disaster potential and probably management deficiencies are being investigated as causal factors

There is not yet information on the applicability of legislation such as the Seveso or Mining Waste Directives. But the extreme impact and the wide spread of pollution across the catchment from a small point source may justify further action, taking into account other relevant instruments such as the Water Framework Directive.

Currently the accident is still not under control and further failures and spills are expected. Measurements in the rivers further downstream of the accident site currently show no indications of long-range contamination.

NATECH risk. Within the requirements of the Seveso II Directive (96/82/EC; EC, 1996 amended by 2003/105/EC; EC, 2003) natural hazards are usually addressed as a potential external cause of major accident scenarios, and thus taken into account by special construction codes and land-use planning measures. Nevertheless, technological major accidents triggered by natural hazards pose specific challenges. In particular, it is likely that a natural hazard will affect multiple sites, which will affect utilities required for emergency response. Response preparedness therefore comprises a broader range of institutions, devices etc. than would be the case for ordinary technological disasters (Krausmann and Cruz, 2008). For example, the earthquake in Turkey on August 17 1999 triggered 21 technological accidents, including confinement collapse in a tank farm of a refinery, and multiple fires (EC, 2004).

In August 2005 hurricane Katrina hit the coast of the Gulf of Mexico and the areas of Louisiana and Mississippi. Katrina had wind speeds of up to 225 km/h and caused wave heights of 9 m (Pine, 2006). Although costs of more than USD 200 billion were attributed mainly to losses to infrastructure, private property and commercial industry including tourism, there were also costs associated with environmental damage which was triggered by the impact of the storm on industrial sites. As the storm forecast was known days before the actual impact, there was enough time for a controlled closure of industrial sites. Nevertheless, Katrina destroyed 44 oil drilling platforms and damaged 299 pipelines (Det Norske Veritas, 2007) leading to considerable pollution in the Gulf of Mexico (Cruz and Krausmann, 2009). Although there was no loss of life or relevant pollution at these locations, the impact after landfall of the storm was more severe. In the Lower Mississippi Corridor near St Louis, a centre of industry, around 27 000 tons of crude oil, oil products and chemicals were discharged.

These examples illustrate two common factors: (1) the ignorance or underestimation of the effect of natural hazards initiating major technological accidents and (2) the incompatibility of certain industrial locations with major accident potential with respect to extreme scenarios caused by natural events.

Consequently, key strategies with respect to NATECH hazards are industry risk management that specifically addresses impacts of natural hazards, and tools to estimate the potential damage, as well as integrated land-use planning and zoning that take specific vulnerabilities into account.

13.4.2 Specific policy on toxic spills

The incidents in 1998 and 2000 raised concern about the hazard potential of toxic spills from mining activities. As a consequence, the European Union initiated legislation on the matter. In 2003, when the amendment 2003/105/EC (EC, 2003) to the Seveso II Directive 96/82/EC (EC, 1996) on the control of major accidents involving dangerous substances came into force, its scope was extended by the addition of the following '...waste land-fill sites (*are in principle excluded from the scope*), with the exception of operational tailings disposal facilities, including tailing ponds or dams, containing dangerous substances ...in particular when used in connection with the chemical and thermal processing of minerals...'. Directive 2006/21/EC on the management of waste from extractive industries (EC, 2006) introduced a chapter on major accident prevention and information similar to the requirements of the Seveso Directive. The reference document on best available technologies for the management of tailing and waste-rock in mining activities (EC, 2009) completed the overall framework.

13.5 Data gaps and information needs

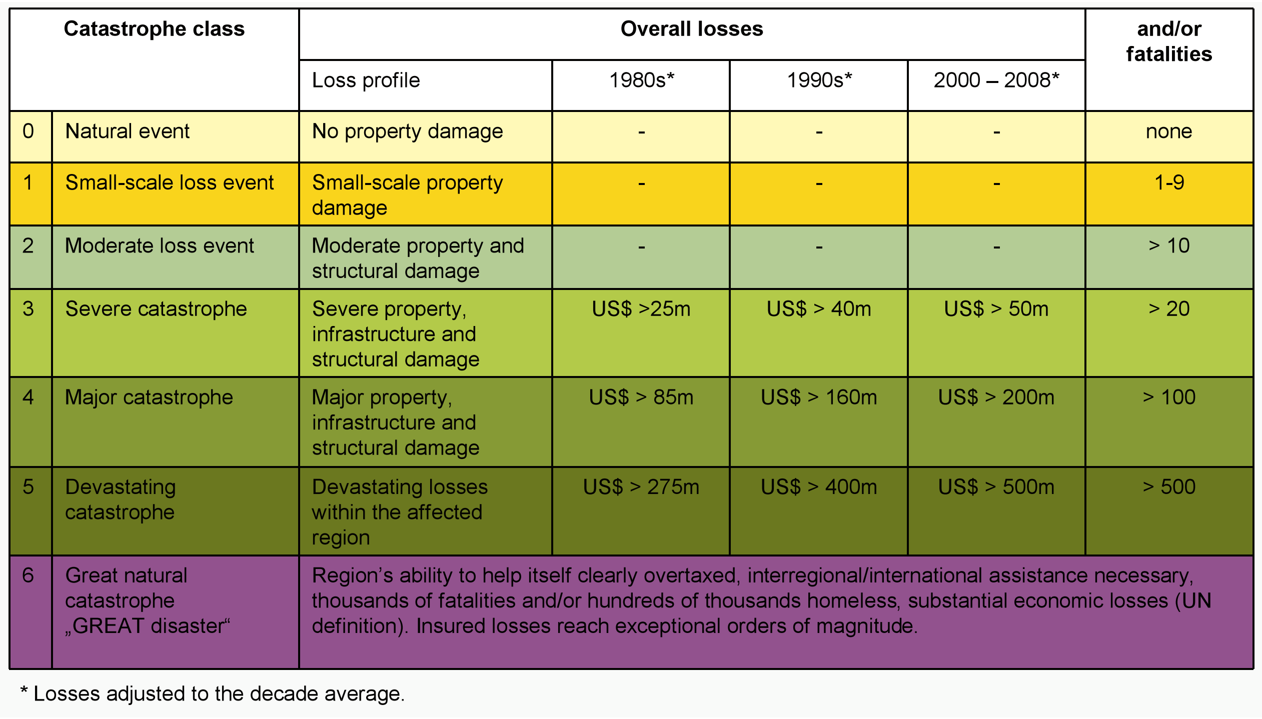
The main problem in gathering information on toxic spills from mining activities lies in the cross-cutting character of the topic, touching various authorities and their competencies. Disasters of this kind may include the fields of natural hazards, technological disasters, mining (representing a usually separate legal entity) and water protection, thereby relating to very different competencies. This may cause reporting obstacles and make it difficult to identify aggregated data.

Annex 1 The EM-DAT and NatCatSERVICE databases

EM-DAT (www.emdat.be) is a database on the occurrence and immediate effects of all disasters (natural and technological) in the world, from 1900 to the present time. It is maintained by the WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) and funded by the US office of Foreign Disaster Assistance (USAID/OFDA). It is located at the Catholic University of Louvain (Belgium). The database is compiled from various sources, including United Nations agencies, non-governmental organisations, insurance companies, research institutes and press agencies. EM-DAT includes information on date and location of an event; the numbers of people killed/affected as well as an estimation of the economic impact, although economic losses do not constitute part of the main criteria to define an event as a disaster.

NatCatSERVICE is provided by insurance company Munich Re (www.munichre.com/geo). It is one of the world's most comprehensive databases on natural hazard-based disasters with more than 28 000 entries. It is based on over 200 sources worldwide, including news agencies, insurance companies, international agencies (UN, EU, Red Cross, etc.), scientific sources and weather and warning services. Every year it records between 600 and 900 hazardous events. It keeps track of all loss events concerning natural hazards that have resulted in material or human losses. Depending on the magnitude of human fatalities and economic losses, each event is assigned to one out of possible six categories, from small-scale events to great natural catastrophes. While all categories have mortality or economic thresholds, the final category is purely qualitative and follows the United Nations definition of a great natural disaster (see Figure A.1). Insured losses are drawn directly from the insurance industry including over 60 branches of the Munich Re. Insured losses reported in the NatCatSERVICE database are actually real paid losses from the insurance industry and include loss estimation for overall losses in addition to the use of official figures from governmental and non governmental sources.

Figure A.1 Catastrophe classes according to Munich Re



Catastrophe class		Overall losses				and/or fatalities
		Loss profile	1980s*	1990s*	2000 – 2008*	
0	Natural event	No property damage	-	-	-	none
1	Small-scale loss event	Small-scale property damage	-	-	-	1-9
2	Moderate loss event	Moderate property and structural damage	-	-	-	> 10
3	Severe catastrophe	Severe property, infrastructure and structural damage	US$ >25m	US$ > 40m	US$ > 50m	> 20
4	Major catastrophe	Major property, infrastructure and structural damage	US$ > 85m	US$ > 160m	US$ > 200m	> 100
5	Devastating catastrophe	Devastating losses within the affected region	US$ > 275m	US$ > 400m	US$ > 500m	> 500
6	Great natural catastrophe „GREAT disaster“	Region's ability to help itself clearly overtaxed, interregional/international assistance necessary, thousands of fatalities and/or hundreds of thousands homeless, substantial economic losses (UN definition). Insured losses reach exceptional orders of magnitude.				

* Losses adjusted to the decade average.

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Executive summary

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European Environment Agency

Mapping the impacts of natural hazards and technological accidents in europe — An overview of the last decade

2010 – 144 pp. – 21 x 29.7 cm

ISBN 978-92-9213-168-5
doi:10.2800/62638

TH-AK-10-013-EN-N
doi:10.2800/62638

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ISBN 978-92-9213-168-5
9 789292 131685

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